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<tr>
<td>Plenary in Salons A &amp; B (PleO4-O6)</td>
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### Schedule-at-a-Glance - Afternoon (1:10PM – 5:00PM)

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<td>Poster Set-up</td>
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<td>Salon D</td>
<td>North Atlantic Fish (NorO1-O5)</td>
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<td>Poster</td>
<td>Fish Physiologist’s Toolbox (FisO11-O15)</td>
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<tr>
<td>Garrison</td>
<td>Early Life History (EarO1-O4, O6)</td>
<td>Hypoxia Tolerance in Fish (HypO6-O10)</td>
<td>Proteomic and Genomics in Fish Biology (ProO11-O15)</td>
<td>Linking Fish Biology to Improved Aquaculture (LinO17-O21)</td>
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<td>Muscular Aspects of Fish Locomotion (MusO1-O5)</td>
<td>Advances in Fish Biology (AdvO11-O15)</td>
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<td>Disease, Parasites and Host Response (DisO1-O5)</td>
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<td>Avalon / Battery</td>
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**Daytime schedule ends ~4:30 – 5:00 PM**

### Schedule-at-a-Glance - Evening

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<th>OSC / MI Tours 3:00 PM on… Informal Social Sundance / Dexas 8:00 PM</th>
<th>LOTEK Tour 4:30 on… Poster Session Salons B/C/D 7:00 – 9:00 PM</th>
<th>Poster Session Salons B/C/D 7:00 – 9:00 PM</th>
<th>Pre-Banquet Reception Courtgarden…6:30 Banquet Salons A / B 7:30 PM</th>
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<th>Speaker</th>
<th>Title and Abstract</th>
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<td>0800</td>
<td>Welcome and Introduction</td>
<td>Dr. Bill Driedzic</td>
</tr>
<tr>
<td>0820</td>
<td>Dr. Barbara A. Block</td>
<td>Hot tunas with cold hearts: linking molecular, integrative, and ecological physiology with pelagic ecosystem processes. (PleO1)</td>
</tr>
<tr>
<td>0850</td>
<td>Dr. Neil B. Metcalfe</td>
<td>How does rate of development affect future viability? (PleO2)</td>
</tr>
<tr>
<td>0920</td>
<td>Dr. Thorsten Schwerte</td>
<td>Milestones and flexibility in early development of the cardio-respiratory system of the model animal zebrafish (<em>Danio rerio</em>) analysed with non-invasive computer assisted image analysis. (PleO3)</td>
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<tr>
<td>0950 - 1020</td>
<td>Break</td>
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</tr>
<tr>
<td>1020</td>
<td>Dr. Bruce D. Sidell</td>
<td>Behold a pale fish: life without oxygen-binding proteins in the Antarctic icefishes. (PleO4)</td>
</tr>
<tr>
<td>1050</td>
<td>Dr. Bernard B. Rees</td>
<td>Triggers and targets of oxygen-dependent gene expression in fish. (PleO5)</td>
</tr>
<tr>
<td>1120</td>
<td>Dr. Trish Schulte</td>
<td>From molecules to behavior: an integrated approach to studying thermal adaptation in fish. (PleO6)</td>
</tr>
<tr>
<td>1150 - 1310</td>
<td>Lunch</td>
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<tr>
<td>Time</td>
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<td>Salon A</td>
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<td>1310</td>
<td></td>
<td>Z. Desta, R. Borgstrom, Z. Gebremarlam and B. O. Rosseland</td>
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<td></td>
<td>Mark Hartl</td>
<td>Ian Fleming and Sigurd Einum</td>
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<td>salmonid movement in a small Newfoundland watershed: how does it affect our traditional views of habitat use and population dynamics?</td>
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<tr>
<td>1350</td>
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<td>Multiple stressor effects of radiation and metals in rainbow trout.</td>
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<td>Mechanism of metallothionein gene regulation in tilapia.</td>
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<tr>
<td>1430</td>
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<td>Time-course changes of Na⁺/K⁺-ATPase, mr cells morphoge and cortisol contents upon copper exposure in juvenile tilapia (Oreochromis mossambicus).</td>
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<tr>
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<td>Differential gene expression in mullets injected with ba/p: phase i metabolism and peroxisome proliferation.</td>
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<tr>
<td>Sala D</td>
<td>Garrison</td>
<td>Signal</td>
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<tr>
<td>Helga Guderley</td>
<td>Don MacKinlay and Alan Youngson</td>
<td>Doug Syme</td>
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<tr>
<td>The effects of competition on the growth of three cohabiting juvenile gadids; <em>Gadus morhua</em>, <em>Gadus ogac</em>, and <em>Urophycis tenuis</em> (NorO1)</td>
<td>Relationships between egg characteristics and maternal traits in two populations of walleye (<em>Sander vitreus</em>). (EarO1)</td>
<td>Muscle, power and steady swimming in fishes. (MusO1)</td>
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<td>Effects of temperature on Atlantic cod morphometric parameters and tissue metabolites and enzymes. (NorO2)</td>
<td>Variation in egg size in Pacific salmon. (EarO2)</td>
<td>How eels swim: muscle recruitment, properties and performance. (MusO2)</td>
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<td>Behaviour at high temperatures: does physiology explain movement of Atlantic salmon (<em>Salmo salar</em>) to cool water? (NorO3)</td>
<td>Seasonal variations in egg quality of the anchoveta <em>E. ringens</em>: a maternal effect to changing environmental conditions. (EarO3)</td>
<td>Lateral muscle distribution and swimming characteristics in some marine fishes. (MusO3)</td>
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<td>Counter gradient variation and links between metabolic rate, temperature and swimming performance in Atlantic cod (<em>Gadus morhua</em>). (NorO4)</td>
<td>The impact of the chorion and external oxygen levels on movement and growth in trout embryos. (EarO4)</td>
<td>The influence of thermal acclimation on scup red muscle power production during swimming. (MusO4)</td>
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<td>Post-hatch performance of Atlantic salmon alevins following egg incubation in naturally variable hyporheic environments. (EarO6)</td>
<td>Understanding the diversity of mechanical function in fish muscle: where to look next? (MusO5)</td>
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<tr>
<td>Time</td>
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<td>Salon A</td>
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<td>Biomonitoring oil-exposure effects using spoonhead sculpin (<em>Cottus ricei</em>) and juvenile longnose sucker (<em>Catostomus catostomus</em>) as sentinel species. (BioO6)</td>
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<tr>
<td>1530</td>
<td>E. Georgiades and D.A. Holdway</td>
<td>S. Rowe and J.A. Hutchings</td>
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<td>Genetic differences in Atlantic cod reaction norms: linking individual and population responses to the environment. (FroO7)</td>
<td>Genetic differences in Atlantic cod reaction norms: linking individual and population responses to the environment. (FroO7)</td>
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<tr>
<td>1610</td>
<td>T. Valentinčič</td>
<td>T. Valentinčič</td>
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<tr>
<td>1630</td>
<td>N.K. MacLeod, J.C. Curtis and J.D. Armstrong</td>
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Tours to the Ocean Sciences Centre/Aquaculture Research and Development Facility (Logy Bay) and to the Marine Institute of Memorial University.

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<td><strong>Garrison</strong></td>
<td><strong>Signal</strong></td>
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<tr>
<td>S.J. Peake</td>
<td>N.A. Curtin and R.C. Woledge</td>
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<tr>
<td>Never measure critical speed again: gait transition as an alternate estimator of maximum aerobic capacity in fish. (NorO6)</td>
<td>Power at the expense of efficiency? (MusO6)</td>
<td>Habitat use and movements of PIT tagged juvenile Atlantic salmon during winter. (TelO6)</td>
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<tr>
<td>Is the cardio-respiratory system of Atlantic cod (Gadus morhua) a limiting factor for survival in extreme environments? (NorO7)</td>
<td>Sink or swim: not all infections impair salmonid swimming ability, even near lethality. (MusO7)</td>
<td>The use of ultrasonic telemetry as a tool in evaluating success of adaptive management activities aiding Atlantic salmon recovery. (TelO7)</td>
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<tr>
<td>Reduced critical swimming speed and burst-coast use in sub-lethal hypoxic conditions in Atlantic cod (Gadus morhua). (NorO8)</td>
<td>Biomechanical design of aerobic muscle in tunas and lamnid sharks. (MusO8)</td>
<td>Juvenile coaster brook trout movements as determined by radiofrequency identification (RFID) telemetry on the south shore of lake superior. (TelO8)</td>
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<td>“Sleepy fish”: metabolic depression in a North Atlantic teleost, Tautogolabrus adspersus. (NorO9)</td>
<td>Swimming performance studies of the mako shark (Isurus oxyrinchus). (MusO9)</td>
<td>Application of acoustic technologies to lake sturgeon movements and habitat use. (TelO9)</td>
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Tours to the Ocean Sciences Centre/Aquaculture Research and Development Facility (Logy Bay) and to the Marine Institute of Memorial University.

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<td>A toxicogenomics approach to endocrine disruptors in the environment. (ImpO1)</td>
<td>Nonrandom group formation in schooling migratory char: causes and consequences for adaptive management. (FroO8)</td>
<td>The impact of copper exposure on the olfactory neuroethology of Coho salmon (Oncorhynchus kisutch). (OlfO9)</td>
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<td>Genetic adaptation to contaminants; physiological, genetic and fitness consequences. (ImpO2)</td>
<td>Variation in social behaviour and reproductive hormones in Arctic char during a spawning season. (FroO9)</td>
<td>Genetic adaptation to contaminants; physiological, genetic and fitness consequences. (ImpO2)</td>
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<td>Gene expression in caged fish as a first-tier indicator of contaminant exposure. (ImpO3)</td>
<td>Individuality of learning in small schools of the common carp (Cyprino carpio). (FroO10)</td>
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<td>Fish swimming in pharmaceuticals – is there a problem? (ImpO4)</td>
<td>Trade-offs between winter feeding and sheltering in Atlantic salmon – the effects of ice-cover. (FroO11)</td>
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<td>Clear as mud: are cattle feedlots responsible for the defeminization of female fathead minnows in the Elkhorn River? (ImpO5)</td>
<td>Adaptive variation in the feeding or sheltering trade-off in Atlantic salmon along an ice-cover gradient. (FroO12)</td>
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<td>Evidence for reproductive pheromone release by the round goby, Neogobius melanostomus, an invasive species in the Great Lakes. (OlfO13)</td>
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<td>Bones and Teeth: Biomineralisation in Fish from Microscopy to Design of Materials</td>
<td>Physiology of Early Life History Stages of Fish</td>
<td>Advances in Fish Biology</td>
<td>Telemetry: Tracking Fish in Nature</td>
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<td><strong>Garrison</strong></td>
<td><strong>Signal</strong></td>
<td><strong>Avalon / Battery</strong></td>
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<td>Don MacKinlay and Alan Youngson</td>
<td>Suzie Currie</td>
<td>Dale Webber</td>
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<td>The life history and behaviour of Pacific groundfish from isotopic records of otoliths. <em>(BonO1)</em></td>
<td>Is early survival connected with parental MHC in Arctic char stock with low genetic variability? <em>(EarO7)</em></td>
<td>The influence of photoperiod on pulsatile urea excretion in toadfish <em>(Opsanus beta)</em>. <em>(AdvO1)</em></td>
<td>Demystifying sturgeon – remote telemetry provides insight into the daily life of white sturgeon in the lower Columbia River. <em>(TelO10)</em></td>
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<td>Fossil-fish biogenic carbonate fluorapatite. <em>(BonO3)</em></td>
<td>Forever young: developmental staging of California grunion in normal and extended incubation. <em>(EarO9)</em></td>
<td>The accumulation of TMAO in elasmobranchs revisited: retention vs. synthesis in the winter skate. <em>(AdvO3)</em></td>
<td>Stock mixing between northern gulf of St. Lawrence and southern Newfoundland cod: the acoustic counting fence. <em>(TelO12)</em></td>
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<td>Evolution of the enameloid microstructure in elasmobranchs. <em>(BonO4)</em></td>
<td>Metabolic costs of feeding and growth in Atlantic cod <em>(Gadus morhua)</em> larvae using microcalorimetry. <em>(EarO10)</em></td>
<td>Hormone-induced spawning of the pacific red snapper <em>(Lutjanus peru)</em> with LHRH-A. <em>(AdvO4)</em></td>
<td>Stable isotope and telemetry evidence for partial migration in Newfoundland cod <em>(Gadus morhua)</em>. <em>(TelO13)</em></td>
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<tr>
<td>Inferring parrotfish pharyngeal mill function from dental morphology, wear and microstructure. <em>(BonO5)</em></td>
<td>Growth and survival of larval capelin in Icelandic waters in response to environmental forcing. <em>(EarO11)</em></td>
<td>External morphology and sex steroids as indicators of gonad state in California sheephead <em>(Semicossyphus pulcher)</em>. <em>(AdvO5)</em></td>
<td>Do cod lek? Evidence from a Newfoundland spawning ground. <em>(TelO14)</em></td>
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<tr>
<td>Room</td>
<td>Salon A</td>
<td>Salon B</td>
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<td><strong>Moderator(s)</strong></td>
<td>Chris Kennedy and Alan Kolok</td>
<td>Ian Fleming and Sigurd Einum</td>
<td>Andy Dittman and Hugh Jarrard</td>
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<td><strong>Thursday</strong></td>
<td><strong>Impacts of Contaminant Exposure on Fish: Molecular Mechanisms to Ecotoxicology</strong></td>
<td><strong>From Individual to Population Processes in Fish</strong></td>
<td><strong>The Physiology of Olfactory and Chemosensory Communication in Fish: From Mechanisms to Behavior</strong></td>
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<td><strong>July 20th</strong></td>
<td><strong>(Late Morning)</strong></td>
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<td>Neurobehavioral responses to visual stimuli in zebrafish developmentally exposed to methylmercury and selenium. (ImpO6)</td>
<td>Mechanisms maintaining body size variation in stream salmonids. (FroO13)</td>
<td>A mixture of novel sulfated steroids functions as a potent migratory pheromone for the sea lamprey (Petromyzon marinus). (OlfO14)</td>
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<td>Biphasic interactions: mechanism of synergism and antagonism of retene toxicity by &quot;alpha-naphthoflavone.&quot; (ImpO7)</td>
<td>Juvenile salmonid growth and use of small central California estuaries. (FroO14)</td>
<td>The urine of male Mozambique tilapia signal social status. (OlfO15)</td>
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<td>How hard is that diet? Implications for metal accumulation and toxicity. (ImpO8)</td>
<td>The cost of catching up: increased mortality following structural growth compensation in the wild. (FroO15)</td>
<td>The anal gland of male blenny Salaria pavo: structure and function. (OlfO16)</td>
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<td>A.L. Val and C.P.F Oliveira</td>
<td>S. Einum and E. Kvingedal</td>
<td>H. Ueda, H. Hino, Y. Yamamoto and F. Morinishi</td>
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<td>Effects of copper and lead on tambaqui, Colossoma macropomum. (ImpO9)</td>
<td>First come, first served? (FroO16)</td>
<td>Olfactory functions related with salmon homing migration. (OlfO17)</td>
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<td>D.M. Janz, J.M. Muscatello, P.M. Bennett and J.M. Kelly</td>
<td>W.E. Tymchuk, L.F. Sundström and R.H. Devlin</td>
<td>S.S. Yun, N. Johnson and W. Li</td>
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<td>Ecotoxicological effects of selenium bioaccumulation in northern pike (Esox lucius). (ImpO10)</td>
<td>Growth and survival tradeoffs leading to outbreeding depression in rainbow trout (Oncorhynchus mykiss). (FroO17)</td>
<td>Synthesized male sea lamprey pheromone summons conspecific females to traps. (OlfO18)</td>
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<tr>
<td>Hypoxia Tolerance in Fish: Effects of Chronic and Intermittent Hypoxia</td>
<td>Physiology of Early Life History Stages of Fish</td>
<td>Advances in Fish Biology</td>
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<td><strong>Steve Reid</strong></td>
<td>Don MacKinlay and Alan Youngson</td>
<td>Suzie Currie</td>
<td>Dale Webber</td>
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<td>Ventilatory acclimatisation to hypoxia in vertebrates. (HypO1)</td>
<td>Alternate foraging modes in young lumpfish (<em>Clytopterus lumpus</em>): balancing food-intake with the energetic costs of foraging. (EarO12)</td>
<td>Changes in hormone and ion concentrations in plasma of spawning and senescing sockeye salmon (<em>Oncorhynchus nerka</em>). (AdvO6)</td>
<td>The northeast regional cod tagging program: migration and growth of Atlantic cod (<em>Gadus morhua</em>) in the Gulf of Maine. (TelO15)</td>
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<td>NMDA receptor function in the brain of anoxia- and ammonia-tolerant goldfish. (HypO2)</td>
<td>Distribution of the digestive hormone cholecystokinin in the digestive tract of larval red drum (<em>Sciaenops ocellatus</em>). (EarO13)</td>
<td>Substrate utilization by goldfish (<em>Carassius auratus</em>) white muscle during glycogen resynthesis. (AdvO7)</td>
<td>Cod on the run - movements of escaped and wild Atlantic cod (<em>Gadus morhua</em>) in a Norwegian fjord. (TelO16)</td>
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<tr>
<td>The effect of hypoxic and anoxic preconditioning on the balance of excitatory and inhibitory amino acids: neuroprotective adaptations of a tropical anoxia tolerant reef shark (<em>Hemiscyllium ocellatum</em>). (HypO3)</td>
<td>Ontogenetic changes in the critical swimming speed of cold–water marine fish larvae, and the role of temperature. (EarO14)</td>
<td>Glutathione dynamics in fish: metabolism, transport, and effects of temperature. (AdvO8)</td>
<td>Tagging of bonefish to study population movements and dynamics. (TelO17)</td>
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<td>Oxygen sensing in fish gills—unique distribution of neurotransmitters suggests different oxygen-sensing mechanisms in hypoxia tolerant fish. (HypO4)</td>
<td>Characterization of the growth hormone – insulin-like growth factor I system during Atlantic halibut metamorphosis. (EarO15)</td>
<td>Patterns of metabolic scaling in three species of teleost fish: evidence for ontogenetic changes in aerobic capacity. (AdvO9)</td>
<td>Migration paths for juvenile southern bluefin tuna: estimating detection rates of cross-shelf arrays. (TelO18)</td>
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<td>Local adaptation to hypoxia in the three-spined stickleback (<em>Gasterosteus aculeatus</em>). (HypO5)</td>
<td>K⁺-independent motility initiation in chum salmon sperm treated with glycerol. (AdvO10)</td>
<td>Monitoring the effects of water management practices on estuarine elasmobranches. (TelO20)</td>
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### Thursday
July 20th
(Early Afternoon)

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<th>Room</th>
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<tr>
<td><strong>Moderator(s)</strong></td>
<td>Chris Kennedy and Alan Kolok</td>
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<td>POSTER SESSION 1</td>
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<tr>
<td><strong>1310</strong></td>
<td>D.L. MacLatchy, R.E.M. Peters, S.C. Courtenay and G.J. Van der Kraak</td>
<td>Development, standardization and validation of mummichog (<em>Fundulus heteroclitus</em>) bioassays to determine effects of endocrine disrupting substances. (<strong>ImpO11</strong>)</td>
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<tr>
<td><strong>1330</strong></td>
<td>C. Kennedy and A. Farrell</td>
<td>Do altered cortisol dynamics play a role in the multifaceted toxicities of oil exposure in teleosts? (<strong>ImpO12</strong>)</td>
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<tr>
<td><strong>1350</strong></td>
<td>B. Rashleigh, M.C. Barber and D. Walters</td>
<td>Characterization of PCB bioaccumulation in the Lake Hartwell foodweb using the aquatox model. (<strong>ImpO13</strong>)</td>
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<td><strong>1410</strong></td>
<td>P.S. Ross, K. Harris, K. Tierney, N. Dangerfield, M. Woudneh, T.G. Brown and C. Kennedy</td>
<td>Characterizing current use pesticide impacts on salmon in British Columbia. (<strong>ImpO14</strong>)</td>
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<tr>
<td><strong>1430</strong></td>
<td>M.G.J. Hartl</td>
<td>The role of ecotoxicology in environmental impact assessment – a new European perspective. (<strong>ImpO15</strong>)</td>
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</table>

**Poster Set-up for Symposia:**
- Advances in Fish Biology (10)
- Biomarkers of Environmental Pollution in Fish (2)
- Bones and Teeth: Biominalisation in Fish from Microscopy to Design of Materials (2)
- Early Life History Stages of Fish (7)
- From Individual to Population Processes in Fish (4)
- Hypoxia Tolerance in Fish: Effects of Chronic and Intermittent Hypoxia (3)
- Impacts of Contaminant Exposure on Fish; Molecular Mechanisms to Ecotoxicology (10)
- North Atlantic Fish (4)
- Olfactory and Chemosensory Communication in Fish: From Mechanisms to Behavior (9)
- Telemetry: Tracking Fish in Nature (6)
- Tropical Fish Biology (14)

**Notes:**
Numbers in parentheses indicate the number of poster contributions in each Symposium.

Detailed listing of poster presentations follows on pages 38-41 for this session.
<table>
<thead>
<tr>
<th>Posters</th>
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| Do common carp uncouple to survive hypoxia? (HypO6) | The DNA barcode of life initiative: what can fishbol offer fish biologists? (AdvO11) | Eat or be eaten: using telemetry data to define use of a nursery area by blacktip sharks. (TelO21) |
| Prolonged hypoxia reduces growth rate and lengths Sda in juvenile sole (Solea solea). (HypO7) | Barcoding the fishes of Atlantic Canada. (AdvO12) | Effectiveness of VR acoustic receivers in monitoring movements of fishes in different marine habitats. (TelO22) |
| Effect of hypoxia, heart rate and adenosine on in vivo glucose uptake in a hypoglycemic fish, Myoxocephalus scorpius. (HypO8) | Molecular cloning and expression analysis of GHRH/PACAP and SSN in Atlantic cod (Gadus morhua). (AdvO13) | Potential methods for measuring activity patterns and energy use in free swimming Atlantic cod (Gadus morhua). (TelO23) |
| Hypoxia regulates telomerase expression in fish. (HypO9) | Comparison of habitat use by juvenile white hake (Urophycis tenuis) and Greenland cod (Gadus ogac) as affected by a predator. (AdvO14) | Automated telemetry data retrieval and organization. (TelO24) |
| Hypoxia affects sex differentiation and development, leading to a male-dominated population in zebrafish (Danio rerio). (HypO10) | Variation in stream habitat and abundance of brook trout and steelhead in two Southern Lake Superior tributaries. (AdvO15) | Sample size analyses using radiotelemetry data. (TelO25) |

Delegates presenting posters please set up your poster during this session.

Preliminary viewing and judging will commence at 3:10PM.
### Thursday July 20th (Late Afternoon)

**Impacts of Contaminant Exposure on Fish: Molecular Mechanisms to Ecotoxicology**

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<tr>
<td>1510</td>
<td>K.R. Solomon</td>
<td>Ecotoxicological risk assessment in aquatic systems: fishing in uncertain waters. (ImpO16)</td>
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<tr>
<td>1530</td>
<td>T.K. Collier</td>
<td>Fish health, from mechanistic studies to population models, as a tool for assessing effects of chemical contaminants. (ImpO17)</td>
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### Poster Viewing and Judging for Symposia:

- Advances in Fish Biology (10)
- Biomarkers of Environmental Pollution in Fish (2)
- Bones and Teeth: Biomineralisation in Fish from Microscopy to Design of Materials (2)
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- Impacts of Contaminant Exposure on Fish: Molecular Mechanisms to Ecotoxicology (10)
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### Notes:

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<td>Steve Reid</td>
<td>Anne Kemp and Gilles Cuny</td>
<td>Dale Webber</td>
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<td>Visualisation of how buried lesser sandeel (Ammodites tobianus) obtain oxygen – and evidence of a fish capable of metabolic depression. (HypO11)</td>
<td>Immunohistochemical observations on collar enamel in gars (Lepisosteus oculatus). (BonO6)</td>
<td>Radio tagging Anguilliform fishes; lessons from lamprey. (TelO26)</td>
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<td>Hypoxia and reproductive trade-offs in an African mouth brooding cichlid. (HypO12)</td>
<td>Protoprismatic enamel in the Australian lungfish, Neoceratodus forsteri (Osteichthyes: Dipnoi). (BonO7)</td>
<td>Implantable dinner bells? Acoustic properties of a Vemco V9 coded transmitter. (TelO27)</td>
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<td>Preliminary poster judging and viewing.</td>
<td>A. Kemp and J.C. Barry</td>
<td>T.L. Liedtke, I.N. Duran and C.D. Smith</td>
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<td>Prismatic dentine in the Australian lungfish, Neoceratodus forsteri. (BonO8)</td>
<td>Transmitter effects: considerations for telemetry studies. (TelO28)</td>
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**Friday**  
**July 21st**  
(Early Morning)  

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<th>Speaker(s)</th>
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<td></td>
<td>Extrapolating from small-scale ecological experiments to large-scale dynamics: density dependence in coral reef fishes. <strong>(FroO18)</strong></td>
<td>Salon B</td>
<td>G. E. Forrester and M. A. Steele</td>
<td>Ian Fleming and Sigurd Einum</td>
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<td>The 6000 km spawning migration of the European eel. <strong>(IntO1)</strong></td>
<td>Salon C</td>
<td>G. van den Thillart, V. van Ginneken and A. Palstra</td>
<td>André Péqueux and Philippe Sébert</td>
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<td>Density-dependent growth of juvenile Atlantic salmon (<em>Salmo salar</em>) at differing spatial scales. <strong>(FroO19)</strong></td>
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<td>J.W.A. Grant, I. Imre, O. Venter and I. Girard</td>
<td>Ian Fleming and Sigurd Einum</td>
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<td>Energy metabolism of European eel (<em>Anguilla anguilla</em>) under pressure. <strong>(IntO2)</strong></td>
<td>Salon C</td>
<td>P. Sérét, A. Vettier, A. Amérand, A. Péqueux and C. Moisan</td>
<td>André Péqueux and Philippe Sébert</td>
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<td>Density-dependent, habitat associated behaviour and recruitment in age 0 cod. <strong>(FroO20)</strong></td>
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<td>0900</td>
<td>Salicylate disrupts interrenal steroidogenesis and brain glucocorticoid receptor expression in rainbow trout. <strong>(ImpO21)</strong></td>
<td>Salon A</td>
<td>A. Gravel and M.M. Vijayan</td>
<td>Chris Kennedy and Alan Kolok</td>
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<td>Fish population recovery following catastrophic disturbance: local versus immigrant contributions. <strong>(FroO21)</strong></td>
<td>Salon B</td>
<td>M.T. Kinnison, D.J. Weese, P. Bentzen, D.N. Reznick and A.P. Hendry</td>
<td>Ian Fleming and Sigurd Einum</td>
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<td>Movement patterns, physiology and population structure of northern bluefin tuna (<em>Thunnus thynnus</em>) as revealed by electronic tags. <strong>(IntO4)</strong></td>
<td>Salon C</td>
<td>B.A. Block, S.I.H. Teo, A. Boustany, A. Walli, H. Dewar, C. Farwell and T. Williams</td>
<td>André Péqueux and Philippe Sébert</td>
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<td>0920</td>
<td>The human pharmaceutical gemfibrozil challenges the antioxidant defense system in goldfish (<em>Carassius auratus</em>). <strong>(ImpO22)</strong></td>
<td>Salon A</td>
<td>C. Mimeault, V.L. Trudeau and T.W. Moon</td>
<td>Chris Kennedy and Alan Kolok</td>
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<td>Rapid evolution of fitness in the wild: an experimental introduction of Trinidadian guppies. <strong>(FroO22)</strong></td>
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<td>A.P. Hendry, S. Gordon, D.N. Reznick and M.T. Kinnison</td>
<td>Ian Fleming and Sigurd Einum</td>
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<td>Male and female European eels: how to meet after a 6000 km trip under pressure? <strong>(IntO5)</strong></td>
<td>Salon C</td>
<td>A. Vettier, A. Amérand, C. Moisan and P. Sébert</td>
<td>André Péqueux and Philippe Sébert</td>
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<tr>
<td>Tropical Fish Biology</td>
<td>Genomics and Proteomic Approaches in Fish Biology</td>
<td>Advances in Fish Biology</td>
<td>Molecular, Cellular and Neuroendocrine Responses to Stress in Fish</td>
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<td>Adalberto Val</td>
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<td>Bruce Barton and Luis Afonso</td>
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<td>N. Miles and R. West</td>
<td>A.Y. Gracey and A.R. Cossins</td>
<td>J.E. Reid and S.J. Peake</td>
<td>M.M. Vijayan, S. Wiseman and N. Aluru</td>
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<td>How important is diadromy and variable life histories for Australian coastal riverine fish communities? (TroO1)</td>
<td>Functional genomics of environmental adaptation in fish. (ProO1)</td>
<td>Behaviour and physiology of smallmouth bass (<em>Micropterus dolomieus</em>) in an experimental fishway. (AdvO16)</td>
<td>Molecular responses to stress in fish; the role of cortisol. (MolO1)</td>
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<td>Diurnal nitrogen excretion rhythm of the ureogenic gobiid fish (<em>Mugilogobius abei</em>). (TroO4)</td>
<td>Development of genomic resources for Atlantic cod (<em>Gadus morhua</em>). (ProO4)</td>
<td>Electretinographic assessment of visual function in six commercially and recreationally important estuarine fishes. (AdvO19)</td>
<td>Aryl hydrocarbon receptor-dependent transcriptional responses in the brain of rainbow trout. (MolO4)</td>
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<td>Water and ion balance in the African lungfish <em>Protopterus dolloi</em> and <em>Protopterus annectans</em>. (TroO5)</td>
<td>Genomic resources for studying early life stage salmonid health. (ProO5)</td>
<td>Assessment of new molecular stress indicators in fish applied to immune stressors. (MolO5)</td>
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<td>A statin drug affects 3-hydroxy-3-methylglutaryl coenzyme A reductase (HMGCoAR) activities in rainbow trout (<em>Oncorhynchus mykiss</em>). (ImpO23)</td>
<td>How lake morphology can predict fish populations. (FroO23)</td>
<td>The behavioural physiology of migration mortality in adult Pacific salmon. (IntO6)</td>
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<td>Differential expression of nuclear receptors in the mullet <em>Chelon labrosus</em> exposed to PFOS and to prestige-like fuel oil. (ImpO24)</td>
<td>Alternative phenotypes in the variable environment: frequency dynamics in coho salmon (<em>Oncorhynchus kisutch</em>). (FroO24)</td>
<td>Renal function, blood pressure and metabolic rates of Fraser River sockeye salmon infected with <em>Parvicapsula minibicornis</em>. (IntO7)</td>
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<td>Potential effect of tebufenozide on lake trout (<em>Salvelinus namaycush</em>) immune response. (ImpO26)</td>
<td>Determining the spatial scale of local adaptation in the Atlantic silverside across the North American latitudinal gradient. (FroO25)</td>
<td>Importance of vision and the influence of light and temperature on activity patterns in migratory sea lampreys. (IntO8)</td>
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<td>1130</td>
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<td>J.A. Nelson, P.S. Gotwalt and C.A. Simonetti</td>
<td>J.B.K. Leonard and A. Sreenivasan</td>
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<td>Population level differences in endurance but not sprint performance are due to phenotypic plasticity in a cyprinid. (FroO27)</td>
<td>A morphometric and physiological comparison of resident and coaster strains of brook trout in a field setting. (IntO10)</td>
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<td>Tropical Fish Biology</td>
<td>Genomics and Proteomic Approaches in Fish Biology</td>
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<tr>
<td>Biochemical and physiological responses to hypoxia in an Amazonian cichlid, <em>Astronotus ocellatus</em>. (TroO7)</td>
<td>Identifying candidate genes in a non model organism: merging genetic mapping and population genomics in the lake whitefish (<em>Coregonus clupeaformis</em>). (ProO7)</td>
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<td>Oxygen chemoreception and reflex development in fish: the involvement of ionotropic glutamate receptors. (TroO8)</td>
<td>The influence on gene-environment interactions on GHR and IGF-1 expression level and their effect on growth in brook char, <em>Salvelinus fontinalis</em>. (IonO3)</td>
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<td>Are the fish of the Amazon prepared to face anthropogenic challenges? (TroO9)</td>
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<td>Stress protein expression in fish: effects of development stage, protein damage and hormones. (MolO10)</td>
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<td>R.L. Sharpe, W. Woodhouse, T.W. Moon, V. Trudeau and D.L. MacLatchy</td>
<td>Beta-sitosterol alters gonadal steroidogenic acute regulatory protein (STAR) expression in goldfish (Carassius auratus). (ImpO29)</td>
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<td>G. De Boeck, J. Hattink, T. Franklin, C. Bucking, S. Wood, P. Walsh and C.M. Wood</td>
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<td>1430</td>
<td>D. Alsop, S. Brown and G. Van Der Kraak</td>
<td>The effects of copper and benzo-a-pyrene on retinoid homeostasis and reproduction in zebrafish. (ImpO32)</td>
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**Poster Viewing and Judging for Symposia:**
- Capture and Discard/Release of Fish: Behavioural and Physiological Aspects (1)
- Cardiovascular Physiology (6)
- Disease, Parasites, and the Host Response (8)
- Genetically Modified Fish: Effects of Ectopic Gene Expression on the Biology of Fishes (6)
- Integrative Physiology of Migrating Fishes (7)
- Ion and Acid-Base regulation in fish (7)
- Linking Fish Biology to Improved Performance in Finfish Aquaculture (8)
- Molecular, Cellular and Neuroendocrine Responses to Stress in Fish (9)
- Welfare of Fish (10)

**Notes:**
Numbers in parentheses indicate the number of poster contributions in each Symposium.

Detailed listing of poster presentations follows on pages 42-44 for this session.
## Posters

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### Posters of Interest

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<td>From lists of proteins to functional sets: proteomics in zebrafish and sunfish. (ProO13)</td>
<td>A biochemical basis for reductions in whole animal metabolic rate during salinity stress in Mozambique tilapia (* Oreochromis mossambicus*). (IonO8)</td>
<td>Impact of Aroclor 1254 on the organismal and cellular stress response in rainbow trout (<em>Oncorhynchus mykiss</em>). (MolO13)</td>
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Delegates presenting posters please set up your poster during this session.

Preliminary viewing and judging will commence at 3:10PM.
### Impact of Contaminant Exposure on Fish: Molecular Mechanisms to Ecotoxicology

**Friday July 21**

(Late Afternoon)

**Room** | **Salon A** | **Room** | **Salon B** | **Room** | **Salon C**
---|---|---|---|---|---
**Moderator(s)** | Chris Kennedy and Alan Kolok | **POSTER SESSION 2** |  |  |  
1510 | S.S. Soares, M. Aureliano, J. Coucelo and C. Gutiérrez-Merino
Cardiac mitochondria as a major target of decavanadate. (ImpO33) |  |  |  |  
1530 | V. Bourret, L. Bernatchez, P. Couture and P.G.C. Campbell
Ecotoxicology of wild yellow perch (*Perca flavescens*) populations chronically exposed to a polymetallic gradient: a genetic approach. (ImpO34) |  |  |  |  
1550 | M.J. Bakke and T.E. Horsberg
Effects of algae produced neurotoxins on brain activity in Atlantic salmon (*Salmo salar*). (ImpO35) |  |  |  |  
Fish kill mechanisms by the ichthotoxic alga *Chattonella marina*. (ImpO36) |  |  |  |  
1630 |  |  |  |  |  

**Poster Viewing and Judging for Symposia:**

- Capture and Discard/Release of Fish: Behavioural and Physiological Aspects (1)
- Cardiovascular Physiology (6)
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**Notes:**

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Detailed listing of poster presentations follows on pages 42-44 for this session.
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<td>Glucokinase (GK) and hexokinase (HK) expression and activities in rainbow trout tissues: changes with food deprivation and re-feeding. (LinO1)</td>
<td>Marine teleost intestinal salt and water absorption. (IonO11)</td>
<td>Aggression, cortisol and monoamines in <em>Oncorhynchus mykiss</em> are modulated by corticotropin-releasing factor (CRF). (MolO16)</td>
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<td>Development and distribution of intestinal enzymatic activity in <em>Paralabrax maculatofasciatus</em> larvae. (LinO2)</td>
<td>A major role for calcium in regulating intestinal ion and water absorption in marine teleosts. (IonO12)</td>
<td>Central influence of CRH on agonistic behaviour in rainbow trout (<em>Oncorhynchus mykiss</em>). (MolO17)</td>
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<td>Use of enriched rotifers and artemia during larviculture of Atlantic cod (<em>Gadus morhua</em>): effects on early growth, survival and lipid composition. (LinO3)</td>
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<td>CRF-related peptides and serotonin as regulators of food intake in rainbow trout (<em>Oncorhynchus mykiss</em>). (MolO18)</td>
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<td>L. Gonzalez-Reynoso and N.W. Pankhurst</td>
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<td>Dietary energy requirement of triploid brook trout, <em>Salvelinus fontinalis</em>. (LinO4)</td>
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<td>Effects of CRF and urocortin on <em>in vitro</em> ovarian steroidogenesis by follicles from <em>Acanthochromis polyacanthus</em>. (MolO19)</td>
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<td>Innate variation in eye-parasite resistance, spleen size and anti-predator behavior in juvenile Arctic charr. (LinO6)</td>
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Preliminary poster judging and viewing.
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<td>The effects of acute, low dosage exposure to a common pollutant on social recognition and shoaling in sticklebacks. (ImpO37)</td>
<td>Frequency distribution of stress coping strategies in five populations of brown trout (Salmo trutta). (FroO28)</td>
<td>In the light of the international polar year 2007-2008: what do we know and what remains to be discovered about polar fish. (CarO1)</td>
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<td>Airborne contaminants and the effect on fish in western U.S. National Parks. (ImpO38)</td>
<td>The role of morphology and swimming performance in the ecological success of wild and cultured European sea bass. (FroO29)</td>
<td>Chronic swim training influences the development of the cardiovascular system in zebrafish. (CarO2)</td>
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<td>Gill surface area and heart size of different strains of Arctic char (Salvelinus alpinus). (CarO4)</td>
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<td>Stress condition in Russian pikeperches. (FroO32)</td>
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<tr>
<td>Brain stereotaxy and gene expression: essentials tools for neuroendocrinology. <em>(FisO1)</em></td>
<td>Production of all-female Atlantic halibut for commercial aquaculture. <em>(LinO7)</em></td>
<td>A gut that does more than make poop: ammonia volatile in the intestinal air breathing loach. <em>(IonO13)</em></td>
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<td>Identification of myostatin interacting proteins using a yeast-two hybrid approach. <em>(FisO2)</em></td>
<td>Effects of water temperature on molecular and phenotypic gender development in Atlantic halibut. <em>(LinO8)</em></td>
<td>Examining the potential effects of digestion in teleost fish. <em>(IonO14)</em></td>
<td>Stress and consequences in the urban ocean –studies on marine fishes of the Southern California Bight. <em>(MolO22)</em></td>
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<td>Ecofish: a tool for instruction in fish ecophysiology. <em>(FisO6)</em></td>
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**VIIth International Congress on the Biology of Fish – Program Guide – Page 26**
| Saturday  
| July 22  
| (Late Morning) | Welfare of Fish | Genetically Modified  
<p>| Fish: Effects of Ectopic Gene Expression on the Biology of Fishes | Cardiovascular Physiology |
| Room | Salon A | Salon B | Salon C |
| Moderator(s) | Gilson Volpato and Victoria Braithwaite | Garth Fletcher and Bob Devlin | Tony Farrell and Michael Axelsson |
| Well-being – do we know what it means for a fish? (WelO1) | Improved transgenic tilapia for accelerated growth. (GenO1) | Sex differences in cardiac biochemistry and physiology in rainbow trout: what have we been missing? (CarO6) |
| 1030 | V.A. Braithwaite | M. Concepcion, J. Reitsma, M. Phelps, E. Mobley and T. Bradley | P.C. Mendonça and A.K. Gamperl |
| Pain perception and suffering in teleost fish. (WelO2) | Overexpression of myostatin in fish. (GenO2) | Nervous and humoral control of cardiac performance in the winter flounder (P. americanus). (CarO8) |
| Do the electric organ discharges of black ghost knife fish (Apterovenus albifrons) serve as indicators for the fish’s welfare status? (WelO3) | Selective breeding of Atlantic salmon (Salmo salar) affects growth hormone action on growth. (GenO3) | Control and function of the venous circulation in fish. (CarO9) |
| Learning capacities of Atlantic cod (Gadus morhua). (WelO4) | Developmental and metabolic rates of growth hormone transgenic Atlantic salmon (Salmo salar) during early ontogeny. (GenO7) | Why don’t hearts fail during maximum prolonged swimming in rainbow trout, Oncorhynchus mykiss? (CarO10) |
| Measuring fearfulness in rainbow trout, Oncorhynchus mykiss: plasticity of a “fixed” trait. (WelO5) | Myogenesis and muscle metabolism in Atlantic salmon (Salmo salar) made transgenic for growth hormone. (GenO5) | |</p>
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### Welfare of Fish

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**Session Legend:** Each Session is identified by Symposium, Oral or Poster, and Order. For example, “OlfO7” is the seventh talk in the Olfactory Symposium and “AdvP1” is the first poster in the Advances in Fish Biology Poster Session.

**Symposium Codes:**

Adv = Advances in Fish Biology
Bio = Biomarkers of Environmental Pollution in Fish.
Bon = Bones and Teeth: Biomineralisation in Fish from Microscopy to Design of Materials.
Cap = Capture and Discard/Release of Fish: Behavioural and Physiological Aspects
Car = Cardiovascular Physiology.
Dis = Disease, Parasites, and the Host Response.
Ear = Early Life History Stages of Fish.
Fis = Fish Physiologist's Toolbox
Fro = From Individual to Population Processes in Fish
Gen = Genetically Modified Fish: Effects of Ectopic Gene Expression on the Biology of Fishes.
Hyp = Hypoxia Tolerance in Fish: Effects of Chronic and Intermittent Hypoxia.
Imp = Impacts of Contaminant Exposure on Fish; Molecular Mechanisms to Ecotoxicology.
Int = Integrative Physiology of Migrating Fishes.
Ion = Ion and Acid-Base regulation in fish.
Lin = Linking Fish Biology to Improved Performance in Finfish Aquaculture.
Mol = Molecular, Cellular and Neuroendocrine Responses to Stress in Fish.
Mus = Muscular Aspects of Fish Locomotion: Anatomy, Physiology, and Biomechanics.
Nor = North Atlantic Fish.
Olf = Olfactory and Chemosensory Communication in Fish: From Mechanisms to Behavior
Ple = Plenary Session
Pro = Proteomic and Genomic Approaches in Fish Biology.
Tel = Telemetry: Tracking Fish in Nature.
Tro = Tropical Fish Biology
Wel = Welfare of Fish
EFFECT OF ARTIFICIAL SUN-LIGHT ON LONG-TERM TOXICITY OF WATER SOLUBLE OIL COMPOUNDS IN ARCTIC MARINE SPECIES

N. Aarab, D.M. Pampanin, A. Nævdal, K.B. Øysæd, T. Baussant, B.K. Larsen
E-Mail: naa@irisresearch.no
IRIS-Akvamiljø, Mekjarvik 12, N-4070 Randaberg, Norway

Session: ImpP9
Abstract: The Barents Sea and Arctic area are generally considered environmentally sensitive areas. With the off-shore oil exploration and production moving towards arctic regions the knowledge about the environmental impact of such activities has to be improved. The spring/summer months in the arctic/sub-arctic areas are characterised by more or less constant light exposure and low temperature, and therefore photo-oxidation may contribute relatively more to degradation of oil than in temperate areas. Photo-toxicity of oil compounds/PAHs is believed to occur via two main pathways called photo-modification and photo-sensitization. Photo-modification consists of chemical alterations of compounds, typically addition of one or several oxygen atom, and the product may be more toxic than the parent compound. The damaging effect to the tissue/organism is believed to be caused by oxidative stress related mechanisms. The primary objective of this exposure experiment was to determine whether UV irradiation enhances the toxicity of crude oil at lower temperatures (around 4 °C) in adult polar cod (Boreogadus saida). Exposure to the water soluble fraction of a North Sea crude oil was done using an oil generator column. The water soluble fraction was diluted to two different concentration levels with a factor 10 in difference. Fishes were exposed for 3 weeks to one of the following condition: 1) control (exposed to visible light only), 2) low concentration of PAHs, visible light, 3) high concentration of PAHs, visible light, 4) low concentration of photo-modified PAHs, visible light and 5) high concentration of photo-modified PAHs, visible light. At the end of the exposure, liver was removed from 10 individuals from each group and divided into tow samples. The first one was for histological analyses and the other one for biomarkers. Preliminary results showed that photo-modified oil compounds had a negative impact on general health and condition of the fish. During oil exposure, the skin colour became paler and the fish lost their appetite. Biomarker analyses (TOSC assay and MDA), related to damage caused by oxidative stress related mechanisms, were performed. Histopathology analysis was carried out: lipofuscin and neutral lipids in liver and morphology of gill. Both biomarker and histological data are discussed. The project was founded by the Research Council of Norway (grant # 159176/S40).

HOW LAKE MORPHOLOGY CAN PREDICT FISH POPULATIONS

M.V. Abrahams & M. Mangel
E-Mail: Mark_AbrAMS@Umanitoba.ca
University of Manitoba & University of California at Santa Cruz

Session: FroO23
Abstract: Based upon known mechanisms of inter and intra-specific competition involving brown trout and arctic char, variation in their foraging behaviour, as well as details of their physiology and variation in thermal tolerance, we sought to determine how such processes may interact with the physical environment at the level of the individual to influence processes visible at the population level. To do this we developed an individual-based population model that produced spawning populations of trout and char within a Scottish loch. Through sensitivity analysis, we identified the specific parameter values that had the greatest impact upon key population parameters, with our focus specifically on the production of a piscivorous morph of the brown trout, the ferox trout. Once we did this, we then explored the role of lake morphology on population structure. Our data indicate that ferox trout are produced only within a particular range lake morphologies. Various population mechanisms are responsible for this, including lake morphology that generate intense intraspecific competition that stunt growth, as well as population mechanisms where very small numbers of large piscivores can exert indirect effects that reduce growth rates within both trout and char populations. That lake morphology can generate such striking population level effects are discussed with respect to the role of conservation ecology and promoting the existence of specific population sub-types.

TRIPLOIDY INDUCTION BY COLD SHOCK IN THE SPOTTED SAND BASS (Paralabrax maculatofasciatus)

E-Mail: silviedumas@hotmail.com
Unidad Piloto de Maricultivos, CICIMAR-IPN. La Paz, B.C.S. Mexico

Session: LinP9
Abstract: Most marine broodstock under culture conditions show problems related to gonad development, reducing growth rates and flesh quality. Chromosome manipulation is a possible solution to these problems. Shock temperature is among the most effective methods to induce triploidy due to the facility of the process. Cold shock was applied to find the optimal conditions for triploidy induction. Spotted sand bass broodstock were kept in 600 L circular tanks connected to a

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recirculation water system. Males and females were injected with LHRH-a at 25 and 12.5 mg kg/fish, respectively. Cold shock was applied at 5, 10 and 15 min after fertilization. Shock temperatures were 12, 8 and 4 ºC during 5, 10, 15 and 20 min each. Embryos were later incubated at 25 ºC. Ploidy was determined by flow citometry in 35 h post-hatched larvae. 100 % triploids were obtained only in the 5 min after fertilization treatment with approximately 80% survival. No significant differences were detected in the percentage of triploidy between the three temperatures. The duration of the treatment showed significant differences in the percentage of triploidy. The survival was significantly lower in the temperature of 12 ºC and 4 ºC compared to the temperature of 8 ºC. The optimal treatment for triploidy induction in the spotted sand bass was to apply a 8 ºC shock, 5 min after fertilization with a duration of 20 min. Supported by SEP-CONACYT, SIP, PIFI, and COFAA-IPN, México.

ENERGETIC COSTS OF PCB-126 EXPOSURE IN RAINBOW TROUT (Oncorhynchus mykiss): IN VITRO STUDIES
S. Al-Hameedi and T.W. Moon
E-Mail: salha049@uottawa.ca
Dept. of Biol., Univ. of Ottawa, Canada

Session: ImpO30
Abstract: Aquatic organisms are continuously exposed to environmental toxicants released from various anthropogenic and non-anthropogenic sources. Many such pollutants including polychlorinated biphenyls (PCBs) and dibeno-p-dioxins induce hepatic detoxifying enzymes. Estimating the activity of hepatic CYP1A (measured as ethoxyresorufin-O-deethylase, EROD) is considered to be a useful biomarker of exposure in many species including fish. A portion of the assimilated energy by the fish is dedicated to detoxification but quantifying the actual proportion of energy going to this process needs clarification. This study proposes that induction of detoxifying enzymes under continued toxicant exposure invokes additional energetic costs to the organism and that detoxification results in the mobilization of energy reserves (lipid, glycogen and protein) and repartitioning of cellular metabolism. To address these questions we first determined that a 24 h exposure to 1nM PCB-126 induced maximal EROD activity in trout hepatocytes in vitro. The effects of detoxification by P4501A on energy metabolism are assessed in the presence of PCB-126 and resveratrol (RVT). RVT, a naturally occurring phytoalexin, inhibits CYP1A activity and expression in mammals and trout, respectively. Preliminary data found that RVT inhibits maximal EROD activity by approximately 50% at 10^{-5} to 10^{-4} M. Studies are currently establishing a dose-response for RVT inhibition of trout hepatocyte EROD activities. Further studies will assess detoxification costs as measured by changes in oxygen consumption, CYP1A1 protein expression and energy metabolism in hepatocytes exposed to PCB-126 and RVT to determine the metabolic costs of detoxification and possible trade-offs required by intoxicated fish. Funded by NSERC Canada.

THE EVOLUTION AND FUNCTION OF TELEOST OLFALCTORY RECEPTORS
Alioto, T.,^1 Luu, P.,^1 Acher, F.,^2 Bertrand, H.O. and Ngai, J.^1
E-Mail: jngai@socrates.berkeley.edu

^1 Department of Molecular and Cell Biology, University of California, Berkeley, California 94720, USA; ^2 Laboratoire de Chimie et Biochimie Pharmacologiques et Toxicologiques, UMR8601-CNRS, Université René Descartes-Paris V, 75270 Paris, France; ^3 Accelrys, 91893 Orsay, France

Session: OlfO1
Abstract: The identification of an odorant’s chemical structure by the vertebrate olfactory system is thought to occur through the combinatorial activity from multiple receptors, each tuned to recognize different chemical features. What are the molecular principles underlying the selectivity of individual odorant receptors for their cognate ligands? As an approach toward addressing this question, we have carried out data mining to identify all the candidate olfactory receptors encoded in the genome of zebrafish, an excellent model for functional and developmental studies on sensory systems. Our efforts have led to the characterization of the complete set of olfactory receptors belonging to the “OR” family (A family GPCRs), as well as two families of receptors showing similarities to the mammalian V1R (A family) and V2R (C family) vomeronasal receptors. A comparative genomics analysis of these gene families in different vertebrates provides insights into the evolutionary processes shaping the vertebrate olfactory receptor repertoire. In addition, molecular modeling illuminates the parameters underlying ligand recognition and selectivity in the C family GPCR chemosensory receptors.
MECHANISMS OF SEAWATER ADAPTATION IN JUVENILE GREEN STURGEON (Acipenser medirostris)

Peter J. Allen¹⁲, Joseph J. Cech, Jr.¹ and Dietmar Kültz²
E-Mail: pjallen@ucdavis.edu
¹Dept. of Wildlife, Fish, and Conservation Biology, ²Dept. of Animal Science, University of California, Davis, USA

Session: IonP1
Abstract: Anadromy is a life history type that is characteristic of many fishes, yet little is known of the mechanisms that confer seawater adaptability in the more ancestral groups, such as Acipenserids or sturgeons. Sturgeons, one of the ancestral groups of Osteichthyes, were formerly of great economic and cultural importance throughout the Northern Hemisphere, but now are greatly imperiled. Therefore, study of these mechanisms has both basic and applied values. Green sturgeon, Acipenser medirostris, which represent sturgeons that migrate into oceanic seawater, are able to tolerate seawater relatively early in their life history. To learn more about the osmoregulatory mechanisms used by this species, and to predict the timing of seawater entry, three different ages (100, 170, and 533 days post hatch; dph) of juvenile green sturgeon were acclimated for 7 weeks to one of three salinities (≤ 3, 10, or 33 ‰). After the acclimation period, blood and intestinal fluids and solids were collected and measured for osmolality, Na⁺, K⁺, Cl⁻, Ca²⁺ and Mg²⁺. Gill, kidney, pyloric caeca, and spiral intestine tissue were collected and measured for Na⁺, K⁺-ATPase activity, and chloride cell size and abundance in the gills using cell dissociation and tissue microarrays quantified by laser scanning cytometry. Sturgeon ion concentrations, tissue enzyme activities, and chloride cell characteristics indicate a body size effect in hypo-osmoregulatory abilities, and that fish > 170 dph most likely make the transition to seawater. Research was funded by the California Bay-Delta Authority, USBR, USFWS, and NSF (NSF-MCB0244569).

TAMBAQUI (Colossoma macropomum) IS RESPONSIVE TO DIFFERENT LEVELS OF PROTEIN AND LIPID

L.C. Almeida, L.M. Lundstedt and G. Moraes
E-Mail: gil@power.ufscar.br
Lab. Adaptive Biochemistry, Federal University of Sao Carlos, Brazil

Session: LinP1
Abstract: Replacement of dietary proteins by fats is a promising perspective to supply energetical needs. The study of digestive secretions in fishes may contribute to solve nutritional problems. The degree of adaptation of digestive proteases, amylase and lipase was undertaken in tambaqui fed with 20, 25, 30 and 35% of protein, and 4, 6, 11 and 14% of lipid in isocaloric diets. Digestive protease was responsive to dietary protein in stomach where the highest specific activity was observed. Unspecific protease activities from intestine were very low. Lipase was observed in all the alimentary canal. The higher activities were observed in stomach. However, pyloric cecum, anterior and posterior intestine were the responsive sections of the gut to the dietary lipid. Amylase was detected in all digestive tract but pyloric cecum was the most relevant amylase producer. Positive correlations were observed between anterior intestine lipase versus dietary lipid (PC=0.931) and pyloric cecum amylase versus dietary protein (PC=0.808). Tambaqui adapts the main digestive enzymes to the food intake. The protease profile of tambaqui underlines a fine adjustment of diet components. The study of the outline on digestive enzymes is becoming a relevant tool to predict and optimize the feed composition of fishes. This work was supported by the Brazil Research Agencies: FAPESP and CNPq.

BIOCHEMICAL RESPONSES TO HYPOXIA: THE FISH MODEL OSCAR

Almeida-Val, V.M.F
E-Mail: veraval@inpa.gov.br
Laboratory of Ecophysiology and Molecular Evolution, National Institute for Research in the Amazon, Brazil.

Session: TroO6
Abstract: Natural episodes of hypoxia occur globally and have different causes and effects. In the Amazon, flood pulses occur annually and cause oscillations in dissolved oxygen periodically, as the daily episodes of severe hypoxia in varzea lakes and igapos. The sequence of responses presented by organisms when facing hypoxia includes behavioral, physiological, metabolic, and biochemical adjustments, all of them thought to be the result of gene regulation and signal transduction. The Amazon fish species referred as Oscar (Astronotus spp,) are tolerant to hypoxia and anoxia, and have become a model for studies of the effects of hypoxia and anoxia. We have shown a strong correlation between such tolerance to hypoxia and fish size for these fish species. This increase in tolerance relies on behavioral changes, metabolic depression, and increased anaerobic power. Different from small animals, larger fish keep their metabolic rates when PO2 decreases. These characteristics are followed by a reduced level of activity and a higher ability for anaerobic metabolism in larger animals. Recent work revealed that they do have many biochemical adjustments in blood oxygen saturation and phosphate related metabolites, such as PCr, ADP and ATP. All these responses involve adjustments of gene regulation and
gene expression. For LDH these adjustments affect its absolute activity. The mRNA rates practically duplicate when animals are exposed to hypoxia and anoxia. In overall, responses to graded and acute hypoxia in Oscar can be described as a coordinated set of biochemical and physiological adjustments, orchestrated by regulatory processes. * Financial support: CNPq and FAPEAM. VMFAV is supported by National Research Council (CNPq).

THE EFFECTS OF COPPER AND BENZO-A-PYRENE ON RETINOID HOMEOSTASIS AND REPRODUCTION IN ZEBRAFISH
D. Alsop¹, S. Brown² and G. Van Der Kraak³
E-Mail: dalsop@uwaterloo.ca
¹Dept. of Biology, U. of Waterloo, ON  ²Environment Canada, Burlington, ON  ³Integrative Biology, U. of Guelph, ON

Session: ImpO32
Abstract: The retinoids (e.g. retinyl esters, retinal and retinoic acid) are acquired through the diet and are essential for normal health and reproduction, although few studies have considered their roles in fish. Retinoids are depleted in fish exposed to environmental contaminants, but the physiological impacts of these changes are unknown. We examined whether a link exists between toxicant exposure, whole body retinoid levels and reproduction in zebrafish. Fish were fed a control diet or diets containing elevated copper (Cu) or benzo-a-pyrene (BaP) for 260 days. Long-term Cu and BaP exposure had no effect on growth or mortality. Conversely, females exposed to Cu and BaP had whole body retinoids reduced by 31-63% (primarily decreased retinal and retinyl esters). Despite the effect on retinoids, Cu and BaP did not effect the expression of retinoic acid metabolizing enzymes or reproduction in terms of number of eggs spawned, fertilization rate or egg retinal content. It seems that the quantity of retinoids in the diet were sufficient to meet the requirement for daily retinal deposition in the eggs. Further studies examined the role of dietary retinoids in reproduction. Zebrafish fed a retinoid deficient diet had lower whole body retinoids, and lower egg retinal content. These studies have shown that retinoid levels are sensitive to Cu and BaP in zebrafish, and are a good indicator of long-term toxicant exposure. The importance of dietary retinoids on the toxicological response were also highlighted, and call for further examination of the retinoids (and their precursors) at different levels within a food web impacted by toxicants. These studies were supported by NSERC.

ARYL HYDROCARBON RECEPTOR-DEPENDENT TRANSCRIPTIONAL RESPONSES IN THE BRAIN OF RAINBOW TROUT
N. Aluru and M.M. Vijayan
E-Mail: naluru@uwaterloo.ca
Department of Biology, University of Waterloo, Canada

Session: MolO4
Abstract: Anthropogenic chemicals activating aryl hydrocarbon (Ah) receptor signalling, including polychlorinated biphenyls (PCBs), impair neuroendocrine responses in a variety of fish species. To understand the molecular basis of this response to PCBs, we utilized a custom trout cDNA microarray and examined the transcriptional responses associated with Ah receptor activation. Using the Ah receptor-specific agonist (β-naphthoflavone; BNF) and antagonist (resveratrol; RVT), we investigated the effect of Ah receptor activation on gene expression pattern in rainbow trout brain. Juvenile trout were fed BNF (10 mg/kg/day), RVT (20 mg/kg/day) or a combination of both (RBNF) for 5 days and the brain sampled for array analysis. Our custom array contains 150 known rainbow trout genes amplified from a variety of target tissues, including brain. Higher CYP1A1 transcripts with BNF revealed the activation of Ah receptor signalling, while this response was inhibited by RVT. BNF treatment significantly decreased several candidate genes involved in neuroendocrine and steroidogenic processes, including proopiomelanocortin, pit-1 and steroidogenic acute regulatory protein. RVT did not abolish all the BNF-mediated transcriptional responses, suggesting activation of pathways that were also Ah receptor-independent. In addition, analysis revealed that RVT by itself significantly impacted the expression of select genes compared to the control group. Overall, Ah receptor activation affects the expression of several key genes involved in the neuroendocrine regulation of stress and reproduction in rainbow trout. Funded by NSERC discovery grant.
INFLUENCE OF DIETARY LIPID OXIDATION AND VITAMIN E ON THE STRESS RESPONSE BY ATLANTIC HALIBUT (Hippoglossus hippoglossus L.)
D. Alves Martins1,2, L. Lewis1, S. Hosoya1, L.O.B. Afonso1, S.P. Lall1 and L.M.P. Valente2
E-Mail: Dulce.Martins@nrc-cnrc.gc.ca
1Institute for Marine Biosciences, National Research Council of Canada, Halifax, Nova Scotia, Canada; 2Instituto de Ciências Biomédicas Abel Salazar, Universidade do Porto, Porto, Portugal.

Session: MolP10
Abstract: Diets for cultured marine fish contain high levels of marine origin polyunsaturated fatty acids, particularly prone to oxidation during feed processing and storage. This may represent a loss of nutritional value and be potentially deleterious to fish health, especially in the absence of an adequate amount of antioxidants. Atlantic halibut juveniles (27.7 ± 2.3g) were fed for 14 weeks with diets containing non-oxidized (control; peroxide value = 0.6 meq kg-1), moderately (peroxide value = 7.5 meq kg-1) or highly oxidized (peroxide value = 15 meq kg-1) fish oil, with or without supplementation of a-tocopherol acetate (0 or 300 IU kg-1). Fish were then subjected to a one-hour heat shock (HS) from 12 to 18 C. Plasma cortisol, glucose and red blood cell hsp/hsc70 levels were determined before the HS, immediately after and 6, 12 and 24 hours after HS. A great deal of individual variation in all the parameters analyzed was observed. Plasma cortisol and glucose levels in all groups increased immediately after the HS and declined to normal levels by 6 hours. The red blood cell hsp/hsc70 levels are currently being analyzed. Preliminary results suggest that control groups increased hsp70 levels in response to heat shock. The other experimental groups, however, already exhibited high levels prior to heat shock. This research was funded by AquaNet and the Foundation for Science and Technology (Portugal).

STEROIDS PROFILE DURING THE REPRODUCTIVE CYCLE OF TABARANA (Salminus hilarii), IN NATURAL ENVIRONMENT AND CAPTIVITY
J.S. Amaral1, R.M. Honji2, R.G. Moreira1
E-Mail: julisuzuki@yahoo.com.br
1Núcleo de Ciências Ambientais – UMC; 2Instituto de Biociências - USP Brazil

Session: IntP2
Abstract: Tabarana, Salminus hilarii (Characiformes) is a migratory specie with ecological importance that inhabits the Upper Tietê River. This project compares the gonadal steroids in sixteen females fished in natural environment at a free flowing part of the Tietê River, eleven females upstream near the dam, and eight females, kept in captivity for seven years. The blood was collected, 17b-estradiol (E2) and 17aOH-progesterone (17aOHP) were measured in the plasma using ELISA kits. The ovaries were weighed for the calculation of Gonadosomatic Index (GSI). The females were classified in 4 different reproductive stages: Resting (Rp), Maturation (Mt), Mature (Md) and Regression (R). GSI increased with proceeding reproductive cycle in all experimental groups and was lower in the animals caught near the dam comparing to the river group during the Rp stage. There was a 14-fold increase of E2 from the Rp to the Mt stage in animals kept in ponds. In the same period, animals caught near the dam and the open river showed a 9-fold and 5-fold increase of E2, respectively. During maturation, levels of 17aOHP raised by factor 4.5 in females caught in the open river, 1.9 for the dam group and 1.6 for the captivity group. Comparing the absolute values of groups from river and captivity, E2 was lower in females of the captivity group compared to the river group during the Md stage. These results show that fish in captivity produces more vitellogenin, but less 17aOHP than fish from the river. This can explain difficulties in spawning fish in captivity, since progesterone is the key hormone of final maturation in most teleosts. Financial support: FAPESP and CNPq.

REACTIVE OXYGEN SPECIES METABOLISM AND SILVERING PROCESS IN EUROPEAN EELS (Anguilla anguilla)
A. Amérand, A. Vettier, P. Sébert and C. Moisan
E-Mail: aurelie.vettier@univ-brest.fr
UHPM, EA3879, Université de Bretagne Occidentale, Brest, France

Session: IntP7
Abstract: Previous works in endotherms have shown that production of reactive oxygen species (ROS) is related to metabolic rate. ROS have important effects on membranes mainly if they contain many polyunsaturated fatty acids. Due to the membrane high content in polyunsaturated fatty acids and high swimming activity during migration, the silver eels (SE) appear as potentially very sensitive to ROS attacks. The question is to know if SE counterbalance this sensitivity by installing special mechanisms before the migration. Thus we have measured hydroxyl radical (OH) production (the most active ROS), antioxidant enzyme activities (superoxide dismutase and catalase), the malondialdehyde content reflecting impact of ROS on cellular and sub-cellular membranes and in parallel oxygen consumption (MO2) on red muscle of yellow
eels (YE) and SE. We have observed that YE exhibit a significantly higher MO$_2$ and OH$^-$ production than SE but both stages present the same OH$^-$ production/MO$_2$ ratio. This result confirms that, as in endotherms, there is a narrow relationship between ROS production and metabolic rate in eels. Moreover SE present a significantly higher malondialdehyde content than YE, despite similar antioxidant activities. This can be explained by the increase in membrane fluidity induced by the silvering process, making the SE very sensitive to ROS membrane attack, which can impedes the migration. However, as a large part of SE migration takes place at depth and that we have previously shown that the OH$^-$ production/MO$_2$ ratio is reversed under pressure, we can conclude that ROS effects are probably limited in SE. Funded by the European contract Q5RS-2001-01836.

**ANTIMICROBIAL ACTIVITY OF CYPRINUS CARPIO HDL AND ITS MAJOR PROTEIN (APOA-I): EVALUATION OF A POSSIBLE MECHANISM**

R. Amthauer, C. Alvarez, J. Villanueva, R. López, and M.I. Concha.
E-Mail: ramthaue@uach.cl

Inst. Bioquímica, Fac. Ciencias, Univ. Austral de Chile, Valdivia, Chile

Session: DisP5

**Abstract:** We have recently shown that carp (Cyprinus carpio) HDL in its major apolipoproteins (apoA-I and A-II) display antimicrobial activity in submicromolar and micromolar concentrations against Gram positive and Gram negative bacteria, including some fish pathogens. Although not highly conserved in amino acid sequence, apolipoproteins A are presumably conserved in its overall structure (amphipathic all-α-helical). Intriguingly, these structural features have been long recognized to be critical for their interaction with eukaryotic membranes to remove cholesterol and phospholipids. In this study we hypothesize that the all-α-helix conformation of this family of apolipoproteins is also important for their antimicrobial activity. Our results show that carp apoA-I disrupts dimiristoylphosphatidyl choline vesicles and also preliminary studies indicate it would display channel-like forming activity in neutral planar lipid bilayers. However, permeabilization assays incubating E. coli cells with increasing concentrations of HDL, using propidium iodide as an indicator failed to demonstrate bacterial membrane permeabilization. On the other hand, we detected HDL and free apoA-I binding to E. coli cells by immunofluorescence and also using RITC-labeled HDL. This binding was specific since it was completely displaced by an excess of unlabeled HDL. According to the present data, carp HDL and apoA-I would bind to the bacterial membrane and possibly alter the membrane function by a mechanism involving lipid solubilization. Funded by DID-UACH S-2005-30.

**CRYPTIC FISHES OF THE NATIONAL PARK OF ISLA ISABEL, MÉXICO**

Arreola-Robles, J. L.², Muñoz-Fernández, V. T.¹, Galván-Villa, C. M.¹ and Ríos-Jara, E.¹
E-Mail: vmunoz@cucba.udg.mx

¹Departamento de Ecología, CUCBA-Universidad de Guadalajara. Carretera a Nogales Km. 15.5, Las Agujas Nextipac, Zapopan, Jalisco. CP 45110 México. ²Instituto Tecnológico de Estudios Superiores de Monterrey, Campus Guadalajara, Mexico

Session: TroP3

**Abstract:** The National Park “Isla Isabel” is located in the Mexican Central Pacific, 40 miles off the coast of the state of Nayarit, (21 50’ N-105 53´ W) and it is characterized by rocky and coraline substrata. This characteristic allowed us to find a high species richness of cryptic fishes. The present information is part of the results of a project financed by the CONABIO during the period of October 2004 to May 2005 focused in determinate the composition of cryptic fishes of the island to establish a protection program. They were collected in two different environments using non aggressive anesthetics to the aquatic ambient (clove essence and menthol): the shallow subtidal between 5 and 15 m depth during SCUBA diving, and the tide pools of some rocky beaches. All organisms collected were fixed in a 10% formaldehyde and water solution and then changed to 70% alcohol for final preservation. A total of 127 organisms were collected in 19 sampling sites around the island. 23 species of 21 genera and 15 families were identified. The most abundant species in the tide pools was Bathygobius ramosus (Family Gobiidae); in the subtidal zone, Cirrhithichthys oxycephalus(Family Cirrhitidae) was the most abundant.
PAIN PERCEPTION IN RAINBOW TROUT (*Oncorhynchus mykiss*): IMPACT OF SOCIAL CONTEXT ON BEHAVIOUR AND PHYSIOLOGY

P. J. Ashley¹, C. R. McCrohan² and L. U. Sneddon¹

E-Mail: pashley@liv.ac.uk

¹University of Liverpool, School of Biological Sciences, Liverpool, UK ²Faculty of Life Sciences, University of Manchester, Manchester, UK

Session: WelO10

Abstract: Recent evidence suggests that fish have some capacity to perceive pain. One theory on attention proposes that pain may take priority and “soak up” a large amount of a limited attention pool. In order to understand the relative importance of the nociceptive experience of rainbow trout (*Oncorhynchus mykiss*) behaviour, respiration rate and plasma cortisol levels of noxiously treated fish were assessed in the presence of “attention competing” social situations. Individual fish, treated with a noxious stimulus, exhibited a marked increase in respiration rate combined with significantly higher cortisol levels when compared to controls. However, when fish were held in groups of three where they established a dominance hierarchy, the dominant fish did not display these physiological responses when given a potentially painful stimulus. Noxiously stimulated dominants did show a significant reduction in agonistic behaviour when compared to both saline controls and pre-treatment baseline measures suggesting a behavioural impairment. However, when established dominant fish were placed in a novel social situation, this reduction in agonistic behaviour was not seen. Therefore, dominant individuals in a familiar social setting show a suspension of normal social behaviour for prolonged periods following a noxious stimulus. Yet in a novel social setting the motivation to assert dominance appears to take priority over the potentially painful experience, with the fish paying more attention to aggression than pain. Funded by BBSRC UK

HYPOXIA REGULATES TELOMERASE EXPRESSiON IN FISH


*E-Mail: bdhwtau@cityu.edu.hk

Centre for Coastal Pollution and Conservation, Department of Biology and Chemistry, City University of Hong Kong, Kowloon, Hong Kong SAR, PRC

Session: HypO9

Abstract: Telomerase not only ensures the maintenance of telomere length in eukaryotes but also plays a role in cellular survival and growth control. Hypoxic regulation of telomerase reverse transcriptase (TERT) gene expression has been reported in a variety of tumor human cells. To ascertain hypoxia also plays a role in TERT regulation in fish, we employed the marine medaka (*Oryzias melastigma*) as a model fish to test the hypothesis that hypoxia regulates TERT gene expression in fish. We first cloned and characterized the TERT cDNA gene, omTERT, from the marine medaka. Computer-aided analysis of the 5′-flanking sequence identified two HRE (hypoxia-responsive element; nt. -283 and -892) cores. Overexpression of Hypoxia Inducible Factor 1 α (HIF-1α) induced the omTERT promoter activity was demonstrated by transient transfection assays. In response to hypoxic stress (1.8±0.2 mg O2 L-1, 96 h), omTERT was upregulated by 2-fold in the testes and 1.6-fold in the livers with a concomitant induction of the hypoxia-inducible factor 1α (omHIF-1α) and erythropoietin (omEpo) genes. Using in situ hybridization, hypoxia-induced increase of omTERT mRNA was evident in the posterior region of liver parenchyma and in the cysts containing spermatogonia. Overall, our in vivo and in vitro data demonstrate hypoxia-mediated transcriptional upregulation of TERT gene in fish. For the first time, hypoxia is identified to be a regulator for expression TERT not only in tumors and human cells, but also in whole fish system, which could pose a protective function on cell growth and survival under hypoxia. Funded by the University Grants Committee of the Hong Kong Special Administrative Region, China (Project no. AoE/P-04/04) and the CityU grant (Project no. 7001834).

UTILIZING RADIOTELEMETRY TO INVESTIGATE PASSAGE BEHAVIOR AND SURVIVAL OF JUVENILE SALMONIDS IN THE COLUMBIA RIVER BASIN

G. A. Axel, E. E. Hockersmith, and D. A. Ogden

E-Mail: Gordon.Axel@noaa.gov

Northwest Fisheries Science Center, NOAA Fisheries Service, 2725 Montlake Blvd. E. Seattle, WA 98112, U.S.A

Session: TelO4

Abstract: Since the listing of Pacific Northwest salmonid stocks under the Endangered Species Act in the 1990s, juvenile salmonid passage behavior and survival have been evaluated throughout the Columbia River Basin. It is essential that regional fisheries managers have site-specific passage information and survival estimates for juvenile salmonids on hand in order to make decisions in the best interests of the species. With recent technological enhancements, radiotelemetry continues to provide critical information on passage and survival for juvenile salmonids at hydroelectric dams and through their reservoirs. Over the last 8 years, our sample sizes have increased tenfold in order to achieve a level of precision...
required to identify the most effective fish passage routes. A wireless network for data acquisition and management, reductions in tag size, and new antenna designs to boost detection efficiencies and impede noise reception will be described. These improvements have enabled us to design more comprehensive behavior and survival studies that will continue to help inform management on strategies to optimize survival for juvenile salmonids. Funded by the U.S. Army Corps of Engineers, Walla Walla District.

IN THE LIGHT OF THE INTERNATIONAL POLAR YEAR 2007-2008:
WHAT DO WE KNOW AND WHAT REMAINS TO BE DISCOVERED ABOUT POLAR FISH
M. Axelsson
E-Mail: m.axelsson@zool.gu.se
Göteborg University, Department of Zoology / Zoophysiology

Session: CarO1
Abstract: Ever since the first observation of the fish fauna by the early polar explorers and the question how these animals could live and function in subzero water temperature, scientists have studied these animals. One reason for these studies is the question: “Are they different from temperate fish species?” and if so are these differences due to the cold temperature as such. In this respect the Antarctic species have been of special interest due to the long isolation in a stable environment. Several questions on the cardiovascular system and its control have been investigated. Data from cardiac performance studies using in situ, isolated heart preparations will be compared with data for non-polar species. The heart of the Antarctic species Pagotenia borchgrevinki and Trematomus bernachii living at -1.86°C is capable of surprisingly high power generation for this cold temperature (2.4 and 2.0 mW g⁻¹ WM, respectively), while the Greenland cod (Gadus ogac) show a low power generation capacity at 0°C (0.7 mW g⁻¹ WM). In contrast, shorthorn sculpin (Myxocepalhus scorpius) caught on the west coast of Greenland and tested at 1°C had a maximal power generation of 2.6 mW g⁻¹ WM, a value not dissimilar to 2.5 mW g⁻¹ WM for sculpins caught off the Swedish west coast and acclimated to and tested at 13°C. The integrated control of the cardiovascular system in these species is more than just the performance of the isolated heart and the data from the in situ perfusion studies will be compared to in vivo data on cardiovascular control mechanisms and possible differences compared to temperate species. Funded by Swedish Research Council and the New Zealand Antarctic program

LORDOSIS IN NATURAL POPULATIONS OF Atherina Lagunae IN THE TUNIS NORTH LAKE
Ayed N.¹, Faure E. ², Quignard J. P. ³, Maamouri F. ³ and Trabelsi M.¹
E-Mail: nediasakli@yahoo.fr
¹Unité de Biologie Marine, Faculté des Sciences. Tunis. TUNISIE. 
²Laboratoire de Systématique Evolutive. Université de Provence. Marseille. FRANCE. ; 
³Laboratoire d’Ichtyologie, Université Montpellier II. Montpellier. France ; 
¹Département de Biologie. Faculté des Sciences. Tunis. TUNISIE

Session: DisP7
Abstract: The vertebral abnormalities are common among fishes (Fundulus heteroclitus, Dicentrarchus labrax, Dentex dentex, Salmo salar, Gobius niger, Solea senegalensis). Presently, this is a significant problem, as it influences the economical success of rearing. However, nothing is on record about the skeletal abnormalities of Tunisian fishes. Atherina lagunae (teleostei, Atherinidae) is an euryhaline species lives in the most Mediterranean lagoons. A total of 2047 fish was caught, monthly, in the Tunis north lake during the period from October 2004 to October 2005. They were preserved in 4 % formalin. Deformed fishes were counted, photographed and radiographed. According to X-ray radiographs, vertebral deformities were noticed, especially in the lumbar region (lordosis). This abnormality was observed in 199 Atherines (81 males and 118 females) and occurred in different classes of ages. The level of spinal anomalies is high and constant and exist in different age classes suggesting a serious ecosystem trouble. Several factors, like temperature, pollution, diet, parasitism can induced these deformities.
CENTRAL INFLUENCE OF CRH ON AGONISTIC BEHAVIOUR IN RAINBOW TROUT (Oncorhynchus mykiss)

T. Backström¹, A. Pettersson² and S. Winberg³
E-Mail: tobias.backstrom@ebc.uu.se
¹Dept of Comparative Physiology, Uppsala University; ²Dept of Food Science, Swedish University of Agricultural Sciences; ³Dept of Basic Science and Aquatic Medicine, Norwegian School of Veterinary Science, Norway

Session: MolO17
Abstract: The outcome of agonistic interactions in social animals is depending on several different factors. One of the factors involved is the hypothalamic-pituitary-interrenal (HPI) axis. In addition to its endocrine effects on the HPI axis, corticotropin releasing hormone (CRH) is also known to affect behaviour. In our study we investigated the effect of CRH on agonistic interaction in rainbow trout (Oncorhynchus mykiss). Fish were kept isolated for one week, after which CRH or the CRH antagonist α-helical CRH1-41 (ahCRH) was administrated through intracerebroventricular (ICV) injection, and the fish were allowed to interact with a weight matched control (given saline ICV) for 1 hour. Two doses of CRH and ahCRH were used, 500 and 1000 µg/ml for CRH, and 1000 and 2000 µg/ml for ahCRH. Behaviour during the fights was quantified and dominance noted at the end. Blood plasma was analysed for cortisol. The injection of 1000 µg/ml CRH had a significant effect on social rank, the CRH treated fish becoming subordinate. CRH injection as well as becoming subordinate following social interaction resulted in significantly elevated plasma cortisol levels. These results suggest that CRH affects social behaviour through central effects. Funded by The Swedish Research Council for Environment, Agricultural Sciences and Spatial Planning (FORMAS).

EFFECTS OF ALGAE PRODUCED NEUROTOXINS ON BRAIN ACTIVITY IN ATLANTIC SALMON (Salmo salar)

M. J. Bakke¹ and T. E. Horsberg
E-Mail: marit.bakke@veths.no
Norwegian School of Veterinary Science, Norway

Session: ImpO35
Abstract: In addition to being lethal at high concentrations, toxins released during harmful algae blooms may have implications for the welfare of fish also in sublethal concentrations. The cellular mechanisms of the toxins used in this study are well described, as well as the effects on the peripheral nervous system. However, little is known about the effects on the central nervous system in fish. Over the past decades the interest in the relation between cognitive abilities and welfare in fish has grown. Some of the areas connected to cognitive functions in mammals and birds correspond to areas in the fish telencephalon. Therefore, effects of the neurotoxins on activity in telencephalon are of special interest. This study aimed to look for changes in metabolic activity in different parts of the brain of Atlantic salmon after exposure to sublethal doses of three different neurotoxins produced by algae. Seawater adapted postsmolts (93.4 g ± 1.9 g) were randomly selected to four groups for i.p. injection of saline (control) or one of the neurotoxins saxitoxin (10µg STX/kg bw), brevetoxin (68µg BTX/kg bw) or domoic acid (6 mg DA/kg bw). After 30 minutes, 14C-deoxyglucose (200 µCi/kg bw) was injected i.m., and the fish were sacrificed after an additional 30 minutes whereupon the head was instantly frozen in liquid propane. Sections of the brain (20 µm) were subjected to autoradiographical examination and the autoradiograms were analyzed digitally. Preliminary results suggest that all studied neurotoxins have an effect on the metabolic activity in various parts of the brain. Possible implications of the findings will be discussed. Funded by the Norwegian School of Veterinary Science.

THE IMPACT OF COPPER EXPOSURE ON THE OLFACTORY NEUROETHOLOGY OF COHO SALMON (Oncorhynchus kisutch)

D.H. Baldwin¹, J.F. Sandahl², J.J. Jenkins² and N.L. Scholz¹
E-Mail: david.baldwin@noaa.gov
¹Northwest Fisheries Science Center, NOAA Fisheries, USA; ²Dept. of Molecular and Environmental Toxicology, Oregon State Univ., USA

Session: OlfO9
Abstract: Dissolved copper is one of the most frequently detected trace elements in surface waters from agricultural and urbanized watersheds in the western United States. We evaluated the sublethal effects of short-term copper exposures on olfactory neurophysiology and the odor-mediated predator avoidance behaviors of juvenile coho salmon (Oncorhynchus kisutch). The swimming activity and alarm behaviors of individual fish were measured using three-dimensional digital video, and recordings from the olfactory epithelium (electro-olfactograms) were used to monitor odor-evoked field potentials from animals at the end of each behavioral trial. In this manner, we obtained paired behavioral and
neurophysiological measurements for each fish. Copper exposure concentrations (0–20 µg/L) and duration (3 h) were chosen to reflect an environmentally realistic range of stormwater runoff conditions. Juvenile coho exposed to copper showed a significantly reduced behavioral response to an olfactory predation cue (conspecific skin extract) that was dose-dependent. Copper exposure also reduced the responsiveness of the olfactory epithelium to L-serine, taurocholic acid, and the alarm substance in a dose-dependent manner. The copper-induced reductions in sensory biology and behavior had similar thresholds (~ 3 ppb) and were highly correlated. These results indicate that short-term copper exposures can impair the neuroethology of juvenile salmon, and that electrophysiological measures of sublethal toxicity have direct implications for behaviors that are important for juvenile survival. Funding was provided by the NOAA Coastal Storms Program.

THE URINE OF MALE MOZAMBIQUE TILAPIA SIGNAL SOCIAL STATUS
E.N. Barata1,2, P.C. Hubbard1, O. Almeida1, A. Miranda1, P. Frade1 and A.V.M. Canário1
E-Mail: ebarata@ualg.pt
1Centre of Marine Sciences of Algarve, Faro, Portugal; 2Dept. of Biology, Univ. of Évora, Portugal
Session: OlfO15
Abstract: In the context of reproduction in teleosts, pheromones have been studied mostly in freshwater species with relatively simple mating systems, in which the urine is the main vehicle of pheromone (hormonal pheromones) release. In the lekking cichlid, Oreochromis mossambicus (Peters 1852), males establish social hierarchies and dominant males dig and defend spawning pits where courtship and mating occur. Therefore this species is suitable to study the role of pheromones in more complex social and mating systems. The current study assessed changes in the urination rate of males in different social contexts, and olfactory sensitivity of both sexes to urine of males with different social rank. During their courtship display, males markedly increased their rate of urination, more evidently in the presence of pre-ovulatory than of post-ovulatory females. Resident males also increased urination rate during aggressive displays on encountering intruding males which did not increase their urination rate; fight inhibited urination in both. Increased urination was also observed during aggressive displays between resident males, but not during fight. High social rank males accumulated more urine and their urine evoked electro-olfactograms of larger amplitude in both sexes than low rank males. These results suggest that males advertise actively their dominant status via chemical signal(s) in the urine. The identity of the chemical compound(s) involved, and the behavioural roles in female mate-choice and male-male interactions are currently under investigation. Funded by FCT (POCTI/BSE/38815/2001 and POCTI/BIA-BDE/55463/2004), Portugal.

REGULATION OF GOLDFISH MACROPHAGE DEVELOPMENT
D.R. Barreda1 and M. Belosevic2
E-Mail: barreda@mail.med.upenn.edu
1Department of Medicine, University of Pennsylvania, Philadelphia, PA, 19104 USA; 2Department of Biological Sciences, University of Alberta, Edmonton, AB, T6G 2E9 CANADA
Session: DisO1
Abstract: Over 100 years after the first description of macrophages by Metchnikoff, there are still questions as to the mechanisms leading to the heterogeneity of their lineage. Current views are based on the mononuclear phagocyte system theory, where all macrophages are derived from circulating blood monocytes and ultimately from hematopoietic stem cells in the bone marrow. Our studies on the regulation of goldfish macrophage development suggested that alternate pathways of macrophage hematopoiesis contribute to this heterogeneity. Characterization of primary kidney macrophage (PKM) cultures from goldfish hematopoietic tissues indicated that three distinct subpopulations developed in response to endogenous macrophage growth factors. Morphological, cytochemical, flow cytometric, and functional characterization of cultured macrophages indicated that these subpopulations corresponded to three distinct stages of macrophage differentiation: early progenitors, monocytes, and “mature” macrophages. There appeared to be a stringent control between those early progenitors that self-renewed, and those that were recruited into the maturation pathways. Furthermore, committed cells developed through two distinct differentiation pathways: one consistent with the “classical” pathway of macrophage development (early progenitors -> monocytes -> mature macrophages), and an “alternate” pathway where mature macrophages developed from early progenitors into mature macrophages. Macrophages developing through the “alternate” pathway represented a unique subset of spontaneously growing cells. Their self-renewal was promoted by endogenous macrophage growth factors (M-CSF), and effectively controlled through the production of endogenous macrophage growth inhibitory factors. Characterization of these MGIF identified a novel soluble form of the CSF-1 receptor. The discovery of sCSF-1R and other positive and negative regulators of fish macrophage development, through a differential cross-screen approach, highlighted the inherent complexity in the hematopoietic regulatory machinery of lower vertebrates. Moreover, characterization of the alternate pathway of macrophage development suggested the existence of evolutionarily-conserved mechanisms contributing to the generation of macrophage diversity.
DIFFERENTIAL STRESS RESPONSES IN THE NILE TILAPIA
SUBJECTED TO ELECTROSHOCK AND SOCIAL STRESSORS
R.E. Barreto¹, and G.L. Volpato¹,²*
E-Mail: gilvolp@gmail.com
¹Dept. Physiology, IBB, Caunesp, Unesp, SP, Brazil; ²Dept. Physiology, CB, UFRN, Natal, RN, Brazil.

Session: WelP6
Abstract: Plasma cortisol and glucose levels were investigated in the Nile tilapia, Oreochromis niloticus, subjected to electroshock and social stressor. First, pre-stressor levels were determined after 5 days of adjusting the fish to experimental aquaria (1 fish/ aquarium). Five days later, the stressor effects on both cortisol and glucose levels were assessed. The stressors were imposed for 60 min: pairing with a larger resident animal (social stressor), or a mild electroshock (AC, 20 V, 15 mA, 100 Hz for 1 min every 4 min). Each stressor was tested in two independent groups, one in which stress was quantified immediately after the end of the 60-min stressor imposition (T60) and in another one 30 min later (T90). Pre-stressor cortisol and glucose values were not statistically different among the groups. Plasma cortisol levels increased at similar magnitude for both electroshock and social stressor. Plasma glucose levels increased significantly for electroshock at both timepoints (T60 and T90), while only at T90 for the social stressor. Therefore, electroshock induces a faster glucose increase than the social stressor. Furthermore, a significant positive correlation between cortisol and glucose was only detected on T90 for the social stressor. These results indicate that a fish species responds differently to different stressors, thus suggesting specificity of fish stress response to stress. Funded by CNPq.

PROTOPRISMATIC ENAMEL IN THE AUSTRALIAN LUNGFISH
(Proceratodus forsteri OSTEICHTHYES:DIPNOI)
Barry, J.C. and Kemp, A.
E-Mail: a.kemp@uq.edu.au
University of Queensland, St. Lucia 4072 Australia

Session: BonO7
Abstract: Tooth plates of the Australian lungfish, Neoceratodus forsteri, were examined to analyse the structure of the enamel and its implications for phylogenetic analyses. Methods used included scanning electron microscopy of fresh fracture surfaces of tooth plates, and microtomed sections of undecalcified tooth plates to reveal crystal structure in high resolution transmission electron microscopy. Lungfish tooth plates are covered by layered radial crystallite enamel with a protoprismatic structure containing minute crystals. The protoprisms are much smaller than the ameloblasts that produced them, and are not homologous to the rods of mammalian enamel. The C-axis of the crystals is parallel to the long axis of the protoprism, and the protoprisms are parallel to surface normal. Crystals within the protoprism are exceptionally long, up to 340 nm in length, and the orientation of the crystals within the protoprism has a woven pattern. Individual crystals do not include a centre dark line, and the surface of the hexagonal crystal is rough, and not a smooth facet, as it is in other forms of biogenic apatite. Despite the appearance of a layered radial crystallite enamel in the light microscope, and in low power transmission electron micrographs of young lungfish tooth plates, mature lungfish enamel has little resemblance in fine structure to the enamel of highly evolved tetrapods like reptiles and mammals. A protoprismatic enamel, containing apatite crystals lacking a centre dark line and having a rough surface, is unusual. This research was funded by the Australian Research Council.

PHYSICAL INJURY AND PHYSIOLOGICAL STRESS IN FISH
FROM ELECTROFISHING: PAST ABUSE AND PRESENT USE
B. A. Barton
E-Mail: bbarton@shaw.ca
Applied Aquatic Research Ltd., Calgary, AB T3C 0K3 Canada

Session: WelO6
Abstract: Electrofishing is a popular tool of researchers and managers for catching fish for routine inventories, sample collections, and population assessments. The technique works on the principle of anodic electrotaxis and its effectiveness is highly dependent on electrical output configuration and water conductivity, as well as fish size, water temperature and behaviour of the species. Improper use of electrofishing, which was reviewed thoroughly by Snyder (2003), can cause mortality, permanent spinal damage and deformity, tissue lesions, and extensive hemorrhage. Modern electrofishing techniques and equipment, which use mainly pulsed DC, can minimize damage to fish when used correctly, such as by adjusting pulse width and frequency settings to suit ambient environmental conditions. However, even exposure to relatively mild electroshock can cause physiological stress in fish, which we documented in juvenile bull trout (Salvelinus confluentus) and Arctic grayling (Thymallus arcticus). Plasma cortisol and glucose in these fishes increased to levels
higher than those associated with a relatively severe handling stressor and lasted up to 24 h, although plasma chloride concentrations changed little. Thus, even if not damaging physically, electrofishing can be physiologically stressful to fish. Care in the field and proper training should therefore always be emphasized to those planning to use this method of fish capture. Snyder, D.E. 2003. Electrofishing and its harmful effects on fish. U.S. Geological Survey, Information and Technology Report USGS/BRD/ITR-2003-0002. 149 p.

BIOMONITORING OIL-EXPOSURE EFFECTS USING SPOONHEAD SCULPIN (Cottus ricei) AND JUVENILE LONGNOSE SUCKER (Catostomus catostomus) AS SENTINEL SPECIES

B. A. Barton, C. J. Mushens, and R. A. Keeler
E-Mail: bbarton@appliedaquatic.com
Applied Aquatic Research Ltd., Calgary, AB T3C 0K3, Canada

Session: BioO6
Abstract: Biomonitoring of an oil pipeline break in a northwestern Alberta stream included an assessment of fish effects using spoonhead sculpin (Cottus ricei) and juvenile longnose sucker (Catostomus catostomus) as sentinel species. Gonadosomatic indices in male sculpins declined from 2.40 upstream to 2.28–1.38 at downstream sites below the oil leak, and in females, declined from 7.12 to 5.88–4.57. Fecundity remained relatively constant (310–341 eggs/fish) except in sculpins immediately below the break point (240 eggs/fish). Sculpin egg weights and diameters were variable (1.05–1.61 mg and 1.06–1.20 mm), but a downward trend was apparent. Steroidogenic capacity of female gonads, measured using in vitro incubations of 15–25 mg egg tissue stimulated with forskolin, decreased from 29.7 pg estradiol/mg tissue in sculpins upstream to as low as 8.29 pg/mg in fish downstream. Sculpin condition factors (K) ranged from 1.01 upstream from the break up to 1.26 downstream, whereas those in males ranged from 1.04 upstream up to 1.21 downstream; K in suckers changed less (1.08–1.15). Hepatosomatic indices in suckers decreased from 1.69 to 1.28 downstream, but increased from 3.67 to 5.24 in female sculpins and from 1.88 to 4.55 in males. Histopathological changes observed in sculpin livers were likely from natural causes, however, and not from oil exposure. Necropsy-based health assessment indices for fish were generally higher downstream than upstream for both species but were also highly variable (sculpins: 1.46 vs. 8.33–25.7; suckers: 0.95 vs. 0.00–5.56).

SEX DIFFERENCES IN CARDIAC BIOCHEMISTRY AND PHYSIOLOGY IN RAINBOW TROUT: WHAT HAVE WE BEEN MISSING?

P. K. Battiprolu, R. S. Farrar, K. J. Harmon, N. S. Pierson and K. J. Rodnick
E-Mail: rodnkenn@isu.edu
Dept. of Biol. Sci., Idaho State Univ., USA

Session: CarO6
Abstract: Unlike numerous mammalian studies, studies of cardiac physiology and metabolism in fishes have paid little attention to sex or the possibility of sex differences. We determined effects of glucose, sex steroids, and Ca$^{2+}$ on cardiac contractility and metabolism in sexually immature, male and female trout. We also measured stored energy (glycogen, protein and triglycerides) in cardiac tissue. Fish were euthanized by blunt trauma. Ventricles were either 1) frozen rapidly and assayed for stored energy substrates or 2) dissected into uniform strips, attached to isometric force transducers, stretched to 90% of Lmax, and electrically-stimulated at 0.5 Hz under aerobic conditions in either glucose or substrate-free media for 60 min at 14 °C. Strips were treated with either testosterone or estradiol and controls received glucose or substrate-free conditions for the duration of experiments during which twitch force (F) and media metabolites were measured. Our results demonstrate that 1) cardiac glycogen was higher in males compared with females; 2) exogenous glucose (independently) and testosterone (males) or estradiol (females) all promoted F; however, increments in contractility were greater in males; 3) lactate release was 2-fold greater in females; and 4) female ventricle strips were more sensitive to Ca$^{2+}$ than males. Similar to mammalian studies, our findings suggest that sex differences exist in cardiac energy metabolism, hormone responsiveness and Ca$^{2+}$ sensitivity. Future studies should document and consider sex as an important variable for cardiac metabolism and performance in fishes. Funded by NIH P20RR16454, NSF-Idaho EPSCoR EPS-0447689, and NSF IOB-517669.
TEMPERATURE AND IGF SYSTEM COMPONENTS AS MARKERS OF FISH GROWTH

Beckman1, BR, Shimuzu2, M, Gadberry1, B, Parkins2, P. and Cooper2, KA

E-Mail: Brian.Beckman@noaa.gov

1Northwest Fisheries Science Center, NOAA Fisheries, Seattle, WA, 2School of Aquatic and Fishery Sciences, University of Washington, Seattle, WA, USA

Session: FisO13

Abstract: Insulin-like growth factor-I is one of the primary endocrine mediators of growth in vertebrates. The actions of IGF-I are extensively modified by a family of IGF binding proteins (IGFBPs) in mammalian systems. The effects of environmental variation on the IGF-I system and subsequently on growth have yet to be fully elucidated in piscine systems. Here we describe the effects of changing temperature regimes on plasma IGF-I and 22 and 41 kDa IGFBP levels. Post-smolt coho were PIT-tagged, placed in eight 1.3m circular tanks and subjected to the following temperature regimes (two tanks each): 11°C Constant, 16°C Constant, 6 to 11°C Fluctuating (daily) and 11 to 16°C Fluctuating (daily). Fish held under each temperature regime were fed either a Hi or Lo ration varying between 1 and 2.5% body weight/day depending upon temperature. All fish were measured at two to three week intervals over the next two months (a total of four samples) and sub-samples of 12 -15 fish/tank was obtained, plasma collected, and plasma IGF-I and 22 and 41 kDa IGFBPs were measured by RIA. IGF-I and 41 kDa IGFBP levels were consistently higher in HiFeed groups as compared to LoFeed groups regardless of temperature. Plasma 22 kDa IGFBP levels were inversely related to feeding rate with higher levels found in LoFeed groups. Significant, positive relations were found between growth, IGF-I, and 41 kDa IGFBP regardless of temperature regime.

VISUALISATION OF HOW BURIED LESSER SANDEEL (Ammodytes tobianus) OBTAIN OXYGEN – AND EVIDENCE OF A FISH CAPABLE OF METABOLIC DEPRESSION

J.W. Behrens, H.J. Staahl, J.F.Steffensen and R.N. Glud

E-Mail: jwbehrens@bi.ku.dk

Mar. Biol. Lab., Uni. of Copenhagen, Helsingor, Denmark

Session: HypO11

Abstract: Sandeels are peculiar in that they are associated with open water, where they swim while feeding, and the sediment into which they bury at night and all winter. Burying lowers the predation pressure and may be an energy saving strategy during unfavorable conditions. Since fish also require O_2 when buried, they seem to prefer sand compared to mud, silt and gravel. Sand contains a larger volume of interstitial water and may thus be a more well oxygenated environment, which could explain sandeel preference for this sediment. Whether sandeel actually obtain O_2 from the interstitial water has never been tested due to technical difficulties, nor has the idea that sandeel decrease metabolism when burried. We used transparent planar optrodes to measure sediment O_2 distribution in alignment with sandeel position and to estimate fish standard metabolic rate (SMR). The latter was used in evaluation with a SMR value obtained by conventional resting respirometry. Water movement over the gills was additionally visualised by digital images of colour pigment flow. O_2 only penetrated a few mm into the sediment, below which conditions were anoxic. Sandeel obtained O_2 by actively pumping water from above the sediment into its mouth and over the gills. When buried the SMR was reduced ~36%. These results are 1) in contrast to the hypothesis that interstitial water contains sufficient O_2 to support sandeel respiration but, 2) confirm the idea of energetically efficient ‘hibernation’. The ecological significance of burying and sediment O_2 penetration under field versus laboratory conditions are discussed. Funded by a COGCI stipend and EU projects COSA, TREAD and COBO.

SWIMMING PERFORMANCE STUDIES OF THE MAKO SHARK (Isurus oxyrinchus)

D. Bernal1, C. Sepulveda2 and J. B. Graham3

E-Mail: dbernal@umassd.edu


Session: MusO09

Abstract: The shortfin mako shark (Isurus oxyrinchus) is an active, warm-bodied epipelagic predator that has a suite of morphological and cardiorespiratory adaptations for an increased aerobic performance. Recent studies on makos have documented the presence of many tuna-like specializations that suggest efficient locomotion, however few studies have examined the swimming performance of these sharks under controlled conditions. Previous respirometry work on one juvenile mako shark has fueled hypotheses regarding high metabolic rates [standard (SMR) and maximum metabolic rates (MMR)] in this regionally endothermic shark. Therefore the present study tested the hypothesis that the mako shark has a higher metabolic rate relative to comparably sized ectothermic species. We measured the metabolic rate of nine juvenile mako sharks swimming in a large swim tunnel respirometer. Swimming VO_2 and tail beat frequency (TBF) were measured at 18±2°C for makos ranging in size from 70 to 95 cm fork length (FL) (4.5- 9.5 kg body mass) and swimming at speeds ranging from 28 to 54 cm s^-1 (0.3-0.7 FLs^-1). The mean (+95% CI) SMR for makos in this study (estimated by extrapolating
the swimming VO₂ data to zero velocity) was 115 (+65, -41) mgO₂·kg⁻¹·h⁻¹, a value comparable to other similar sized ectothermic species. However, the MMR measured [540 mgO₂·kg⁻¹·h⁻¹ for a 4.9 kg mako swimming at 54 cms⁻¹ (0.7 FLs⁻¹) and a TBF of 69 beats min⁻¹] remains among the highest documented for any shark. Although we observed a consistent and limited TBF range for all nine sharks (mean ± SEM: 60.8 ± 0.5; ranging from 57 to 69 beats min⁻¹), the higher MMR of the mako (when compared at the same swimming speed and temperature) suggests that this group may have a higher aerobic scope for activity relative to other ectothermic shark species.

CRF-RELATED PEPTIDES AND SEROTONIN AS REGULATORS OF FOOD INTAKE IN RAINBOW TROUT (Oncorhynchus mykiss)

N. J. Bernier and V. A. Ortega
E-Mail: nbernier@uoguelph.ca
Dept. of Integrative Biology, Univ. of Guelph, Canada

Session: MolO18

Abstract: While corticotropin-releasing factor (CRF) and serotonin (5-HT) are generally recognized as key regulators of the anorexigenic stress response in vertebrates, the proximal effects of these central messengers on food intake in rainbow trout are not known. Therefore, the objectives of this study were to determine the individual and interactive effects of CRF-related peptides and 5-HT on food intake in trout. Intracerebroventricular injections of native trout CRF and urotensin I (UI) both suppressed food intake in a dose-related manner and UI was significantly more potent than CRF. Co-injection of either CRF or UI with the CRF receptor antagonist -hCRF(9-41) blocked the reduction in food intake induced by CRF-related peptides. 5-HT administration also inhibited feeding and the anorexigenic effects of 5-HT were reversed by -hCRF(9-41) co-injection. In a separate study we assessed whether the appetite-suppressing effects of ammonia exposure are associated with changes in forebrain CRF-related peptide mRNA levels and serotonergic activity. Trout were exposed to one of four ammonia treatments (0, 500, 750, 1000 mol/L N) for 24h or 96h. Food intake decreased in a dose-dependent manner after 24h with all groups showing some recovery after 96h. The appetite-suppressing effects of ammonia exposure were associated with region, time, and dose specific increases in forebrain CRF and UI mRNA levels and serotonergic activity. These results identify CRF, UI, and 5-HT as anorexigenic agents in rainbow trout and suggest that the reduction in food intake associated with ammonia exposure in this species may be at least partly mediated by these central mediators of the stress response. Funded by NSERC.

INDUCTION OF PEROXISOMAL GENE EXPRESSION IN MULLETS EXPOSED TO PFOS AND TO A HEAVY FUEL OIL SIMILAR TO THE PRESTIGE OIL

E. Bilbao, MP. Cajaraville and I. Cancio
E-Mail: ibon.cancio@ehu.es
Dept. Zoology & Animal Cell Biology, UPV/EHU, Basque Country

Session: ImpP1

Abstract: Organic xenobiotics reach aquatic environments and upon accumulation into biota they exert a wide variety of biological effects. Among them, peroxisome proliferation has been observed as the increase of peroxisomal volume density, accompanied by the transcriptional induction of genes involved in lipid metabolism, mainly those coding for enzymes of the β-oxidation pathway, such as palmitoyl-CoA oxidase (AOX) and thiolase (PT). The aim of this work was to study expression variations of peroxisomal genes, AOX, PT and catalase (CAT) in liver of thicklip grey mullets Chelon labrosus, after exposure to potential peroxisome proliferators (PPs). Similarly, expression of the phase-I metabolism CYP1A1 gene was studied. For this purpose mullets were exposed for 2 and 16 days to the typical mammalian PP compound perfluorooctanesulfonate and to fresh (F) and weathered (WF) heavy fuel oil, similar to that spilled by the Prestige tanker in the Northern Iberian Peninsula in November 2002. After 2 days of exposure, AOX and CYP1A1 expression was significantly induced. F also induced AOX enzyme activity significantly. Although no differences were observed in AOX activity after 16 days, F exposure significantly induced AOX and CYP1A1 expression. CAT expression was only significantly induced after 16 days of exposure, in all cases, reflecting a possible oxidative stress. No changes were observed in PT expression. Further work is necessary to conclude the usefulness of studying peroxisome proliferation at the transcriptional level as a useful biomarker of exposure to organic pollutants. Funded: Spanish MEC (REN:2002-02982/MAR, VEM2003-20082-C06), Basque Government (ETORTEK-IMPRES) & UPV/EHU (consolidated groups).
DIFFERENTIAL GENE EXPRESSION IN MULLETS INJECTED WITH B(A)P: PHASE I METABOLISM AND PEROXISOME PROLIFERATION
E. Bilbao, O. Díaz de Cerio, MP. Cajaraville and I. Cancio
E-Mail: ibon.cancio@ehu.es
Lab. Cell Biology & Histology; Dept. Zoology & Animal Cell Biology, University of the Basque Country, E-48080, Basque Country

Session: BioO5
Abstract: Mullets inhabit severely polluted estuarine environments in contact with xenobiotics that may cause a wide variety of biological effects such as induction of biotransformation metabolism and peroxisome proliferation (PP). Organic xenobiotics such as PAHs are known to transcriptionally induce cytochrome p450 enzymes, for instance CYP1A1, and have been proposed to activate peroxisomal enzymes, mainly those of the b-oxidation pathway. The aim of this work was to clone peroxisomal genes and to determine their expression under different natural and pollutant exposure conditions in Chelon labrosus in comparison with the well characterized induction of CYP1A1 expression. Fragments of genes coding for peroxisomal enzymes were cloned through PCR using degenerate primers: 552 bp for catalase, 832 bp for palmitoyl-CoA oxidase (AOX) and 327 bp for thiolase (PT). Moreover, 1431 bp of CYP1A1 were cloned. Tissue expression pattern was determined by semi-quantitative PCR in juvenile and mature mullets collected in winter and spring. Liver showed the highest expression followed by gills and spleen. Then gene expression was studied in liver and gills of juveniles, 1 and 7 days after a single intraperitoneal injection of benzo(a)pyrene. CYP1A1 was significantly induced after 1 day of exposure in liver and gills. This was accompanied by significant inductions of PT in liver and AOX in gills. Catalase expression was induced after 7 days in both organs. Thus, B(a)P alters peroxisomal gene expression in fish, where PP could be considered a biomarker of exposure to PAHs. Funded: Spanish MEC (REN:2002-02982/MAR, VEM2003-20082-C06), Basque Government (ETORTEK-IMPRES) & UPV/EHU (consolidated groups).

IMMUNE RESPONSE OF CATFISH STRAINS EXPOSED TO VIRULENT Edwardsiella ictaluri
L. Bilodeau and B. C. Peterson
E-Mail: abilodeau@ars.usda.gov
USDA-ARS, Catfish Genetics Research Unit, Thad Cochran National Warmwater Aquaculture Center, USA

Session: DisO7
Abstract: Survivorship to ESC (Enteric Septicemia of Catfish) varies among and within strains of commercially raised catfish, however the immunological basis for differences in susceptibility are not well-understood. We measured mortality, pathogen levels (bacterial DNA), responses of toll-like receptor (TLR3 and TLR5) mRNA expression, and lysozyme activity during experimental challenge with virulent Edwardsiella ictaluri in channel catfish (Ictalurus punctatus) strains: USDA103, Red River (RR), USDA103 x Red River, and Blue catfish (I. furcatus), as well as USDA103 x Blue. Fish were sampled during a 21 day challenge. Mortality levels varied between strains, Blue being the least susceptible (24% mortality) and USDA103 most susceptible (65% mortality). Differences in lysozyme activity paralleled these results with USDA103 having the highest mean lysozyme activity (67.3±28.7 U/mL) and BLUE with the lowest (13.2±3.2 U/mL). Pathogen levels were highest in USDA103 (1.1x104 ± 6.4x103 ) and lowest in Blue (3.4x102 ± 9.3x101). There were no notable differences in TLR3 expression, however upregulation was evident during challenge in all strains in all tissues. TLR5 mRNA expression differed by strain in all tissues and over time in spleen and stomach. Similar to differences found in mortality and lysozyme activity, Blue TLR5 mRNA levels differed from the more susceptible channel catfish strains. Both the phenotypic and immune responses measured here suggest that variation in susceptibility to ESC is a function of differences in innate immune response. Understanding these differences will be crucial for enhancing the immune system through selective breeding and in developing disease management protocols. Funded by USDA-ARS.

IMPORTANCE OF VISION AND THE INFLUENCE OF LIGHT AND TEMPERATURE ON ACTIVITY PATTERNS IN MIGRATORY SEA LAMPREYS
T.R. Binder, and D.G. McDonald
E-Mail: tbinder@uoguelph.ca
Department of Integrative Biology, University of Guelph, Canada

Session: IntO8
Abstract: For most of their migration, sea lampreys (Petromyzon marinus) are active at night and seek light-refuge in the day. At the end of the season they switch to 24-hour activity. This is thought to result from their progression to blindness at this time, but could also be due to rising water temperatures. The goal of this study was to understand the influence of light and temperature on activity patterns in migratory sea lampreys, and to determine the overall importance of vision. We developed a non-invasive blinding technique and used video and PIT tag telemetry to monitor activity in the lab under
various light and temperature regimes. Results were field-validated using PIT tag and radio telemetry to compare migratory activity and refuge use in control and blinded lampreys. Daytime refuge was integral to the normal activity patterns of lampreys. Denied refuge, they displayed extensive daytime activity and nocturnal activity was diminished. Blinding had no affect on diel activity and did not reduce the willingness/capacity of lampreys to find refuge in the lab or field. Light-avoidance was mediated by photoreceptors localized in the tail of the lampreys. High temperatures altered both the amplitude and periodicity of spontaneous activity in the lab. At 15°C activity was almost exclusively nocturnal, but daytime activity accounted for 16 and 22% of the total activity at 20 and 24 °C. Our results indicate 1) that nocturnal activity and daytime light-avoidance are distinctly different behaviours, 2) that vision is not important to migrating sea lampreys, and 3) that temperatures above 20°C cause a shift to 24-hour activity. Funded by NSERC and the Great Lakes Fisheries Commission.

INTRACELLULAR Na⁺-CONCENTRATION IN RAINBOW TROUT CARDIOMYOCYTES
R. Birkedal and H.A. Shiels
E-Mail: Rikke.Birkedal@manchester.ac.uk
Faculty of Life Sciences, The University of Manchester, Manchester, UK

Session: CarO12
Abstract: In cardiomyocytes, the Na⁺/Ca²⁺-exchanger (NCX) plays a more prominent role in excitation-contraction coupling in lower vertebrates than in mammals. The primary function of the NCX is to remove Ca²⁺ from the cytosol during relaxation in exchange for Na⁺. However, in some fish species Na⁺-influx across the sarcolemma during excitation can cause the NCX to operate in reverse mode and pump Ca²⁺ into the cell. Thus the NCX can be an important source of Ca²⁺ for the Ca²⁺-transient. Furthermore, and in contrast to in mammalian cardiomyocytes, the influx of extracellular Ca²⁺ via NCX is able to trigger release of intracellular Ca²⁺ from the sarcoplasmic reticulum in the cardiomyocytes of some fish. The activity of NCX is highly dependent on the intracellular Na⁺-concentration ([Na⁺]). However, the in vivo [Na⁺]i in fish cardiomyocytes is unknown. In the present experiments, we used the Na⁺-indicator SBFI to record [Na⁺]i at 7, 15 and 21°C in cardiomyocytes at rest and stimulated to contract at increasing frequencies. We report the range of physiological [Na⁺]i in rainbow trout cardiomyocytes at different temperatures. We discuss this data in relation to the physiological role of the NCX as a Ca²⁺ influx pathway and its relative contribution to the Ca²⁺-transient. Finally we consider how these relationships change with acute changes in temperature and contraction frequency. Funded by The BBSRC and The Danish Natural Science Research Council.

MITOCHONDRIAL POSITIONING AND RESTRICTION OF ADP-DIFFUSION IN RAINBOW TROUT CARDIOMYOCYTES
R. Birkedal¹, M. Vendelin² and H. Shiels¹
E-Mail: Rikke.Birkedal@manchester.ac.uk
¹Faculty of Life Sciences, The University of Manchester, UK; ²Institute of Cybernetics, Tallinn University of Technology, Estonia

Session: CarP5
Abstract: The intracellular diffusion of ADP is restricted in cardiomyocytes. This is indicated by a high apparent mitochondrial KM for ADP (KM ADP) in skinned fibres. Mammalian skinned fibres display a single apparent KM ADP. In contrast, skinned fibres from rainbow trout and other species of ectothermic vertebrates exhibit two apparent KM ADP's. In this study, we tested the hypothesis that the two apparent KM ADP's in trout skinned fibres were due to an uneven distribution of mitochondria. Isolated ventricular cardiomyocytes from trout were loaded with mitotracker to visualize the three-dimensional arrangement of mitochondria by confocal microscopy. The arrangement was quantified by estimating the distribution of mitochondrial centres relative to each other. Our results from rainbow trout cardiomyocytes are discussed in relation to results from rat cardiomyocytes. Funded by The BBSRC, The Danish Natural Science Research Council and The EU Marie Curie Reintegration Grant.

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HOT TUNAS WITH COLD HEARTS: LINKING MOLECULAR, INTEGRATIVE, AND ECOLOGICAL
PHYSIOLOGY WITH PELAGIC ECOSYSTEM PROCESSES
Barbara A. Block
E-Mail: bblock@Stanford.edu
Tuna Research & Conservation Center, Stanford University, Pacific Grove CA. 93940

Session: PleO1
Abstract: Tunas are capable of exceptionally high metabolic rates and robust cardiac outputs. Tunas have counter-current
vascular heat exchangers (retia mirabilia) that conserve metabolic heat, allowing the warming of swimming muscle,
viscera, brain and eyes above ambient water temperatures. Archival tagging data indicate that bluefin tunas are the most
endothermic of the Thunnus clade, regularly maintaining tissue temperatures 10 to 21 °C above ambient. In the wild,
bluefin tuna maintain elevated body temperatures and occupy a broad thermal niche. Electronic tagging studies indicate that
northern bluefin tunas in the Atlantic and Pacific oceans occupy high latitude waters and undertake extensive migrations,
traveling over 15,000 km in a single year. In the lab, we have compared the metabolic and cardiovascular traits that appear
to underlie the bluefin tuna’s high-performance in the open ocean. These fish have a higher capacity for calcium release and
reuptake at the myocyte level, increased SERCA2 enzyme activity, and higher expression of ryanodine receptor proteins
when compared to albacore, yellowfin and big-eye tunas. Integrative physiological studies indicate that bluefin tuna
maintain higher heart rates and higher whole body metabolic rates than yellowfin tuna. Bluefin tunas have a thermal
optimum for metabolism and appear to defend a thermal neutral zone. The relationship between field and lab observations
provides the opportunity to link mechanistic physiology, behavior, ecology and evolution and provides new tools for
understanding the speciation of pelagic fishes. Supported by NSF, Packard & Moore Foundations

MOVEMENT PATTERNS, PHYSIOLOGY AND POPULATION STRUCTURE
OF NORTHERN BLUEFIN TUNA (T. thynnus) AS REVEALED BY ELECTRONIC TAGS
B. A. Block1, S. L. H. Teo1, A. Boustany1, A. Walli1, H. Dewar1, C. Farwell2 and T. Williams2
E-Mail: bblock@Stanford.edu
1Tuna Research and Conservation Center, Stanford University, USA 2Monterey Bay Aquarium, USA,

Session: IntO4
Abstract: An electronic tagging program was initiated for Atlantic bluefin tuna (ABFT) in 1996 to assess large-scale
movement patterns, population structure, breeding site fidelity, and thermal physiology and behavior of western-tagged
bluefin tuna. Over 910 electronic tags have been deployed in the western north Atlantic Ocean. Archival-tagged bluefin
tuna have been recaptured (n=105) providing tracks up to 4.8 years in length. Approximately 270 pop up satellite archival
tags have surfaced and transmitted data to Argos satellites after 2 to 260 days post-tagging. Together, these two data sets
provide geoposition data that delineate two populations, one utilizing spawning grounds in the Gulf of Mexico and another
from the Mediterranean Sea. Trans-Atlantic movements of western-tagged bluefin tuna reveal site fidelity to known
spawning areas in the Mediterranean Sea. Bluefin tuna that occupy western spawning grounds move to central and eastern
Atlantic foraging grounds occupying breeding areas in the west that are often 26 °C or higher in April, May or June.
Movement patterns and oceanographic data reveal regions of foraging and breeding aggregations for western bluefin tuna.
Unique diving and thermal behaviors are observed on the spawning ground and tunas are often located in regions of
oceanographic eddies. Information from electronic tags informs international managers when and where bluefin tuna can be
protected and provides an indication of the physiological limitations of the fish and causes of mortality. Physiological
research indicates that the bluefin may be thermally stressed in the warmer Gulf waters and at the top end of the cardiac
function curve. Similar electronic tagging studies have been initiated in the Pacific ocean on Pacific bluefin tuna. Recovery
of archival tags (n=110) is high (~40%). The data are providing detailed information on the movements and physiology of
Pacific bluefin tuna along the North American coast. Supported by Moore and Packard Foundations, NSF and NOAA and
the Monterey Bay Aquarium.

ECOTOXICOLOGY OF WILD YELLOW PERCH (Perca flavescens) POPULATIONS
CHRONICALLY EXPOSED TO A POLYMETALLIC GRADIENT: A GENETIC APPROACH
V. Bourret1, 2, L. Bernatchez2, P. Couture1 and P.G.C. Campbell1
E-Mail: vincent.bourret.1@ulaval.ca
1Institut National de la Recherche Scientifique, Centre Eau-Terre-Environnement, Canada, 2Dept. Of Biology, Laval
University, Canada

Session: ImpO34
Abstract: In the regions of Sudbury, Ontario and Rouyn-Noranda, Québec, mineral exploitation has been considerable for
decades, producing equally considerable effects on the aquatic ecosystems. Numerous studies suggest that chronic metal
exposures have exerted selective pressures leading to differences in metal tolerance and handling capacities. By associating
genetic distances with an index of metal contamination (liver metal concentrations), we were able to consider a novel, genetic approach to resolve problems in ecotoxicology. Using eight microsatellite loci, we examined genetic distance at three spatial scales: (1) between regions with different histories of chronic metal exposure; (2) among populations (n=10) from lakes with different degrees of metal exposure located along metal gradients within a given region; and (3) among individuals (n=50) with different capacities for tissue metal handling, selected from the same contaminated population. Thus, this study allowed us to examine the role of metal contamination as a selective force in a species that appears to demonstrate some degree of adaptation to environmental contamination. Funded by NSERC.

LARVAL VERTICAL MIGRATION BEHAVIOUR AND SELF-RECRUITMENT OF ANADROMOUS RAINBOW SMELT (Osmerus mordax)
I.R. Bradbury1, K Gardiner2, P.V.R. Snelgrove2 and P. Bentzen1
E-Mail: ibradbur@dal.ca
1Marine Gene Probe Lab, Dalhousie, Halifax NS, Canada; 2Ocean Sciences Centre, Memorial Univ. of Newfoundland, Canada

Session: FroO4
Abstract: Dispersal and connectivity between estuarine populations is regulated through the pelagic larval stage during which active contributions such as vertical migration may play a significant role. We examined larval vertical migration in rainbow smelt (Osmerus mordax) through a series of lab-based experiments conducted 0-7 and 90 days post-hatch. Larvae held in 2m columns were exposed to light, current and salinity treatments. We observed a shift in migration behaviour between development stages. At 1-week post-hatch, larvae displayed negative geotaxis independent of treatment. Older larvae however, displayed negative geotaxis irrespective of light position, and positive geotaxis in the dark. We hypothesized that this shift decreases dispersal through an interaction with seasonal trends in estuarine hydrography. The hypothesis of limited dispersal was examined through a larval and oceanographic survey in Salmonier estuary and an analysis of microsatellite DNA polymorphism between spawning sites. Passive drifters and larval abundance suggest limited dispersal and low export from the estuary. Estimates of local recruitment based on assignment of multilocus genotypes indicate local populations are significantly structured and are 70-90% self-recruiting. Our results suggest that the observed larval vertical migration behaviour results in limited larval transport and as a result anadromous smelt populations may be largely self-recruiting despite an extensive pelagic period. Funding by The Harris Foundation, NSERC, and The Killam Trusts.

PAIN PERCEPTION AND SUFFERING IN TELEOST FISH
V.A. Braithwaite
E-Mail: v.braithwaite@ed.ac.uk
P. Boulcott Institute of Evolutionary Biology, Edinburgh University, UK

Session: WelO2
Abstract: The recent experimental work revealing trout (Oncorhynchus mykiss) possess nociceptors (specialised receptors that respond to noxious stimuli) has forced us to query whether fish can suffer (Sneddon et al. 2003). To address this issue we have reviewed experimental work that has focused on the cognitive capacities of different teleost species. Behavioural observations have found that in a number of tasks, fish have similar learning and memory capacities to those observed in rodents; for example, they learn to move around a novel environment using the same types of cue that rats use when tested in a maze. In a related series of studies, work has revealed that teleost brains are more complex than previously realized. In particular, ablation studies have shown that the teleost forebrain contains structures involved in processing complex information associated with emotion, spatial locations and timing (Broglio et al. 2003). Ablation of these key areas prevents the fish from solving tasks that have an emotional or spatial aspect to the experimental design. These neural regions, known as the lateral and medial pallial areas, show remarkable homology with specialized regions found in mammalian and avian brains (the hippocampus and the amygdala). When such homology in brain structure is combined with assays of teleost cognitive capacity, there appears to be compelling evidence that fish do have the capacity to suffer fear and pain. Funding by BBSRC, UK. References: Broglio C, Rodriguez F and Salas C 2003 Spatial cognition and its neural basis in teleost fishes. Fish and Fisheries: 4, 247-255. Sneddon, L. U., Braithwaite, V. A. & Gentle, M. J. (2003) Do fish have nociceptors: evidence for the evolution of a vertebrate sensory system. Proceedings of the Royal Society. 270, 1115-1121.
ACID-BASE REGULATION IN AN OSMOCONFORMER, THE PACIFIC HAGFISH (Eptatretus stoutii)
C.J. Brauner¹, D. Baker¹, J. Rummer¹, B. Sardella¹ and J.M. Wilson²
E-Mail: brauner@zoology.ubc.ca
¹Department of Zoology, University of British Columbia, Canada. ²Ecofisiologia, Centro Interdisciplinar de Investigação Marinha e Ambiental, Porto, Portugal

Session: IonO2
Abstract: The Pacific hagfish is a “text book” osmoconformer, and its’ plasma ion composition is similar to seawater, especially with respect to plasma Na⁺ and Cl⁻ levels. Acid-base disturbances in aquatic breathers are usually corrected through acid-base relevant ion transfer at the gills (ie Na⁺/H⁺ or Cl⁻/HCO₃⁻), ultimately altering plasma Na⁺ and/or Cl⁻ levels. However, if hagfish are strict osmoconformers and do not have the ability to regulate these ions, acid-base regulation would be impaired. Based upon the feeding behaviour of hagfish, metabolic and/or respiratory acidoses are likely to occur. We exposed Pacific Hagfish (Eptatretus stoutii) to three levels of environmental hypercarbia (2%, 6% and 10% CO₂, balance air), extra- and intracellular acid-base status were monitored for up to 96h of exposure, and gill pouches sampled for branchial ion transport protein analysis. At all levels of hypercarbia, a pronounced acidosis was observed (e.g., pH<7 at 10% CO₂ in 3h), but significant compensation occurred within 48h. Interestingly, [HCO₃⁻] in the blood reached up to 100 mM (in exchange for Cl⁻), the greatest level of HCO₃⁻ accumulation observed in any vertebrate exposed to short-term hypercarbia. Thus, although the hagfish is an osmoconformer, it is one of the most effective vertebrates in dealing with a respiratory acidosis which is likely associated with the high levels of plasma Cl⁻. This research was supported by an NSERC Discovery grant to CJB.

BEHAVIOUR AT HIGH TEMPERATURES:
DOES PHYSIOLOGY EXPLAIN MOVEMENT OF ATLANTIC SALMON (Salmo salar) TO COOL WATER?
C. Breau, S. J. Peake and R. A. Cunjak
E-Mail: cindy.breau@unb.ca
Canadian Rivers Institute, Department of Biology, Univ. of New Brunswick, Fredericton, NB, Canada

Session: NorO3
Abstract: During the summer, wild salmonids occasionally experience water temperatures that approach their upper lethal limit (29°C). In the Little Southwest Miramichi River (NB, Canada), juvenile Atlantic salmon of different age classes exhibit different behavioural responses to high temperatures. Yearling (1+) and two-year (2+) old salmon cease feeding, abandon territorial behaviour, and swim continuously in aggregations near cool water sources; however, young-of-the-year (0+) fish continue to feed and defend territories. This study was conducted to determine if the behavioural shift in 2+ individuals occurs when basal metabolic rate, driven by increasing water temperature, approaches active metabolic rate and anaerobic pathways are recruited to provide energy to support vital processes. Behaviour (feeding, swimming), oxygen consumption, circulating lactate, glucose and cortisol levels, and muscle lactate and glycogen were measured in fish acclimated to temperatures between 16°C and 28°C. Results indicate that oxygen consumption of the 2+ fish increased with temperature and reached a plateau at 26ºC, a temperature that also corresponded to a significant increase in lactate levels and cessation of feeding. In contrast, oxygen consumption in 0+ fish did not plateau, feeding continued and lactate did not increase, even at the highest temperatures tested. We therefore conclude that some behavioural responses of 2+ salmon to temperature stress may be employed in an effort to mitigate physiological imbalances associated with an inability to aerobically support basal metabolism. Funded by Canada Research Chairs Program and O’Brien Fellowship.

FREQUENCY DISTRIBUTION OF STRESS COPING STRATEGIES IN FIVE POPULATIONS OF BROWN TROUT (Salmo trutta)
D Brelin¹, E Petersson2&3 and S Winberg¹&4
E-Mail: daniel.brelin@ebc.uu.se
¹Dept. Comparative Physiology, Uppsala University; ²Dept. Zoology, Uppsala University; ³Dept. Freshwater Research, Swedish Board of Fisheries; ⁴Dept. Basic Science and Aquatic Medicine, Norwegian School of Veterinary Medicine, Norway

Session: FroO28
Abstract: In a previous study we stated the existence of two distinct stress coping strategies in a sea-ranched brown trout population using a method were each fish faced a series of tests, each test including quantifiable key characteristics of stress coping strategies; 1) Physiological stress response after confinement, 2) Behavioural response during hypoxia and 3) Aggression towards a conspecific intruder. Here, using the same method, we show that five brown trout populations with different origins, but reared under the same conditions, differ in their physiological stress response, behaviour during
hypoxia and aggression. If individuals are classified as proactive and reactive based on post stress blood plasma noradrenaline levels (high noradrenaline is a key characteristic of proactive individuals) the frequency distribution implies that populations with hatchery origin are biased towards having higher frequencies of proactive individuals than populations having wild origin. This study was supported by the Swedish Research Council for Environment, Agriculture Sciences and Spatial Planning (FORMAS).

EFFECTS OF REARING DENSITY AND PHYSICAL STRUCTURE
ON THE PRE- AND POST-RELEASE PERFORMANCE OF HATCHERY REARED SALMONIDS
S. Brockmark1, J.I. Johnsson1, T. Bohlin1 and J. Dannewitz2
E-Mail: sofia.brockmark@zool.gu.se

1Anim. Ecol., Depart. of Zoology, Göteborg University, Sweden; 2Swedish Board of Fisheries, Inst. Freshwater Res., Drottningholm, Sweden

Session: WelO11
Abstract: The development of essential life-skills in supplementary reared fish are generally constrained by standard hatchery conditions, where fish are confined at unnaturally high densities in environments lacking the variability normally found in nature. We manipulated these factors in a series of studies in hatcheries using Atlantic salmon (Salmo salar) and brown trout (Salmo trutta) to evaluate the effects on pre- and post-release performance. Overall, while the physical structure had inconsistent effects on performance, the effects of rearing density were clear and consistent. In particular, behavioural studies demonstrated that fish reared at low densities had a competitive advantage due to higher food intake than fish reared at high densities. Consequently, fish reared at reduced density reached a larger size both in culture and when released in a natural stream. However, the treatments had no effects on post-release survival. In the hatchery, fish kept at reduced density had less fin damage compared to fish reared at standard densities. In addition, density negatively affected the effective population size (Ne), where high density increased variance in survival among families during the first period of life. Our results suggest that modifications of density in supplementary rearing may increase pre- and post-release growth, welfare and genetic diversity. Funded by Elforsk, the Swedish Energy Agency, the National Board of Fisheries and the Swedish Environmental Protection Agency.

FROM SEQUENCE TO SICKNESS: USING GENOMICS AND BIOTECHNOLOGY
TO UNDERSTAND AQUATIC ANIMAL PATHOGENS
L.L. Brown
E-Mail: laura.brown@nrc-cnrc.gc.ca
National Research Council of Canada, Institute for Marine Biosciences, Halifax, Nova Scotia, B3H 3Z1

Session: ProO6
Abstract: We are studying the interactions between Atlantic salmon (Salmo salar) and Aeromonas salmonicida, the causative agent of furunculosis. We have sequenced the genome of the bacterium to enable us to investigate virulence factors and other gene products that may have application as vaccines candidates. Using knockout mutants of A. salmonicida, we have identified virulence factors. Proteomics studies have revealed differential protein production such as superoxide dismutase, pili and flagellar proteins, type three secretion systems, and we describe their roles in A. salmonicida pathogenicity. A DNA microarray of A. salmonicida genes was used for genomic hybridizations to compare selected A. salmonicida isolates, as well as other Aeromonas species and subspecies with that of the sequenced strain. Results showed that variation among the virulence associated genes increased across sub-species and species boundaries. In investigating the host, salmon were challenged with A. salmonicida and samples of the bacterium and the host tissues were taken at selected times post-infection. From the host, EST libraries were made from mRNA and suppressive subtractive hybridization revealed differential gene expression. These data were used to select genes for an Atlantic salmon cDNA microarray that we use to investigate the functional genomics of the host response to A. salmonicida. By linking genome sequencing, functional genomics, proteomics, carbohydrate analysis, metabolomics/metabolomics, and immunological assays, we are taking an integrated and innovative approach to pathogenesis research.
EFFECT OF TEMPERATURE STRESS ON CLINICAL INFECTIONS
OF NODAVIRUS IN ATLANTIC COD (Gadus morhua)
L. Bruce1, 2, S.C. Johnson1, S.A. Sperker1 and L.L. Brown1
E-Mail: lisa.bruce@nrc-cnrc.gc.ca
1National Research Council of Canada, Institute for Marine Biosciences, Halifax, NS, Canada; 2Department of Biology, Dalhousie University, Halifax, NS, Canada

Session: DisP2
Abstract: Losses due to nodavirus (NNV) disease are one of the main impediments to the successful culturing of many marine fish species. The virus can cause 100% mortality in larvae; however, empirical evidence suggests that NNV is carried within the juveniles and adults without obvious clinical signs. The goal of this study is to examine the role of elevated temperature in NNV disease in Atlantic cod. Two hundred cod (20-30g), from a population suspected to be carriers of NNV, were evenly stocked in 10 tanks. Five tanks were held at ambient seawater (4-6oC) and five at 17oC. Fish in 4 tanks at each temperature (total 160 fish) were injected i.p. with 108 TCID50 ml-1 NNV. One tank at each temperature (total 40 fish) was injected with culture medium only. Fish were monitored for disease and samples for RT-PCR were obtained over a 21 day period. Although high proportions (>75%) of both the control and challenged groups tested positive for NNV there were no signs of disease in control groups or challenged groups held at ambient temperature. Forty one percent of the challenged fish held at 17oC showed signs of disease. Our results show that cod can be carriers of NNV and that elevated temperature can cause overt disease. We are presently determining whether there is a relationship between temperature, presence of virus and the expression of immune-related genes known to be important in viral diseases.

INDIRECT EFFECTS OF LOW DOSES OF RADIATION ON RAINBOW TROUT (Oncorhynchus mykiss)
C. Bucking1, A. O’Neill2, M. Kilemade2, R. Smith1, C. Mothersill2 and C. Seymour2
E-Mail: buckincp@mcmaster.ca
1Department of Biology, McMaster University Canada; 2Medical Physics, McMaster University Canada

Session: ImpO18
Abstract: Radiation pollution can have both direct and indirect effects on aquatic life. Bystander effects, which occur when an irradiated cell or organism produces a signal that is recognized by non-irradiated cells, which then react as if they themselves had been irradiated, are an example of indirect effects. While bystander effects have been demonstrated in vitro, in vivo demonstrations are lacking, and this is the first study to demonstrate that bystander effects are produced in vivo in fish. Rainbow trout (Oncorhynchus mykiss) were exposed to low levels of radiation (1 Gy), and then placed in proximity to naïve fish for 2 h. These naïve fish were then sampled, and tissue explants examined for evidence of the bystander effect. Tissues exposed to the surrounding environment (i.e. gills and epithelium) showed evidence of producing a bystander effect. Internal organs showed a varied response, with the spleen producing and effect, while the kidney did not. These results suggest that fish do not need to be exposed directly to radiation to exhibit radiation effects, and aquatic radiation pollution can be spread not only by currents but by fish populations themselves. Funded by NSERC and the Canadian Research Council.

EXAMINING THE POTENTIAL EFFECTS OF DIGESTION IN TELEOST FISH
C. Bucking and C. M. Wood
E-Mail: buckincp@mcmaster.ca
Department of Biology, McMaster University Canada

Session: IonO14
Abstract: While there is evidence for drinking during feeding and the importance of the gastrointestinal (GI) tract in piscine osmotic regulation has been suggested, the handling of water during digestion in freshwater fish is relatively unknown. Freshwater rainbow trout (Oncorhynchus mykiss; 300-350 g) were fed to satiation with a standard diet spiked with ballotini beads, allowing for the determination of consumption rates and water absorption by X-ray analysis. Following careful dissection of the GI tract, the contents from each section (stomach, caeca, mid and posterior intestine) were analyzed for water content at various time points, and the movement of water along the tract was examined. Surprisingly the stomach appeared to be the site of the largest water fluxes (7 ml kg⁻¹), due to either: drinking events or endogenous water loss, a potentially beneficial consequence of digestion. The anterior intestine also showed significant water fluxes (4 ml kg⁻¹), most likely from a combination of bile and pancreatic secretions. Each section exhibited unique temporal trends along the GI tract, indicating that time-dependent processes are at work during digestion. Funded by NSERC Discovery
MOLECULAR MARKERS TO IDENTIFY POPULATIONS OF LEPEPOPHTHEIRUS SALMONIS IN COASTAL WATERS OF BRITISH COLUMBIA

T. Burke and I. Novales Flamarique
E-Mail: tmburke@sfu.ca
Simon Fraser University, Dept. of Biological Sciences, Burnaby, BC, Canada

Session: DisO3
Abstract: Microsatellites, tandem repeat DNA segments found throughout the eukaryotic genome, experience high mutation rates due to their repetitive nature. These high mutation rates allow for population divergences at the genetic level to occur over a short period of time. By studying the allelic variability of many loci from individuals separated temporally or geographically, gene flow and relatedness between populations can be deciphered. We are using microsatellites to study genetic variations unique to specific populations of the parasitic salmon louse (Lepeophtheirus salmonis) in British Columbia. Nine polymorphic loci have been successfully amplified for two geographically distant groups of L. salmonis, one from the Skeena Estuary and the other from the Broughton Archipelago of British Columbia. Preliminary analyses of three loci show polymorphic variability between populations and population-specific alleles. These findings suggest that microsatellites are a powerful tool to determine salmon louse population source. Funded by British Columbia Innovation Council.

AUTOMATED TELEMETRY DATA RETRIEVAL AND ORGANIZATION

B. J. Burke, B. F. Jonasson, K. E. Frick, G. A. Axel, E. E. Hockersmith, B. L. Iverson, and M. A. Kaminski
E-Mail: brian.burke@noaa.gov
Northwest Fisheries Science Center, NOAA Fisheries Service, 2725 Montlake Blvd. E, Seattle, WA  98112 USA

Session: TelO24
Abstract: Whether using remotely-sensed tags for small-scale animal movement studies or to assess large-scale survival and behavior, data retrieval and organization are often some of the most time consuming and technically challenging aspects of a research project. Furthermore, the complexity and quantity of telemetry data can make analysis and interpretation difficult. We describe steps one can take to automate much of this process, increasing overall project productivity, accuracy, and reliability. From 2 May until 16 July 2005, we radio tagged and released 14,781 juvenile salmonids in the Snake River and tracked their downstream migration through the hydropower system. We collected data via an array of 80 stationary radiotelemetry receivers located over 120 kilometers of river. At regular intervals, the receivers were automatically downloaded. Data were sent via ftp to a local server and loaded into an Oracle database, where they were filtered and summarized. The automation scripts sent an email each morning with fish detection summaries and receiver diagnostics. This timely supply of information can often drive the schedule for tagging additional fish and/or receiver maintenance and repair, reducing the downtime of receivers and increasing efficiency of biologists. Moreover, any or all of these steps can be modified to fit individual research projects, regardless of scope or tagging methodology. Funding: U.S. Army Corps of Engineers.

SAMPLE SIZE ANALYSES USING RADIOTELEMETRY DATA

B. J. Burke, M. L. Moser and E. E. Hockersmith
E-Mail: brian.burke@noaa.gov
Northwest Fisheries Science Center, NOAA Fisheries Service, 2725 Montlake Blvd. E, Seattle, WA  98112 USA

Session: TelO25
Abstract: Radiotelemetry is expensive and few researchers are able to use more than 100 tags per year. Precision and accuracy of results from these studies can only be estimated by assuming a specific distribution of the response variable. For example, how many tags are needed for precise estimates of passage time over a dam, or to detect a difference in survival rate between groups of fish? Over the past eight years, we radio tagged several thousand adult and juvenile Chinook salmon, steelhead trout, and Pacific lamprey in the Columbia River Basin and evaluated several metrics of performance (e.g., dam passage time and survival). Across a suite of potential sample sizes, we generated 10,000 datasets with known underlying distributions by sub-sampling (with replacement) our original dataset. For each sample size, we estimated the probability of finding a significant difference between the sub-sample and the original dataset (i.e., probability of rejecting the true hypothesis that the sub-sample and the original dataset were drawn from the same population; comparable to a Type I Error). We then sub-sampled the dataset a second time, but shifted the distribution in the sub-sample by varying amounts to the left or right. We estimated the probability of erroneously accepting the null hypothesis that the two datasets came from the same underlying distribution for each sample size/shift combination (comparable to a Type II Error). Results from these analyses indicated that minimum sample sizes required for many
metrics to maintain an alpha level of 0.05 were between 50 and 80 tagged fish. We also found that minimum samples sizes depended more on the type of metric being evaluated than the species of fish tested. Funding: U.S. Army Corps of Engineers.

ANAEROBIC EXERCISE RESULTS IN FUNCTIONAL RED BLOOD CELL SWELLING IN SANDBAR SHARKS (Carcharhinus plumbeus)
P. Bushnell\textsuperscript{1}, R. Brill\textsuperscript{1}, S. Schroff\textsuperscript{1}, R. Seifert\textsuperscript{1}, M. Galvin\textsuperscript{1} and J. Musick\textsuperscript{4}
E-Mail: PBushnell@iusb.edu
\textsuperscript{1}Dept of Biological Sciences, Indiana University South Bend; \textsuperscript{2}National Marine Fisheries Service, Northeast Fisheries Science Center; \textsuperscript{3}Dept of Biology, Pomona College; \textsuperscript{4}Dept of Fisheries Science, Virginia Institute of Marine Science

Session: CapP1
Abstract: We used blood from juvenile sandbar sharks maintained in shoreside tanks (control sharks), and from animals one hour after being caught by hook and line (exercise-stressed sharks), to construct oxygen dissociation curves. We also measured blood hemoglobin, hematocrit, red blood cell count, plasma and intracellular pH, and NTP concentration. As expected, exercise-stressed sharks were acidicotic and had elevated blood lactate levels. We also found clear evidence of red cell swelling: exercise-stressed sharks had higher hematocrit and red cell volume, and lower mean cell hemoglobin concentration. Surprisingly, at comparable plasma pHs, blood oxygen affinity was higher (i.e., P50 was lower) in exercise-stressed sharks. Results from isolated hemoglobin solutions indicated that the leftward shift in the oxygen dissociation curves of exercise-stressed sharks could be due reduction in intracellular NTP levels resulting from red cell swelling. Intracellular pH in exercise-stressed sharks was, however, also alkalinized relative to plasma pH. Not surprisingly, we found sandbar shark red blood cells to be unresponsive to exogenous catecholamines. We believe this is the first report that elasmobranchs may be able to prevent decreases in blood oxygen affinity accompanying post-exercise acidosis, just as teleosts are well known to do. Partially funded by IU South Bend Faculty Research Award and SMART Grant.

SUBSTRATE UTILIZATION BY GOLDFISH (Carassius auratus) WHITE MUSCLE DURING GLYCOGEN RESYNTHESIS
K.I.R. Butts and C.L. Milligan
E-Mail: kibutts@uwo.ca
Dept. of Biology, Univ. of Western Ontario, Canada

Session: AdvO7
Abstract: Studies on metabolic recovery from exhaustively exercised salmonids have shown lactate produced from exercise is retained for in situ glycogenesis. Cyprinids do not accumulate lactate with exercise and this suggests a potential difference in substrate utilization for glycogenesis. The purpose of this study was to examine substrate utilization during muscle glycogenesis in goldfish (Carassius auratus) using an in vitro muscle slice preparation. It was hypothesized that the preferred extracellular substrate would be glucose and it would be preferentially incorporated into the glycogen pool. Fish were exhaustively exercised to reduce muscle glycogen; tissue slices were extracted from epaxial white muscle and incubated in media containing physiological concentrations of various substrates for one hour.14C-glucose was added, [14C]O2 and incorporation of extracellular glucose carbon into the glycogen pool were measured. Muscle slices incubated in lactate, palmitate and alanine all synthesized glycogen (P=2.8x10-9, F=14.32, df=6,54), but glucose stimulated maximal glycogenesis. When tissue slices were incubated in glucose+ lactate or glucose+ palmitate glycogenesis was significantly reduced compared to incubation in glucose alone (P=9.96x10-20, F=53.01, df=6,49). Using 14C-glucose, the major fate of extracellular glucose was glycogenic, accounting for only 10-15% of net glycogenesis, which was reduced to 1-5% in the presence of either lactate or palmitate. These results suggest that goldfish muscle utilizes a different substrate than salmonids for white muscle glycogenesis. Funded by an NSERC Discovery Grant awarded to CLM

VARIATION IN STREAM HABITAT AND ABUNDANCE OF BROOK TROUT AND STEELHEAD IN TWO SOUTHERN LAKE SUPERIOR TRIBUTARIES
G.R. Cain, T.J. Anderson, and J.B.K. Leonard
E-Mail: gcain@nmu.edu
Biology Department, Northern Michigan University, Marquette MI, USA

Session: AdvO15
Abstract: Potadromous stocks of coaster brook trout (Salvelinus fontinalis) were once abundant in Lake Superior yet experienced sharp declines by 1900. The interaction between native brook trout and exotic steelhead Oncorhynchus mykiss is unclear in Lake Superior tributaries. Prior work examining interactions between these two species has mainly focused on
stream resident populations. Some studies suggest that habitat characteristics influence species abundance and partitioning. We examined stream habitat conditions and the relative abundance ratios of brook trout and steelhead. Six 150 m sites were surveyed at monthly intervals in two streams within Pictured Rocks National Lakeshore from May to November in 2004 and 2005. Significant negative correlations between mean current velocity and brook trout abundance relative to steelhead were observed for September and October, 2004 (p<.05) and June and July, 2005 (p<.02) in Mosquito River. A significant negative correlation (p<.01) between mean site depth and relative brook trout to steelhead abundance index was observed in the Mosquito River for 2005 (May – October). Our results suggest brook trout and steelhead interactions and habitat selection in Lake Superior tributaries may differ from those observed in stream resident population studies. Instream variation of habitat characteristics as well as seasonal changes in stream conditions influenced the relative abundances of brook trout and steelhead. Funded by the National Parks Service, NMU, National Fish and Wildlife Foundation, and Trout Unlimited.

**SOCIALLY MEDIATED FEAR LEARNING IN ONCORHYNCHUS MYKISS**

R. E. Carpenter¹ and C.H. Summers¹,²

E-Mail: recarpen@usd.edu

¹Department of Biology; ²Neuroscience Group, Basic Biomedical Sciences, University of South Dakota, Vermillion, SD 57069, USA

**Session:** MolO24

**Abstract:** Rainbow trout in captivity interact aggressively, and form distinct social hierarchies. The most aggressive fish, as measured by decreased latency to attack, become dominant. We hypothesized that fish, like mammals, have the capacity to learn spatial tasks under socially stressful conditions. Four equally sized compartments were created using opaque Plexiglas in a 70-gal tank. A small juvenile rainbow trout was placed in one of the center compartments, and a large fish was placed in the adjacent center compartment. A small hole leading to an empty compartment was available to the smaller fish during the interaction. This escape hole was large enough for the smaller, but not the larger fish to pass through. Once a day the water inflow to the tank was turned off; 15 s later the center divider was removed and the fish were allowed to interact for 15 min, or until the small fish escaped. The larger fish were very aggressive, and the learning curve for subordinate fish was dramatic, with an approximately 600% improvement in escape time over 7 d. Plasma samples for cortisol measurement were taken 3 d before and 1 d after social interaction. For the samples taken after the trials, fish were presented with the inflow water off but no large fish challenge. Fish learning to escape using the opening showed no significant elevation in plasma cortisol. However, fish not learning to escape exhibited a four-fold increase in plasma cortisol. Elevated cortisol levels may represent a slow return to baseline after repeated social defeat. However, inflow water off has been demonstrated to be a sufficient conditioned stimulus to provoke increased plasma cortisol concentrations. Elevated plasma cortisol levels may therefore represent fear conditioning in non-escaping fish, demonstrating learning in these fish as well.

**INCREASED ONCORHYNCHUS MYKISS LOCOMOTION STIMULATED BY CRF COINCIDES WITH ELEVATED MONOAMINERGIC ACTIVITY**

Russ E Carpenter¹, Gina L Forster², Michael J Watt¹,², Travis J Ling¹, Craig Bockholt³ and Cliff H Summers¹,²

E-Mail: recarpen@usd.edu

¹Biol; ²Div Basic Biomed Sci, Univ S Dakota, Vermillion SD; ³Gavins Point National Fish Hatchery, Yankton SD USA

**Session:** MolP2

**Abstract:** Corticotropin-releasing factor (CRF), serotonin (5-HT) and dopamine (DA) are strongly linked to stress and anxiety behaviors in vertebrates, including rainbow trout. As a neuromodulator in the brain, CRF has been demonstrated to have anxiogenic properties in mammals, which are often characterized by increased locomotion and stereotyped behavior in familiar environments. We hypothesized that this anxiogenic behavioral function of CRF will also be exhibited in a teleost fish. Rainbow trout were treated with icv injection of aCSF, 500 or 2000 ng ovine CRF, or not injected. Time of forward movement and position in the water column were measured for 5 min both before and after treatment. Blood and brains were analyzed for cortisol, DA and 5-HT by ELISA and HPLC. Trout injected icv with either dose of CRF exhibited elevated locomotion, but treatment did not affect water column position preference. Injection with either aCSF or CRF produced significant increases in plasma cortisol, but aCSF-injected fish did not exhibit any behavioral changes. Therefore CRF, perhaps via 5-HT and DA, and not cortisol, is responsible for changes in trout locomotion. However, only the highest dose of CRF produced elevated 5-HT and DA in subpallium and raphe, suggesting that other factors or brain regions may be involved in eliciting behavioral responses. It suggests that CRF-induced locomotory behavior in rainbow trout is associated with 5-HT and DA responses in the subpallium and raphe, which may reflect the expression of stress/anxiety behavior and may be analogous to CRF-induced behavior in mammals. Supported by NIH grant P20 RR15567.
AGGRESSION, CORTISOL AND MONOAMINES IN ONCORHYNCHUS MYKISS ARE MODULATED BY CORTICOTROPIN-RELEASING FACTOR (CRF)
Russ E Carpenter¹, Michael J Watt¹,², Gina L Forster², Craig Bockholt¹ and Cliff H Summers¹,²
E-Mail: recarpen@usd.edu
¹Biology; ²Div Basic Biomed Sci, Univ S Dakota, Vermillion SD ³Gavins Point National Fish Hatchery, Yankton SD USA

Session: MolO16
Abstract: Corticotropin-releasing factor (CRF) stimulates an increase in locomotion and elevated dopamine and serotonin in amygdala/striatum and raphé. Increased locomotion does not translate into successful aggressive social encounters. However, icv injected CRF does influence the nature of aggressive interaction by changing the number of attacks and retreats, latency to attack and the cortisol and monoamine responses. Rainbow trout were treated with icv injection of aCSF, 500 or 2000 ng ovine CRF, or not injected. The effect of CRF in the brain suggests increased anxiety in fish. This increased anxiety is manifest by counterintuitive effects of CRF, such as reduced latency to attack, but also a reduction in the total number of attacks. While the number of attacks are fewer, the number of retreats are also fewer. The influence of CRF appears to have a greater impact on winners, more than losers, of dyadic interactions. For example, only dominant fish exhibit reduced latency to attack and fewer retreats. In un.injected pairs of control fish, the dominant individual always attacks more often than the subordinate individual, but with CRF treated fish winning did not require in more aggression. As has been demonstrated previously, social stress stimulates increased cortisol levels in both winners and losers of aggressive interaction. Blood and brains were analyzed for cortisol and monoamines by ELISA and HPLC. Our research suggests that multiple stresses produce additive cortisol responses. However, icv CRF in addition to social stress blunts cortisol responsiveness in winners and losers. Supported by NIH grant P20 RR15567.

INFERRING PARROTFISH PHARYNGEAL MILL FUNCTION FROM DENTAL MORPHOLOGY, WEAR AND MICROSTRUCTURE
Carr, A.C., Tibbetts, I. R., Kemp and A., Drennan, J.
E-Mail: a.kemp@uq.edu.au
University of Queensland, St. Lucia 4072 Australia

Session: BonO5
Abstract: Morphology, occlusal surface topography, macrowear and microwear features of parrot fish pharyngeal teeth were investigated to relate microstructural characteristics to the function of the pharyngeal mill, using scanning electron microscopy of whole and sectioned pharyngeal jaws and teeth. Species used were Scarus rivulatus, Scarus psittacus and Scarus frenatus, as well as Clorurus gibbus and Clorurus sordidus. Pharyngeal tooth migration is anterior in the lower jaw (fifth ceratobranchial) and posterior in the upper jaw (paired third pharyngobranchials) making the interaction of occlusal surfaces and wear generating forces complex. The extent of wear can be used to define three regions through which teeth migrate: a region containing newly erupted teeth showing little or no wear; a mid region in which the apical enameloid is swiftly worn; and a region containing teeth with only basal enameloid remaining that shows low to moderate wear. The microstructure of the enameloid, and the shape of the occlusal surface alters as the teeth progress along the pharyngeal jaw, generating conditions that appear suited to the reduction of coral particles. It is likely that the interaction between these particles and algal cells during the process of the rendering of the former is responsible for the rupture of the latter, with the consequent liberation of cell contents from which parrotfish obtain their nutrients. This research was funded by the Australian Research Council.

SEX COMPOSITION OF THE GROUP AFFECTS SOCIAL INTERACTIONS AND ENERGY DEMAND IN THE NILE TILAPIA
T.B. Carvalho¹, E. Gonçalves-de-Freitas¹ and G.L. Volpato²,³
E-Mail: gilvolp@gmail.com
¹Dept. Zoology and Botany, IBILCE, Caunesp, Unesp, SP, Brazil; ²Dept. Physiology, IBB, Unesp, SP, Brazil; ³Dept. Physiology, CB, UFRN, Natal, RN, Brazil.

Session: WelP10
Abstract: The effects of sex composition of Nile tilapia groups on social interactions and energy demand were investigated. Size-matched adult fish were distributed in treatments: MM = 4 males; FF = 4 females; and MF = 2 males and 2 females. Ten groups were tested in each treatment. Grouping lasted for 11 days and behavioral interactions were registered at the 2nd, 6th and 10th days, 15 min per day in each aquarium. Fish were feed deprived during the whole period, and then body weight loss was determined. Both behavior and growth were investigated in terms of the group, instead of the individual. Group biomass weight loss indirectly indicated energy cost. Gonad inspections and nest building revealed that all the fish were reproductive. MF treatment showed higher frequency of total social interactions, display and hierarchy
stability. Display significantly affected total interactions. Although mean biomass weight loss was not affected by treatments, it was significantly correlated with frequency of direct fights in MF treatment. These results demonstrate that the sexual composition of Nile tilapia groups affects social interactions and hierarchy stability, thus increasing energy expenditure in behavior, mainly for reproduction, a fact that may increase energy demands. Funded by CNPq. The aim of this work was to determine LC50 for ten fish species of the Rio Negro in ion-poor water and absence of dissolved organic carbon (DOC). Fish were held in INPA's groundwater ([Na⁺], 0.83; [K⁺], 0.45; [Ca²⁺], 0.16; [Mg²⁺], 0.036; [Cl⁻], 0.90 mg/l; [Cu], 7.0 mg/l; hardness= 6.15 mgCaCO₃/L; DOC < 1mg C/L; pH= 6.8), and exposed to different Cu concentrations, ranging from 10 to 400 mgCu/l (as CuCl₂·2H₂O), in chambers with flow-through system always maintenance ratio of 0.8g of fish per liter of water. In all tests, our results showed that Characids species were more sensitive to copper than both catfish and cichlid species. Hemigrammus rhodostomus is the most sensitive analyzed species with a calculated LC50 values, what may be related either to their similar size or their well defined phylogenetic status. Further, our data suggest that copper sensibility may be related to phylogenetic position of animals, probably due to differences in homeostatic and ionoregulatory mechanisms.

**APOLIPOPROTEINS A-I AND SERUM AMYLOID A DURING ACUTE PHASE IN RAINBOW TROUT**

*(Oncorhynchus mykiss)*

A. Casado, Villarroel, F, Amthauer, R, and M.I. Concha

E-Mail: margaritaconcha@uach.cl

Inst. Bioquimica, Fac. Ciencias, Univ. Austral de Chile, Valdivia, Chile

**Session:** DisP8

**Abstract:** In mammals, apolipoproteins A-I (ApoA-I) and serum amyloid A (A-SAA) correspond to negative and positive acute phase reactant proteins (APR), respectively. This implies that its hepatic synthesis and plasma levels are regulated by pro-inflammatory cytokines during the acute phase. HDL and its major apolipoprotein (ApoA-I) are very abundant plasma proteins in most teleosts and we have recently shown that it displays important antimicrobial activity in carp and trout. On the other hand, the induction of the A-SAA transcript has been previously described in trout; however the protein has not been detected in fish. Therefore, this study attempted to evaluate both apolipoproteins as potential acute phase markers in trout. Using RT-PCR, immunohistochemistry, Western and dot blot analyses we show that neither the hepatic transcript nor the plasma levels of ApoA-I differ significantly in sick and healthy fish. The same results were obtained in isolated hepatocytes treated with LPS. On the contrary, we confirmed that a-saa mRNA is induced in liver of diseased fish and LPS treated-hepatocytes. Moreover, A-SAA protein was detected for the first time in supernatants of LPS-treated hepatocytes but not in the plasma of naturally infected or LPS-treated fish. Surprisingly, A-SAA was not clearly detected in hepatocytes from sick or LPS-treated fish, but intense label was observed in what seem to be by infiltrating monocytes/macrophages in the portal region of the liver. These results show that ApoA-I would not constitute a negative APR in the trout, which could represent an important advantage for its innate immunity. Funded by Fondecyt 1050637 and DID-D-2005-13.

**HIGHER SERCA2 ACTIVITY IN TUNA HEARTS: COMPARATIVE ASPECTS OF TEMPERATURE DEPENDENCE**

P. C. Castilho*, A. M. Landeira-Fernandez1, J. Morrissette* and B. A. Block*

E-Mail: castilho@stanford.edu

TRCC*, Hopkins Marine Station, Stanford University, 1Inst. Bioq. Med. UFRJ, Brasil

**Session:** CarP1

**Abstract:** Tunas are regional endotherms that experience wide ambient temperature gradients. Although internal tissue temperatures are elevated in some species in all tunas, the heart functions at ambient temperature. Elevated heart rates in tunas are related to an increase of intracellular calcium stores and excitation-contraction (E-C) coupling. The cardiac sarco/endoplasmic reticulum Ca²⁺-ATPase (SERCA2) plays a major role during cardiac E-C coupling, transporting Ca²⁺ from cytosol into the lumen of the sarcoplasmic reticulum (SR) and thus promoting the relaxation of the muscle. Measurements of oxalate supported Ca²⁺-uptake in SR enriched atrial vesicles from four species of tuna showed that bluefin tuna has at least a 2 fold higher Ca²⁺-uptake rate than the other tunas at all temperatures tested. The highest atrial Ca²⁺-uptake for all tunas was in bluefin at 30°C (23.32±1.58 mmolCa²⁺/mg/min). The coupling ratio (Ca²⁺-uptake / ATP hydrolysis ratio) from atrial SERCA2 in all tunas tested showed a bell shape with a higher ratio at temperatures between 20-30°C. Western blots reveal an increase in SERCA2 content associated with higher Ca²⁺ uptake rates and ATPase activities in bluefin tuna. Ryanodine receptors are also highly expressed in the hearts of tunas. These results indicate that an increase in E-C coupling proteins contribute to the high heart rates that sustain the high metabolic demand in bluefin tuna. We propose that higher rates of SERCA2 activity could be an important evolutionary step for high metabolic rates and the evolution of endothermy in bluefin tunas. Funding: NSF and Monterey Bay Aquarium.
STOCK MIXING BETWEEN NORTHERN GULF OF ST. LAWRENCE AND SOUTHERN NEWFOUNDLAND COD: THE ACOUSTIC COUNTING FENCE

M. Castonguay1, J.-L. Beaulieu1, J. Brattey2, J. Spingle3, A. Fréchet1, and S.E. Campana4

E-Mail: castonguaym@dfo-mpo.gc.ca

1Department of Fisheries and Oceans, Institut Maurice-Lamontagne, Canada; 2Department of Fisheries and Oceans, Northwest Atlantic Fisheries Centre, Canada; 3Fisheries, Food and Allied Workers, Canada; 4Department of Fisheries and Oceans, Bedford Institute of Oceanography, Canada

Session: TelO12
Abstract: Tracking movements of animals at sea in deep water for long periods has long posed problems. Winter mixing between cod from the northern Gulf of St. Lawrence (Divisions 3Pn4RS) and cod off southern Newfoundland (Division 3Ps) may slow down cod recovery in the Gulf. The purpose of this study was to estimate mixing rate of northern Gulf cod into southern Newfoundland using automated monitoring telemetry methods. We inserted 50 kHz individually-coded transmitters into the abdominal cavity of 262 adult cod. We deployed a total of 80 receivers near bottom every mile that covered the entire distance along management lines separating Divisions 3Pn and 3Ps, and 4R and 3Pn. Two additional shorter receiver lines were also deployed on Burgeo and St. Pierre Banks. Based on two independent measures of receiver detection efficiency, we estimated the percentage of northern Gulf cod crossing into 3Ps in the fall to be 61%. The main month that Gulf cod entered 3Ps was December while the main month of return to the Gulf was April. This study provides the first firm evidence that the majority of northern Gulf cod mixes with 3Ps cod in winter and that northern Gulf cod are present in 3Ps in variable proportion in April when the research vessel survey is carried out there, which may bias survey results. Current area closures in winter in 3Ps to protect the Gulf stock appear quite adequate. This study was funded by DFO’s Fisheries Science Collaboration Program.

VISUAL AND CHEMICAL CUES MODULATING REPRODUCTION IN THE NILE TILAPIA

A.L.S. Castro1, E. Gonçalves-de-Freitas2, C. de Oliveira3 and G.L. Volpato4,5

E-Mail: gilvolp@gmail.com

1,2Dept. Zoology and Botany, IBILCE, Caunesp, Unesp, SP, Brazil; 3Dept. Biology, IBILCE, Unesp, SP, Brazil; 4Dept. Physiology, IBB, Caunesp, Unesp, SP, Brazil; 5Dept. Physiology, CB, UFRN, Natal, RN, Brazil

Session: OlfP2
Abstract: We tested the effect of visual or chemical communication on the modulation of reproductive behavior in the Nile tilapia (Oreochromis niloticus). Adult males and females were randomly distributed in couples to the following experimental treatments (N = 14 couples each): a) Visual Communication: one male and one female in two contiguous glass aquaria were allowed to view each other, but no other sensorial contact was permitted; b) Chemical Communication: an opaque partition prevented visual communication and chemical communication between the aquaria, but water circulated (~3L/min) continuously between them; c) Chemical and Visual Communication: the fish could view the opposite sex and the water recirculated between them; d) Isolation: male and female were kept completely isolated from each other. Both treatments allowing visual contact (with or without chemical communication) significantly increased courtship movement (undulation behavior) irrespective of sex (p < 0.05). These two treatments also increased the gonadosomatic Index in males, but not in females. The number of nests and area of the built nests were similar for all the treatments. These results indicate that vision cues were more important than chemical cues to induce reproductive behaviors and gonad development in the Nile tilapia. Funded by CNPq.

SEASONAL VARIATIONS IN EGG QUALITY OF THE ANCHOVETA (E. ringens): A MATERNAL EFFECT OF CHANGING ENVIRONMENTAL CONDITIONS

LR Castro1, G Claramunt2, MC Krautz1, A Llanos-Rivera1, Y Rojas2, C Valero1 and P Moreno2

E-Mail: lecastro@udec.cl

2 Laboratorio de Biologia Pesquera. Depto de Ciencias del Mar. Universidad Arturo Prat. Chile

Session: EarO3
Abstract: It has been proposed egg size might be an adaptive trait to enhance offspring survival under different environmental conditions. Usually, it is assumed that larger size eggs produce larger and more robust larvae. However, less attention has been paid to changes in relative concentrations of biochemical components within the egg, and their potential relationship with environmental conditions during the spawning season. Here we report variations in egg quality (intra-ovarian oocyte size; recently spawned-egg size, total protein content, total lipid content, TAGs and cholesterol of recently
spawned eggs, obtained throughout the main spawning season of two anchoveta populations (23oS vs 36oS) located in the Humboldt Current. We also assessed, from experiments carried out under natural temperature conditions, whether differences in hatch success occurred from the different size eggs produced along the spawning season. Eggs spawned by the southern, colder water, population were larger, contained a larger amount of proteins and lipids than eggs spawned by the northern, warmer water, females. Intra-ovaric oocyte size, spawned-eggs size and total lipid content of recently spawned eggs decreased as the spawning season progressed but proteins, TAGs and Cholesterol did not. Hatching success also decreased along the spawning season, especially in the southern population. The environmental conditions during the spawning season show that temperature was lower and turbulence was maximum at the beginning of the season in both areas but more markedly in the southern zone, suggesting that egg size and lipid content (other than cholesterol and TAGs; possibly fatty acids) may be of major importance during the harsh winter conditions experienced by the southern early life stages. Financial support by FONDECYT grant 1030819 to LR Castro & G Claramunt.

SELECTED WATER VELOCITIES OF CALIFORNIA COHO SALMON DURING THE PARR-SMOLT TRANSFORMATION
Joseph Cech Jr., Shana Katzman, Jonathan Greathouse, Julie Roessig, Justin Graham and Javier Miranda
E-Mail: jjcech@ucdavis.edu
Dept. of Wildlife, Fish, and Conservation Biol. and Center for Aquatic Biol. and Aquaculture, Univ. of California, Davis, USA
Session: IntP4
Abstract: Juvenile coho salmon, Oncorhynchus kisutch, undergo many physiological changes during their transformation from a freshwater parr to a migratory, seawater-capable smolt. Coho migrate downstream from mid-March to a peak in mid-May. During the migratory season, coho apparently move towards the surface and across the breadth of their streams during nighttime hours and either swim or drift downstream with the current (peak between midnight and 01:00 hours), according to field observations from Canada. Our objective was to document the selected water velocities of juvenile cohos in a calibrated, laboratory flow table, between April 2 and June 20. Using video analysis of flow table swimming patterns, groups of 3 cohos increased their preferred water velocity over this period, with the preference being especially pronounced during nighttime (regression analysis, p< 0.05). Moving to swifter currents should facilitate the downstream movements of these young cohos, as they develop through the parr-smolt transformation period. In California, where coastal coho salmon populations are endangered, this information should assist watershed and hatchery managers in optimizing juvenile salmon survival. We thank the California Department of Water Resources, the US Bureau of Reclamation, and the Anadromous Fish Restoration Program (of the USFWS and the USBR) for financial assistance.

ADULT WHITE STURGEON SWIMMING PERFORMANCE IN A LABORATORY FISH LADDER: PASSAGE EFFICIENCY AND STRESS RESPONSE TO EXERCISE
E-Mail: jjcech@ucdavis.edu
1Dept. of Wildlife, Fish, and Conservation Biology and 2Civil and Environmental Engineering, Univ. of California, Davis; 3California Dept. of Water Resources, U.S.A
Session: IntO9
Abstract: In California upstream migrations by anadromous fishes, especially non-salmonid species such as sturgeon are blocked or impeded by several dams and weirs. Many existing passage structures (e.g., fish ladders) are designed for salmonid species and are known to be inadequate for sturgeon upstream passage, considering these species’ size and behavior (primarily benthic cruising, “non-jumping” species). To assist in the design of a “sturgeon-friendly” ladder, we investigated the passage behavior, swimming performance, passage efficiency, and stress responses of wild white sturgeon Acipenser transmontanus. Over a 3-y period, we tested several types of fish ladder structures, leading to a 24.4-m-long laboratory ladder with 5 vertical energy-dissipating baffles at a 4% bed slope. Successful passage (>50% reached upstream-end) was achievable with fish in healthy condition versus sturgeon in poor pre-experiment condition (13%), although these fish demonstrated improved passage success (40%) with subsequent additional baffle design improvements. Fish blood sampling, showed a mild stress response to pre-test handling, a more severe one after the strenuous swimming exercise in the fish passage structure, and a return to “baseline” (pre-exercise) values 24 h after experiments. Research supported by CALFED.
MECHANISM OF METALLOTHIONEIN GENE REGULATION IN TILAPIA

W.L. Chan, A. P-L. Cheung and K.M. Chan
E-Mail: kingchan@cuhk.edu.hk
Dept. of Biochemistry, Chinese University, Sha Tin, Hong Kong SAR, China

Session: BioO3

Abstract: Metallothionein (MT) gene expression is inducible by many heavy metal ions and hence a reliable biomarker of exposure to heavy metal contamination. Zn\(^{2+}\) is able to bind to and activate the metal responsive element (MRE) binding transcription factor-1 (MTF-1). However, heavy metals apart from Zn\(^{2+}\), such as Cd\(^{2+}\) and Cu\(^{2+}\), fail to activate the binding of MTF-1 to MREs despite they can cause a strong induction of MT gene expression. How other metal ions induce MT gene transcription remains unknown. Using tilapia as a model, we found that MTF-1 transcription factor existed as two isoforms: MTF-1L (long) and MTF-1S (short), by cDNA cloning. To study their respective roles in the regulation of MT gene expression, this study focuses on tiMT transcription factor and its promoter. The tiMT promoter region was cloned and sequenced, with a total of seven putative MREs identified in a gene promoter of 2118 bp. Electrophoretic Mobility Shift Assay (EMSA) was performed to study the MRE-binding properties of MTF-1 from the whole cell extract of Hepa-T1 cell-line (a liver cell-line from tilapia). All MREs were able to bind with MTF-1 and MREb and MREG gave the strongest binding in EMSA. The tiMT promoter was also cloned into a luciferase reporter vector and was transfected into Hepa-T1 cell line to study its activity in heavy metal treatments. Heavy metals including Cd\(^{2+}\), Cu\(^{2+}\), Hg\(^{2+}\), Pb\(^{2+}\) and Zn\(^{2+}\) were able to induce a significant induction of tiMT promoter activity. Funded by a Direct Grant by University Grants Committee.

DIFFERENTIAL INVOLVEMENT OF NITRIC OXIDE (NO)
IN PITUITARY ADENYLATE CYCLASE-ACTIVATING POLYPEPTIDE (PACAP)
AND DOPAMINE (DA) STIMULATION OF GROWTH HORMONE (GH) SECRETION IN GOLDFISH

J.P. Chang, G. Mitchell, G.S. Sawisky and C.J. Wong
E-Mail: john.chang@ualberta.ca
Department of Biological Sciences, University of Alberta, Canada

Session: FisO15

Abstract: NO mediates GH release responses to gonadotropin-releasing hormones in goldfish. In this study, we investigated the role of NO in mediating the GH-releasing actions of PACAP and DA using primary cultures of goldfish pituitary cells in perfusion. GH responses were quantified by radioimmunoassay. Maximal stimulatory concentrations of PACAP and DA or a D1 agonist were applied as 5-minute pulses. One-hour exposures to inhibitors commenced 20 minutes prior to stimulator addition. Treatment with NO synthase inhibitors (AGH, 1400W and 7-Ni) and NO scavengers (rutin hydrate and PTIO) did not reduce PACAP action. In contrast, 7-Ni, rutin hydrate and PTIO decreased the GH response to DA. These results suggest that PACAP and DA, two cyclic AMP- and Ca\(^{2+}\)-activating hypothalamic factors, differ in the use of NO signalling in goldfish somatotropes. (Supported by NSERC.)

THE VERTEBRAL DEFORMITY OF THORNFISH (Terapon jarbua)
IN THERMAL EFFLUENT OUTLET OF A NUCLEAR POWER PLANT IN TAIWAN

C.W. Chang\(^1\), Y.T. Wang\(^2\) and W.N. Tzeng\(^1\)*
E-Mail: wnt@ccms.ntu.edu.tw

\(^1\)Institute of Fisheries Science, National Taiwan University, Taipei, Taiwan, ROC; \(^2\)Fisheries Research Institute, Council of Agriculture, Executive Yuan, Taipei, Taiwan, ROC.

Session: BonP1

Abstract: The vertebral deformity of fish was rarely found in the natural waters. However, a great number of deformed thornfish, Terapon jarbua, was found in the thermal effluent outlet of a nuclear power plant in the northern Taiwan since 1993. Seventy-eight deformed fish collected in the thermal effluent outlet were examined with roentgenogram and with bone staining following trypsin digestion, to further understand the vertebral deformity. Results show that there are three types (single-, double- and triple-peaks) of spinal curvatures classified and the percentage occurrences were 34.4%, 63.9% and 1.6%, respectively. The first peak occurred at the 7th vertebra and the 2nd at the 19th vertebra. Steepness, length/height ratio and top angle of the spinal curvatures were not correlated to the fish length, indicating that the deformity may occur at any phase of the developmental stage of the fish. The mechanism of the deformity is still not clear, although this can be related to the current velocity, thermal pollution, heavy metal, and nuclear radiation. However, the most possible factor may be temperature which led to the vertebral overgrowth and curvature. On the other hand, the deformed fish will not influence the human health. However, the phenomena of having vertebral deformity may provide new insight into the effect of the temperature on the ossification of fishes. The study was funded by Environmental Protection Administration, Executive Yuan, Taiwan, ROC.
EFFECTS OF PHENANTHRENE ON TAMBAQUI (*Colossoma macropomum*):

**LC50, GROWTH AND HEMATOLOGY**

C.V. Chávez¹, N. Tafur² and A.L. Val¹

E-Mail: cchavez@inpa.gov.br

¹Laboratory of Ecophysiology and Molecular Evolution, INPA, Manaus, Brazil; ²SUSAM, Brazil

Session: ImpP10

**Abstract:** Acute and sublethal toxicities of phenanthrene were tested on freshwater fish tambaqui (*Colossoma macropomum*). Trimmed Spearman-Karber method was used to calculate the LC50. Median lethal concentration (LC50) was 0.94 mg/L (0.91-0.97) for 96 hours. Tambaqui was exposed to 5, 25 and 50% of CL50 of phenanthrene for 4 weeks to test their effects on growth and hematological properties. Regular methods were used to calculate growth and analyze hematological parameters. The final weight gain (WG), average weight gain (WG%), specific growth rate (SGR), feed efficiency (FE), condition factor (CF) and hemoglobin (Hb) were significantly decreased in fish exposed to phenanthrene, whereas plasma glucose (Glu), lactate (Lac) and methemoglobin (MetHb) levels were increased significantly. However, hepatosomatic index (HSI), feed conversion (FC), red blood cell (RBC) count, hematocrit (Ht), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC) and mean corpuscular volume (MCV) levels of tambaqui were not significantly affected by phenanthrene exposure. The central finding from these data is that tambaqui exposed to phenanthrene at more than 5% of CL50 are likely to experience negative impacts on fish health and basic physiological functions. Funded by Pronex Program /FAPEAM and CNPq and Belgian Embassy in Peru.

DOMINANCE, BODY SIZE AND SUBSTRATE SELECTION IN THE AMAZONIAN ANGELFISH, (*Pterophyllum scalare*)

S. Chellappa¹, M.S.R.F. Cacho¹, M.E. Yamamoto², G.L. Volpato²,³ and F.A. Huntingford⁴

E-Mail: gilvolp@gmail.com

¹Aquatic Bioecology, CB, UFRN, Natal, RN, Brazil; ²Dept. Physiology, CB, UFRN, Natal, RN, Brazil; ³Dept. Physiology, IBB, Unesp, SP, Brazil; ⁴Division of Environ. and Evolutionary Biology, Inst. of Biomed. and Life Sciences, Univ. of Glasgow, U.K.

Session: TroP6

**Abstract:** The angelfish, *Pterophyllum scalare*, a native cichlid from the Amazonian basin of Brazil, exhibits complex reproductive behaviour involving aggressive competition for territory, mates, courtship and parental care. Conflict resolutions and spatial distribution of this species were investigated using sexually mature angelfish of different body sizes. Behavioural observations were carried out on five groups. Each group consisted of three males of different body size and two mature females, in an aquarium using three types of Amazonian aquatic vegetation as spawning sites. Observations of social interactions were concentrated on male-male attacks. The territorial area defended by males with different aggression levels was registered, in addition to the distance between territories and substrate preference. Reproduction variables, such as egg/larva survival rates and reproductive cycle duration, were tested for correlation with aggression and spatial distribution variables. The results indicate that differences in male body size influenced dominance, territory possession, substrate quality and mate preference. Spatial distribution was also related to aggression and body size, demonstrating a group distribution pattern during male reproductive competitions. The aggressive behaviour of dominant males was positively correlated with egg and larva survival. Funded by CNPq.

PAIN SENSITIVITY OF FISH AND ANALGESIA INDUCED BY OPIOID AND NONOPIOD AGENTS

L. Chervova

E-Mail: lily_chervova@mail.ru

Dept. of Ichthyology, Faculty of Biology, Lomonosov Moscow State Univ., Russia.

Session: WelP2

**Abstract:** In fish, pain sensation and modulation of behavior by nociceptive stimuli have been studied little as of yet. This is because pain, as a type of sensory modality, is difficult to study especially in voiceless and nonmammalian species. Experiments were performed on common carp (*Cyprinus carpio* L.), rainbow trout (*Oncorhynchus mykiss*) and White Sea cod (*Gadus morhua marisalbi* D.). An originally optico-mechanical system was elaborated to record the behavioral responses to aversive stimuli. The stimulation (bursts of short pulses 0.5 ms of current 0.5-2.0 mA, with frequency 300/s) and registration of the caudal peduncle movement were induced using a computer control. Nociceptive thresholds (NT) were measured at 5-min intervals for 1 h before and 1-2 h after administration of analgesic agents. Drugs used were mu agonists tramadol, dermorphine and beta-casomorphine, kappa agonist U-50488, delta agonist DADLE, and nonopioid analgesic agents sydnophenum, analginum, novocainum. Administration of drugs produced dose-dependent and lasting for at least 1 h (up to 2-3 h in some fish) increase of NT in 1.5-3.0 times. The higher the dose, the more quickly it acted. Tramadol had no analgetic effect if naloxone, an antagonist of opioid receptors, was administered before. These results: 1)
suggest that fish as higher vertebrates have nociceptive and both opioid and nonopioid antinociceptive systems; and 2) it takes part in the control of fish behavior on the level of central mechanisms. Funded by Russian Foundation for Basic Research N 06-04-49266, by the Council on Grants by the President of the Russian Federation, State Leading Scientific Schools, and the Programm “Universities of Russia”.

TRIPLOID INDUCTION, SURVIVAL AND GROWTH IN ARCTIC CHARR (Salvelinus alpinus)
Marcia A. Chiasson and Tillmann J. Benfey
E-Mail: r539b@unb.ca
Department of Biology, University of New Brunswick, Canada

Session: LinO11
Abstract: As commercial aquaculture continues to grow, farmers are looking towards new species – such as Arctic charr – for culture. Challenges associated with Arctic charr culture, such as early maturation and escapees, may be overcome by the use of sterile triploids. The aim of this research is to evaluate the suitability of triploid Arctic charr for commercial aquaculture. Triploidy was induced by a 9500 psi hydrostatic pressure shock applied for 5 minutes at 210 °C-min post-fertilization, which produced a 100% triploid population. Ploidy was confirmed by flow cytometric analysis of erythrocyte DNA content. Mean DNA content of diploid (2n) nuclei was exactly 50% greater than that of triploid (3n) nuclei. Survival from the eyed stage until the first grading selection (1850 °C-days after first feeding) of 2n fish (81-88%) was greater than that of 3n fish (55–81%). Eight families of 2n and 3n Arctic charr (100 fish of each ploidy per family) were grown together in two tanks from May 2005 (720 °C-days after first feeding) until October 2005 (2220 °C-days after first feeding). Wet weight and fork length of all fish was measured every four weeks. Fish were fed a commercial diet and showed variable growth rates. From May to October 2005, the average specific growth rate of 2n and 3n was 2.87 and 2.75, respectively. The results of this research will be of direct relevance to local fish farmers, and is supported through the Atlantic Innovation Fund.

PHYSIOLOGICAL EFFECTS OF PETROLEUM AND CHEMICALLY DISPERSED PETROLEUM ON TWO AMAZON FISH SPECIES
E-Mail: chippari@inpa.gov.br
Laboratory of Ecophysiology and Molecular Evolution, National Institute for Research in the Amazon, Manaus, AM, Brazil

Session: TroP13
Abstract: The responses of Amazon fishes to petroleum are similar to adjustments improved in response to hypoxia. This can be explained as a maximization of oxygen transfer to tissues as petroleum affects oxidative and xenobiotic metabolisms, which increases overall oxygen demand. Chemical dispersants contain anionic and non-ionic surfactants, which are used to mitigate oil spills. In previous tests, tambaqui (Colossoma macropomum) presented changes in gill permeability and disturbance of ion transport after exposure to chemically dispersed petroleum. The effects of petroleum and chemical dispersant (Corexit 9500®) on respiratory and hematological parameters, ion balance and gene expression in two Amazon species, tambaqui (Colossoma macropomum) and oscar (Astronotus ocellatus), were assessed. Both species were exposed to petroleum and dispersant+petroleum during different periods of time (03, 06, 12, 24 and 48 hs). Experimental animals exhibited significant changes of their hematological parameters over time. Plasma glucose of Oscar, except for 3 hour group, was higher (p<0.05) in all animals exposed to petroleum and chemically dispersed petroleum. In tambaqui, plasma glucose was increased in 24 and 48 hour group, indicating a higher level of energy demand in experimental animals. LDH gene expression was increased in Oscar exposed to dispesant+petroleum, indicating that the anaerobic metabolism is activated during exposition to contaminants. The activation of this gene was also observed in animals exposed to anoxia. These data confirm that crude oil causes hypoxia related responses in the analyzed fish species, thought that the dispersant does not affect the effect of crude oil alone. (supported by FAPEAM, CNPq, FINEP and PETROBRAS).
EFFECTS OF PETROLEUM ON TWO FISH SPECIES OF THE AMAZON

E-Mail: chippari@inpa.gov.br
Laboratory of Ecophysiology and Molecular Evolution, National Institute for Research in the Amazon, Manaus, AM, Brazil

Session: TroP12
Abstract: Large reserves of petroleum and gas are being exploited near the city of Coari along the Urucu River, a tributary of the Amazon River. The oil is transported in oil barges to Manaus, nearly 650 kilometers down the river, to be refined. Although strict safety procedures are observed, there is always a risk of an oil spill both at the wellhead and during transportation. The aim of this work was to assess the effect of petroleum on two species that occur along the river used for oil transport (Coari-Manaus), over different exposure regimes, using physiological parameters. The species chosen was Astronotus ocellatus (Oscar) and Liposarcus pardalis (acari-bodó). Both species were exposed to various periods of time (03, 06, 12, 24 48 and 96hs). Oscar is more sensitive than acari-bodó to petroleum exposure, based on the analyzed parameters. The former species presents many alterations on its hematological parameters, including plasma glucose that was increased over exposure times, except for 3hs group, while acari-bodo showed no changes of plasma glucose. These results are supported by the LC50 values for these species, that are 36,33 mL/L for A. ocellatus and 77,76 mL/L L. pardalis. (supported by FAPEAM, CNPq, FINEP and PETROBRAS).

GENE EXPRESSION PROFILE OF ZEBRAFISH GILL EXPOSED TO LOW TEMPERATURE

E-Mail: pphwang@gate.sinica.edu.tw
1Inst. of Fish. Sci., National Taiwan Univ.; 2Inst. of Cellular and Organismic Biol., Academia Sinica; 3Depart. of Aquat. Biosci., National Chiayi Univ.; 4Depart. of Life Sci., National Taiwan Univ., Taiwan. ROC

Session: ProO3
Abstract: Microarray analysis was used to compare the global changes of gene expression in gill of zebrafish after exposed to low temperature for 1 day and 30 days. We identified 28 and 67 genes to be up-regulated by short-term and long-term low temperature treatments, respectively, while 113 and 140 genes were respectively down-regulated. 161 genes were found to show different expression patterns between short-term and long-term treatments. We selected 12 genes to confirm microarray results by Real-time PCR. The differential expressed genes were classified by gene ontology method and categorized in several group: metabolism, signal transduction, ion transport and cytoskeleton. We further investigated the expression profiles of the genes related to ion regulation in zebrafish gill during low temperature acclimation. Low temperature caused significant stimulation of several ionocyte marker genes (trpv6, atp1a1a.2, atp1b1b, ncc, atpv6 and ca2a), which are relevant to Ca^{2+} and Na^{+} uptake mechanisms as well as acid-base regulation. These data suggests that zebrafish may have different strategies for short- and long-term acclimation to cope with the low temperature environments. In addition, regulation in ion balance mechanisms is an important physiological response in zebrafish gill during low temperature acclimation.

LONGITUDINAL AND LATERAL DISPLACEMENT OF JUVENILE CALIFORNIA STREAM FISHES IN RESPONSE TO SIMULATED PULSED FLOWS

S.N. Chun1, S.A. Hamilton2, D.E. Cocherell2, J. Graham1, G.J. Jones2, J.B. Miranda2 and J. J. Cech, Jr.2
E-Mail: jjcech@ucdavis.edu
1Visger & Associates Inc., CA; 2Dept. of WFCB and CABA, UC Davis; 3CA Dept of Fish and Game

Session: AdvP6
Abstract: Pulsed flows for hydropower and whitewater rafting can benefit people, but effects on stream fish are largely unknown. We investigated longitudinal and lateral displacement of three stream fishes in response to simulated pulsed flows. Longitudinal displacement was tested by varying velocities [slow (0.10 m/s), medium (0.31 m/s), fast (0.46 m/s), medium, and slow] in a glass flume (16.5 x 0.6 m). Fish location, velocities, substrate use, and swimming activity were recorded. Rainbow trout, hardhead, and Sacramento suckers showed no net movement from their central starting point (except one hardhead impinged at the downstream screen). Rainbow trout selected higher velocities than the other species during slow intervals and hardhead selected higher velocities during the first medium velocity. Sacramento suckers were associated with substrate less than the other species. Lateral displacement was tested in a 2.0 x 1.2-m artificial stream incorporating a main channel (16 cm-width) and sloped gravel bank (102 cm) after either short (2-h) or long (16-h) acclimation. Experiments flooded and subsequently dewatered the gravel area. Fish location, substrate use, and stranding
were recorded. All three species remained near the bottom substrate. While trout inhabited the bank more after long acclimation, hardhead and suckers inhabited the bank more after short acclimation. Only 29% of hardhead and 17% of Sacramento suckers stranded following the short acclimation. Funded by the PIER Program of CA Energy Commission and the Division of Water Rights of the State Water Resources Control Board through the Pulsed Flow Program at UC Davis.

**WHY BE COOL? – BEHAVIOURAL THERMOREGULATION AND PHYSIOLOGICAL RECOVERY AFTER EXHAUSTIVE EXERCISE IN SALMONIDS**

P. C. Chung and J. D. Kieffer  
E-Mail: celia.chung@unb.ca

Dept. of Biology, University of New Brunswick Saint John, Canada.

**Session:** NorP2  
**Abstract:** It has been demonstrated that when under physiological stress, salmonids select a temperature lower than their previous acclimation temperature. Recent work has shown that thermoregulatory behaviour occurs in lizards and frogs following exhaustive exercise. This phenomenon has not been examined fully for fish. This study examined whether juvenile brook trout (Salvelinus fontinalis) utilise behavioural thermoregulation to offset the physiological costs associated with recovery from exhaustive exercise. Behavioural experiments will assess whether juvenile trout “choose” cooler temperatures post-exercise. Physiological experiments, including oxygen consumption and metabolite recovery under different temperature regimes, will also be conducted. It is expected that the choice of recovery temperature shown in the behavioural experiments will reflect the fish’s strategy to balance between the physiological needs of decreasing oxygen consumption and metabolite recovery.

**TEMPERATURE ACCLIMATION AND THE TROUT HEART**

R. H. Clapp1, J. Whitehead1, H. Dobrzynski2 and H. A. Shiels1  
E-Mail: holly.shiels@manchester.ac.uk

1Faculty of Life Sciences; 2Faculty of Medicine, University of Manchester, UK

**Session:** CarP3  
**Abstract:** Fish hearts undergo morphological and biochemical changes during temperature acclimation. These changes are thought to allow the heart to cope with the physical and physiological challenges of operating at the new temperature. The aim of the present study was to look at how temperature acclimation affected the conduction pathways of the rainbow trout heart (Oncorhynchus mykiss). Fish were acclimated to 4 and 15 °C for at least four weeks prior to experimentation. The effect of temperature acclimation on fish heart morphology was assessed using two methods. First, cardiac myocytes were isolated using enzymatic digestion, stained with the lipophilic dye di-8-ANEPPS and the 3-dimensional structure was assessed that allowed detail measurement of cell size. Second, histological preparations were prepared and cell size was calculated using light microscopy. Cold induced hypertrophy was evident with both methods. Immunocytochemistry was used to examine the conduction system. We identified connexin43 fluorescence staining within both the atrium and ventricle illustrating how gap junctions are arranged in cardiac tissue from 15 °C acclimated fish. Future work will examine how this pattern is affected by temperature. Funded by The BBSRC.

**SALMONID MOVEMENT IN A SMALL NEWFOUNDLAND WATERSHED: HOW DOES IT AFFECT OUR TRADITIONAL VIEWS OF HABITAT USE AND POPULATION DYNAMICS?**

K. D. Clarke and D. A. Scruton  
E-Mail: clarkekd@dfo-mpo.gc.ca

Fisheries and Oceans Canada, Science Branch, St. John’s, NL, Canada

**Session:** FroO1  
**Abstract:** Traditionally, studies on salmonid population dynamics and habitat use have sampled populations in representative ‘habitat types’ throughout a given watershed. The main assumption underlying this sampling design was that stream salmonids were restrictive in their movements and thus the information gained from the representative sites could be extrapolated over the entire system. Recently, the concept of restrictive movement within stream salmonids has been bought into question. To investigate the affect movement may have on our traditional views of habitat use a ‘traditional’ population sampling program was conducted concurrently with an individual marking program in a small watershed located on the southern Avalon Peninsula, Newfoundland, Canada. Habitat use of the main lacustrine habitat sampled, Stoney Pond, was dynamic with a distinct seasonal pattern. Brook charr exhibited large movements and used Stoney Pond in the fall, post spawning, and through the winter but where almost absent in the pond during the summer. While movements of juvenile Atlantic salmon were less pronounced, there was an immigration of two/three year old fish into Stoney Pond during the early summer period. Overall, movement by salmonids was pronounced with habitat shifts...
being observed for both species of interest, although these changes occurred at different scales. Results suggest that the connectivity of habitats should be considered when sampling for or managing salmonid populations. Funded by Environmental Sciences Strategic Research Fund (DFO).

**LIPIDS, FATTY ACIDS AND AMINO ACIDS AS INDICATORS OF EGG AND LARVAL VIABILITY IN ATLANTIC COD (Gadus morhua)**

M. Clarke¹, C. C. Parrish¹ and R. Penney²

E-Mail: mjclarke@mun.ca

¹Ocean Sciences Centre, Memorial Univ. of Newfoundland, Canada; ²Department of Fisheries and Oceans, St. John’s, NL, Canada

**Session:** LinP7

**Abstract:** An understanding of the factors affecting egg and larval quality can serve as a means to separate poor eggs from high-success eggs, thus allowing producers to select viable eggs that will result in maximum rates of fertilization, hatch, and larval survival. Biochemical composition is being examined as an indicator of egg and larval viability in cod, correlating fertilization rates, hatch rates and survival with profiles of lipids, fatty acids and amino acids. Batches of eggs spawned from cultured cod broodstock at the OSC facilities were used, with fertilization rates ranging from 66% - 99%, and hatching success ranging from 4.5% to 96%. Samples were taken at six stages from spawn to yolk-sac absorption (10 dph). Analysis of the samples will be carried out in spring/summer of 2006. Lipid analysis will be carried out using an Iatroscan Mark V TLC/FID analyzer. The fatty acid and amino acid composition of the sample will be analyzed by gas chromatography with a flame ionization detector. Samples will then be sorted according to fertilized vs. unfertilized eggs, hatching success, and survival to see if there are statistical relationships between lipid, fatty acid and amino acid profiles and egg viability, looking both at each individual stage and at the changes over time. Statistical analysis will be done using ANOVA and multiple comparison tests. Funding by Department of Fisheries and Oceans.

**SURVIVAL ESTIMATES OF OUTMIGRATING JUVENILE SALMONIDS IN THE LOWER COLUMBIA RIVER AND ESTUARY, 2002-2004**

B. J. Clemens and C. B. Schreck

E-Mail: Ben.Clemens@oregonstate.edu

Oregon Cooperative Fish and Wildlife Research Unit, Dept. of Fisheries and Wildlife, Oregon State Univ., USA

**Session:** TelO1

**Abstract:** Survival estimates of outmigrating juvenile salmonids in the 223 rkm expanse of the non-impounded lower Columbia River and estuary were heretofore nonexistent. We estimated survival of barge-transported and in-river migrating (ROR) juvenile salmonids in the lower Columbia River estuary, and tested two hypotheses: (1) there is no difference in survival of juvenile salmon with regards to transportation history or (2) migration date. Juvenile steelhead (Oncorhynchus mykiss) and spring/summer and fall Chinook (O. tshawytscha) were tagged with either radio or acoustic tags and released throughout their outmigrations. A series of receiver arrays in the lower Columbia River estuary enabled us to detect or ‘recapture’ these animals and thus estimate survival. Survival estimates were considerably variable across release days, periods, and years. ROR fall Chinook fared better than their barged counterparts during all releases in 2002, and in the last four releases in 2003. Barged fall Chinook also survived in lower proportions as the season continued, coincident with decreasing river flows and increasing water temperatures. ROR and barged steelhead survival estimates were not significantly different in either 2002 or 2003. Based on our results, we suggest an adaptive barge-transportation program that is dependent upon river flows, barge stocking densities, and fish condition. Funded by the U.S. Army Corps of Engineers.

**BARCODING THE FISHES OF ATLANTIC CANADA**

S. L. Clifford¹, L. Van Guelpen², E. L. Kenchington¹,³ and P. Bentzen¹

E-Mail: Stephen.Clifford@dal.ca

¹Dept. of Biology, Dalhousie University, Halifax, Nova Scotia; ²Atlantic Reference Centre, Huntsman Marine Science Centre, St. Andrews, New Brunswick; ³Bedford Institute of Oceanography, Department of Fisheries and Oceans, Dartmouth, Nova Scotia

**Session:** AdvO12

**Abstract:** Fishes are the most diverse group of vertebrates with approximately 20,000 marine species occurring globally including more than 850 in Atlantic Canada. Species identifications in fish, especially morphologically based approaches can be challenging because of their high diversity and profound changes in appearance during development. DNA-based
approaches have the potential to transform the task of identification by providing reliable, cost-effective and rapid diagnosis of species identity across all life stages including eggs and larvae. In addition, DNA-based approaches have applications in delimiting cryptic species, and enable identifications where traditional methods are not applicable such as from fish scales and other body parts as well as processed products. Standardized DNA reference sequences (barcodes) are being generated for all marine fish species found in Atlantic Canada as part of the global Fish Barcode of Life Initiative (FISH-BOL). The mitochondrial cytochrome c oxidase subunit I (COI) is being used as the principle barcode gene region and DNA sequences are linked to physical voucher specimens and in an electronic database (BoLD). Several hundred marine fish specimens from throughout eastern Canada have been collected and DNA barcodes generated. Results from the Atlantic Canadian fish barcoding project will be presented and applications to fish biology discussed. This research is funded by NSERC.

**FISH HEALTH, FROM MECHANISTIC STUDIES TO POPULATION MODELS, AS A TOOL FOR ASSESSING EFFECTS OF CHEMICAL CONTAMINANTS**

T.K. Collier

E-Mail: Tracy.K.Collier@noaa.gov

Environmental Conservation Division, Northwest Fisheries Science Center, NOAA Fisheries, Seattle WA USA

Session: ImpO17

**Abstract:** Environmental regulations have long relied on lethality tests, generally with safety factors, to protect aquatic species from the effects of chemical contaminants. With more and more fish species being listed under ESA and other endangered species statutes in other countries, there has been a greater emphasis on assessing and protecting fish health, rather than relying on lethality tests. Using a wide range of approaches, we have now shown that by focusing on fish health, better decisions can be made concerning how to maintain or improve water and sediment quality. For example, polycyclic aromatic hydrocarbons (PAHs) have long been assumed to be primarily either narcotic or carcinogenic compounds, but studies of the developmental toxicology of PAHs show that they exhibit a complex range of specific toxic effects, differing widely between PAH congeners. Thus different approaches for protecting aquatic species from the effects of PAHs will likely be necessary. Olfactory-mediated behaviors are shown to be compromised by comparatively low levels of dissolved toxicants, and our results suggest that current water quality criteria (for current use pesticides and metals) are not protective for these behavioral endpoints. Finally, putting empirical data on fish health endpoints into next generation population dynamic models is demonstrating that chemical contaminant exposure of fish is of the same (or even greater) magnitude as other major stresses, such as passage through hydropower systems on the Columbia River.

**INCREASED DISEASE-INDUCED MORTALITY IN OUTMIGRANT SALMON DUE TO ENVIRONMENTAL STRESSORS REDUCING HOST RESISTANCE**

T.K. Collier¹, F.J. Loge², M.R.Arkosh³, T.R. Ginn¹ and L.J. Johnson¹

E-Mail: tracy.k.collier@noaa.gov

¹NW Fisheries Science Center, NOAA Fisheries, Seattle WA; ²U. Cal. Davis, Davis, CA

Session: DisO6

**Abstract:** Infectious disease within outmigrating juvenile salmon in the Columbia River Basin has been shown to be modulated by environmental stressors, including chemical contaminants and passage through the hydropower system. These stressors influence host-susceptibility, resulting in increased disease-induced mortality. We have developed and applied a dose(stressor)-structured population dynamic model, which shows that chemical (both in the river and the estuary) and in-river (dam passage and predation) stressors influence host-susceptibility and increase the force of infection (defined as the per capita rate of infection) in outmigrant Chinook salmon (*Oncorhynchus kisutch*). Using the marine bacterium Listonella anguillarum as a model pathogen, together with empirical data from both laboratory and field studies, our model shows that chemical and in-river stressors increase the cumulative incidence of delayed disease-induced mortalities in Chinook salmon. Using reasonable estimates of estuarine residence times, increased mortalities ranged from 3-18%, which are sufficient to markedly alter population trajectories. The development and application of this model shows that sublethal effects resulting in reduced disease resistance can be significant factors involved in limiting salmon recovery. Increased understanding of host-susceptibility, and mitigation of environmental stressors which increase disease transmission, could represent a significant contribution to our ability to recover listed populations of Pacific salmon. Funded by NOAA’s West Coast Center of Excellence in Oceans and Human Health, and the National Science Foundation.
OVEREXPRESSION OF MYOSTATIN IN FISH
M. Concepcion¹, J. Reitsma¹, M. Phelps¹, E. Mobley² and T. Bradley¹,²
E-Mail: tbradley@uri.edu
¹Dept. of Fisheries, Animal and Veterinary Science, ²Dept. of Cell and Molecular Biology, University of Rhode Island, USA

Session: GenO2
Abstract: Muscle growth and development in domestic animals is controlled by an array of intrinsic and extrinsic factors. One of the more recently discovered regulators is myostatin, a member of the transforming growth factor β (TGF-β) superfamily. Myostatin is synthesized in muscle cells and inhibits proliferation and differentiation of myoblasts, limiting growth rate and muscle mass in domestic animals. Disruption or inactivation of the myostatin gene has been demonstrated to markedly enhance growth in several species of domestic and laboratory animals. The most striking example of myostatin inactivation is observed in the double-muscled Belgian Blue breed of cattle. Comparable enhancement of muscle mass has been produced in mice by inactivation of the functional myostatin gene (i.e., knockout) or overexpression of mutants (i.e., dominant negative approach). More recently the myostatin gene has been identified in a variety of divergent species of fish including white bass, rainbow trout, Atlantic salmon, gilthead seabream and channel catfish. However, it remains unclear whether myostatin functions in fish as it does in terrestrial vertebrates. To investigate the function of myostatin in muscle biology and growth of fish, transgenic rainbow trout (Oncorhynchus mykiss) were produced by microinjection of newly fertilized eggs with 10⁷ copies of a construct coding for rainbow trout myostatin or the myostatin prodomain and containing a myosin light chain promoter limiting expression to muscle tissue. The effects of expression of the transgene on muscle development and growth are being investigated. If myostatin is found to be the primary negative regulator of muscle growth in fish, inactivation of the molecule holds promise for enhancing aquaculture. This research was supported by USDA NRICGP grant #2003-35206-13506.

APOLIPOPROTEIN A-I: A POTENTIALLY IMPORTANT ANTIMICROBIAL PROTEIN IN TELEOST FISH
M.I. Concha¹, V. Smith², K. Castro¹, A. Bastías¹, F. Villarroel¹ and R. Amthauer
E-Mail: margaritaconcha@uach.cl
Instituto de Bioquímica, Facultad de Ciencias, Campus Isla Teja, Universidad Austral de Chile, Valdivia, Chile

Session: DisP4
Abstract: In a previous study we showed that high density lipoprotein (HDL), which corresponds to the most abundant plasma protein in the carp (Cyprinus carpio), displays antimicrobial activity, suggesting its participation in the innate immunity of teleost fish. The major HDL-associated apoprotein, apoA-I, was purified by sequential affinity and gel-filtration chromatographic steps from carp and rainbow trout (Oncorhynchus mykiss) plasma, to evaluate if it was responsible for the antibacterial activity of HDL. Using a microtiter broth dilution assay, we show that apoA-I from both species displays broad spectrum antibacterial activity in the micromolar range (EC50 0.3–9 mM), even against fish pathogens (e.g. Yersinia ruckeri and Pseudomonas sp). Moreover, a synthetic peptide derived from the carboxyl-terminal region of carp apoA-I not only have antibacterial activity but also synergizes with lysozyme in a radial diffusion antimicrobial assay. This peptide shares some structural features with the group of linear a-helical cationic antimicrobial peptides described in many vertebrates. Western blot analysis of the chymotrypsin digestion products of HDL-associated apoA-I shows that the stable truncated protein lacks its C-terminal end suggesting that a similar peptide could be released in vivo by an insult-regulated protease like chymase. Finally, the presence of apoA-I in the skin mucus and the expression of apoA-I in the epidermis, gill epithelia and intestinal mucosa, which correspond to the main primary defense barriers in fish, highlights the potential relevance that apoA-I could have as an effector of innate immunity in teleosts. Funded by Fondecyt 1050637 and DID-UACH S-2004-40.

ADAPTIVE PLASTICITY IN ENDANGERED ATLANTIC WHITEFISH: IMPLICATIONS FOR POPULATION GENETIC STRUCTURE?
A.M. Cook and P. Bentzen
E-Mail: amcook@dal.ca
Marine Gene Probe Lab, Biology Department, Dalhousie University, Nova Scotia, Canada

Session: FroO26
Abstract: Atlantic whitefish (Coregonus huntsmani) is an endangered species endemic to a single moderately acidified watershed in southwest Nova Scotia. The species has low genetic diversity (microsatellite He= 0.17) and low population numbers (1000-2000). Our goal was to determine Atlantic whitefish’s adaptive evolutionary potential through studying their inherent phenotypic plasticity. This was examined by norms of reaction for hatch rate and larval survival of Atlantic whitefish when exposed to a range of pHs. Five Atlantic whitefish single pair matings were performed in captivity.
Resultant progeny were subjected to pH levels of 4, 4.3, and 4.6 just prior to hatch, and were tracked until 8-days post hatch. Results showed significant divergence in norms of reaction between matings with two groups evident. The groups were separated by their observed hatch rate at pH 4.3, with the upper group at 84.4 (3.13)%, and the lower at 31.8 (5.32)%. Comparatively, hatch rates were similar for all families at pH of 4 and 4.6 with rates of 22.8 (11.7)% and 88.4 (9.6)%. Across all families survival rate of yolk-sac larvae increased with pH and ranged from 91.5 (2.4)% to 98.2 (0.89)%. Interestingly, the coefficient of variation of body size for survivors and mortalities was 1.6 and 8.7 respectively. This result suggests stabilizing selection may be acting on Atlantic whitefish yolk-sac larvae under pH stress. Overall, stabilizing selection and differences in intraspecific norms of reaction may play a significant role in altering the population genetic structure in this endangered species. Funded by DFO and an NSERC Discovery Grant to P.B.

OXYGEN SENSING IN FISH GILLS—UNIQUE DISTRIBUTION OF NEUROTRANSMITTERS SUGGESTS DIFFERENT OXYGEN-SENSING MECHANISMS IN HYPOXIA TOLERANT FISH
E.H. Coolidge and W.K. Milsom
E-Mail: Coolidge@zoology.ubc.ca
Dept. of Zoology, Univ. of British Columbia, Vancouver, Canada

Session: HypO4
Abstract: Numerous studies have determined approximate locations of chemoreceptive cells in freshwater fish, with the majority of evidence showing the gills as the primary oxygen-sensing site. We investigated the distribution of putative neurotransmitters and markers for neuroepithelial cells in the first and second gill arches of freshwater fish with varying degrees of hypoxia tolerance using immunohistochemistry. We are comparing the patterns of immunoreactivity in two distantly related species with different hypoxia tolerances (Onchorhyncus mykiss and Carassius auratus) and two species from the same genus (Hoplias) that possess distinct differences in habitat and hypoxia tolerance, to establish a relationship between patterns of distribution and hypoxia tolerance. Our results for trout and carp indicate there are unique patterns of serotonergic, catecholaminergic, and purinergic cells in these species consistent with differences in internal and external O2 sensing, and we predict we will see a similar distribution pattern in the closely-related but ecologically distinct traira (Hoplias malabaricus) and trairão (Hoplias lacerdae). Whole-fiber nerve recording studies are in progress to determine whether electrophysiological responses are also consistent with the histological data and whole animal responses. Funded by NSERC.

BREATHING IN THROUGH THE GILL AND OUT THROUGH THE GUT – UNUSUAL GAS EXCHANGE AND ACID-BASE BALANCE IN FISH AT HYPERSALINITIES
C.A. Cooper and R.W. Wilson
E-Mail: chris.cooper@ex.ac.uk
School of Biosciences, Hatherly Laboratories, University of Exeter, Exeter, Devon, UK.

Session: IonO3
Abstract: To prevent dehydration and maintain homeostasis in a hyperosmotic environment, marine teleost fish imbibe copious amounts of seawater and absorb high concentrations of Na⁺ and Cl⁻ across the intestine to drive fluid absorption. The mechanisms for fluid absorption coupled with Na⁺ and Cl⁻ transport are well established, however there is another, previously unrecognised yet essential mechanism that aids fluid absorption. Marine teleosts secrete high levels of bicarbonate (HCO₃⁻) that precipitate Ca²⁺ from the imbibed seawater in the intestine as insoluble carbonate (CaCO₃). The removal of osmotically active Ca²⁺ ions as carbonate creates an osmotic gradient that facilitates water transport. At hypersalinites drinking rates increase and it was predicted that HCO₃⁻ secretion would also increase because of the elevated intestinal Ca²⁺ concentrations from the imbibed water. To test this hypothesis external Ca²⁺ concentrations were doubled in normal seawater, which resulted in an approximately 2-fold increase in HCO₃⁻ secretion and subsequent CaCO₃ excretion. A proportional increase in HCO₃⁻ secretion relative to salinity (and hence Ca²⁺ concentration) has major implications for certain physiological processes at hypersalinites (e.g. 60 ppt). For example, HCO₃⁻ is produced within the cell from metabolic CO₂. At these hypersalinites blood total CO₂ significantly decreases and it is predicted that a major fraction of metabolic CO₂ will be excreted via the intestine as HCO₃⁻ ions and CaCO₃. Additionally, increased intestinal HCO₃⁻ base secretion at high salinities, must be matched by acid excretion elsewhere, with the gills being the most likely candidate as they are the primary site of acid-base regulation. Funded by BBSRC.
ASSESSING ECOLOGICAL RISK OF TRANSGENIC TILAPIA TO HETEROSPECIFICS

A. Cooper¹, W. Senanan² and A.R. Kapuscinski³
E-Mail: coop0162@umn.edu

¹Conservation Biology Graduate Program, Univ. of Minnesota, USA; ²Dept. of Aquatic Sciences, Burahpa Univ., Thailand; ³Dept. of Fisheries, Wildlife and Conservation Biology, Univ. of Minnesota, USA

Session: GenO9
Abstract: Ecological risk assessment of transgenic fish is complex and largely untested, requiring both qualitative and quantitative methodologies to determine their fitness and invasiveness relative to con- and hetero-specifics. Nile tilapia (Oreochromis niloticus), a key aquaculture species in Thailand, routinely escape, establishing feral populations. Many assumptions are made regarding this non-native’s impact(s) on heterospecifics that people depend on for food; however, few quantitative data are available regarding their ecology, behaviour, and invasiveness. Growth-enhanced transgenic tilapia are available for potential farming in Thailand, although they have not been adopted at this time. This study aims to increase our understanding of the effects of growth enhancement on behaviour and displays of interference competition between tilapia and selected heterospecifics, which may arise if growth-enhanced transgenic tilapia enter Thai ecosystems. Experiments in laboratory aquaria and outdoor ponds use non-transgenic, growth-enhanced transgenic, and surrogate growth-enhanced tilapia. All are derived from a line of feral Thai tilapia. Surrogates were given a single injection of sustained release recombinant bovine growth hormone (rbGH) formulation (Posilac®). Results show that surrogates exhibit growth enhancement relative to controls when fed to satiation, and chosen heterospecifics exhibit sufficient diet and habitat-use overlap with feral Thai tilapia. Upcoming lab and field competition experiments based on these findings will be presented. Funding provided by USAID and a MacArthur Scholar Award.

EFFECT OF THE TEMPERATURE ON THE COUPLING BETWEEN CA²⁺ TRANSPORT AND ATP HYDROLYSIS BY SERCA1 FROM MARLIN HEATER ORGAN AND RABBIT MUSCLE

Costa, D.C.F.¹, Landeira-Fernandez, A.M.¹ and Block, B.²
E-Mail: dcosta@bioqmed.ufrj.br

¹Instituto de Bioquímica Médica, CCS/UFRJ, RJ, Brasil; ²Hopkins Marine Station of Stanford University, Pacific Grove, CA, USA

Session: AdvP2
Abstract: The inability to limit heat loss, while respiring through gills, prevents most fish from maintaining body temperatures higher than ambient. However, among the order Scombroidei (tunas, billfishes and swordfish), the ability to retain metabolic heat and elevate tissue temperatures is widespread. Billfishes and swordfish employ a strategy of cranial endothermy warming the brain and eyes with a specialized thermogenic tissue called heater organ. This tissue is derived from eye skeletal muscle and expresses a unique thermogenic phenotype with no contractile filaments, but retained all the cellular components involved in energy metabolism and Ca²⁺ mobilization. The sarcoplasmic reticulum Ca²⁺-ATPase (SERCA) maintains a low cytoplasmic Ca²⁺ concentration by pumping Ca²⁺ from the cytosol into the sarcoplasmic reticulum (SR) lumen at the expense of ATP. The aim of this work was to investigate the activity of SERCA1 from blue marlin (Makaira Nigricans) heater organ and compare activity with the well-known SERCA1 rabbit skeletal muscle as a function of the temperature. The rate of ATP hydrolysis catalyzed by SERCA1 from marlin heater organ was highly temperature dependent, while the rate of Ca²⁺ uptake displays low temperature dependence. Calculations of the ratio between Ca²⁺ uptake and ATP hydrolysis (coupling) at 10°C was ~0.7 but as the temperature increases to 25°C, this ratio decreases to ~0.3. For the rabbit SERCA1, this ratio was almost the same at all temperature tested (~1.7). As a result, we observed that the SERCA1 pump from heater tissue is less coupled, and also as the temperature of the medium increases this ratio decreases. Taken together these results suggest that the inefficiency of the SERCA1 pump from blue marlin heater organ can be involved in thermogenesis. Support by NSF and FAPERJ.

“SLEEPY FISH”: METABOLIC DEPRESSION IN A NORTH ATLANTIC TELEOST, TAUTOGOLABRUS ADSPERSUS

I. Costa, W.R. Driedzic and A.K. Gamperl
E-Mail: icosta@mun.ca

Session: NorO9
Abstract: In order to survive the cold winter months, many animals are known to depress their metabolism below basal values, spending the winter in a torpid state. In ectotherms, the literature regarding metabolic depression mainly focuses on reptiles and amphibians, although some fish species appear to exhibit this behaviour. The cunner (Tautogolabrus adspersus), a member of the Labridae family, exhibits winter dormancy (i.e. becomes inactive and stops feeding) when seawater temperatures fall below 5°C, but it is unknown if this is actually ‘torpor’. Thus, we are examining how routine metabolic rate (MR Rout) and cardiac function vary with season. Wild, adult cunners were kept under ambient conditions
(photoperiod/temperature) for a year and their MR\textsubscript{rest} determined at 5 temperatures: 0°C (dormant/inactive); 5°C (coming out of dormancy); 9 and 14°C (active); and 5°C (going into dormancy). High Q\textsubscript{10} values (>4) were recorded between most temperatures. Further, preliminary results show a MR\textsubscript{rest} of ~8 mg O\textsubscript{2} kg\textsuperscript{-1} h\textsuperscript{-1} for fish at 0°C, which would result in an extremely high Q\textsubscript{10} (from 0 to 5°C). Cardiac function values at 14°C (e.g. cardiac output ~30 ml min\textsuperscript{-1} kg\textsuperscript{-1}; heart rate ~46 beat min\textsuperscript{-1}) were within the range expected for other teleosts. To determine if the cunner actually becomes torpid during winter (i.e. the reduction in MR\textsubscript{rest} observed is not solely due to the Q\textsubscript{10} effect on biological processes), and look at temperature-dependent changes in cardiac function, acute temperature challenges are being performed. We will measure MR\textsubscript{rest} and cardiac function in animals acclimated to 0 and 5°C, and following acute transfer from 5 to 0°C and 0 to 5°C. The results of these acute challenges will also be reported. Funded by NSERC.


Cota-Meza, M. Soledad
E-Mail: mcota@ipn.mx
CICIMAR-IPN. Ave. Inst. Politécnico Nacional s/n, CP 23000, La Paz Baja California Sur, México

Session: AdvP1
Abstract: The vertical migrations of zooplankton are to avoid predators and maximize food intake. The aim of this study is to describe the vertical distribution of dominant species of fish larvae and chaetognaths in the SW Gulf of California (2001-2002). The organisms were collected by close-open-close plankton net of 505-µ mesh at nine sampling stations at four depths (0-50 m, 50-100 m, 100-150 m, and 150-200 m). Chaetognath and larval abundances were standardized to organisms/10 m\textsuperscript{2}. The dominant species of chaetognaths were \textit{Sagitta enflata} and \textit{S. decipiens} in all periods. \textit{Sagitta enflata} tends concentrate in the two upper levels and \textit{S. decipiens} in the two deeper levels. The vertical distribution of the fish larvae most abundant and frequent was \textit{Vinciguerria lucetia} in the two levels closer to the surface from spring to autumn, \textit{Diogenichthys lateratus} between 100- and 150-m depth from spring to autumn, \textit{Triphoturus mexicanus} at all four levels in summer, and the larvae of \textit{Opisthonema sp.} in the top level in spring and \textit{Sardinops caeruleus} in winter. The vertical distribution of the chaetognath \textit{S. enflata} and the fish larvae of \textit{V. lucetia} from spring to autumn, \textit{Ophistonema sp.} in summer, and \textit{S. caeruleus} in winter tend to coincide in the upper levels, whereas the chaetognath \textit{S. decipiens} was associated mainly with \textit{D. lateratus} and \textit{T. mexicanus} larvae in the two deeper levels. Because of the carnivorous nature of the chaetognath \textit{Sagitta spp.} and to their to its different vertical distribution, it is possible that they tend to consume different prey.

THE INFLUENCE ON GENE-ENVIRONMENT INTERACTIONS ON GHR AND IGF-1 EXPRESSION LEVEL AND THEIR EFFECT ON GROWTH IN BROOK CHARR (\textit{Salvelinus fontinalis})

G. Côte, G.M.L. Perry, P. Blier and L. Bernatchez
E-Mail: guillaume.cote@giroq.ulaval.ca
1 Biology Dept., Université Laval, QC, Biology and 2Chemistry Dept.,UQAR, QC, 3Biology Dept, University Park Campus, Los Angeles, CA

Session: ProO8
Abstract: Variation in heritabilities among environments is generally explained by a change in additive genetic variance or a weak genetic correlation between trait expression in different environments. Both explanations suggest the presence of a genotype-by-environment (GxE) interaction, indicating that genotypes differ in their response to environmental conditions. Despite empirical data that support both hypotheses, there remains much to discover regarding the genetic underpinnings of fluctuations in VA and VE among environments. We investigated the impact of rearing environment on variance components of growth and the expression of two key genes associated with growth, insulin-like growth factor (IGF-1) and growth hormone receptor (GHR). Differences in IGF-1 and GHR expression between fish, grouped according to their genetic value for growth (EBV), were evaluated using quantitative PCR. Fish reared in fresh water grew 40% faster (p < 0.001) than fish issued from the same families, but reared in salt water (20‰). Similarly, additive genetic variance was 25% greater (p=0.020) in freshwater (VA= 0.080) than in salt water (VA= 0.064). In contrast, both IGF-1 (p=0.074) and GHR (p=0.003) expression was highest in saltwater. Furthermore, although IGF-1 expression correlated significantly with growth, the strength of this relationship varied both among EBV groups and between environments. Altogether these results reveal a significant genetic effect of IGF-1 on growth and confirmed the importance of GxE interactions. Funded by AquaNet & VRQ.
MUSCLE, POWER AND STEADY SWIMMING IN FISHES
D. J. Coughlin
E-Mail: djcoughlin@mail.widener.edu
Department of Biology, Widener University, Chester, PA, USA

Session: MusO1
Abstract: Fish power steady undulatory swimming by employing longitudinal bands of red (slow-twitch, aerobic) muscle. Over the last 15 years a number of studies have examined longitudinal variations in red muscle recruitment, activation conditions and power output during swimming. During this time, I have focused on “typical” undulatory swimmers - fishes that swim with moderate levels of body bending – including scup, trout and bass. The methods of inquiry include in vivo measurements of muscle activation (EMGs) and length change (sonomicrometry), in vitro measurements of muscle contractile properties and power output during swimming (workloop technique) and molecular analysis of the protein correlates of longitudinal variations in contraction kinetics. Scup, trout and bass all produce the majority of power for steady swimming with muscle from the caudal half of the red myotome, although there are inter-specific differences in the relative contribution of rostral vs. caudal muscle. At low swimming speeds, the caudal muscle is the only component of the myotome with detectable recruitment. At higher steady swimming speeds, the pink muscle (if present) is recruited to enhance aerobic performance. The lower power in the rostral myotome is a function of the disadvantageous activation conditions of the muscle during swimming. All three species do show longitudinal variations in the contractile kinetics of the muscle, with the rostral red muscle displaying faster rates of activation and/or relaxation compared to caudal muscle. Faster contractile properties in the rostral myotome may permit it to make at least some contribution to power production during steady swimming. Longitudinal variations in the expression of muscle proteins such as troponin and parvalbumin correlate with rostral-caudal shifts in contraction kinetics. Funded by NSF.

TEMPORAL DIFFERENTIATION: CONTINUOUS VS. DISJUNCT SPAWNING RUNS
IN ANADROMOUS RAINBOW SMELT (Osmerus mordax)
M.W. Coulson, I.R. Bradbury, and P. Bentzen
E-Mail: mcoulson@dal.ca
Marine Gene Probe Lab, Biology Department, Dalhousie University, Nova Scotia, Canada.

Session: FroO5
Abstract: While the importance of spatial separation to population divergence has often been studied, the influence of temporal separation has received much less attention. We assessed temporal genetic differentiation within three spawning locations for anadromous smelt (Osmerus mordax). At one location, spawning activity occurs continuously over a two-month period; at the other two locations spawning occurs over a similar period, but with a 3-4 week break in spawning activity between two distinct runs of fish. At all locations, ‘early’ and ‘late’ spawning smelt were sampled about 1-2 months apart. FST values indicated that significant genetic divergence exists between runs separated with a ‘break’ in spawning activity (0.0056-0.0067), while no significant effect of structuring was present across the two sampling periods of the continuous run (0.0027). This demonstrates the importance of spawning time as well as degree of connectivity between temporally separated individuals in contributing to population differentiation. By removing the spatial effect, we can assess temporal effects which may often be obscured when they occur in the context of geographically separated populations. In smelt, the magnitude of genetic differentiation associated with temporal effects appears to be comparable in magnitude to genetic differentiation seen on regional scales when there are little or no temporal differences in spawning. The level of temporal differentiation in smelt is similar to that seen in some anadromous salmonids (e.g. Oncorhynchus nerka) and suggests a general importance for ‘isolation by time’ in the maintenance of intraspecific diversity. Funded by an NSERC Discovery Grant to PB.

PROLONGED HYPOXIA REDUCES GROWTH RATE
AND LENGTHENS SDA IN JUVENILE SOLE (Solea solea)
C. Couturier1, D. Chabot*2, A. Prinet3 and G. Claireaux3
E-Mail: chabotd@dfo-mpo.gc.ca
1CNRS-CRELA, L’Houmeau, France; 2Institut Maurice-Lamontagne, Fisheries & Oceans Canada, Mont-Joli, QC; 3ISEM, Sète, France

Session: HypO7
Abstract: The aim of the study was to determine the consequences of reduced water oxygenation on growth performance and digestion kinetics (SDA) of juvenile sole. A growth experiment was conducted under 30 and later 40% oxygen saturation, or under 100% saturation for the entire experiment (7 months). Compared to normoxia, fish maintained at 30% saturation displayed reduced growth (~30%), but a compensatory growth was observed after water oxygenation was...
increased to 40% saturation. A respiration experiment measured oxygen consumption (MO2) following food ingestion at 30, 40 and 100% saturation. Changes in the time course of SDA were fully explained by the metabolic constraints imposed by the dwindling scope for metabolic activity. In normoxia, peak oxygen demand during SDA represented 55% of aerobic metabolic scope, and the duration of SDA was linearly correlated to meal size. At 40% saturation, fish metabolic resources were sufficient to accommodate the post-prandial increase in metabolic rate and both peak MO2 and SDA duration were similar to what was observed in normoxia. On the other hand, a reduction in peak MO2 was observed at 30% saturation and was compensated by an increase in the duration of SDA. It is proposed that the observed reduction in growth performance at 30% saturation, and the subsequent compensatory growth at 40% saturation, resulted from the modulation of aerobic metabolic scope by ambient water oxygenation. Funded by the Conseil général de la Charente Maritime and European Commission 5th Framework Program, Research Program QOL-2001-3 (ETHOFISH).

SOFTWATER ACCLIMATION AND IONREGULATION AS A PRECURSOR TO ACUTE AND CHRONIC METAL EXPOSURE IN ZEBRAFISH (Brachydanio rerio)
P.M. Craig, C.M. Wood and G.B. McClelland
E-Mail: craigpm@mcmaster.ca
Biology Department, McMaster University. Hamilton, Ontario, Canada

Session: IonO16
Abstract: Recently, zebrafish have been adopted as a model for toxicology, in particular for the study of metals, due to their ability to tolerate softwater. However, little is known about the physiology and ionoregulatory abilities of zebrafish in softwater. In this study, we examined the adaptive ability of zebrafish over a period of 7 days with a progressive softwater exposure (Na+ & Ca2+ < 200 mM, pH 6.5). Gill tissue was sampled daily and mRNA expression levels of various ion and metal transporters were quantified by real-time qPCR. Additionally, changes in enzyme activities of gill Na+/K+ATPase and carbonic anhydrase were quantified. Using whole-body digests, it appears that zebrafish are able to maintain whole body ion concentrations with little fluctuation, despite low ambient ion levels. Moreover, we did see significant increases in gill epithelium calcium channel and gill carbonic anhydrase expression, plus a transient increase in Na+/K+ATPase enzyme activity indicating an upregulation of ion regulatory channels and enzymes to cope with a low ion medium. These results demonstrate the need for proper controls to account for the changes in ion regulatory parameters during softwater acclimation needed for toxicology studies. Additionally, care should be taken when interpreting results when protective ions, such as Na+ and Ca2+ are added back into the medium during acute and chronic copper exposure experiments. Funding provided by an NSERC-CRD grant to both Chris Wood and Grant McClelland.

EFFECTS OF TROUT FARM EFFLUENTS ON SMOLTS OF ATLANTIC SALMON (Salmo salar)
N. Crooks¹, J.H. Best², L. Evans¹, A. Moore³ and C.P. Waring¹
E-Mail: neil.crooks@port.ac.uk
¹Institute of Marine Sciences, University of Portsmouth, UK; ²English Nature, Peterborough, UK; ³CEFAS, Lowestoft Laboratory, Lowestoft, UK

Session: OlfP7
Abstract: The life cycle of Atlantic salmon, Salmo salar, involves smoltification, which prepares juveniles for the transition between freshwater and seawater. It is possible that exposure to effluents from fish farms affects this transformation leaving the smolts ill prepared for survival at sea. Fourteen smolts were caged 50m downstream and fourteen caged 50m upstream of a rainbow trout farm on the river test, Wiltshire in May 2005. All control fish survived the 3 day exposure, whilst 13 out of 14 fish exposed to fish farm effluent survived. Muscle moisture content showed no significant difference (P > 0.001). Analysis of blood showed no significant difference for osmolality (P > 0.001), sodium (P > 0.001), and chloride (P > 0.001). Potassium levels of fish exposed to fish farm effluent was significantly higher than that of controls (P < 0.001). Histopathology of kidneys showed no significant difference in density of c-shaped nephrons, (P > 0.001), s-shaped nephrons (P > 0.001), and glomerular nephrons (P > 0.001). Density of nephrons did show a significant difference (P < 0.001) with fish exposed to effluent having greater densities than control fish. Histopathology of gills showed thickening of the secondary lamellae with fish farm exposed smolts showing significantly thicker lamellar than control fish (P < 0.001). There was no significant difference with regard to secondary lamellar lifting, (P > 0.001), Secondary lamellar clubbing, (P > 0.001), Lamellar hyperplasia (P > 0.001).There was a significant difference in mucous cell density in fish farm exposed fish compared to the control group (P < 0.001). Funded by DEFRA and CEFAS
EVOLUTION OF THE ENAMELOID MICROSTRUCTURE IN ELASMOBRANCHS
G. Cuny
E-Mail: gilles@snm.ku.dk
Geological Museum, Natural History Museum of Denmark, University of Copenhagen, Øster Voldgade 5-7, Copenhagen K, Denmark

Session: BonO4
Abstract: A triple-layered enameloid has long been considered an autapomorphy of the Neoselachii. However, new phylogenetic analysis of the Neoselachii no longer consider the Batoidea as derived Squalea, but as the sister-group of the Galea+Squalea, and teeth of the Batoidea appear devoid of a triple-layered enameloid. In order to study the evolution of the enameloid microstructure among elasmobranchs, fossil teeth of hybodont, Batoidea, Squalea and Galea have been studied using a Scanning Electron Microscope. Preliminary results indicate a tendency to the reduction of the enameloid in the batoid lineage, compared with that of the hybodont, while it becomes more complex among the neoselachian sharks (Galea + Squalea). Certain Triassic taxa of uncertain affinities, like Vallisia and Doratodus are therefore likely to represent primitive batoids. Among neoselachian sharks, their parallel-bundled enameloid shows few radial bundles in the Triassic taxa, but at the beginning of the Jurassic, this tissue shows the same complexity as in modern taxa. The general reduction of ornamentation of the crown of neoselachian sharks during their evolution seems to be due to a reduction of early mineralisation sites at the surface of the tooth during its development. However, it is still unclear whether it is these early mineralisation sites that triggered the appearance of a triple-layered enameloid. Finally, this study also highlights the necessary change in enameloid microstructure for the hybodont sharks to develop a cutting dentition. Funded by Marie Curie Fellowship, NERC, and the University of Copenhagen.

STRESS PROTEIN EXPRESSION IN FISH: EFFECTS OF DEVELOPMENT STAGE, PROTEIN DAMAGE AND HORMONES
S. Currie, S. L. Fowler, N. Osborne, K. Reddin and J. Rendell
E-Mail: scurrie@mta.ca
Department of Biology, Mount Allison University, Sackville, NB, Canada

Session: MolO10
Abstract: We are interested in understanding the role of stress proteins (hsp) in protecting fish from environmental insults, such as high temperature and exposure to contaminants, and how whole animal responses to environmental stress interact with changes at the level of the gene and protein to ensure survival of the animal. Using antibodies specific for salmonid hsp70, hsc70 and hsp90, we have shown that the cellular response to temperature stress varies with tissue type, intracellular compartment and developmental stage of rainbow trout, Oncorhynchus mykiss. To determine whether these differing patterns of induction were a result of the degree of protein damage, we also measured the expression of ubiquitin in the cellular compartments of liver and heart tissue of juvenile and adult trout. We found that the cellular fractions with the most damage are those with the least hsp70 and greatest hsp90 induction suggesting that hsp70 acts to prevent protein damage while hsp90 is responsible for damage control. Furthermore, we have shown that the heat shock-induced induction of hsp is augmented by the stress hormone, adrenaline, demonstrating a clear link between the cellular and hormonal responses to stress in fish. The association of hsp with possible hormone signalling pathways is also evident in our work on environmental estrogens. In vitro experiments in trout hepatocytes suggest that hsp90 chaperone activity is an important part of the physiological mechanism of endocrine disruption in fish. This work was supported by NSERC, New Brunswick Foundation for Innovation and Fisheries and Oceans Canada.

POWER AT THE EXPENSE OF EFFICIENCY?
N.A. Curtin and R.C. Woledge
E-Mail: n.curtin@imperial.ac.uk
Div. Biomedical Sciences, Imperial College London, UK

Session: MusO6
Abstract: Power output and efficiency are two aspects of muscle energetics particularly relevant to locomotor performance. Efficiency is the ratio of energy output to input; specifically for muscle contraction, the ratio of power output to the rate of energy use. Our aim was to discover the relationship between power and efficiency; is one optimised at the expense of the other? Rate of energy use is the sum of the power and rate of heat production, and is proportional to the rate of ATP usage. Our values for efficiency are based on measurements of power output and the rate of heat production, deduced from the rise in muscle temperature during contraction. We measured the efficiency of white myotomal muscle fibres isolated from dogfish (Scyliorhinus canicula) using protocols that mimicked those during normal locomotion. The stimulation phase and duty cycle, and the frequency of sinusoidal movement were varied (12°C). At each frequency and
optimal stimulus phase, the dependences of power and of efficiency on stimulus duty cycle were very different. Power generally increased with increasing stimulus duty cycle, whereas efficiency decreased. At 2.5 Hz movement a single twitch gave optimal efficiency; increasing the stimulus duty cycle to 0.4 raised power by 82%, but decreased efficiency by a 32%. Thus high power can be achieved at the expense of efficiency by adjusting the stimulus duty cycle. Funded by the Royal Society and BBSRC, UK.

REGIONAL CHANGES IN NEUROTRANSMITTERS LEVELS IN FLOUNDER (Platichthys Flesus) BRAIN DURING TIDAL ASSOCIATED VERTICAL MOVEMENTS
A. Damasceno-Oliveira1,2, B. Fernandez-Duran1, J. Goncalves1,2 and J. Coimbra
E-Mail: aol@ciimar.up.pt
1CIIMAR-Centre for Marine and Environmental Research, Oporto, Portugal; 2ICBAS-Institute for Biomedical Sciences, University of Oporto, Portugal

Session: IntP1
Abstract: Hydrostatic pressure (HP) is an important thermodynamic and environmental factor affecting fish. Usually they are, or can be, adapted to specific HP ranges. However, little is known about the effects of cyclic variations in HP that fish are challenged with. It is well known that many species perform daily or tidal cyclic vertical movements during spawning or feeding migrations. In previous experiments, we studied the involvement of brain monoamines in physiological responses to changes in HP. The aim of the present study was to explore further implications of tidal associated HP cyclic variations. Seawater acclimated european flounder were exposed to cyclic HP (100-800 kPa) for 7 and 14 days by using pressurizing systems capable of simulating cyclic vertical migrations. The most significant effect that has been observed is the NA and 5-HIAA content reduction in fish submitted to cyclic HP comparing to the control fish maintained at 100 kPa. This reduction was particularly noticed in specific brain regions. Quantification of cortisol bile metabolites (free and conjugated) showed no differences between the experimental groups, indicating a similar level of stress, if that occurred. Partially supported by FCT, Ministry for Science and Higher Education.

INFLUENCE OF GENDER, SEX HORMONES AND TEMPERATURE ON PLASMA IGF-I CONCENTRATIONS IN SUNSHINE BASS
Kenneth B. Davis and Matthew McEntire
E-Mail: kbdavis@msa-stoneville.ars.usda.gov
Harry K. Dupree Stuttgart National Aquaculture Research Center, USDA/ARS, P. O. Box 1050, Stuttgart, AR, USA

Session: FisO12
Abstract: Plasma insulin-like growth factor-I (IGF-I) concentrations in male and female sunshine bass were determined in March, early April and late April in outdoor ponds at a commercial farm. Growth and IGF-I concentrations in sunshine bass fed with estrogen, testosterone, methyl testosterone or a control diet were also determined. Female fish were always larger than male fish, however plasma IGF-I concentrations were always higher in male fish and increased as the pond temperature increased in both sexes. Gonadal development was largest in both sexes in March and declined to a regressed state by the end of April and the same pattern of change occurred with plasma estrogen and testosterone. Growth was reduced in fish fed all three sex hormones, although the effect of estrogen was the most pronounced. Fish fed the control diet had the highest IGF-I level, androgen fed fish had intermediate levels and estrogen fed fish had the lowest IGF-I concentration after 4 weeks on the diet. Plasma IGF-I concentrations appeared to respond to the increasing temperatures and were suppressed by sex hormones. Exogenous sex hormones delivery in the food resulted in a decrease in plasma IGF-I, feeding and growth. Plasma IGF-I concentrations do not appear to explain the sexually dimorphic growth in sunshine bass.

DISRUPTION OF IONOREGULATION IN SPINY DOGFISH UNDER METAL EXPOSURE
G. De Boeck1, J. Hattink1, T. Franklin2, C. Bucking2, S. Wood2, P. Walsh3 and C.M. Wood2
E-Mail: gudrun.deboeck@ua.ac.be
1University of Antwerp, Antwerp, Belgium; 2McMaster University, Hamilton, Canada; 3RSMAS, Miami, USA

Session: ImpO31
Abstract: Squalus aquanthias or spiny dogfish is about 10 times more sensitive to silver exposure as similarly sized teleosts and in fact, sensitivity approached that of freshwater teleosts [1]. Toxicity appeared to be particularly related to a failure of the urea retention mechanism which occurs in part via a Na-coupled, inwardly directed “back-transporter” [2]. Silver and copper show very similar toxic actions in both marine and freshwater fish, inhibiting Na+/K+ ATPase and causing
osmoregulatory distress, and both Ag and Cu can act as a Na analogue and competitor in gill transport systems and may out-compete Na thereby blocking the urea back-transporter. Therefore we examined if Cu had similar effects as Ag on ion transport, urea transport and energy metabolism. From a first exposure to 0 or 500 µg Cu/L, it was immediately evident that Cu was less toxic to dogfish. Survival in both control and exposed fish was 100%, there was no detectable increase in urea efflux and plasma ions and pH remained stable over the entire 96 hour exposure. 1000 µg Cu/L and 1500 µg Cu/L resulted in a mortality of 50 % and 85 % respectively. Even at these acutely lethal concentrations there was no convincing increase in urea efflux, but plasma Na and Cl were elevated. Rectal gland perfusions confirmed urea loss during exposure to Ag, but not to Cu. It can be concluded that whereas Ag affects Na and urea transport, Cu only affects Na transport in spiny dogfish. We acknowledge the support of the Reasearch Foundation of Flanders and the International Copper Association. [1] De Boeck et al 2001 Aquat.Toxicol. 54: 261-275, [2] Fines et al 2001 Am.J.Physiol. 280: R16-R24

MINIMIZING INTERACTIONS BETWEEN SEA TURTLES AND CHESAPEAKE BAY POUND NETS: A GEAR MODIFICATION BASED ON BEHAVIORAL RESPONSE DIFFERENCES
J. DeAlteris¹, R. Silva¹, H. Milliken² and H. Hass²
E-Mail: jdealteris@uri.edu
¹University of Rhode Island and ²National Marine Fisheries Service, USA

Abstract: Offshore pound net leaders in the Virginia portion of Chesapeake Bay incidentally take protected sea turtles. To reduce this take, a modified leader was developed. The top two-thirds of the traditional mesh leader was replaced with spaced vertical ropes. The modification was based on perceived behavioral differences of finfish and sea turtles. Four offshore pound nets were monitored twice daily using both side scan sonar and visual inspections to identify sea turtle - pound net leader interactions. In 2004, seven sea turtles were encountered interacting with the pound net leaders in the study. Six hardshell turtles were found in the control leader and one leatherback was found in the experimental leader. In 2005, 15 hardshell turtles were found interacting with the pound net leaders in the study, all occurred in the control leader. The results of a negative binomial regression analysis on the combined 2004 – 2005 data indicate the modified leader significantly reduced sea turtle interactions. Finfish were sampled from the nets in the study each time they were harvested. The results of paired t-tests and Wilcoxon matched-pairs signed-ranked test indicated no significant catch weight differences, while the results of qualitative length frequency analysis indicated no substantive differences in size selectivity between the two leaders.

ONTOGENY OF CALCIFICATION OF THE TESSELLATED SKELETON
M. N. Dean¹, Wen-An Chiou¹, S. Gorb² and A. P. Summers¹
E-Mail: mdean@uci.edu
¹Univ Calif., Eco Evo Bio, 321 Steinhaus Hall, Irvine, CA 92697, USA ²Max Planck Institut, Heisenbergstr. 3, 70569 Stuttgart, GERMANY

Abstract: A key component of the high level of performance of the elasmobranch skeleton is its tessellation: in most elements, the soft hyaline cartilage core is tiled with an outer rind of calcification, comprised of abutting blocks called tesserae. However, not only are we ignorant of the calcification mechanism of shark cartilage, we do not know whether it is homologous in any respects to vertebrate mineralization pathways. We examined ultrastructural changes in calcification across ontogeny in the jaws of the round stingray (*Urobatis halleri*) using electron microscopy and histological techniques. The uncalcified cartilage of early embryonic stages (35-65mm DW) is highly cellular, with hypertrophic chondrocytes occluding the matrix. Cell size and density shows a marked decrease in late embryos (<65mm DW) when tesserae arise as thin plates (100 µm wide, 50 µm deep). At the calcification front, chondrocytes are flattened and arranged in series along their long axes; these cell “strings” are engulfed by globular calcification and incorporated intact into forming tesserae, creating cell-rich laminae with small passages connecting adjacent entombed cells. Cell spaces (lacunae) at the margins of tesserae are apparently continuous with cells invested in the fibrous intertesseral joints connecting tiles. Chondrocyte size and density continue to decrease to the adult stage as tesserae widen and deepen by 2-3 and 3-5 times, respectively. These preliminary data indicate that elasmobranch chondrocyte size and density decrease with age, as in endochondral ossification, yet lack the end-stage hypertrophication and cell-death of the tetrapod pathway. Funded by JEB Traveling Fellowship and UCI CORCLR grant to MND.
A TOXICOGENOMICS APPROACH TO ENDOCRINE DISRUPTORS IN THE ENVIRONMENT
N. D. Denslow1, N. Garcia Reyero1, M. S. Sepulveda2, E. F. Orlando3, K. H. Watanabe4, K. Kroll1, I. Knoebl5, D. Villeneuve6 and G. Ankley6
E-Mail: ndenslow@ufl.edu
1Dept. Physiol Sci, University of Florida, Gainesville, FL 32611; 2Dept. Forestry & Nat. Resources, Purdue University, West Lafayette, IN 47907; 3Dept. Biol. Sci., Florida Atlantic University, Boca Raton, FL 33431; 4Dept. of Environ. and Biomolec. Systems, Oregon Health & Science University, Beaverton, OR 97006; 5U.S. EPA, ORD, NERL, EERD, Cincinnati, OH 45268, 6U.S. EPA, ORD, NHEERL, MED, Duluth, MN 55804

Session: ImpO1

Abstract: Using toxicogenomics, we are determining predictive gene expression profiles for endocrine disrupting compounds with known modes of action. We are quantifying changes in gene expression along the HPG axis for fathead minnows (Pimephales promelas) exposed to endocrine disruptors. We used three doses of ethinylestradiol, 2, 10 and 50 ng/L for 48 hr and three doses of the antiestrogen ZM189,154 and a mixture of the two and quantified changes in gene expression in liver, brain and gonad. As expected, genes involved in the production of good quality eggs are upregulated in a dose responsive manner with ethinylestradiol, while other genes are down regulated by the exposures. Genes that are altered include those involved in reproduction, stress, energy production, blood coagulation, fatty acid transport, sex hormone synthesis and metabolism, among others. These novel molecular biomarkers must be integrated with traditional end points, which point to adverse effects in growth, reproduction and stability of populations. Funded by USEPA STAR grant #831848.

IDENTIFYING CANDIDATE GENES IN A NON MODEL ORGANISM: MERGING GENETIC MAPPING AND POPULATION GENOMICS IN THE LAKE WHITEFISH (Coregonus clupeaformis)

Derome, N., Rogers, S. and L. Bernatchez
E-Mail: Nicolas Derome
Québec Océan, Département de Biologie, Université Laval, Québec, Québec, Canada, G1K 7P4

Session: ProO7

Abstract: Understanding the genetic basis of adaptation is a major goal of evolutionary biology. Both Quantitative Trait Locus (QTL) mapping and gene transcription profiles (cDNA microarrays) have independently contributed to the identification of candidate regions or genes associated with adaptation. Here, we integrate these methods to identify candidate genes underlying adaptive divergence in the lake whitefish (Coregonus clupeaformis). This species complex exhibits remarkable ecological divergence towards the use of limnetic and benthic resources in several northern temperate lakes, whereby behavioural, physiological, and morphological differences between dwarf and normal ecotypes have been maintained by divergent natural selection. Using cDNA microarrays, we identified 51 differentially expressed genes that correlated with parallel phenotypic divergence of two independent sympatric dwarf and normal population pairs. The expression of these genes was measured as a phenotypic trait for QTL analysis (eQTL) in 40 individuals from a backcross family reared in the lab. QTL analysis using over 900 mapped AFLP and microsatellite markers localized 19 differentially expressed genes to the map. Notably, two major candidate loci linked to QTL were also under the effect of parallel directional selection among natural populations, providing strong support for the hypothesis that these genes are implicated in the genetic basis of adaptive divergence in this species. The hypothesis that phenotype-environment association predicts a genotype-environment association was tested by comparing the cisco (C. artedi), a limnetic coregonid specialist that exhibits phenotypic convergence with the dwarf whitefish. We found that the same candidate genes were up-regulated in both cisco and dwarf lake whitefish. Altogether, these results demonstrate the potential of integrating classical association studies and comparative genomic to identify targets of natural selection during adaptive divergence.

PLASMA ANTIFREEZE PROTEIN LEVELS PARTIALLY RESPOND TO PHOTOPERIOD THROUGH LIVER HYPERTROPHY IN ATLANTIC WOLFFISH (Anarhichas lupus)

Mariève Desjardins1, Nathalie R. Le François2, Garth L. Fletcher3 and Pierre U. Blier1
E-Mail: marieve_desjardins@yahoo.ca
1Laboratoire de biologie évolutive, Département de Biologie, Université du Québec à Rimouski (UQAR), 300 Allée des Ursulines, Rimouski, Québec, Canada, G5L 3A1; 2Centre Aquacole Marin, 6 rue du Parc, Grande-Rivière, Québec, Canada, G0C 1V0; 3Memorial University of Newfoundland (MUN), Ocean Sciences Centre, St-John’s, Newfoundland, Canada, A1C 5S7

Session: NorP3

Abstract: The Atlantic wolffish (family: Anarhichadidae), as some other marine teleosts inhabiting temperate and polar regions, produces plasma antifreeze proteins (AFP) to prevent freezing when facing sea-ice. Few detailed studies have been
carried out on the seasonal modulation of plasma AFP levels. If temperature and photoperiod are known to regulate these seasonal changes, how they act on the wolffish organism to trigger this physiological response is still largely unknown. The objectives of the present study are 1) to assess the seasonal AFP production levels over an annual cycle in juvenile Atlantic wolffish (Anarhichas lupus) and 2) to search for a link with the hepatic condition and metabolic enzyme activities, the liver producing and exporting the plasma AFP. Thermal hysteresis (TH), hepatosomatic index (HSI) and hepatic enzyme activities were measured in two groups of fish. One group was exposed to seasonal temperature, and the other to constantly warm temperatures, both within a natural photoperiod treatment. Liver hypertrophy was observed in winter samples from fish submitted to both thermal environments, and TH and HSI were found to be positively correlated. There was no evidence of higher enzymatic activity levels per g tissue or proteins as the plasma AFP levels were increasing; only activities expressed as U per total liver mass increased during the winter, in both groups. According to those results, it can be concluded that AFP synthesis capacities in Atlantic wolffish are positively related to liver hypertrophy and that such an hypertrophy is induced by photoperiod rather than temperature, as previously thought.

HIGH MERCURY LEVEL IN A SMALL FISH SPECIES, THE STRAIGHT FIN BARB (Barbus paludinosus), DRIVEN BY ONTOGENETIC NICHE SHIFTS
Z. Desta², R. Borgstrom¹, Z. Gebremariam¹ and B. O. Rosseland
E-Mail: zerihun.desta@umb.no
¹Norwegian University of Life Sciences, Department of Ecology and Natural Resources Management, Postboks 5003, N-1432, Ås, Norway; ²Debub University, Faculty of Natural Sciences, Department of Applied Biology, P.O.Box 5, Awassa, Ethiopia

Session: BioO1
Abstract: The diet, habitat use, and mercury level of the small barb (Barbus paludinosus) was studied in Lake Awassa for a period of one year from February 2003 to January 2004. Stable isotope signatures of nitrogen and carbon were used to determine changes in trophic positions by different sizes. The small barb mainly occupied the protected benthic habitats (littoral and profundal) of the lake, and it rarely ventured into the open water. The δ13C value ranged –24 to –19‰, and it showed that the carbon source for B. paludinosus was benthic, and this was consistent with the observed habitat use. Small individuals (≤ 60 mm LT) mainly preyed upon ostracods, intermediate sizes (60-100 mm) on aquatic insects and gastropods, and a tiny cyprinodont fish, Aplocheilichthys antinorii, dominated the diet of large fish (100-160 mm). The Hg concentration was positively correlated with fish size, and ranged from 0.02 to 0.74 mg kg⁻¹, although some large individuals had concentrations < 0.1 mg kg⁻¹. The positive correlation between fish size and δ15N values showed the shift towards larger prey in larger individuals. The study suggests that the unexpectedly high Hg concentration in this small fish species was due to the diet shift from invertebrate to the fish prey A. antinorii. This study was fully financed by the Norwegian Program for Development, Research, and Higher Education (NUFU) project.

ASSESSMENT OF PRESSURE-SHOCK INDUCED TRIPLOIDY FOR CONTAINMENT OF TRANSGENIC SALMON
R.H. Deivin, C.A. Biagi, D. Sakhhrani and K.-W. Eom
E-Mail: devlinr@dfo-mpo.gc.ca
Fisheries and Oceans Canada, West Vancouver, BC, Canada

Session: GenP4
Abstract: The potential use of transgenic fish in aquaculture has raised uncertainties regarding possible environmental risks should they escape into nature. The use of effective physical and biological containment methods have been proposed to prevent reproductive interaction between transgenic fish and conspecifics in nature, and thus limit risks to a single generation. To date, triploidy has been most often proposed as a sterilization method for salmonids since it effectively ablates sexual development in females and causes functional sterility in males. Escapes of salmon from aquaculture facilities can occur on a large scale (e.g. 500,000 animals), and consequently a critical feature determining the usefulness of a containment method is the level to which sterility can be induced on very large scales. Thus, we have examined the efficacy of pressure-shock induced triploidy for induction of sterility in GH transgenic coho salmon under a range of conditions. We have found that, around standard conditions which yield high levels of triploidy, varying pressure, shock duration, incubation temperature, and shock timing post fertilization had little effect on triploidy frequencies. Effects of individual mothers (i.e. egg lots) were correlated with varying triploidy success, as was egg age post ovulation. Overall, among more than 56,000 treated salmon, greater than 99% triploidy could be achieved in most batches, indicating that for this system, triploidy could significantly reduce the potential effects of escapes of small numbers of transgenic salmon into nature. Nevertheless, repeated escapes, or escapes of large numbers, may result in the introduction of fertile animals into nature. Funded by the Canadian Regulatory System for Biotechnology.
APPLICATION OF ACOUSTIC TECHNOLOGIES TO LAKE STURGEON MOVEMENTS AND HABITAT USE
Terry A. Dick, D. Block, C. Gallagher and Auhiui Yang
E-Mail: tadick@cc.umanitoba.ca
Department of Zoology, University of Manitoba, Winnipeg, Manitoba, R3T 2N2

Session: TelO9
Abstract: Lake sturgeon are extirpated from much of their former range in western Canada and will soon be listed as endangered. For these reasons it is difficult to find unperturbed populations to study. We report on a relatively unperturbed population on the Pigeon River at Round Lake, Manitoba and on populations from the Winnipeg River where there are a series of hydro electric reservoirs. The following equipment was used: RoxAnn and Quester Tangent acoustic systems to describe substrate and depth, the RDI current profiler to estimate currents and Vemco VRAP and VR2 receivers to monitor sturgeon movements. In Round Lake juvenile and sub-adult sturgeon generally frequented similar habitats with extensive activity at the inlet and outlet to the lake. Depth tags indicated some sub-adults spent considerable time in the water column and lake sturgeon occurred more frequently over fine substrates. In Numao Lake on the Winnipeg River, using the VRAP system, the movements of cultured and wild sturgeon were found to be similar after an initial period for the cultured sturgeon to become familiar with their new environment. A second study, using Vemco CVR2 receivers and cultured sturgeon, below the Seven Sisters dam was designed to determine if suitable sturgeon habitat remained after diversion of the main river flow. Results show there is some suitable habitat below the dam and the spillway and that there are seasonal movements in and out of the area.

LATITUDINAL DECREASE OF ALLELIC DIVERSITY IN AN IMMUNO-COMPETENCE GENE: FURTHER SUPPORT FOR HOST-PATHOGEN CO-EVOLUTION IN ATLANTIC SALMON?
M. Dionne1, K. Miller2, F. Caron3 and L. Bernatchez1
E-Mail: melanie.dionne@giroq.ulaval.ca
1Biology Dept., Université Laval, Québec, Canada, 2Pacific Biological Station, DFO, B-C, Canada, 3Ministère des Ressources Naturelles et de la Faune, Québec, Canada

Session: DisO2
Abstract: In Atlantic salmon, as in other vertebrates, the major histocompatibility (MHC) class II gene is involved in bacterial and parasite resistance. It is assumed that a high allelic diversity confers resistance to a greater number of different pathogens. In a co-evolutionary context, pathogens maintain a diversifying selection pressure on their host population and the intensity of this selection pressure has been shown to vary with three factors which themselves decrease with latitude and water temperature: i) pathogen richness, ii) pathogen virulence and iii) length of the cohabitation period (summer period). The objective of this study is to test the hypothesis that genetic diversity at an immuno-competence gene will decrease with latitude, as would be predicted from these patterns in pathogen community. Results show that MHC class II allelic diversity decreases with latitude ($r^2 = 0.28; p = 0.002$) which agrees with the initial hypothesis. We are currently challenging further this hypothesis by contrasting patterns of latitudinal decrease in allelic diversity at the MHC gene with those of neutral genetic markers, namely microsatellite loci. Funded by NSERC.

LIFE STAGE AND ODORANT-INDUCED CHANGES IN OLFACTORY SENSITIVITY IN COHO SALMON (Oncorhynchus kisutch)
A.H. Dittman1, D. May2, D. Baldwin1, N. Scholz2 and J. Athos1
E-Mail: andy.dittman@noaa.gov
1Northwest Fisheries Science Center, NOAA-Fisheries, USA, 2School of Aquatic and Fishery Sciences, Univ. of Washington, USA.

Session: OlfO4
Abstract: Over the lifetime of an organism, the sensitivity of the olfactory system to specific odors may change in response to developmental changes, hormones, environmental stimuli, and odorant exposure. Salmon provide an excellent model for studying such changes because almost every aspect of their lives is influenced by olfaction and they experience dramatic developmental and environmental transitions (smolting, maturation, freshwater vs. oceanic rearing). Furthermore, the homing migrations of salmon are governed by olfactory discrimination of home stream odors that juvenile salmon learn (imprint to) prior to their seaward migrations. Our previous studies demonstrated that salmon imprinted to the odorant phenylethyl alcohol developed a long-term sensitization of peripheral olfactory neurons to this odorant. To further examine the mechanism of peripheral sensitization during imprinting, we exposed juvenile coho salmon to L-Arginine during smolting, the presumptive sensitive period for imprinting. Arginine is a potent salmon odorant for which a candidate odorant receptor has been identified. To assess life stage and olfactory imprinting associated changes in the sensitivity of the olfactory system to arginine, we recorded electrical field potentials (electro-olfactograms) generated in response to arginine and measured mRNA expressions levels of the candidate arginine receptor at several life stages. Our results
suggest that olfactory sensitivity and odorant receptor expression changes over the lifetime of the salmon and that previous odor exposure can influence olfactory responses. Funded by the BPA, the NWFSC, and the HSRG.

**OLFATORY ORGANS OF FRESHWATER CATFISH (Ameiurus melas) ARE FUNCTIONAL IN HIGHLY PURIFIED WATER**

Jurij Dolenšek in Tine Valentinčič

E-Mail: jurij.dolensek@bf.uni-lj.si

Department of Biology, University of Ljubljana, Večna pot 111, 1000 Ljubljana, Slovenia

Session: OlfO2

Abstract: Cilia and microvilli of olfactory receptor neurons (ORNs) of freshwater fishes are embedded in a thin mucous layer directly exposed to water. Freshwater contains low ion concentrations of Cl⁻ and Na⁺ which are often <50mg/l. We recorded electroolfactogram (EOG) and single ORN responses to amino acids in highly purified water (R>1.8x10^6Ωcm; Na⁺=7±2µg/l; K⁺=50±5µg/l; Ca²⁺=5±2µg/l; Mg²⁺=0.5±0.1µg/l) in situ for up to 6 hours. The correlation between the magnitude of the EOG in dechlorinated tap and in highly purified water in response to amino acids (L-norvaline, L-alanine, L-methionine, L-leucine, L-lysine, L-lysine, L-arginine and L-proline) was high (Pearson, R=0.94, p<0.05). Most ORNs responding to amino acid stimuli in highly purified water lacked spontaneous activity. The number of ORNs responding to amino acids correlated highly with the amplitude of the EOG (Pearson R=0.9, p<0.001). A dose-response study of responses to L-norvaline also revealed a high correlation between the number of spontaneously inactive (silent) ORNs and EOG amplitudes (Pearson R=0.97, p<0.05). The majority of silent ORNs responded to the two most effective amino acids, L-methionine and L-norvaline. Not all the ORNs that responded to L-norvaline responded to L-methionine and vice versa. Twenty-four percent of spontaneously inactive ORNs responded to one amino acid only, while other neurons responded up to 6 of 10 tested amino acids. The responses of the catfish olfactory organ to amino acids in highly purified water confirmed its functionality in waters with extremely low ion concentrations. Funded by Slovenian Ministry of Education and Science grant P0-0509-0487

**MOLECULAR BIOMARKERS FOR PETROLEUM CONTAMINATION IN THE AMAZON FISH ASTRONOTUS OCELLATUS (OSCAR)**

N. A. dos Anjos¹,², A.L. Val¹, K. Schirmer² and S. Scholz²

E-Mail: nanjos@ufz.de

¹National Institute for the Research in the Amazon INPA, Ecophysiology and Molecular Evolution Laboratory LEEM, Amazonas Brazil; ²Center for Environmental Research UFZ, Dept. Cell Toxicology, Leipzig-Germany

Session: TroP9

Abstract: The Urucu area is located at the Amazon River 700 km southwest of Manaus/Brazil. It is an area of petroleum exploration which could result in pollution of water bodies through effluents of the petroleum industry or accidental spills. In order to monitor the potential biologic effects of petroleum contaminations we tried to establish molecular markers for fish native to the Amazon River. First, an established test system, the zebrafish embryo test, was used to identify differentially expressed genes suitable to detect sub-acute effects. Embryos were exposed to the water fraction of an oil/water mixture and the expression of the genes cyp1a, mt, hsp70, maft, ahr and hmox were analyzed. Cyp1a was found to be induced even if water was contaminated with low amounts of oil (0.024 %). Mt was induced at higher concentrations (6.25 %). Second, we identified the sequence of the cyp1a homologue of the Amazon fish Astronotus ocellatus (Oscar). The expression of cyp1a and its corresponding protein levels in Astronotus are currently analyzed in fish exposed to oil-contaminated water and are also foreseen to be analyzed in field samples. Funding: CNPq, CTPetro, DAAD and GenDar-T.

**IONOREGULATORY RESPONSESOF TAMBAQUI COLOSSOMA MACROPOMUM TO CRUDE PETROLEUM AND TO CRUDE PETROLEUM CHEMICALLY DISPERSED**

Duarte, R.M., Matsuo, A.Y.O. and Val, A.L.

E-Mail: polegas@hotmail.com

Laboratory of Ecophysiology and Molecular Evolution, National Institute for Amazon Research, Alameda Cosme Ferreira, 2926. 69083-500 Manaus, Amazonas, Brazil

Session: ImpP5

Abstract: The aim of this work was to assess the effect of crude petroleum and crude petroleum chemically dispersed on the ionic regulation in juvenile of tambaqui (Colossoma macropomum). We estimated the Na⁺ unidirectional flux through the gill epithelium, besides the net flux of K⁺ and Cl⁻ of the animals exposed to treatments. Our results show that hydrocarbons chemically dispersed are able to act at the gill level, changing permeability and modifying the ion transport
through the membrane in tambaqui, resulting in net losses (Jnet) of Na⁺, K⁺, and Cl⁻, particularly, during the first hours of exposure. Unidirectional Influx (Jin) and efflux (Jout) of Na⁺ changed after exposure to petroleum chemically dispersed (OC+DIS), with diffusive losses (p < 0.05) in the first six hours and increases in influx of Na⁺, particularly after 9 hours of exposure. Tambaqui showed ability to reduce ion gill permeability, decreasing the net losses (Jnet) of Na⁺ and Cl⁻ after 24 hours of exposure, however, K⁺ losses stayed increased (p <0.05) throughout the experimental period, probably due to larger toxic action of chemically dispersed hydrocarbons on gill epithelium. CNPq, Finep, Petrobrás.

BIOLOGICAL EFFECTS OF COPPER ON FISH OF THE AMAZON
E-Mail: polegas@hotmail.com
Laboratory of Ecophysiology and Molecular Evolution, National Institute for Amazon Research, Alameda Cosme Ferreira, 2926. 69083-500 Manaus, Amazonas, Brazil

Session: TroP10
Abstract: The aim of this work was to determine LC50 for ten fish species of the Rio Negro in ion-poor water and absence of dissolved organic carbon (DOC). Fish were held in INPA’s groundwater ([Na⁺], 0.83; [K⁺], 0.45; [Ca²⁺], 0.16; [Mg²⁺], 0.036; [Cl⁻], 0.90 mg/l; [Cu], 7.0 g/l; hardness= 6.15 mgCaCO₃/L; DOC < 1mg C/L; pH= 6.8), and exposed to different Cu concentrations, ranging from 10 to 400 µgCu/l (as CuCl₂·2H₂O), in chambers with flow-through system always maintenance ratio of 0.8g of fish per liter of water. In all tests, our results showed that Characid species were more sensitive to copper than both catfish and cichlid species. Hemigrammus rhodostomus is the most sensitive analyzed species with a calculated LC50-96 hours of 12.81 µgCu/l. Catfishes copper sensibility ranged from 18.01 to 74.14 µgCu/l for Otocinclus hasemani and Dianema urostriatum, respectively. The three cichlid species analyzed presented closer LC50 values, what may be related either to their similar size or their well defined phylogenetic status. Further, our data suggest that copper sensibility may be related to phylogenetic position of animals, probably due to differences in homeostatic and ionoregulatory mechanisms.

REDUCED CRITICAL SWIMMING SPEED AND BURST-COAST USE IN SUB-LETHAL HYPOXIC CONDITIONS IN ATLANTIC COD (Gadus morhua)
J.-D. Dutil¹, E.-L. Sylvestre*, L. Gamache¹, H. Guderley² and R. Larocque¹
E-Mail: dutiljd@dfo-mpo.gc.ca
¹Institut Maurice-Lamontagne, Department of Fisheries and Ocean, 850 route de la Mer, Mont-Joli (Québec) G5H3Z4, Canada. ²Université Laval, Department of Biology, Québec (Québec) G1K 7P4 Canada

Session: NorO8
Abstract: The impact of hypoxia upon swimming performance and oxygen consumption was investigated in Atlantic cod by carrying swimming tests and recording oxygen consumption for 14 individuals exposed to 7 levels of hypoxia within the non-lethal range they usually encounter in the estuary and Gulf of St. Lawrence (35 to 100% oxygen saturation). Swimming performance and energy expenditures were assessed by measuring critical swimming speed (Ucrit.), speed at first burst coast movement (Ub-c), maximum oxygen consumption (MO₂max), oxygen consumption at first burst coast (MO₂ b-c), and the number of burst-coast performed during the tests. Ucrit linearly decreased in parallel with Ub-c as oxygen saturation decreased. MO₂max and MO₂ b-c were also positively correlated with oxygen saturation. However, the slope for MO₂max was more than 3 fold that for MO₂ b-c, with MO₂max falling down to MO₂ b-c at around 35% oxygen saturation. As the total distance swam in the test decreased with decreasing oxygen saturation, the number of burst-coast movements performed in Ucrit was also reduced. For velocities below 50 cm s⁻¹, there was no difference in the active metabolic rate across levels of hypoxia, which means that oxygen availability did not impair oxygen consumption at lower velocities. At higher velocities, ambient oxygen limited oxygen consumption leading to the earlier exhaustion and lower critical swimming speeds of cod exposed to reduced oxygen availability. The low oxygen tensions prevailing on the bottom in the deep channels can impair the swimming capacity of cod and may contribute to low productivity of the stock in the estuary and northern Gulf of St.Lawrence. This study was funded by the Department of Fisheries and Oceans through the Science Strategic Fund.
PROTEOMIC ANALYSIS OF THE EPIDERMAL MUCUS OF ATLANTIC SALMON (Salmo salar): BIOLOGICAL INDICATORS OF STRESS
Russell H Easy1,2 and Neil W Ross1
E-Mail: Russell.easy@nrc.ca
1Institute for Marine Biosciences—National Research Council, 1411 Oxford Street, Halifax, NS, Canada B3H 3Z1
2Department of Biology, Dalhousie University, 1411 Oxford Street, Halifax, NS, Canada B3H 2Z1
Session: MolO9
Abstract: The epidermis of most teleost fish is covered with a layer of mucus containing proteins with various protective functions. Alterations in the physiological state can lead to a change in the expression of proteins required for metabolic processes including those involved in stress and immunity. Proteomic techniques can identify proteins in mucus that may be correlated with specific stressors; these proteins can serve as biological indicators. Our study is aimed at defining which proteins are present in mucus and under which conditions do the levels of these proteins change. Fish were exposed to sea lice (Lepeoptheirus salmonis) at an infection level of approximately 100-150 infective copepodids/fish and mucus was collected and sampled at 6, 10 and 20d post infection. Plasma cortisol levels were higher in fish infected with sea lice in comparison to non-infected fish. Using 2 dimensional gel electrophoresis, a proteomic map of salmon skin mucus was developed and proteins identified in the mucus included calmodulin, β-actin, apolipoproteins and fish keratin. Proteins that were found to be consistently up-regulated in fish infected by sea lice included transferrin, which is known to be involved in innate immunity. We will further characterize these proteins and the effects of other stressors including long- and short-term handling stress. This work is partially funded by the NRC’s Genomics and Health Initiative.

NHE2 EXPRESSION IN THE RECTAL GLAND OF THE SPINY DOGFISH (Squalus acanthias)
Susan L. Edwards1,3 and James B. Claiborne. 1,2,3
E-Mail: Susan.Edwards@jcu.edu.au
1School of Veterinary & Biomedical Sciences, James Cook University, Cairns, Australia, 2Department of Biology, Georgia Southern University, Statesboro, GA, USA and 3Mt Desert Island Biological Laboratory, Salisbury Cove, ME, USA
Session: IonP4
Abstract: Physiological studies using isolated dogfish rectal glands have demonstrated the presence of sodium dependant bicarbonate reabsorption and proton excretion mechanisms in the rectal gland tubules. Excretion of protons from the rectal gland tubules was strictly sodium dependant and Na⁺/H⁺ exchange was inhibited in the presence of HOE694, the total absence of exchange in the presence of the inhibitor suggests that the mechanism responsible for the exchange was either NHE1 or NHE2. Electroneutral sodium/hydrogen exchange has been identified in virtually all cell types mediating the exchange of extracellular sodium for intracellular protons. It plays a vital role in the regulation of cell volume, transcellular reabsorption of Na⁺ and intracellular pH. Previous investigations demonstrated the effects of carbonic anhydrase on the pH of rectal gland secretions, however, to date there has been no quantification of net acid excretion in the rectal gland and the role of the rectal gland in systemic pH regulation is unknown. In this study, we have used a homologous shark NHE2 antibody and immunohistochemical techniques to identify an NHE isoform in the rectal gland tubular epithelial cells of the spiny dogfish.

WHAT MAKES THE SOUTHWEST ATLANTIC HAKE (Merluccius hubbsi) SO RESILIENT ?
M. Ehrlich1, G. Macchi1,2, M. Pájaro1, L. Machinandiarena1, D. Brown1 and P. Betti1
E-Mail: mehrlich@inidep.edu.ar
1National Institute for Fisheries Research and Development (INIDEP), Mar del Plata, Argentine. 2Argentine Council for Research and Technology (CONICET).
Session: EarP5
Abstract: Argentine hake is the most important demersal species in the SWA and is heavily fished with cleare signs of overfishing as catches are sustained by decreasing spawning biomass and a few age groups. However stock remains, and annually a mean catch (1992-2002) of 423,586 t was landed. There are two identified fishing stocks, limited by the 41°S parallel. There are some features corresponding to reproduction and early life history which can explain this high resilience. Hake has many spawning grounds in the Argentine shelf and an extended reproductive season from december to march in the south stock and from march to june in the north stock. Hight batch fecundity ranging from 100,000 to 2,300,000 hydrated oocytes, and a spwaning frequency from 7 to 10 days. Total egg production is hight ranged between 855 x 1012 eggs in the peak of southe rn stock spawning season to 39 x 1012  eggs at the end .There are noticeable differences in larval growth between both stocks. The larval development is very fast and a larvae of 28-29 mm total length has completed the definitive fin structure and a functional wide mouth is acquired at 3 mm. At 20 mm the larvae starts settlement and daily vertical migration sharing a pelagic and bottom food and protection environm ent. All this features accounts that hake is a “r” strategist which can find favorable conditions for survive and growth. Funded by INIDEP.
PITUITARY HORMONE PURIFICATION BY CONTINUOUS-ELUTION ELECTROPHORESIS
I.E. Einarsdottir¹, L. Anjos², J. Hildahl¹, B.Th. Björnsson¹ and D.M. Power²
E-Mail: ingibjorg.einarsdottir@zool.gu.se
¹Dep Zoology, Göteborg University, Göteborg, Sweden; ²Centro de Ciências do Mar, Universidade do Algarve, Campus de Gambelas, Faro, Portugal.

Session: FisO3
Abstract: Widely used methods for peptide hormone purification, such as gel filtration chromatography combined with rpHPLC, are time-consuming and often give low yields and instable proteins. The Model 491 Prep Cell from Bio-Rad provides a continuous-elution electrophoresis technique to separate proteins. The protein mixture runs through a cylindrical gel, proteins are separated by size and charge, as they elute from the matrix and are collected using a fraction collector. Sub-samples are assessed by SDS-PAGE and protein identity is verified by Western blot analysis. We applied this technique to separate putative hormones from adult Atlantic halibut pituitaries. Soluble proteins from homogenized pituitaries were denatured and subjected to continuous-elution electrophoresis. The fractions sampled contained purified proteins with molecular sizes ranging from 10 to 33 kDa. Fractions containing proteins with molecular weights of approximately 21, 24, 28 and 32 kDa were identified as putative growth hormone, prolactin, somatolactin and gonadotropins. These were analyzed further by mass spectrometry (MS) and identified with peptide mass protein fingerprinting. Good yield of highly purified GH was obtained, identified, and found to be biologically stable. Subsequently, it was used for radioactive labeling and as standards in a homologous RIA. Using this assay, the GH was measured in halibut larvae from start-feeding through metamorphosis, showing a stable size-related GH content of the head region. Funded by the EU.

FIRST COME, FIRST SERVED?
S. Einum and E. Kvingedal
E-Mail: sigurd.einum@nina.no
Norwegian Institute for Nature Research, Trondheim, Norway
Session: FroO16
Abstract: Behavioural mechanisms may maintain or amplify within-population variation in fitness-related traits of wild populations. Studies conducted under controlled environments are often required to disentangle the effects of such mechanisms from confounding factors. However, predictions from such studies are sometimes at odds with field experiments (e.g. effects of dominance status on growth rates). Here we present a field study testing for effects of prior residency, a behavioural mechanism that has repeatedly been shown to produce strong competitive advantages under controlled conditions. Individually tagged one-year-old juvenile Atlantic salmon were released in two waves (4d apart) at 9 stations along a stream, with the total number varying among stations. Quantitative electrofishing was conducted by the end of the growth season to estimate growth rates, dispersal and survival. No differences in dispersal rates or survival were observed between owners and intruders. Spatial variation in overall mean growth was density dependent. However, only in one of the 9 release stations did owners significantly outgrow intruders, whereas no significant difference was found within the other 8 stations. Thus, any positive effect of prior residency appears to be, at best, weak. Furthermore, across stations, there was a tendency for the benefit of being an owner to be stronger in release stations with good overall growth. These results contrasts with expectations from lab studies, and suggests that competitive outcomes on the population level may be more complex than those predicted from extrapolation of individual competitive abilities. Funded by the Research Council of Norway.

HOW EELS SWIM: MUSCLE RECRUITMENT, PROPERTIES AND PERFORMANCE
D.J. Ellerby
E-Mail: dellerby@wellesley.edu
Department of Biological Sciences, Wellesley College, 106 Central Street, Wellesley, MA 02481, USA.
Session: MusO2
Abstract: Eels (Anguilla sp.) swim by undulating the majority of their elongated body axis. This places them at one extreme of a range of teleost axial swimming styles. Their mechanism for generating swimming movements is similar in some respects to other teleosts. A wave of myotomal muscle contraction generates a posteriorly moving wave of body curvature as a means of generating thrust. In contrast to other more stiff bodied undulatory swimmers, an axial shift in muscle properties and function is largely absent. Eels are also unusual in being able to use their myotomal muscles to locomote on land. Theoretical analyses had suggested that highly undulatory swimming was inherently inefficient in comparison to more stiff-bodied swimming styles. This seems puzzling, given the prodigious reproductive migrations undertaken by eels. However, recent energetic studies indicate a low cost of transport and relatively high efficiency for anguilliform swimming.
COMPARISION OF GROWTH RATE, CONDITION FACTOR, FOOD CONVERSION RATIO AND MORTALITY OF RAINBOW TROUT (Onchorhincus mykiss) BETWEEN TWO RECIRCULATING SYSTEMS

H. Emadi, H. Hosseinizadeh Sahafi1 and A. Toussi2
E-Mail: h_hosseinizadeh@yahoo.com

1No. 297, Fatemi Ave., Iranian Fisheries Research Institute, Tehran, IRAN, 2No.111, Shirazi Str., Nil Aquatic Industrial Co., Tehran, IRAN

Session: LinO20
Abstract: Different types of recirculation systems were introduced in Iran during last years. Research project was implemented to obtain growth parameters of Rainbow Trout (Onchorhincus mykiss) in modified fresh water recirculating system. Bimonthly samples were collected from 50 Rainbow Trout during 2004-2005. Growth rate, mortality, Condition factor, and food conversion ratio were calculated according to length, weight, and feed used in the ponds. This indexes were compared with reference Norwegian recirculation system (Echofish) by statistical methods. Results show that there were differences between mortality rats in two systems (p<0.001). Special growth rate were significantly differ from modified recirculation system with reference Norwegian recirculation system(p<0.001) i.e., 5.26%/D for norwegian recirculation system and 6.7%/D for modified recirculation system. Food conversion ratio were higher in modified recirculation system (1.29%) compare with Norwegian recirculation system (0.92%). Condition factor was 1.48 in Norwegian recirculation system and 1.51 in modified recirculation system. The relation ship between parameters were discussed.

ENERGETICS RELATED TO UPSTREAM MIGRATION OF ATLANTIC SALMON IN VERTICAL SLOT FISHWAYS

E.C. Enders1, C.J. Pennell1, R.K. Booth2 and D.A. Scruton1
E-Mail: enderse@dfo-mpo.gc.ca

1Fisheries and Oceans Canada; 2Lotek Wireless, Canada

Session: TelP4
Abstract: Key impacts of hydropower development in rivers are physical obstructions representing barriers for migrating fish. Considerable efforts have been expended to construct fishways that allow fish to bypass the obstructions. However, fishway designs have seldom considered fish behaviour and energetics. We used electromyogram (EMG) telemetry to analyse swimming energetics in relation to turbulent flow and passage success of 14 adult Atlantic salmon (Salmo salar L.) ascending in two vertical slot fishways on the Exploits River, Newfoundland, Canada. Wild Atlantic salmon were collected at the fishway entrances. EMG transmitters were surgically implanted in the fish. EMG signals were calibrated against swimming speed using a Blazka type respirometer. After calibration, fish were released below the fishway. Data loggers continuously monitored EMG signals and migration time as Atlantic salmon approached, entered and ascended the fishways at Bishop’s Fall and Grand Falls. Turbulent flow structures in the fishway were measured using an Acoustic Doppler Velocimeter. Of the 14 fish that were tagged, 11 individuals were recorded approaching the fishway, but only five individuals were recorded ascending the fishway. Our results indicated that (1) tagging delayed the fish by a month in the upriver migration; (2) passage success differed between the two fishways; and (3) EMG signals were related to turbulent flow characteristics. This information furthers our understanding of behavioral responses of Atlantic salmon in relation to turbulent flow in fishways and may provide engineers with valuable data in future design of fishways. Funded by Natural Resources Canada’s (NRCan) Panel for Energy Research and Development (PERD).

HABITAT USE AND MOVEMENTS OF PIT TAGGED JUVENILE ATLANTIC SALMON DURING WINTER

E.C. Enders1, M. Stickler2, C.J. Pennell1, D. Cote3, K. Alfredsen2 and D.A. Scruton1
E-Mail: enderse@dfo-mpo.gc.ca

1Fisheries and Oceans Canada; 2Department of Hydraulic and Environmental Engineering, Norwegian University of Science and Technology, Norway; 3Parks Canada, Terra Nova National Park of Canada, Canada

Session: TelO6
Abstract: Habitat use and movements of juvenile Atlantic salmon (JAS, Salmo salar L.) during summer have been extensively studied over the last two decades. Recent telemetry studies have demonstrated that JAS may perform frequently longer movements and occupy larger home ranges than previously assumed. However, few studies have analysed the mobility patterns during winter, although winter conditions have been suggested as a bottleneck for JAS survival. To comprehend the effects of ice formation and dynamic hydraulic variables on the mobility of parr during winter, 145 JAS were tagged using Passive Interactive Transponder (PIT) technology in a natural stream. Fish were tracked in a 450 m long river reach characterised by different riverbed gradients using both fixed gate antennae and manual tracking devices. JAS were relocated during late autumn, freeze-up, mid and late winter, twice a day during five consecutive days at each survey.
Fish positions were geo-referenced and corresponding physical habitat variables were measured on each position. The results indicate that (1) JAS undertook significantly more and longer movements in late autumn than during winter; (2) fish had a clear preference for habitat choosing boulder substrate with interstices representing refuge; and (3) JAS showed higher mobility in sections with higher gradient and dynamic ice formation than in sections with lower gradient and static ice formation. This research was funded by Natural Resources Canada’s (NRCan) Panel for Energy Research and Development (PERD).

**ACID-BASE REGULATION IN THE AFRICAN LUNGFISH, (Protopterus annectens)**
A. Esbaugh, L. Kenney, S.F. Perry and K.M. Gilmour
E-Mail: aesbaugh@uottawa.ca
Department of Biology, University of Ottawa

**Session:** IonO1

**Abstract:** Dipnoi are thought to represent an evolutionary link between fish and tetrapods. As such, these organisms are ideal to study the evolution of physiological systems from water breathers to air breathers. In this study, we used a variety of physiological and molecular techniques to examine the mechanisms of acid-base regulation in lungfish, in particular, whether lungfish exhibit regulatory mechanisms more similar to those of fish or tetrapods. To this end, we amplified several genes thought to be involved in acid-base regulation, including the Na⁺/HCO₃⁻ exchanger (NBC1), V-type H⁻ ATPase, and two different cytoplasmic carbonic anhydrases (CA). Interestingly, phylogenetic analysis of each of these genes suggested that they are more similar to those of tetrapods than to those of fish. Real-time PCR analyses revealed that both NBC1 and the V-type H⁻ ATPase were highly expressed in the kidney and gill, while one of the cytoplasmic CA isozymes was highly expressed in each of kidney and gill. Immunohistochemistry and in situ hybridization were used to localize the H⁺ ATPase to the apical lamellar epithelium of the gill, and the apical regions of kidney tubules. NBC1 was more broadly localized across the lamellar tissue and kidney tubules. The presence and localization of these genes in both the kidney and gill is consistent with mechanisms of acid-base regulation used in fish. The dynamic regulation of these proteins in response to imposed acid and base loads will also be discussed. Funded by NSERC.

**A STATIN DRUG AFFECTS 3-HYDROXY-3-METHYLGLUTARYL COENZYME A REDUCTASE (HMGCoAR) ACTIVITIES IN RAINBOW TROUT (Oncorhynchus mykiss)**
C. Estey and T.W. Moon
E-Mail: chelsie.estey@gmail.com
Dept. of Biol., Univ. of Ottawa, Canada

**Session:** ImpO23

**Abstract:** The enzyme 3-hydroxy-3-methylglutaryl coenzyme A reductase (HMGCoAR) is the rate-limiting enzyme involved in endogenous cholesterol production in mammals. Given the conservation of enzymes and receptors across species, HMGCoAR may serve a similar role in fish. Statin drugs are a highly prescribed group of cholesterol lowering drugs that function by specifically inhibiting HMGCoAR. These drugs are detected in effluents from Canadian municipal wastewater treatment plants and, therefore, could potentially inhibit HMGCoAR in fish. HMGCoAR transcript levels were assessed in rainbow trout and the tissues found to exhibit the greatest band intensities were brain, gill, intestine, liver and stomach. A radioactive activity assay for HMGCoAR was optimized to examine the effect of the statin drug cerivastatin on enzyme activities in both brain and liver tissues from two size classes of trout (75 g and 250 g). Inhibition of HMGCoAR activity occurred in both the liver and the brain with the greatest inhibition seen in those tissues prepared from the smaller trout. That is, liver tissue from 75 g fish exhibited an IC₅₀ value (concentration required to inhibit 50% of HMGCoAR activity) as low as 5 nM compared with an average IC₅₀ of approximately 26 nM using the same tissue from the 250 g fish. These results demonstrate that cerivastatin inhibits HMGCoAR activities in trout tissues at concentrations consistent with those reported for the mammalian enzyme, and suggest that statins could potentially modify endogenous cholesterol synthesis in this fish species. Funded by NSERC Canada and Pfizer, Inc.
SEDIMENT-BOUND ORGANIC POLLUTANTS IN THE REDDS OF ATLANTIC SALMON (Salmo salar) AND THEIR POTENTIAL IMPACT ON THE EMBRYOS
L. Evans1, N. Crooks1, A. Moore2 and C. Waring3
E-Mail: lucy.evans@port.ac.uk
1Institute of Marine Sciences, University of Portsmouth, UK, 2CEFAS Laboratory, Lowestoft, UK

Session: OlfP8
Abstract: Many studies have examined the effects of redd siltation and hypoxic hyporheic (redd) water on the survival of Atlantic salmon embryos. However, few studies have examined the effects of organic pollutants bound to the silt and/or the effects of organic pollutants in redd water at field sites. Therefore, the present study collected sediment and redd water from salmon spawning sites in five natural spawning grounds in chalk streams in the South of England. The sites were on the River Wylye, River Nadder and River Avon, all within the Avon catchment, Wiltshire, UK. Artificial redds consisting of a hyporheic sampler and sediment infiltration baskets were created in close proximity to natural redds. During the natural spawning season mesh boxes containing salmon eggs were placed in the artificial redds. Egg boxes were removed at set time intervals until hatched alevins were found. Mortality rates differed markedly between the sites. The weight and diameter of the embryos showed a significant difference between River Nadder and River Wylye sites, (P<0.001 and P=0.013 respectively). Also, a significant difference between the same sites was found in the embryo weights when sampled 7 days later (P=0.001). Soxhlet extraction of different particle sizes of the sediment samples and GCMS analysis showed high concentrations of organic pollutants at all of the sites. Analyses of water samples showed detectable concentrations of triazines, PAHs, organochlorine pesticides (OCPs) and carboxylic acids. The data shows that sediment-bound organic pollutants and redd water contamination can impact upon salmon early life stage development in natural spawning grounds. Funded by DEFRA.

REGULATION OF APOPTOSIS IN ZEBRAFISH OVARIAN FOLLICLES: INVOLVEMENT OF CASPASES AND CATHEPSINS
A. J. Eykelbosh and G. Van Der Kraak
E-Mail: gvanderk@uoguelph.ca
Dept. of Integrative Biology, University of Guelph, Canada

Session: FisO11
Abstract: Atresia is the regulated elimination of follicles by apoptosis leading to the survival and ovulation of only the most viable follicles. Zebrafish were used to investigate the biochemical markers of ovarian follicular atresia in teleosts. Vitellogenic follicles incubated in serum-free medium underwent apoptosis based on the cleavage of DNA into 180 bp fragments and by immunohistochemical detection of fragmented DNA. The activities of the executioner enzyme caspase–3 and the lysosomal protease cathepsin B in follicle cell extracts increased with time in serum-starved follicles. A cell permeable cathepsin B inhibitor blocked both the serum-starved induction of cathepsin B activity and caspase-3 activity in zebrafish follicles suggesting a direct link between activation of lysosomal enzymes and induction of apoptosis. These studies have identified markers that may be used for studies investigating the role of endogenous regulators and environmental factors in the initiation of ovarian follicular atresia in teleosts. Supported by NSERC.

THE BEHAVIOURAL PHYSIOLOGY OF MIGRATION MORTALITY IN ADULT PACIFIC SALMON
A.P. Farrell1, S.G. Hinch2, S. Cooke3, G. Crossin2, T. Mathes2, D. Patterson4, J. Young5, S. Larrson5, G. Wagner5, M. Shrimpton1 and G. Van der Kraak8
E-Mail: farrellt@interchange.ubc.ca
Session: IntO6
Abstract: The ‘late-run’ sockeye stock complex is one of the major groups of salmon in the Fraser River, the most productive salmon river in Canada. Historically, these fish milled in the estuary for several weeks before initiating fall spawning migrations. Starting in 1996, they and other groups of salmon arrived to the estuary at normal times but commenced river migration immediately entering freshwater 5-6 weeks earlier than normal in some years. Associated with this abnormal behaviour has been extraordinarily high mortality. In recent years, mortality during the migration ranged from 90-96%. This high mortality phenomenon has caused the collapse of fisheries and emergency listing of stocks. We initiated a large multi-year research project in 2002, which involved whole-body physiological assessments and tracking of physiologically biopsied fish that carried transmitters from ocean to spawning areas. Abnormally behaving and prematurely dying fish had unusual ionic, osmotic and energetic states. Lab and field experiments indicate that mortality is related to
both acute exposure to high river temperatures and chronic exposure to warm temperatures which accelerates disease, energy use and senescence.

CHARACTERIZATION OF THE NORMAL PHYSIOLOGICAL STATUS OF WESTERN NORTH ATLANTIC COD (Gadus morhua) IN THE WILD
M.A. Farrington\textsuperscript{1}, J.W. Mandelman\textsuperscript{1} and H. Arnold Carr\textsuperscript{2}
E-Mail: mfarr@neaq.org
\textsuperscript{1}Research Department, New England Aquarium, Boston, MA, \textsuperscript{2}American Underwater Search and Survey, Ltd., Cataumet, MA

Session: NorP1
Abstract:
Basal physiological levels of selected blood parameters were pursued by obtaining samples within one minute of hooking from individually jigged Atlantic cod. Because comparative studies in wildlife biology often strive to evaluate the effect of anthropogenic disruption on the physiology, biology or life history of a particular organism, the characterization of a normal control is necessary. Defining normal physiological parameters for any wild species is difficult to estimate because even minor disruptions in natural behavior will certainly modify these profiles. This is especially true for aquatic organisms since researchers generally remove specimens from their environment in order to obtain samples. One approach for resolving this dilemma uses long-term captive animals fitted with a cannula whose biological concentrations have stabilized. However, it is not unreasonable to consider that the captive environment may not give rise to typical physiological profiles found in fish living in their natural habitat. For that reason, forty-one blood samples were collected and processed at sea. Whole-blood hemato crits were evaluated immediately. Whole blood extracts for lactate plus plasma and sera fractions were flash frozen in liquid nitrogen then stored at $-80^\circ$C until assay in the laboratory (spectrophotometry; NOVA blood chemistry analyses) for protein (plasma), Na\textsuperscript{+}, Cl\textsuperscript{-}, K\textsuperscript{+} ions and cortisol (serum) and whole-blood lactate anion. The values obtained were compelling given the rapid collection protocol and the comparison with values published in the literature. Funding for this study: NOAA Saltonstall-Kennedy grant and the New England Aquarium’s Research Department.

CHANGES IN THE IMMUNE SYSTEM OF ATLANTIC SALMON (Salmo salar) EXPOSED TO LONG-TERM STRESS
M. D. Fast\textsuperscript{1} S. Hosoya\textsuperscript{1,2}, L.O.B. Afonso\textsuperscript{1} and S. C. Johnson\textsuperscript{1}
E-Mail: stewart.johnson@nrc-cnrc.gc.ca
\textsuperscript{1}Institute for Marine Biosciences, National Research Council, Canada; \textsuperscript{2}Graduate School of Agricultural and Life Sciences, Univ. of Tokyo

Session: MolO6
Abstract: It is generally considered that long term stress causes decreased immune function in fish. In this study we examined the effects of 4 weeks of daily handling stress (15 seconds out of water) on plasma cortisol (free and total) and glucose levels, liver HSP70 levels, expression of interleukin 1 $\beta$ (IL-1$\beta$) and killing of head kidney macrophages by Aeromonas salmonicida. Samples were collected weekly prior to the application of the daily stress. With the exception of an increase in plasma glucose levels at 1 week there were no significant differences in plasma parameters of HSP70 levels. There was a significantly higher unstimulated IL-1$\beta$ expression in stressed fish over the first two weeks. Prior to stress and at 3 and 4 weeks unstimulated IL-1$\beta$ expression levels were not different from the controls. At weeks 1, 2 and 3 the magnitude of IL-1$\beta$ response of isolated head kidney macrophages to lipopolysaccharide (LPS) stimulation was reduced in $>90\%$ of the stressed fish. At 4 weeks there was no significant difference in inducible IL-1$\beta$ expression between the groups. Macrophages isolated from stressed fish showed significantly decreased survival when exposed to A. salmonicida. The implications of these changes in the immune system will be discussed with respect to the use of classical indicators of stress to predict possible effects on the immune system of fish. This work was funded by NRC Genomics and Health Initiative.
RT-PCR DETECTION OF CYP1A RNAM IN ASTRONOTUS OCELLATUS (ACARÁ-AÇU) EXPOSED TO DISPERSANT PLUS CRUDE OIL

M.S. Ferreira-Nozawa¹, A.R. Chipari-Gomes², R. Araújo², S.R. Nozawa¹, T. L. A. S. Nascimento², A. L. Val², V.M.F. Almeida-Val²
E-Mail: mnozawa@niltonlins.br
¹Centro Universitário Nilton Lins, Manaus, Brazil; ²Laboratório de Ecologia e evolução Molecular (LEEM) INPA, Manaus, Brazil

Session: TroP2
Abstract: The widespread occurrence of aquatic environmental contamination has focused attention on the urgent need for sensitive and precise diagnostic tools, or biomarkers, with a predictive capability in assessment of toxic contaminant impact (Moore and Simpson, 1992). In aquatic environments, induction of cytochrome P4501A (CYP1A) activity is commonly used as a biomarker for monitoring exposure of fish to environmental pollutants. However, many aspects of CYP1A regulation are not yet understood, including dose-response relationships. Studies in our laboratory using semi-quantitative RT-PCR to investigate the sensitivity of acará-açu (Astronotus ocellatus) to crude oil and dispersant have demonstrated a high level expression of CYP1A in this condition. In the experimental assays we used different conditions: the fishes were exposed to crude oil, chemically dispersed oil (crude oil plus dispersant) and water as control. These results suggest that for this species the chemically dispersed oil presents more toxicity than the crude oil itself. Financed by CNPq and FAPEAM.

ADAPTIVE VARIATION IN THE FEEDING OR SHELTERING TRADE-OFF IN ATLANTIC SALMON ALONG AN ICE-COVER GRADIENT

A. G. Finstad*, T. Forseth, O. Ugedal, and T.F. Næsje
E-Mail: anders.finstad@nina.no
Norwegian Institute for Nature Research

Session: FroO12
Abstract: We tested for adaptive variation in the feeding or sheltering trade-off in relation to ice cover in Atlantic salmon through common environment tank and stream channel experiments. We used six populations of Atlantic salmon originating from a climatic gradient (59 – 70 °N), ranging from insignificant natural ice-cover (southern populations) to several months of extensive ice-cover conditions (northern populations). All populations reduced growth rates in darkness in the laboratory environment. However, the growth reductions in darkness (ice-cover) was almost four times as large in southern compared to northern populations. This population effect was due to higher food consumption and higher growth efficiency in the dark for fish from the northern populations. There was also a corresponding energetic response to ice-cover for fish held in semi-natural streams and fish from northern populations remained a higher frequency of feeding irrespectively of ice-cover treatment. The variation in response to ice-cover between populations was partly due to physiological differences (food consumption efficiency in darkness) and partly due to differences in activity related metabolic costs (behaviour). Northern fish are more dependent on energy intake in order to survive the winter than southern, and our results indicate that i) northern populations are selected for feeding priority and higher risk taking, and ii) adaptations to local ice-cover conditions are results of selection both on physiological and behavioural traits. Founded by the Norwegian Research Council and Statkraft Energy Inc.

A DESCRIPTION OF GADOID PATHOGENS FOUND IN WILD AND CULTURED COD (Gadus morhua)

S. Flynn¹, D. Barker², D. Cone³ and M. Burt⁴
E-Mail: Shawn.flynn@mi.mun.ca
¹Marine Institute, Memorial Univ. of Newfoundland, Canada; ²Malaspina University-College, Nanaimo, British Columbia, Canada; ³St. Mary’s University, Nova Scotia Canada; ⁴The Univ. of New Brunswick, Canada

Session: DisO8
Abstract: We conducted a survey of viral, bacterial, protozoan and metazoan parasites of wild and cultured cod in the Bay of Fundy, NB and in Fortune Bay, NL. We identified Nodavirus, Aeromonas salmonicida, a new genus of Monogenean parasite and an as yet unidentified hemorrhagic disease. This sentinel work is very valuable for the future of gadoid aquaculture. Funding for this project was provided through the NSERC Collaborative Research Development Program.
EXTRAPOLATING FROM SMALL-SCALE ECOLOGICAL EXPERIMENTS TO LARGE-SCALE DYNAMICS: DENSITY DEPENDENCE IN CORAL REEF FISHES

G. E. Forrester1 and M. A. Steele2
E-Mail: gforrester@uri.edu

1Dept. of Natural Resources Science, University of Rhode Island, Kingston, RI 02881, USA; 2Marine Science Institute, University of California, Santa Barbara, CA 93106 USA

Session: FroO18

Abstract: Although field experiments allow rigorous tests of ecological hypotheses, they are usually limited to small spatial scales. We often want to know if their findings extrapolate to larger scales, especially when seeking to apply their results to conservation and management. We show first that the results of experiments detecting density-dependent mortality of reef fish on small habitat patches scale-up to have similar effects on much larger entire reefs that are the size of small marine reserves and approach the scale at which some reef fisheries operate. This result is in accord with a scaling model which indicates that localized events can be aggregated to describe larger-scale interactions with minimal distortion. Ongoing work is testing whether the biological interactions causing density dependence also scale up. Experiments on small habitat patches reveal that locally density-dependent mortality is inflicted by predators. As prey become crowded, they suffer a progressively increasing shortage of structural refuges. A manipulation of refuge abundance on entire reefs suggests that a similar interaction occurs at this much larger scale. The results so far suggest that careful extrapolation from small-scale experiments identifying species-interactions may be possible, and so should improve our ability to predict the outcomes of alternate management strategies for coral reef fishes.

TRADE-OFFS BETWEEN WINTER FEEDING AND SHELTERING IN ATLANTIC SALMON – THE EFFECTS OF ICE-COVER

T. Forseth, A.G. Finstad, O. Ugedal and T.F. Næsje
E-Mail: torbjorn.forseth@nina.no
Norwegian Institute for Nature Research, Norway

Session: FroO11

Abstract: Salmonid fishes make different trade-offs between feeding and sheltering during winter, depending on energetic status and time of year. Through tank and stream channel experiments manipulating light and cover, we explored how such trade-offs are influenced by ice-cover conditions. In tank environments juvenile salmon from a northern population grew equally well in darkness and in light, whereas southern salmon were not able to grow in darkness. All fish had higher food consumption in light than in darkness, and northern salmon had higher growth efficiency in darkness. Higher efficiency was due to lower metabolic rates in darkness (30%) and lower activity costs. In stream channel environments all fish had negative growth, but whereas northern salmon loss significantly less energy under simulated ice-cover (23 %), southern salmon showed no treatment effect. The lower energy loss under cover in northern salmon was due to higher food consumption and lower metabolic rates. The present study thus shows that both physiological traits and the behavioural trade-offs between feeding and sheltering are influenced by ice-cover, and indicates that different populations respond differently to changes in ice conditions. A simple energetic model showed that removal of ice due to e.g. climate change has the potential to influence winter survival of Atlantic salmon. Field estimates of winter survival supported the modelling, as survival was twice as high (60 and 30 %) in ice covered sections of the northern study river compared to sections without ice, below the outlet of a hydropower station. Moreover, food consumption was lower in the sections without ice-cover. Funded by the Norwegian Research Council and Statkraft Energy Inc.

THE RESPONSE OF FINFISH TO SIDE OPENING GRIDS

Daniel G. Foster and John W. Watson
E-Mail: Daniel.G.Foster@noaa.gov
U.S. NOAA Fisheries, Southeast Fisheries Science Center, P.O. Drawer 1207, Pascagoula, MS, 39568, USA

Session: CapO9

Abstract: Grids are used extensively throughout the world for the exclusion of unwanted bycatch from shrimp trawls. This study, conducted in the Gulf of Mexico, was designed to document the behavior of finfish in relation to a grid designed to exclude bycatch out of the side of the trawl extension and compare the fish behavior to that of a top opening grid. The demersal and pelagic species observed in this study were small enough to pass between the bars of the grid and escapement was a result of behavioral responses. Under daylight towing conditions, the response fish to the side opening grid was found to be a typical predator avoidance response. Fish turned at a 90o angle to the line of the bars and passed horizontally down the grid face maintaining a small distance forward of the grid. When clear passage was evident, fish passed out of the
escape opening. The same grid was evaluated in a top opening configuration. As with the side opening grid, pelagic fish exhibited a successful avoidance strategy. However, demersals resisted being vertically displaced by the upward sloping bars and the escape rate was much lower than with the side opening grid. Both grid configurations were also observed during night towing conditions using infrared illumination. While fish were able to detect the oncoming grid, the avoidance reaction by all species was erratic resulting in random escapement. The results of this study suggest that with sufficient ambient lighting, pelagic fish appear to be able to negotiate side or top opening grids equally well. However, the side opening grid offers a more natural avoidance route for demersal species.

HABITAT UTILIZATION OF ATLANTIC STURGEON IN THE DELAWARE RIVER:
A COLLABORATIVE TELEMETRY APPROACH
D. A. Fox and P. C. Simpson
E-Mail: dfox@desu.edu
Department of Agriculture and Natural Resources, Delaware State University, USA

Session: TelP2
Abstract: Record harvest levels combined with poor water quality and slow reproductive rates likely caused the collapse of the Delaware River Atlantic sturgeon (Acipenser oxyrinchus oxyrinchus) population during the late 1800’s. In May, 2005 we initiated a project to characterize habitat utilization patterns of sub-adult and adult Atlantic sturgeon using both active and passive (Vemco Ltd.VR2) telemetry. To date, 12 juvenile Atlantic sturgeon (785mm –1225mm FL) have been implanted with ultrasonic transmitters (Vemco Ltd. V-16, 6-H, 69.0 kHz). Cooperative tracking by multiple research groups via passive and active tracking has resulted in over 50,000 detections. Results suggest Atlantic sturgeon utilize specific habitat characterized by hard-bottom substrate and depths ranging from 5–15m which is deeper than previously reported for the Delaware River. Continuous monitoring of movements using passive and manual tracking, revealed telemetered Atlantic sturgeon exhibit greater activity during the early summer and fall periods, where movements occasionally exceeded 100km/day and rates reached 8.7km/hr. By early November, 50% of tagged animals had migrated to the marine environment. Instances of transmitter relocation during winter months suggest juvenile Atlantic sturgeon are overwintering in the Delaware River. Recent genetic findings coupled with collection of YOY Atlantic sturgeon indicates a relict spawning stock exists, although by-catch and boat strike mortalities may be restricting population recovery. These results show the power of collaborative telemetry projects through use of a standardized platform system which multiple groups can utilize. Funding was provided through the USFWS State Wildlife Grants Program, NOAA’s Anadromous Fish Conservation Act Funding, and NOAA’s Educational Partnership Program.

NONRANDOM GROUP FORMATION IN SCHOOLING MIGRATORY CHARR:
CAUSES AND CONSEQUENCES FOR ADAPTIVE MANAGEMENT
D. J. Fraser1, P. Duchesne2 and L. Bernatchez2
E-Mail: Dylan.fraser@dal.ca
1Dept. of Biol., Dalhousie Univ., Canada; 2Dept. of Biol., Laval Univ., Canada

Session: FroO8
Abstract: Genetic tools provide new avenues to explore links between individual fish behaviour and population biology. Here, we use 20 microsatellite loci to investigate the genetic composition of 53 schools of adult and sub-adult migratory brook charr (Salvelinus fontinalis) sampled from the known, overlapping feeding areas of two populations in Mistassini Lake (Québec). We test whether schools are population-specific and whether individuals from the same population within schools are kin (half- or full-siblings). Randomization tests reveal a tendency for most schools to be population-specific, but some schools are population mixtures. Significantly more kin are found within schools than expected at random for both populations (≈ 21-34% of the total number of school members). This result, combined with the observed size range of individuals, indicates that stable associations between kin may occur beyond juvenile stages for up to four years. A high proportion of school members, however, were non kin (≈ 66-79%). We discuss the hypothesis that the stable kin groups, rather than arising from kin selection, are instead a by-product of familiarity based on individual selection for the maintenance of local adaptations related to migration (natal and feeding area philopatry). Our study is significant because it suggests that there is some degree of permanence in the composition of wild fish schools, and that schools can be hierarchically-structured (from population members down to family groups). The relevance of these findings is discussed in relation to human exploitation and the maintenance of genetic variability within fish populations. Funding by NSERC.
JUVENILE SALMONID GROWTH AND USE OF SMALL CENTRAL CALIFORNIA ESTUARIES

E.V. Freund and R.B. MacFarlane
E-Mail: ellen.freund@noaa.gov
National Marine Fisheries Service, Santa Cruz, CA, USA

**Session:** FroO14

**Abstract:** The importance of estuaries in salmonid early life history varies depending on the species. Research has focused on salmonid use of large estuaries that remain open to the ocean all year. Smaller estuaries, which may close seasonally due to sandbar formation and low stream flow, have received little study. This investigation focuses on seven small estuaries across ~130 km of California’s central coast. These creeks have established steelhead (*Oncorhynchus mykiss*) populations, three have established coho (*O. kisutch*) populations, and two had juvenile coho in 2005 for the first time in almost 20 years (although all of the creeks historically supported coho). Juvenile salmonids move into the estuary as early as March and are found there through the rest of the year, although the behavior of each species is different depending on location. When a sandbar forms, the water quality of an estuary (now a lagoon) can change dramatically due to increases in temperature, cessation of water outflow and processes of nutrient cycling. Estuaries were seined monthly. Coho and steelhead (>65mm FL) were PIT-tagged to calculate growth and estuary residence time throughout the year. Growth rates in the estuaries are high and fluctuate seasonally. Small archival temperature loggers were attached to steelhead after sandbar closure in one lagoon. Recovered tags showed steelhead spend most time in the mid to lower temperature range of waters available, whether ambient water temperature range is 10-16 °C or 16-21 °C. Funded by the National Marine Fisheries Service.

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MEASURING FEARFULNESS IN RAINBOW TROUT (*Oncorhynchus mykiss*):
PLASTICITY OF A “FIXED” TRAIT

A. J. Frost, A. Winrow-Giffen, P. J. Ashley and L. U. Sneddon
E-Mail: a.j.frost@liv.ac.uk)
University of Liverpool, School of Biological Sciences, Liverpool, UK

**Session:** WelO5

**Abstract:** The bold-shy continuum is a major factor in behavioural variation, with the degree of boldness, or conversely fearfulness, being regarded as a fixed trait throughout contexts. These “personality traits” are thought to reflect different stress coping styles with bold individuals adopting a proactive style and fearful individuals a reactive style. Stress, a major problem in aquaculture, has led to suggestions to selectively breed for proactive styles, but little is known about the welfare consequences of this strategy. We examined the plasticity of boldness in rainbow trout to determine whether prior experience influences behavioural performance such that individuals experiencing emboldening events become bolder and those subjected to negative experiences more fearful. Fish were deemed either bold or shy via a novelty test and then were either allowed to observe bold or shy individuals responding to novel stimuli or were given the experience of winning or losing fights. Observers were then retested for their response to novelty; bold individuals that watched shy demonstrators displayed a decrease in their degree of boldness adopting a shy, more fearful approach. Both the positive and negative experiences of winning and losing significantly decreased fearfulness in shy subjects. Shy winners and losers decreased their latency to approach the novel object, with winners also making more physical contact with the object. Bold winners remained bold and their behaviours were unchanged whereas bold losers became shyer, increasing their latency to approach a novel object. Fearfulness in rainbow trout appears to be context specific and is affected by prior experience. Funded by The University of Liverpool.

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THERMAL SENSITIVITY OF CONTRACTILITY AND EXCITATION-CONTRACTION COUPLING IN TUNA CARDIAC MUSCLE

G. Galli1, M. Musyl3, R. Brill4 and H. Shiels1
E-Mail: holly.shiels@manchester.ac.uk

1The University of Manchester, UK, 2The University of Birmingham, UK 3The University of Hawaii, USA and 4Virginia Institute of Marine Science, USA

**Session:** CarO15

**Abstract:** The factors enabling bigeye tuna to maintain cardiac function over a broad range of temperatures remain largely unknown. Several studies have pointed to enhanced specialisations in E-C coupling processes as a possible contributing factor. We examined the thermal sensitivity of cardiac ventricular and atrial muscle from three pelagic species, the mahimahi, the yellowfin tuna and the bigeye tuna. Isolated muscle preparations were electrically paced and exposed to a temperature gradient, mimicking the temperatures associated with a descent through the thermocline. This experiment was then repeated in the presence of the sarcoplasmic reticulum (SR) inhibitors, ryanodine and thapsigargin. In all species studied, reducing temperature caused an initial increase in force, followed by a progressive decline. Reducing temperature below 10oC resulted in a severe decrease in force or cessation of contraction. Bigeye tuna cardiac muscle maintained higher
contractile force at lower temperatures compared with yellowfin and mahimahi. SR inhibition had little effect on yellowfin or mahimahi, while causing significant reductions in force in atrial muscle, and modest reductions in ventricular muscle from the bigeye tuna. Our results support the hypothesis that bigeye tuna cardiac muscle is less temperature sensitive than other pelagic species which frequent shallower depths, and this increased tolerance may be due to enhanced E-C coupling. We thank the staff and crew of the NOAA ship Oscar Elton Sette, The BBSRC, and the Company of Biologists for supporting this work.

THE LIFE HISTORY AND BEHAVIOUR OF PACIFIC GROUNDFISH FROM ISOTOPIC RECORDS OF OTOLITHS
Y.W. Gao 1,2, R.A. Svec1, S.H. Joner1, G.G. Bargmann3 and D.L.G. Noakes4
E-Mail: gaoy@olypen.com
1Makah Fisheries Management, PO Box 115, Neah Bay, WA 98357, USA; 2School of Fisheries, Huazhong Agricultural University, Wuhan, Hubei 430070, P.R. China; 3Washington Department of Fish & Wildlife, Olympia, WA 98501, USA; 4Department of Fish & Wildlife, Oregon State University, Corvallis, OR 97331, USA

Session: BonO1
Abstract: The study of stable oxygen and carbon isotope ratios of otoliths (18O/16O or d18O, and 13C/12C or d13C) has yielded valuable information on the life history and behaviour of some commercially important fish species along the Pacific west coast, particularly in identification of spawning aggregations and stock structure. Here we present a comparison study from otoliths of Pacific halibut (Hippoglossus stenolepis), sablefish (Anoplopoma fimbria), Pacific cod (Gadus macrocephalus), and yelloweye rockfish (Sebastes ruberrimus). In general, the d18O values of Pacific groundfish started with a low range from -0.5 to 0.5‰ VPDB, and then increased to +1.8 ~ 2.5‰ VPDB as the fish get sexual maturity. The initial low isotopic values correspond to the natal sources, while the stable higher isotopic values correspond to the adult stage before the fish were caught. Similar isotopic variations were found in d13C from -5.0 to -2.5‰ VPDB at the breeding stock and from -0.5 to 0.5‰ VPDB as adults. The stable d18O values at the adult stage indicate that these groundfish might live at similar oceanic conditions, whereas their different d13C values in the juvenile stage reveal that the fish might have different diet or food sources. The age-2 or 3 may be a critical period for halibut, sablefish and cod, as this is the time for these fish to migrate or move to deeper ocean waters. However, the unchanged d18O values of yelloweye rockfish show that the species did not move from juvenile to adult stage as other groundfish did, but a trophic shift as the fish grew. Thus we concluded that combination of d18O and d13C in otoliths has the potential to be used as a natural tag to examine the life history and behaviour of marine fish.

USE OF ENRICHED ROTIFIERS AND ARTEMIA DURING LARVICULTURE OF ATLANTIC COD (Gadus morhua): EFFECTS ON EARLY GROWTH, SURVIVAL AND LIPID COMPOSITION
A. S. Garcia, C.C. Parrish and J.A. Brown†
E-Mail: alesachsida@hotmail.com
Ocean Science Centre, Memorial University of Newfoundland, Canada.

Session: LinO3
Abstract: A feeding experiment was conducted to evaluate the effect of live-food enriched differently on the early growth, survival and lipid composition of Atlantic cod larvae (Gadus morhua). The enrichments tested during rotifer phase were: 1) Spray-dried Schizochytrium sp., 2) Spray-dried Cryptochodinium sp., and 3) A combination of spray-dried Schizochytrium sp. and Pavlova sp. paste. The same treatments were tested during the Artemia phase in addition to a combination of a lipid-rich emulsion and spray-dried Schizochytrium sp. as a fourth treatment. At the end of the rotifer period (37 days post hatch) the treatments resulted in similar growth curves but the larvae from treatment 3 (1.50 ± 0.11 mg dry weight) were significantly heavier than treatment 2 (1.03 ± 0.04 mg dry weight). At 37 dph, larvae from treatment 3 had amounts of phospholipids (242.21 ± 6.64 mg.g-1 dry weight) and total lipids (341.77 ± 6.43 mg.g-1 dry weight) significantly higher than the other treatments. At the end of the experiment the larvae fed with Schizochytrium sp.-enriched Artemia were significantly heavier (12.06 ± 1.13 mg dry weight) than those from treatment 3 (6.49 ± 0.32 mg dry weight) and those from treatment 4 (5.31 ± 0.20 mg dry weight). Larvae from treatment 1 had levels of DHA (20.32 ± 0.84% of total fatty acids) significantly higher than treatments 2 and 3, and levels of arachidonic acid (6.02 ± 0.14% of total fatty acids) significantly higher than the other treatments. The combination of an algae paste and spray-dried Schizochytrium sp. resulted in the best survival through the 59 days of larviculture. This research was funded by AquaNet.
USE OF ENRICHED ROTIFERS AND ARTEMIA DURING LARVICULTURE OF HADDOCK (Melanogrammus aeglefinus): EFFECTS ON EARLY GROWTH, SURVIVAL AND LIPID COMPOSITION.

A. S. Garcia¹, C.C. Parrish¹, J. A. Brown¹, S. C. Johnson and S. Leadbeater¹

¹Ocean Science Centre, Memorial University of Newfoundland, Canada; ²Faculty of Marine Biosciences, National Research Council, Canada; ³Centre for Coastal Studies and Aquaculture, University of New Brunswick, Canada

Session: LinP4

Abstract: A feeding experiment was conducted to evaluate the effect of live-food enriched differently on the early growth, survival and lipid composition of haddock larvae (Melanogrammus aeglefinus). The enrichment treatments used during the rotifer phase were: 1) Spray-dried Schizochytrium sp., 2) Spray-dried Cryptocodinium sp., and 3) A combination of spray-dried Schizochytrium sp. and Pavlova sp. paste. Treatments 2 and 3 were tested during the Artemia phase in addition to a combination of a lipid-rich emulsion and spray-dried Schizochytrium sp. as a third treatment. At the end of the rotifer phase, there were no significant differences in the growth rates produced by the different treatments. In contrast, during the Artemia phase, the larvae fed with Cryptocodinium sp. – enriched Artemia (6.05 ± 0.29 mg dry weight) performed significantly better than those fed with Schizochytrium sp. + Pavlova sp. –enriched Artemia (4.46 mg ± 0.30 dry weight). Larvae fed with Artemia enriched with a combination of a lipid-rich emulsion and spray-dried Schizochytrium sp. had significantly higher contents of phospholipids (77.31 ± 2.34 mg.g⁻¹ dry weight) and total lipids and (117.97 ± 2.88 mg.g⁻¹ dry weight). The combination of an algae paste and spray-dried Schizochytrium sp. resulted in the best survival through the 43 days of larviculture. This research was funded by AquaNet.

OPTIMIZATION OF ACETYLCHOLINESTERASE AND METABOLIC ENZYME ACTIVITY
IN MULTIPLE FISH SPECIES

E. Georgiades and D. A. Holdway

Faculty of Science, University of Ontario Institute of Technology, Canada.

Session: BioO7

Abstract: There is widespread concern that sub-lethal exposure to pesticides may harm non-target aquatic organisms. Measurement of brain acetylcholinesterase (AChE) activity is commonly used as a biomarker of pesticide (organophosphates and carbamates) exposure in fish, as the critical effect of most members of these pesticide classes is AChE inhibition. As an AChE inhibition of >20% is often required to confirm a depression in enzymatic activity, we propose the additional measures of metabolic enzymes to show the brain’s functional state via aerobic/anaerobic capacity. Metabolic enzymes such as citrate synthase (CS) and lactate dehydrogenase (LDH) are involved in cellular respiration and ATP production. Having previously been used as measures of cellular aerobic and anaerobic capacity, respectively, these enzymes have the potential to be biomarkers of xenobiotic exposure. An examination of AChE, CS and LDH activity in the brains of a range of fish species occupying different trophic levels is essential to investigate the full extent of the effects of sub-lethal or pulse exposures to pesticides. This investigation explores the optimization of microplate methods for AChE, CS and LDH activity in multiple fish species

IN MULTIPLE FISH SPECIES

CREATINE KINASE AND INTRACELLULAR ENERGY TRANSPORT
IN HEART MUSCLE OF ECTOTHERMIC VERTEBRATES

H. Gesser¹, R. Birkedal² and D.H. Jensen¹

¹Institute of Biological Sciences, University of Aarhus, Denmark; ²Faculty of Life Sciences, University of Manchester, UK.

Session: CarO11

Abstract: In cardiac cells, creatine kinase (CK) catalyzing the reaction ADP + phosphocreatine (PCr) ↔ ATP + creatine (Cr) can occur both free in the cytosol and bound to cellular structures. In mammalian cardiac cells, the mitochondrial fraction of CK (Mi-CK) is bound to the inner mitochondrial membrane near the adenine nucleotide translocase (ANT). In the microenvironment around Mi-CK and ANT, the ATP/ADP ratio is very high and as a result, Mi-CK produces PCr. This PCr diffuses into the cytosol and reaches the cytosolic CK. A fraction of the cytosolic CK is bound near myosin ATPase and uses PCr to rephosphorylate ADP to ATP close to the myosin-ATPase sites. The question arises if these couplings are a general feature and occur in cardiac cells from ectothermic vertebrates which are either more inactive
and/or live at low temperatures. Here, ATP-metabolism should be less limited by diffusion rates and presumably less dependent on a coupling of CK to mitochondria and the contractile proteins. Our results on skinned cardiac fibres suggest that the coupling between mitochondria and CK is less tight in ectothermic species. However, although the CK activity relative to the ATP hydrolyzing capacity shows a large species variation, it appears on average to be as high in ectothermic vertebrates as in endothermic ones. Furthermore, the CK bound to the contractile proteins seems to be of significant importance as the myosin-ATPase activity recorded with isolated myofibrillar preparations was considerably increased in the presence of PCr. Supported by The Danish Natural Science Research Council (FNU)

GILL SURFACE AREA AND HEART SIZE OF DIFFERENT STRAINS OF ARCTIC CHARR (Salvelinus alpinus)
H. Gíslason and H. Thorarensen
E-Mail: helgi@holar.is
Holar University College, Iceland.

Session: CarO4

Abstract: The size of the heart and the gills of different species of fish is closely linked to levels of activity. However, little is known about the variability in the size of the cardiorespiratory organs of different populations within a species. In this study, we compared the morphology and the size of gills and ventricles in different populations of Arctic char. In one experiment, fish from anadromous and resident populations were reared in a common garden experiment. The specific gill area of the river population was 291 mm$^2$ g$^{-1}$ and more than twice as large as that of the resident population (137 mm$^2$ g$^{-1}$). Moreover, the relative heart mass of the anadromous population (0.08% of body mass) was 30% larger than that of the resident population (0.06%). Interestingly, although having significantly larger cardiorespiratory organs, the river population did not perform any better in prolonged swimming tests than the lake population. In a separate study, the size of the cardiorespiratory organs of wild fish from three anadromous and three resident Arctic char populations were compared. In contrast to the earlier experiment, the results of this study did not show any clear difference between resident and migratory population. The results of these two studies indicate that both hearts and gills of anadromous populations may be larger than those of lake populations when reared under identical conditions. However, the size of the cardiorespiratory organs of charr is also influenced by environmental factors, such as temperature, which also contribute to variability between different populations. Funded by Holar University College Res. Fund.

CATCHING-RELATED STRESSORS AND CORTISOL RESPONSE IN EASTERN PACIFIC ROCKFISHES
H. Gliniak, C.G. Lowe and K.M. Kelley
E-Mail: hgliniak@gmail.com
Marine Biology Program, California State University Long Beach, USA

Session: MolP9

Abstract: Eastern Pacific nearshore and shelf rockfishes are subjected to intensive fishing-related stressors, particularly in the populous southern California region. Furthermore, given the depths at which rockfishes are typically caught, they show obvious signs of barotraumas, such as exopthalia, abdominal bloating, and stomach and cloacal eversion. These animals' physiological responses to these stressors and to methods intended to mitigate effects of barotraumas (e.g., airbladder venting, rapid return to depth using cages) may play an important role in whether they will survive these experiences. In all vertebrates, including fishes, environmental stressors induce a neuroendocrine response that leads to increased circulating levels of the steroid hormone, cortisol. In Pacific rockfishes, this key physiological system has not been characterized. In our studies, a variety of rockfish species (Sebastes semicinctus, S. miniatus, S. umbrinus, S. serviceps, S. hopkinsi, S. rubrivinctus, S. caurinus, S. elongatus, S. paucispinis, S. atrovirens, S. goodie, S. auriculatus, S. carnatus, and S. constellatus) have been subjected to hook and line catching, followed by extended captivity in on-board tanks or in cages brought back down to normal depths. Findings to date indicate that basal levels of cortisol in all rockfish tested (individuals caught and rapidly blood sampled within 1-20 min) are similar to those of other fish and vertebrate groups (<20 ng/ml). However, the subsequent cortisol response to catching, handling and captivity appears to be variable across rockfish species, ranging from dramatic increases (up to 200 ng/ml) to none. Results from different species and experimental treatments will be discussed. [H.H.M.I. Grant #52002663]
DOES SOCIAL STATUS AFFECT THE PHYSIOLOGICAL RESPONSE TO STRESSORS?
Gollock, M.J. and Gilmour, K.M.
E-Mail: mgollock@uottawa.ca
Biological Sciences, University of Ottawa, Canada

Session: MolO23
Abstract: There is a growing base of literature that indicates that social stress can have a significant detrimental effect on the physiology and behaviour of a number of fish species. This can result in decreased growth, immunosuppression and mortality. Subordinate fish generally exhibit increased activity levels of the Hypothalamo-Pituitary-Interrenal axis when compared to dominant fish, and this has been suggested as a cause of the negative effects described. To date, however, there has been little research into how chronic social stress affects the ability of a fish to respond to additional imposed stressors. In the present study, we paired juvenile rainbow trout to form a dominance hierarchy, and fish were observed for 72 hours after pairing. Fish were assigned a dominant or subordinate status using well-established indices of behaviour. After 72 hours of social interactions, blood samples were taken for measurement of cortisol, glucose and ACTH and 24 hours later, immediately after a 1 hour netting stress. In addition, the impact of social status on interrenal cell sensitivity to ACTH was examined. As expected cortisol levels in subordinate fish were higher than those in dominants prior to netting stress. Cortisol levels, post-stress are higher in both groups of fish. Interestingly there was no significant effect of social status on cortisol levels post-stress. Funding provided by NSERC and PREA.

POTENTIAL METHODS FOR MEASURING ACTIVITY PATTERNS AND ENERGY USE IN FREE SWIMMING ATLANTIC COD (Gadus morhua)
Gollock, M.J.1, Hunter, K.2, Freeman, M.3, Syme, D.4, McKinley, R.S.2 and A.K. Gamperl1
E-Mail: mgollock@mun.ca
1Ocean Sci. Centre, Memorial Univ. of Nfld; 2Fac. of Ag. Sci., Univ. British Columbia; 3Dept. of Zoology, Univ. of Guelph; 4Department of Biol. Sci., Univ. of Calgary

Session: TelO23
Abstract: To date, there is limited information available on the activity patterns of free-swimming fish, especially marine fish, and how this relates to metabolic expenditure. Thus, we used swim-tunnel respirometry to assess 3 potential methods for measuring the relationship between activity and metabolic rate in cod. The 3 methods were: Electromyography (EMG), which measures muscle electrical activity; Sonomicrometry (S), which uses transceiver crystals to measure changes in muscle length; and Differential pressure sensors (DPS), which when placed on the caudal peduncle, measure pressure changes associated with each tailbeat. The variability in data obtained using S was much greater than for either EMG or DPS, and thus is not suitable. EMG data for red muscle showed a good relationship with swim speed (although higher ‘n’ values may be required for defining the relationship at higher swim speeds), and thus this method shows great promise once acoustic EMG tags are available. The relationship between DPS output (as integrated or differential pressure) and swim speed was also highly significant. However, two issues must be resolved before this device can be used effectively: 1. Fish intra-peritoneally implanted with the DPS tag had lower Ucrit values (by 30%) and increased cost of transport as compared to untagged fish (possibly due to tag size, 39g, or sensor placement); 2. Preliminary tank experiments show that high values of integrated/differential pressure (which may be associated with rapid turning, not bursts of activity) can contribute significantly to estimates of mean swimming speed, and thus metabolic expenditure. Funded by NSERC and AquaNet.

USE OF SALT DURING TRANSPORTATION OF AIR BREATHING PIRARUCU JUVENILES (Arapaima gigas) IN PLASTIC BAGS
L. C. Gomes1, E. C. Chagas1, R. P. Brinn2, R. Roubach3, C. E. Coppati4 and B. Baldisserotto5
E-Mail: levy@cpaa.embrapa.br
1Embrapa Amazônia Ocidental, Brazil, 2Florida International University, USA, 3Instituto Nacional de Pesquisas da Amazônia, Brazil, 4Universidade Federal de Santa Maria, Brazil

Session: TroP11
Abstract: Previous study demonstrated that transportation of pirarucu juvenile in plastic bags is a suitable procedure, although it stimulated some stress responses. The objective of this study was to investigate the addition of salt as a stress mitigator in pirarucu juveniles during transportation in plastic bags. Fish were placed in 30-L polyethylene bags with 10 L of water at a density of 12 fish/bag (40 g/L) with different table salt (NaCl, 97%) concentrations in the water: 0, 1, 3, 5 g/L (3 replicates). Transportation took 3 h and afterwards fish were transferred to 1-m3 floating cages installed inside an earth pond for recovery. Fish stress responses were evaluated before, during and after transportation procedure. The analyses performed were: cortisol, glucose, lactate, hematocrit and waterborne net Na+, Cl-, K+ and Ca2+ fluxes. Cortisol exhibited an increase after transport with 1g salt/L and at 24h after transportation for all treatments showing a latency period in their response. Glucose exhibited a similar pattern for all treatments with a significant increase before and after transportation,
returning to basal levels in 24 h. Lactate concentrations increased before transportation and after transportation, presenting a significant decrease in all treatments. Addition of salt in the transport water increased Na⁺, Cl⁻ and Ca²⁺ net fluxes in pirarucu. Using salt during pirarucu juvenile transportation should be avoided since there is no reduction on stress responses and causes osmoregulatory disturbances. Funded by CNPq, grant # 475093/2003-8.

PARTIONING OF NUTRIENT UPTAKE AND GAS EXCHANGE IN THE GUT OF *Misgurnus anguillicaudatus*
A. F. Gonçalves¹,², F. Castro¹, C. M. Pereira², J. Coimbra¹, and J. M. Wilson¹.
E-Mail: filipa4@gmail.com
¹ Ecofisiologia, Centro Interdisciplinar de Investigação Marinha e Ambiental, Porto, Portugal. ² Biology, U. Minho, Braga Portugal.

Session: TroP14
Abstract: *Misgurnus anguillicaudatus* is a facultative air breathing teleost fish that makes use of its hind gut as an air breathing organ (ABO). The intestine is well vascularized with intraepithelial capillaries making it well suited for gas exchange but what are the consequences for nutrient uptake, the traditional function of the intestine? The alimentary canal was examined histologically to assess differences between three regions of the gut. The three regions of the gut: fore-, mid- and hind-gut have been functionally considered as the digestive, spiral and respiratory zones, respectively. The intestinal Na⁺:glucose cotransporter (SGLT1) and H⁺:peptide cotransporter (PepT1) play important roles in the absorption of carbohydrate and di,tri peptides in the gut of fishes and other animals and were used as markers for nutrient uptake function. In the present study, we partially sequenced SGLT1 and PepT1 cDNAs by RT-PCR and determined their tissue distributions and if diet composition or fasting affect their expression at the mRNA level. SGLT1 mRNA was found in kidney, liver and in the three zones of the gut except the most distal part. PepT1 mRNA was found in heart, liver, and fore and mid-gut. PepT1 mRNA was not detected in the hindgut (intestine). It was not possible to modulate the expression of SGLT1 and PepT1 with diet. Our results clearly show the presence of SGLT1 transcript in the respiratory zone of the intestine indicating an overlap in function. In the case of PepT1, this overlap was limited to the mid-gut. Supported by FCT grant POCTI/BSE/47585/2002.

EFFECTS OF CRF AND UROCORTIN ON IN VITRO OVARIAN STEROIDOGENESIS BY FOLLICLES FROM Acanthochromis polyacanthus
Gonzalez-Reynoso, L. and Pankhurst, N.W.
E-Mail: Luis.GonzalezReynoso@jcu.edu.au
Fish Endocrinology Laboratory, James Cook University, Townsville, Australia

Session: MolO19
Abstract: Corticotropin Releasing Factor (CRF) and Urocortin I (Uc), the mammalian orthologue of fish Urotensin I, are peptides that regulate several physiological stress responses in mammals, and in fish regulate interrenal cortisol release. We evaluated their effects on fish gonadal steroidogenesis as part of a project assessing stress signals with potential to regulate stress inhibition of reproductive physiology in fish. Follicles from the spiny damselfish Acanthochromis polyacanthus were incubated for 18 h in L15 medium at 7 per well in 24-well plates, with CRF or Uc at 10⁻⁷ or 10⁻⁸ M, in the presence or absence of human chorionic gonadotropin (hCG, 100 U.ml⁻¹), to test their effects on basal and gonadotropin-stimulated testosterone (T) and 17b-estradiol (E2) production. CRF had sporadic inhibitory (in 2 out of 12 fish) as well as stimulatory effects (in 1 out of 12 fish) on both basal and hCG-stimulated steroidogenesis. Uc inhibited basal T but not E2 production in the 5 fish evaluated indicating that its inhibitory effects are exercised before T production. Uc also had a nonsignificant tendency to inhibit hCG-stimulated steroidogenesis. This the first demonstration of consistent in vitro inhibition of steroidogenesis in female teleosts, by a stress hormone. Currently, additional in vitro experiments and in vivo evaluation of Uc and its antagonists during a stress protocol are being conducted to assess the potential role of Uc in stress inhibition of gonadal steroidogenesis.

NA⁺ CAUSES AN INTRACELLULAR ACIDIFICATION IN ISOLATED TROUT GILL MITOCHONDRIA-RICH (MR) CELLS: A NEW MODEL FOR TRANSEPITHELIAL NA⁺ UPTAKE
G. Goss, M. Tresguerres and S.K. Parks
E-Mail: greg.goss@ualberta.ca
Department of Biological Sciences, University of Alberta

Session: IonO17
Abstract: We subjected isolated mitochondria-rich (MR) cells from rainbow trout to real time fluorescent intracellular pH (pHi) imaging in an effort to better understand the mechanisms of ion and acid-base transport in MR cells. MR cells from
the freshwater trout gill epithelia were isolated following the protocol set up by Goss et al. 2001. After plating (2 hours on poly-L-lysine treated coverslips), cells were loaded with BCECF-AM and then subjected to pH imaging using an imaging station located in our laboratory. Interestingly, we observed at least two distinct and separate behaviours for pH regulation in our isolated MR cells suggesting at least two subtypes of cells. We found that ~77% of cells from the mixed MR cell fraction demonstrated a puzzling Na⁺-induced pH acidification behaviour versus 23% which exhibited expected Na⁺-induced pH alkalinization behaviour (n=227). This Na⁺-induced acidification was a puzzling but interesting finding that required re-working of current model in order to explain properly. Using pharmacological analysis, we found that amiloride (500 mM), phenamil (50 mM) and DIDS all prevented the Na⁺-induced acidification in these cells. These results required re-interpretation of the model for Na⁺ transport in the gill in order to be congruent. We suggest a new working model for transepithelial Na⁺ uptake at the freshwater fish gill whereby Na⁺ enters apically via a Na⁺ channel and is extruded into the bloodstream via a basolateral Na⁺/HCO₃⁻ co-transporter. (Support by and NSERC Discovery Grant to GG and Killam and Donald Ross Post graduate scholarships to MT)

FUNCTIONAL GENOMICS OF ENVIRONMENTAL ADAPTATION IN FISH
A. Y. Gracey¹ and A. R. Cossins²
E-Mail: gracey@usc.edu
¹Marine Environmental Biology, University of Southern California, USA; ²School of Biological Sciences, University of Liverpool, UK

Session: ProO1
Abstract: A key factor in the survival and continued success of organisms in climatically variable environments is their ability to display a suite of adaptive responses that promote both the constancy of their constituent physiological processes and increase tolerance to damaging or lethal conditions. Relatively little is known about the mechanisms underpinning these responses in aquatic organisms. Deploying a high-throughput microarray-based approach, we have investigated the transcriptional component of the common carp (Cyprinus carpio), to cold and hypoxia. A microarray was constructed using 10,000 mostly non-redundant cDNA amplicons isolated from a collection of normalized and serially-subtracted cDNA libraries. A time-course analysis of the transcriptional response to environmental cold and hypoxia will be discussed in detail. Discrete and overlapping sets of genes were regulated in different tissues in response to environmental change, suggesting that the differentiated tissues possess distinct functional roles in adaptation. The integration of these expression data provide a uniquely broad overview of the complex process of adaptive regulation in vertebrate animals following exposure to environmentally significant stress. Funded by NERC, UK.

DENSITY-DEPENDENT GROWTH OF JUVENILE ATLANTIC SALMON (Salmo salar)
AT DIFFERING SPATIAL SCALES
J.W.A. Grant, I. Imre, O. Venter, and I. Girard
E-Mail: grant@vax2.concordia.ca
Department of Biology, Concordia University, Canada

Session: FroO19
Abstract: The growth rate of individual fish typically decreases with increasing population density, providing an important component of density-dependent population regulation. The ideal free distribution, however, predicts that important components of fitness, like individual growth rate, will be constant across habitats differing in density. These contrasting expectations reflect differences in spatial scale and fish mobility; density-dependent growth is expected at large spatial scales, whereas density-independent growth is expected at small spatial scales when fish can sample alternative habitats. We investigated how growth rate is affected by density at differing spatial scales. In a long-term data set collected at Catamaran Brook, New Brunswick, the growth rate of young-of-the-year Atlantic salmon decreased strongly with increasing density. Similar patterns were observed for most other populations of stream-dwelling salmonids in the literature. Within sites at Catamaran Brook, salmon show strong preferences for microhabitats of intermediate depth and current velocity. However, the growth rate of young-of-the-year salmon did not differ between preferred and not preferred foraging locations, consistent with the ideal free distribution. How growth rate changes with density provides important clues about the mobility of individual fish and the freedom with which fish can choose between alternative habitats. Funded by NSERC.
NON-STEROIDAL ANTI-INFLAMMATORY DRUGS (NSAIDS) MODIFY CELLULAR STRESS RESPONSE IN RAINBOW TROUT LARVAE
A. Gravel, and M.M. Vijayan
E-Mail: agravel@sciborg.uwaterloo.ca
Dept. of Biol., University of Waterloo, Canada

Session: MolP7
Abstract: We investigated the role of NSAIDs in the regulation of the cellular stress response in trout larvae. The larvae were exposed to two concentrations (1µg/L and 1000 µg/L) of either salicylate (SA) or ibuprofen for 96 h and the liver tissue sampled. A subset of these treated fish were then subjected to a standardized heat shock (HS: +10ºC for 1 h) and sampled at 1, 4 or 24 h post-HS. Salicylate did not affect the unstimulated heat shock protein (hsp)70 expression, whereas ibuprofen (1000 µg/L) significantly elevated basal hsp70 expression in trout larvae. As expected, heat shock significantly increased liver hsp70 expression in the control larvae at 4 and 24 h post-HS. Salicylate did not modify this HS-induced hsp70 response, whereas ibuprofen inhibited the hsp70 expression at 24 h post-HS. The HS response also resulted in a significant drop in whole body glucose content at 4 and 24 h in the control group, suggesting the utilization of glucose as an important fuel for hsp70 synthesis. This was further confirmed by the significantly higher liver hexokinase activity post-HS. Salicylate, but not ibuprofen, completely abolished this HS-mediated whole body glucose response, despite a significantly higher hexokinase activity. The lack of change in glucose utilization, in spite of hsp70 expression, suggests that SA impacts the energy re-partitioning of the heat shock response, while ibuprofen disrupts the heat shock response. Taken together, our results suggest that SA- and ibuprofen-mediated disruption of the cellular stress response in trout larvae involve distinct mode of action. The study was supported by NSERC Discovery grant.

SALICYLATE DISRUPTS INTERRENAL STEROIDOGENESIS AND BRAIN GLUCOCORTICOID RECEPTOR EXPRESSION IN RAINBOW TROUT
A. Gravel and M.M. Vijayan
E-Mail: agravel@sciborg.uwaterloo.ca
Dept. of Biol., University of Waterloo, Canada

Session: ImpO21
Abstract: Varying levels of pharmaceuticals, including salicylate, have been reported in the aquatic environment, but few studies have actually addressed their impact on aquatic organisms. We tested the hypothesis that these pharmaceuticals are endocrine disruptors in fish by examining their impact on interrenal corticosteroidogenesis in rainbow trout. Indeed, acute adrenocorticotrophic hormone (ACTH)-mediated cortisol production in interrenal cells in vitro was significantly depressed (20-40%) by these pharmaceuticals. We tested the hypothesis that this interrenal dysfunction involved inhibition of the steroidogenic capacity in trout. For this, trout were fed salicylate-laced feed (100 mg/kg body wt) for three days and along with assessing the interrenal capacity for cortisol production, we also ascertained the transcript levels of key proteins involved in corticosteroidogenesis, including steroid acute regulatory protein (StAR), peripheral-type benzodiazepine receptor (PBR), cytochrome P450 side chain cleavage (P450scC) and 11β-hydroxylase. Salicylate treatment did not affect the resting plasma cortisol levels, whereas the acute ACTH-stimulated cortisol production was significantly reduced in the interrenal tissue. This disruption of steroid production by salicylate coincided with a significant drop in the gene expression of StAR and PBR, but not P450scC or 11β-hydroxylase, compared to the sham treated fish. Glucocorticoid receptor (GR) protein content, but not mRNA levels, in the brain was also significantly depressed by salicylate. Taken together, salicylate is a corticosteroid disruptor in trout and the targets include the key rate-limiting step in the interrenal corticosteroid biosynthetic pathway and brain GR signaling. Funded by NSERC discovery.

ARE MARBLED LUNGFISH OBLIGATE AIR BREATHERS? – RATES OF AERIAL RESPIRATION IN PROTOPTERUS AETHIOPICUS
J. M. Green,1 C. Mlewa2 and R. Dunbrack1
E-Mail: jmgreen@mun.ca
1Dept. of Biol., Memorial Univ., Canada and 2Dept. of Fisheries, Moi Univ., Kenya

Session: AdvP5
Abstract: Although it has long been assumed that African lungfish (Protopterus) are obligate air breathers, no field studies have determined the frequency of aerial respiration in free swimming individuals. To help fill this gap in knowledge we measured the frequency of air breathing in radio tagged Protopterus aethiopicus in Lake Baringo, Kenya. We made use of the fact that in lakes with moderately high conductivity, signals from radio tags should only be detectable when tags are near or above the surface. We verified this phenomenon by lowering a radio tag into the water and measuring its detectability at distances up to ~1 km as a function of tag depth. Results indicated that the signal was invariably detected when the tag was within ~10 cm of the surface, as it would be when a tagged fish was air breathing. The frequency of aerial
respiration in Protopterus was then investigated by surgically implanting four lungfish with radio tags. During the first 4 hrs following their release, these tagged lungfish decreased their rate of aerial respiration to less than once per 30 min. However, following this initial period (4.5 hrs), no aerial respiration was detected in any of these fish. Tracking of 12 lungfish implanted with acoustic tags indicated that short term movements of L. Baringo lungfish were limited, thus it is probable that radio tagged subjects ceased aerial respiration rather than moved outside the detection range of the receiver. These data suggest that at least some lungfish are not obligate air breathers in the normoxic environment of L. Baringo and that the characterization of this species as an obligate air breather may need to be reevaluated. Funded by NSERC, IDRC and CIDA (Canada) and Moi Univ., Kenya.

DENSITY-DEPENDENT, HABITAT ASSOCIATED BEHAVIOUR AND RECRUITMENT IN AGE 0 COD
R.S. Gregory
E-Mail: GregoryR@dfo-mpo.gc.ca
Fisheries & Oceans Canada, St. John’s, Newfoundland, Canada

Session: FroO20
Abstract: Density-dependant processes recruitment of fish populations worldwide. However, the mechanisms by which these processes operate are not clear, especially at low population size. In the coastal waters off Newfoundland, Greenland cod (Gadus ogac) and the historically more abundant Atlantic cod (G. morhua) exhibit high recruitment variability from pelagic larvae and juveniles through to juveniles associated with seaboards, where they spend most of their lives. In contrast with predictions of many models, juvenile cod density is often a poor predictor of adult population size. In a series of studies, I used net sampling, mark-recapture, and risk experiments, to examine the effect of recruitment abundance, on habitat-associated packing, predator-induced mortality, and site fidelity in age 0 cod in Newman Sound, during the decade 1995-2005. In low recruitment years, age 0 cod exhibited a strong association with eelgrass (Zostera marina) habitat, high site-fidelity, and anti-predator strategies consistent with cover use. In contrast, in high recruitment years, age 0 cod associations with vegetated habitat were weak, site-fidelity was low, and an anti-predator strategy was predominated by shoaling behaviour. Substantive differences existed in the behaviour of juvenile cod during high relative to low recruitment years. These results suggest that we must be cautious when assuming that the behaviour of fish is similar at high and low population size. Funded by the Natural Sciences & Engineering Research Council of Canada, Fisheries & Oceans Canada, Parks Canada, and Memorial University of Newfoundland

WELL-BEING – DO WE KNOW WHAT IT MEANS FOR A FISH?
G. Griffin & C. Gauthier
E-Mail: ggriffin@ccac.ca
Canadian Council on Animal Care, Ottawa, ON K1P 5G4, Canada

Session: WelO1
Abstract: The Canadian Council on Animal Care (CCAC), is the national agency responsible for setting and maintaining standards for animal care and use in science. CCAC bases its guidance on the understanding that good animal welfare and good science go hand in hand. Faced with an increasing number of fish being used for research, teaching and testing, the CCAC considered it prudent to develop specific guidelines on: the care and use of fish for research, teaching and testing (2005). The purpose of the guidelines is to provide a framework for the implementation of best practices both for the housing and husbandry of fish, as well as for scientific procedures. The process of guidelines development can involve consideration of areas where there is little scientific certainty or where scientific evidence needs to be tempered by other ethical considerations; for example the potential for pain and distress experienced by fish. Although based on scientific evidence and expert opinion, the understanding of constitutes well-being for fish is an emerging field. This presentation will highlight challenges faced by the CCAC subcommittee, and discuss the thinking behind some of the recommendations. The guidelines focus on minimizing stress for fish through good facility design; appropriate enclosures; attention to water quality; meeting species specific nutritional needs; and provision of an environment that addresses the behavioral needs of the fish. In publishing these guidelines the CCAC also recognized that additional research is needed in order to improve the manner in which are currently used.
MARINE TELEOST INTESTINAL SALT AND WATER ABSORPTION

Grosell, M.1, Taylor, J.1, Genz, J.1, Gilmour, K.M.2 and Perry, S.F.2
E-Mail: mgrosell@rsmas.miami.edu

1RSMAS, University of Miami, FL; 2University of Ottawa, On., Canada

Session: IonO11

Abstract: In marine teleost fish, continuous diffusive water loss is compensated by seawater ingestion. Imbibed seawater is desalinized by the esophagus resulting in roughly iso-osmotic intestinal fluids allowing for water absorption across the intestinal epithelium. Apical anion exchange (AE) contributes by as much as 70 % to Cl– uptake and thereby water absorption. Hydration of endogenous epithelial CO2 contributes, to varying degree in different species, HCO3– for exchange with Cl across the apical membrane. In toadfish, the H+ resulting from the CO2 hydration reaction is excreted across the basolateral membrane via Na+/H+ exchange (NHE) which relies on the Na+ gradient established by the lateral Na+/K+--ATPase (NKA). Acute transfer of rainbow trout from freshwater to 65% seawater (SW) results in increased plasma osmolality stabilizing after 48 hours while intestinal fluids display rapid changes in response to induced drinking and intestinal fluid absorption. Intestinal fluid composition confirms a quantitatively important role for the pyloric cecae in fluid absorption and demonstrates rapid onset of water transport. Transcription of cytosolic carbonic anhydrase (CAc) and extracellular CA4, as well as NKA, NHE, the Na+/HCO3–-cotransporter (NBC) and the H+-pump measured by qPCR display transient increases following SW transfer resulting in elevation of abundance of some, but not all associated proteins and increased overall CA activity in the intestinal tissue. These SW induced changes in transcription and protein abundance of acid-base transporters and CA transcription and activity further supports the proposed important role of intestinal HCO3– secretion for marine osmoregulation. (Supported by NSF IAB 0416440 to MG).

ONTOGENETIC CHANGES IN THE CRITICAL SWIMMING SPEED OF COLD–WATER MARINE FISH LARVAE, AND THE ROLE OF TEMPERATURE

L. Guan, P.V.R. Snelgrove and A.K. Gamperl
E-Mail: V52lg@mun.ca
Ocean Sciences Centre, Memorial University of Newfoundland, Canada

Session: EarO14

Abstract: Most studies on behavioral contributions to dispersal and recruitment during early life history stages have focused on coral reef fish. For cold ocean environments, high variation in seasonal temperature and development times suggest that parallel studies on active behavior are needed for cold-water species. Thus, we examined the critical swimming capability (Ucrit) of marine fish larvae (from hatch to metamorphosis) from 2 contrasting species: Gadus morhua (Atlantic cod) and Myoxocephalus scorpius (shorthorn sculpin); a pelagic and bottom spawner, respectively. Within-species comparisons showed that sculpin reared at 6 oC had lower initial Ucrit values, but a faster Ucrit increase through development as compared with 3 oC conspecifics, ultimately resulting in faster swim speeds at metamorphosis (10.5 vs. 9.1 cm s–1). In contrast, although cod larvae reared at 10oC were faster swimmers at first feeding than 6 oC fish, temperature differences were absent after the first week. These results show that temperature influences the trajectory of larval swim speed development, but that the relationship is species-specific. Although 6oC sculpin and cod of similar length had equivalent Ucrit values, the smaller size of cod at hatch (5.3 vs. 10.8 mm for sculpin) resulted in much lower age-specific Ucrit values for cod. These data have significant implications for how swimming activity of the two species might affect dispersal, particularly in the first few weeks post-hatch. Overall, our data suggest that spawning mode and rearing temperature influence the swimming capacity of cold-water marine fishes, with important ramifications for biophysical models of dispersal. Funded by NSERC.

MECHANISMS OF THERMAL COMPENSATION OF FISH MUSCLE OXIDATIVE CAPACITY: MODIFICATION OF MITOCHONDRIAL MEMBRANES AND THE IMPACT UPON ACTIVITY OF ETS COMPLEXES

H. Guderley1, E. Kraffe1,2 and N. Martin1
E-Mail: Helga.guderley@bio.ulaval.ca

1Dép. de biologie, Univ. Laval, Québec, P.Q. G1K 7P4; 2Univ. de Bretagne Occidentale, Brest, France

Session: IntO3

Abstract: As branchial respiration imposes a virtually absolute link between body and environmental temperatures in fish, adaptation to habitat temperatures is a critical step of seasonal and migratory physiology in fish. A major level at which adjustments occur is in the phospholipid composition of membranes, with marked shifts in classes and fatty acid composition accompanying thermal change. These changes have the potential of facilitating the catalytic activity of membrane proteins. Nonetheless, acclimation to cold temperatures leads many species of fish to increase mitochondrial volume densities in their tissues, particularly their skeletal muscle, suggesting additional scope for increasing aerobic capacity. As the impact of the phospholipid composition of mitochondrial membranes on the activity of membrane bound
complexes has received little attention in ectotherms, we examined the time course of changes in activity and composition in mitochondria isolated from oxidative muscle of rainbow trout (*Oncorhynchus mykiss*). Mitochondria were isolated, characterized for their oxidative capacity, contents of adenylate nucleotide translocator, cytochromes and proteins, phospholipid and fatty acid compositions as well as the activity of the respiratory chain complexes. These properties were assessed for cold acclimatized trout, for trout sampled shortly after transfer to warm temperatures (15 °C) and after 6 weeks of warm acclimation. We found that specific modifications in membrane composition accompany changes in the activity of respiratory chain complexes and contribute to changes in tissue aerobic capacity. Funded by NSERC, VRQ/RAQ.

**TROUT BEHAVIORAL RESPONSE TO PULSED FLOWS: INVESTIGATIONS UTILIZING RADIO AND ELECTROMYOGRAM TELEMETRY**

S.A. Hamilton¹, S.N. Chun², J.B. Miranda¹, G.J. Jones³, D.E. Cocherell¹, L.C. Thompson¹, J.J. Cech¹ and A.P. Klimley¹

E-Mail: jjcech@ucdavis.edu

¹Dept of Wildlife, Fish and Conservation Biology, UC Davis; ²Visger and Associates, Inc., Mather, CA

**Session:** TelP1

**Abstract:** Our objectives were to elucidate how pulsed flows, water releases, for hydroelectric generation and whitewater rafting affect adult fish survival, movement and behavior. Sections of the American River are managed differently: portions like the South Fork below Chili Bar Dam are pulsed daily throughout summer other portions are maintained at stable low flows and rarely pulsed. Although we focused our efforts on daily pulse effects, we also had the opportunity to investigate a pulse in a stream that rarely experiences flow fluctuations. We utilized radio and electromyogram telemetry to track wild and hatchery rainbow trout and wild brown trout during pulse events. Weekly locations of two groups of ten hatchery trout, SL 28.8 ± 0.59 cm and 35.7± 0.66 cm, were determined from July to October using radio telemetry to evaluate potential seasonal differences between early summer and fall. Electromyogram telemetry was used to record individual activity over a single day’s pulse. Nine tagged hatchery trout were calibrated in a Brett-type respirometer, relating muscle activity to tail beat, speed, and oxygen consumption, then released in the South Fork. Tracking began before the river started rising and continued as the flow stabilized and decreased. Fish movement and activity will be analyzed during flow fluctuations using a general linear model. We will present the results and conclusions from the study. Funded by the Pulsed Flow Program Management Team and the CEC.

**POTENTIAL EFFECT OF TEBUFENOZIDE ON LAKE TROUT (Salvelinus namaycush) IMMUNE RESPONSE**

D. Hamoutene ¹, J.F. Payne¹, H. Volkoff², J. Guinney³ and L. Fancey ¹

E-Mail: Hamoutened@dfo-mpo.gc.ca

¹Science Branch, DFO, PO Box 5667, St John’s, NL, Canada, A1C 5X1; ²Biology Department, MUN, St John’s, NL, Canada, A1B 3X9; ³Oceans Ltd. 85 Lemarchant Road, St John’s, NL A1C 2H1

**Session:** ImpO26

**Abstract:** Mimic® is a pesticide based on a commercial formulation of tebufenozide used for the control of various insects on fruits and vegetables. There is very little direct information on the immunotoxic potential of tebufenozide. We exposed lake trout (*Salvelinus namaycush*) to one pulse of 1 ppm of Mimic® (0.25 ppm tebufenozide) every 3 days (12 pulses in total). Water dilution was such that the theoretical concentrations of tebufenozide in the exposure tank would be 0.15, 0.09, 0.05, 0.03 ppm after 6, 12, 18 and 24 hours respectively. Cell numbers and respiratory burst responses of circulating white blood cells (WBCs) as well as head-kidney (HK) WBCs were investigated by using flow cytometry (FCM), Nitro-Blue Tetrazolium (NBT) tests and cell observation. Results demonstrated a significant increase in HK WBCs stimulation of respiratory burst with NBT detection. No difference in cell stimulation indices was observed in circulating WBCs (FCM and NBT test). On the other hand, FCM data of whole blood samples showed a decrease in percentage of cells capable of high respiratory burst in the exposed fish. However, caution seems warranted in using Tebufenozide on crops or in forest spray programs near lakes and streams. Funding is provided by the National Pesticide Research Fund.
GONADOTROPIN INDUCED SYNCHRONOUS CHANGES OF MORPHOLOGY AND GONADAL DEVELOPMENT IN THE JAPANESE EEL (*Anguilla japonica*)

Y. S. Han¹, W. N. Tzeng¹ and I C. Liao²
E-Mail: d8225002@yahoo.com.tw

¹Inst. of Fish. Sci., Col. of Life Sci., NT Univ., Taipei, Taiwan; ²Chair Prof., NTO Univ., Dept. of Aqua., Col. of Life and Res. Sci., Keelung, Taiwan

Session: IntP6

Abstract: In a previous study, we had observed synchronous changes of morphology and gonadal development in wild Japanese eel during the silvering process. In this study, we aimed to identify the key hormone responsible for this phenomenon. Yellow eels captured in the Kaoping River were repeatedly injected with human chorionic gonadotropin (HCG), and changes of morphology and gonadal development were examined. After five weekly injection of HCG at a dosage of 0.75 U/g body weight, eels was classified into well-responsive and poor-responsive groups according to skin coloration. Approximately 50 % of males and 20 % of females were responsive to become silver eels.  Mean age, total length, body weight, condition factor, gonadosomatic index (GSI), fin-index (FI), hepatosomatic index (HSI) and ocular index (OI) were significantly higher in well-responsive eels than in poor-responsive eels. The mean digestosomatic index (DSI), in contrast, significantly decreased in well-responsive eels compared to poor ones. OI was positively correlated and DSI was negatively correlated with the GSI in both sexes. These results indicated: 1) Well developed eels are more sensitive to HCG treatment; 2) The skin color, eye size, gonadal development and digestive tract shrinkage were synchronous after HCG injection; and 3) The pituitary – gonad axis plays important role on eel silvering. Funded by Council of Agriculture, Executive Yuan, Taiwan, ROC.

THE ROLE OF MORPHOLOGY AND SWIMMING PERFORMANCE IN THE ECOLOGICAL SUCCESS OF WILD AND CULTURED EUROPEAN SEA BASS

C. A. Handelsman¹, J. A. Nelson¹ and G. Claireaux²
E-Mail: chande1@towson.edu

¹Dept. of Biological Sciences, Towson Univ., USA; ²Station Méditerranéenne de l’Environnement Littoral, Sète, France

Session: FroO29

Abstract: The ecological performance of animals can be considered a component of Darwinian fitness. In many fish, the ability to swim may contribute to individual fitness. However, while swimming performance of fish is frequently measured in the laboratory, its contribution to success in the field is rarely evaluated. Juvenile European sea bass (*Dicentrarchus labrax*) were assessed for sprint and endurance swimming performance and substantial variation was found in both. Furthermore, sprint and endurance performance were found to be repeatable on a short term basis and across a 10 °C temperature gradient (sprint) and following 5-months under simulated natural conditions (endurance; p < 0.05). These repeatable differences make these traits potentially useful as fitness parameters. To examine one possible source of individual variation in sprint swimming performance and to evaluate our results within the morphology-performance-fitness paradigm, European sea bass that were swum also underwent geometric morphometric analysis of body morphology. Replicate groups of wild and cultured fish were subsequently released into mesocosms where survival depended on nutrient acquisition from a natural forage base and evading avian predators for 14 weeks. Wild fish exhibited a more fusiform body shape and achieved faster sprint velocities than cultured conspecifics. Additionally, wild fish outperformed cultured sea bass in the mesocosms (35% vs. 0% survivorship). The significance of morphological variation and sprint performance to the ecological performance of European sea bass populations will be discussed. Funded by the U.S. NSF and CNRS (France).

INTERRELATIONSHIPS AMONG TEMPERATURE, METABOLISM AND SWIMMING PERFORMANCE IN PACIFIC COD

S.K. Hanna, A.H. Haukenes, R.J. Foy and C.L. Buck
E-Mail: fnskh@uaf.edu

School of Fisheries and Ocean Sciences, University of Alaska Fairbanks, USA

Session: NorO5

Abstract: Physiological constraints may contribute to the observed changes in relative abundance of Pacific cod seen in association with interdecadal changes in sea surface temperatures. To examine this concept, we determined critical swimming speed (Ucrit) and oxygen consumption rates of adult cod, acclimated at either 4 or 11 °C, during swim performance tests in a swim tunnel. In addition, we measured hematocrit and concentrations of cortisol, glucose, lactate, sodium, chloride, potassium and total protein in plasma from resting and exhausted fish to assess the impact of swim trials on fish condition. Neither mean Ucrit (1.07 body lengths/s) nor resting oxygen consumption rates differed significantly between temperature treatments, although fish acclimated at 11°C showed a 40% greater oxygen consumption at rest than
those at 4°C. Maximum metabolic rate was significantly higher in fish acclimated at 11°C than 4°C acclimated fish. Before exercise, cortisol concentrations as well as hematocrit values were greater for fish acclimated at 4°C than those at 11°C. Following exhaustive exercise cortisol, lactate, glucose and protein were increased relative to levels observed at rest in both temperature groups while sodium and chloride concentrations were significantly greater in fish acclimated at 4°C than those at 11°C. Although swimming performance did not differ between the two groups, increased levels of cortisol in the low temperature group prior to swim trials indicate stress associated with this temperature. In addition, greater maximum metabolic rate in the high temperature group suggests increased energy requirements for exercise at higher temperatures. Funded by NOAA, USDA and Rasmuson Foundation.

VARIATION IN SOCIAL BEHAVIOUR AND REPRODUCTIVE HORMONES IN ARCTIC CHARR DURING A SPAWNING SEASON
L. A. Hansen¹, H. K. Johnsen² and B. Damsgård¹
E-Mail: linda.hansen@fiskeriforskning.no
¹Fiskeriforskning (Norwegian Institute of Fisheries and Aquaculture Research), N-9291 Tromsø, Norway; ²Norwegian College of Fishery Science, University of Tromsø, N-9037 Tromsø, Norway.

Session: FroO9
Abstract: Individual behaviour is related to external and internal stimuli, with interactions between environment, physiology and behaviour affecting the reproduction of fish. The plasma levels of testosterone (T), estradiol (E2) and 11-ketotestosterone (11-KT) were monitored monthly through a spawning season in a group of 30 mature and immature male and female Arctic charr (Salvelinus alpinus). The fish were individually marked and video observed, and the individual frequencies of aggressive, courtship and redd digging behaviours were examined. Maturation and the frequency of performed reproductive behaviours were not related to initial weight, length or condition factor. Unlike the mature fish, the immature fish seldom performed chases, bites and nips, and never performed courtship or redd digging behaviours. An increase in occurrences of mature male aggressive interactions in late September coincided with the onset of male defense of females and courtship. These behaviours were observed when plasma T levels had started to decrease, plasma levels of 11-KT were still increasing, the males were running-ripe and the first females had ovulated and initiated redd digging. A minority of the mature female fish performed redd digging. The hormone profiles differed temporally in these females and they were more frequently aggressive than the non-digging mature females. The results suggest that the dynamics of individual physiology and reproductive behaviour is influenced by social interactions, potentially promoting and inhibiting the expression of certain reproductive behaviours. The study was financially supported by the Norwegian Research Council.

WHY DON’T HEARTS FAIL DURING MAXIMUM PROLONGED SWIMMING IN RAINBOW TROUT, (Oncorhynchus mykiss)?
L.M. Hanson¹ and A.P. Farrell²
E-Mail: hanson@zoology.ubc.ca
¹Dept. of Zool., Univ. of B.C., Canada and ²Faculty of Land & Food Sys. & Dept. of Zool., U.B.C., Canada

Session: CarO10
Abstract: As rainbow trout approach exhaustion during prolonged exercise, their venous blood becomes hypoxic, acidic and hyperkalemic. Despite the fact that these factors are recognized to have detrimental inotropic and chronotropic effects on cardiac performance, the heart, which is bathed predominantly by venous blood, maintains a maximum cardiac output. Rainbow trout are known to release catecholamines during exercise, and therefore we hypothesize that adrenergic stimulation is critical in maintaining maximum cardiac performance under these adverse conditions in vivo. To test this hypothesis, maximum cardiac performance was assessed with in situ rainbow trout hearts using a hyperkalemic (5.0 mM), acidic (pH 7.5) perfusate with and without maximal adrenergic stimulation (500 nM adrenaline). Under normoxia (20 kPa) and with tonic stimulation (5.0 nM adrenaline), hearts produced only 44.8% ± 14.6% of maximum cardiac output (Qmax) when exposed to the hyperkalemic, acidic perfusate, indicating that even if blood was fully oxygenated there was no refuge from cardiac impairment under these relevant conditions. However, with maximum stimulation, maximum cardiac performance was maintained under hyperkalemic and acidic conditions over a wide range of oxygen availability, from normoxia to 2.0 kPa, an oxygen tension (Po2) close to venous Po2 measured in vivo. Extending the level of hypoxia to 1.3 kPa resulted in a 43.6% ± 2.8% decrease in Qmax. Our results suggest that adrenergic stimulation of the trout heart is critical in maintaining maximum performance during prolonged swimming tests, and probably during all forms of exhaustive activity and recovery, when venous blood is hyperkalemic, acidic and hypoxic. Funded by NSERC.
FINE-SCALE TEMPORAL AND SPATIAL ANALYSES OF LARGEMOUTH BASS BEHAVIOUR USING A 3-D WHOLE-LAKE ACOUSTIC TELEMETRY OBSERVATORY

K. C. Hanson¹, S. J. Cooke¹, C. D. Suski²*, G. Niezgoda¹, F. J. S. Phelan², C. Hasler³ and D. P. Philipp⁶

E-Mail: cory.suski@mnr.gov.on.ca

¹Dept. of Biology, Carleton Univ., Canada; ²Harkness Laboratory of Fisheries Research, Ontario Ministry of Natural Resources, Canada; ³Lotek Wireless Inc., Canada; ⁴Queen’s Univ. Biological Station, Canada; ⁵Dept. of Biology, Queen’s Univ., Canada; ⁶Illinois Natural History Survey, USA.

Session: TelP3

Abstract: A whole-lake acoustic telemetry array was utilized to monitor the three-dimensional position of largemouth bass (Micropterus salmoides) as part of an ecological observatory. Code division multiple access (CDMA) technology enabled the simultaneous monitoring of 20 transmitters (equipped with pressure and temperature sensors) at 15 sec intervals with sub-meter accuracy. The distance moved by largemouth bass, assessed both on a daily and hourly basis, varied by season and was positively correlated with water temperature. Visualization of fish swimming paths revealed that some fish occupied discrete areas and made localized movements, whereas other individuals made lengthier journeys covering much of the lake in periods of as little as one day. Fish exhibited diurnal activity patterns that were most distinct in the spring and less so during the late fall and winter. Also, analysis of fish behaviour was possible at a finer temporal scale that allowed for the investigation into instantaneous swimming speeds across the seasons. When the telemetry data-set was queried to simulate 24 hour manual tracking intervals, manual tracking data underestimated daily movement and swimming speeds by at least 75 fold. The data set was also queried to investigate the possibility of interactions amongst individuals, defined as when two fish were within visual range of each other for extended periods of time. This study identifies the importance of evaluating fish activity at multiple spatial (whole lake to sub-meter position) and temporal (seasonal to seconds) scales and illustrates the potential of CDMA telemetry to yield such data.

THE ROLE OF ECOTOXICOLOGY IN ENVIRONMENTAL IMPACT ASSESSMENT – A NEW EUROPEAN PERSPECTIVE

Mark G. J. Hartl

E-Mail: m.hartl@ucc.ie

Department of Zoology, Ecology and Plant Science, University College Cork, Ireland

Session: ImpO15

Abstract: Environmental risk assessment usually follows a phased approach, where risk is a function of exposure and toxicity. Phase I establishes likely environmental hazards and potential for exposure during manufacture, transport, use and disposal of a particular chemical (in the case of pesticides, how are non-target species affected?). A decision, based on the information from Phase I, is made whether or not to move to Phase II, a tiered ecotoxicological evaluation, in which the fate and effects of chemicals as well as the species-specific risk are defined. Along with intimate knowledge of the physico-chemical characteristics of a chemical, ecotoxicity tests, therefore, become a fundamental part of any environmental impact or risk assessment. General and specific toxicity test are required for which appropriate endpoints or biomarkers need to be developed in order to set environmental standards that allow the enforcement of policies regulating all aspects of potentially harmful chemicals. One of the challenges facing policy makers in Europe following the recent expansion from 15 to 25 member states (plus another 7 candidate countries), all with widely differing standards, is the harmonisation of test procedures and environmental legislation. REACH, the new registration, evaluation and authorisation policy for chemicals in the European Union that will be coming into force in 2007, will help to tackle this problem. The new policies will have wide-ranging socio-economic impacts, help to protect the environment and, where possible, prescribe the use of alternative test methods in environmental risk assessment, thus reducing unnecessary animal testing. Providing the new policy measures are successfully implemented, the drive towards developing novel and more sensitive tests, will undoubtedly also present a challenge to ecotoxicologists.

FUNCTION OF FISH CARDIAC POTASSIUM CHANNELS UNDER THERMAL STRESS

Minna Hassinen, Vesa Paajanen, Jaakko Haverinen and Matti Vornanen

E-Mail: matti.vornanen@joensuu.fi

University of Joensuu, Department of Biology, Joensuu, Finland

Session: CarO13

Abstract: Potassium currents of cardiac myocytes provide thermal plasticity for the fish heart function (Vornanen et al. Am.J.Physiol. 282:R1191-1199, 2002). The purpose of this study was examine the molecular basis of K current function under chronic thermal stress in rainbow trout (Oncorhynchus mykiss) and crucian carp (Carassius carassius). Molecular cloning, quantitative PCR and patch-clamp methods were used to identify genes of the inward rectifier potassium channels, temperature-dependent expression of gene transcripts and K current function at single-channel and whole-cell level.
respectively. Transcripts of Kir2.1 and Kir2.2 inward rectifier K channels were expressed in the heart of both teleost species. In crucian carp Kir2.2 was the dominant form, while in rainbow trout Kir2.1 was more abundant than Kir2.2. Thermal acclimation did not affect Kir channel transcripts in rainbow trout, whereas in crucian carp expression of Kir2.2 was strongly depressed by acclimation to cold (4 degrees). At the functional level, the inward rectifier K currents of both species were, however, modulated by thermal acclimation. These findings suggest that thermal plasticity of the cardiac inward rectifier K current is not exclusively achieved by differential expression of gene transcripts, but may also involve temperature-dependent changes in the regulation of channels by intracellular polyamines, the natural blockers of these K channels. This study was supported by the Academy of Finland (grant#210400).

MIGRATION BEHAVIOR AND SURVIVAL THROUGH THE LOWER COLUMBIA RIVER OF ARTIFICIALLY RECONDITIONED KELT STEELHEAD (Oncorhynchus mykiss)

D.R. Hatch¹, R. Branstetter¹, J. Whiteaker¹, D. Fast², J. Blodgett², T. Newsome², B. Bosch² and M. Johnston²

¹Columbia River Inter-Tribal Fish Commission, Portland, OR, USA; ²Yakama Nation Fisheries, Toppenish, WA, USA

Session: TelO3

Abstract: All wild steelhead populations originating above Bonneville Dam on the Columbia River are listed under the U.S. Endangered Species Act. A promising approach to effectively increase natural production of wild steelhead is to capitalize on their iteroparous life history strategy by capturing fish during the early stages of their outmigration and applying steelhead kelt reconditioning. Reconditioning is the process of culturing post-spawned fish so that they survive, grow, and undergo gonad recrudescence for a repeated spawning event. We evaluated two steelhead management strategies by using hydroacoustic telemetry to track individuals and evaluate survival, travel time, and behavior in the lower 233km of the Columbia River. The experiment consisted of two treatment groups; one group that was collected, and immediately transported and released at rkm 233, and the second group that was collected, placed in a reconditioning facility for 6 weeks and then transported and released at rkm 233. Treatment group survival to the ocean ranged from 0 to 53% with an important temporal component. Travel time from release to the estuary ranged from 3 to 25 days. At least two distinct migration patterns were observed in the estuary. The first was a linear movement to the ocean and the second oscillated with the tide in the upper reaches of the estuary. Future work will attempt to link estuary migration pattern with plasma ion concentrations and gill ATPase activity. Funded was provided by the Bonneville Power Administration.

THE USE OF ULTRASONIC TELEMETRY AS A TOOL IN EVALUATING SUCCESS OF ADAPTIVE MANAGEMENT ACTIVITIES AIDING ATLANTIC SALMON RECOVERY

J.P. Hawkes¹, R. Saunders¹ and A. Vashon²

¹NOAA’s National Marine Fisheries Service, Northeast Fisheries Science Center, Orono, Maine USA; ²United States Department of Agriculture, Animal and Plant Health Inspection Service Wildlife Services, Augusta, Maine USA

Session: TelO7

Abstract: Declining abundance of Maine’s remnant Atlantic salmon populations over the past few decades prompted their listing in 2000 as a federally endangered species. Since 1997, NOAA’s National Marine Fisheries Service has been using ultrasonic telemetry to assess the emigrating smolt dynamics of these populations. Telemetry arrays were designed to monitor migration behavior and timing, and survival through the riverine, estuarine, and near-shore marine environments. The data collected have provided insight into several emigration threats that may be impeding recovery. Data from telemetry work has been used to formulate hypotheses about factors that negatively effect populations and managers are testing these theories through mitigation measures such as avian deterrent activities, pilot liming projects, and alternative stocking strategies. The ultrasonic telemetry work has generated an improved understanding of smolt emigration dynamics and fostered the development of adaptive management strategies to enhance the recovery of the remnant salmon populations in Maine.

THE EFFECT OF WATER TEMPERATURE ON SWIMMING IN MARINE FISHES

P. He

E-Mail: Pingguo.he@unh.edu

Institute for the Study of Earth, Oceans and Space and New Hampshire Sea Grant, University of New Hampshire, 137 Morse Hall, Durham, NH 03824, USA

Session: CapO7

Abstract: Most fish species, except a few large pelagic animals, are poikilothermic, with their body temperatures approximating those of water surrounding them. Because of that, water temperature can be considered one of the most
important environmental factors affecting fish. This paper explores some key areas where water temperature affects swimming mechanics, kinematics, hydrodynamics, and capacity, in a few commercial marine fish species. The maximum swimming speed of fish is reduced due to slower contraction of its lateral white muscle at low temperatures. Endurance of swimming is reduced due to lower oxygen uptakes as well as slower red muscle contraction at lower temperatures. The consequential effect of water temperature related swimming behavior and capability change can result in changes of size and species selectivity and capture efficiency of mobile gears. Changes in swimming behavior can also alter encountering probability of fish with stationary gears such as gillnets, affecting their fishing range and capture efficiency.

LATERAL MUSCLE DISTRIBUTION AND SWIMMING CHARACTERISTICS IN SOME MARINE FISHES
P. He\(^1\) and C. Wardle\(^2\)
E-Mail: Pingguo.he@unh.edu

\(^1\)Institute for the Study of Earth, Oceans and Space and New Hampshire Sea Grant, University of New Hampshire, 137 Morse Hall, Durham, NH 03824, USA. \(^2\)FRS Marine Laboratory (Retired), P. 0. Box 101, Victoria Road, Aberdeen, AB9 8DB, UK

Session: MusO3
Abstract: This paper reports the relationship between the differing proportions of lateral muscle along the length of the body and the resulting swimming behavior. Cross-sections cut at several positions along their bodies allowed measurement of the area of the white muscle and the red muscle in 45 individuals of eight species. The species included Atlantic mackerel (Scomber scombrus), saithe (Pollachius virens), pollack (Pollachius pollachius), herring (Clupea harengus), eel (Anguilla anguilla), ling (Molva elongata), albacore tuna (Thunnus alalunga), and swordfish (Xiphias gladius). Mackerel and herring have the largest proportion of the red muscle to total muscle while eel have the smallest proportion measured. The different distribution patterns of red and white muscle cross sectional areas reflect the cyclic pattern of force required during the wave-like swimming motions in fish using their body and caudal fin for swimming. Cross sectional area of muscle is proportional to potential force the muscle can generate. One can therefore argue that at their maximum speed all the anaerobic fast white muscle is used to form the wave of locomotion involved in moving the rear part of its body and the caudal fin and reacting cyclically with the water. The different cross section areas along the body reflect the different phases of the force cycle involved in the tail sweep. The same is true for the red muscle at the maximum sustained speed when the red muscle is employed aerobically. The paper explains muscle distribution, time-force relationship, and the resulting muscle and swimming implications.

RAPID EVOLUTION OF FITNESS IN THE WILD: AN EXPERIMENTAL INTRODUCTION OF TRINIDADIAN GUPPIES
A.P. Hendry\(^1\), S. Gordon\(^1\), D.N. Reznick\(^2\) and M.T. Kinnison\(^3\)
E-Mail: andrew.hendry@mcgill.ca

\(^1\)Redpath Museum and Dept. of Biology, McGill Univ., Canada; \(^2\)Dept. of Biol., Univ. of California Riverside, USA; \(^3\)Dept. of Biol. Sci., Univ. of Maine, USA

Session: FroO22
Abstract: Abrupt environmental change can impose strong directional selection on local populations. If these populations are to persist, they must show rapid adaptation. Many studies have shown that environmental change can indeed drive the adaptive evolution of specific traits. Overall adaptation, however, is an integrated product of changes in multiple traits subject to selection. We examine these aspects of adaptation in a population of Trinidadian guppies that were experimentally introduced 7 years previously into a river that lacked guppies, the Damier. We first use mark-recapture experiments in the Damier to show that a large waterfall separates two distinctive selective environments: high predation and low predation. We next show that the guppies in these two environments differ in some traits (male colour and female life history) known to be under divergent selection between predation regimes. Finally, we use an experimental reintroduction into the Damier to demonstrate that local guppies now show higher survival than do guppies from the original ancestral source. These differences confirm that a major fitness component (survival) can show rapid evolution in the wild. Funded by NSERC, NSF, and McGill University.
SHARK TRACKER: AN INTERACTIVE AQUARIUM DISPLAY FOR PUBLIC EDUCATION

M.R. Heupel
E-Mail: mheupel@mote.org
Mote Marine Laboratory, Center for Shark Research, Sarasota, Florida, USA

Session: TelP5

Abstract: Using state-of-the-art technology to study marine species results in an ever changing knowledge base among scientists and managers that may or may not reach the public. Mote Marine Laboratory and Aquarium have attempted to address this issue by building an interactive aquarium exhibit for public display and informal education. The exhibit is based on research conducted to monitor the long-term movement patterns of juvenile sharks inside a coastal nursery area in Florida. To demonstrate this research a live animal aquarium exhibit is being constructed to mimic shark monitoring efforts. Interactive animations of shark movements from the actual study are integrated into the exhibit and available on the internet for use by the public and school groups. Incorporating this simple, intuitive and interactive display into an aquarium exhibit enables learners of all levels to comprehend how the project works and understand the results. This highly visual, interactive exhibit provides a unique and intuitive learning experience for school groups and adults who visit the Mote Marine Aquarium. The author encourages scientists to consider informal science education efforts via in house displays or on-line content to help educate the public on new advances in marine technology and to keep them interested in advances in coastal ecology and marine biology.

EAT OR BE EATEN: USING TELEMETRY DATA TO DEFINE USE OF A NURSERY AREA BY BLACKTIP SHARKS

M.R. Heupel and C.A. Simpfendorfer
E-Mail: mheupel@mote.org
Mote Marine Laboratory, Center for Shark Research, Sarasota, Florida, USA

Session: TelO21

Abstract: Although many species of fish utilize nursery areas, data on how the nursery is used and its benefits to the individuals who use it are often unknown. Over a period of four years the presence, movement patterns and behaviors of a population of juvenile blacktip sharks (Carcharhinus limbatus) was monitored within a nursery area using acoustic telemetry. Individual sharks were fitted with transmitters in each of the four years and monitored via an array of Vemco VR2 acoustic receivers. Sharks were present within the nursery for periods of 1 to 167 days and showed very similar behavior patterns across years. Telemetry data from individuals was compared to data concerning prey species presence, available habitat and movement patterns of the overall population. Based on this long-term study it appears that shark distribution and movement patterns within the nursery area indicate that predator avoidance plays a greater role in nursery area habitat use than prey distribution. Young sharks were found to use habitat not occupied by largest prey densities. In each year of study sharks aggregated during daylight hours and dispersed at night. This behavior pattern suggests predator avoidance during daylight hours is important. The use of acoustic monitoring provided valuable data concerning this population that was previously unknown and it helping to re-define current thinking about shark nursery utilization.

DEVELOPMENT OF GENOMIC RESOURCES FOR ATLANTIC COD (Gadus morhua)

B.Higgins1, C.Kozera1, B.A.Curtis1, J.Tarrant Bussey1, H.Verheul1, B.J.Parsons1, K.C.Park2, J.Symonds3, S.C.Johnson2 and S.Bowman1
E-Mail: sbowman@genomeatlantic.ca

1The Atlantic Genome Centre, Halifax, Canada; 2National Research Council Institute for Marine Biosciences, Halifax, Canada; 3The Huntsman Marine Science Centre, St. Andrews, Canada

Session: ProO4

Abstract: The Atlantic cod genomics and broodstock development project (www.codgene.ca) will tightly integrate the development of extensive molecular tools for Atlantic cod with two family-based breeding programs located in Newfoundland and New Brunswick. This project will generate large numbers of expressed sequence tags (ESTs) from multiple tissues and individuals to capture the maximum number of genes possible, and to detect sequence variation within those genes. Sequences will be mined to identify single nucleotide polymorphisms (SNPs) for use in genetic mapping and analysis of quantitative trait loci (QTL) identified within the two breeding programs. A cod gene microarray will also be developed for use in expression analysis. To date, several normalised cDNA libraries have been generated and sequenced at low coverage, sequences have been clustered and a preliminary analysis conducted. These results have been used to assess the effectiveness of library normalisation, to confirm that 3’ end sequencing will be informative in cod, and to allow an initial analysis of sequence polymorphism. Comparison of cod ESTs with genomic sequence generated for other fish species has been used to investigate cod gene structure, and to predict intron locations in cod EST sequences. Cod intron size, and frequency of intron length polymorphism in the populations contributing to the broodstock programs, has been
assessed using exon primed intron crossing (EPIC) PCR. The results of initial EST sequencing, and the potential for developing EPIC genotyping protocols for use in Atlantic cod breeding and in population studies, will be discussed. (Funding information at www.codgene.ca)

CHARACTERIZATION OF THE GROWTH HORMONE – INSULIN-LIKE GROWTH FACTOR I SYSTEM DURING ATLANTIC HALIBUT METAMORPHOSIS
J. Hildahl1, I.E. Einarsdottir1, M. Galay-Burgos2, G. Sweeney2, D. Power3 and B.Th. Björnsson1
E-Mail: jon.hildahl@zool.gu.se
1Dept. Zool., Göteborg University, Sweden; 2School Biosci., Cardiff University, Wales, UK; 3Centro Ciên.Mar, University of Algarve, Portugal

Session: EarO15
Abstract: The GH-IGF-I system is critical for proper growth and development in fish and thus is likely to play a role in the control of flatfish metamorphosis. In order to characterize the role of GH and IGF-I in Atlantic halibut development, hormonal content (GH and IGF-I RIA) and receptor gene expression (GHR and IGF-IR QPCR) was assessed during normal and abnormal metamorphosis. GH larval head content increases throughout normal metamorphosis in parallel with larval weight. The full-length GHR (hhGHRfl) mRNA and IGF-I protein levels change in parallel and in a stage-specific manner, with the highest levels at pre-metamorphosis followed by down-regulation. Two IGF-IR isoforms are regulated differently; isoform one (hhIGF-IR1) mRNA increases from pre-metamorphosis to post-metamorphosis, while isoform 2 (hhIGF-IR2) mRNA is highest at early pre-metamorphosis and decreases prior to the onset of metamorphosis. In larvae experiencing arrested development, mRNA levels for hhGHRfl and hhIGF-IR1 and IGF-I larval content are depressed relative to normal individuals, whereas GH content, hhIGF-IR2 mRNA levels and weight are not changed. Decreasing hhGHRfl mRNA and IGF-I protein levels during metamorphosis suggest that GH tissue sensitivity decreases during metamorphosis while IGF-I tissue sensitivity increases. The data provide new evidence suggesting that GHR and IGF-IR levels may be of critical importance for metamorphic success in Atlantic halibut. Funded by the EU and FORMAS.

IDENTIFICATION OF AN OLFACTORY IMPRINTING-RELATED GENE IN SALMON
H. Hino1, T. Iwai2, M. Yamashita2 and H. Ueda1
E-Mail: h-hlool@fsc.hokudai.ac.jp
1Laboratory of Aquatic Ecosystem Conservation, Graduate School of Fisheries Sciences, Hokkaido University, Sapporo, Hokkaido, 2Laboratory of Molecular and Cellular Interactions, Graduate School of Science, Hokkaido University, Sapporo, Hokkaido, and 3Laboratory of Aquatic Ecosystem Conservation, Field Science Center for Northern Biosphere, Hokkaido University, Sapporo, Hokkaido, Japan

Session: AdvP9
Abstract: Anadromous salmonids are well known for accurate homing migrations guided by an imprinted memory of their natal stream. Since Hasler and his co-workers proposed the olfactory hypothesis on salmon homing in the 1950’s, many behavioral and electrophysiological studies have indicated important functions of the olfactory system (olfactory epithelium, olfactory nerve, and olfactory bulb) in salmon. We attempted to identify olfactory imprinting-related genes of lacustrine sockeye salmon (Oncorhynchus nerka) by a subtractive hybridization technique of representational difference analysis (cDNA-RDA) using olfactory system of 1- (smolt stage) and 3-year-old fish (feeding migration stage). We obtained a partial clone from a subtractive cDNA library of 1-year-old fish (SOIG; Sockeye salmon Olfactory system Imprinting related Gene). The SOIG contains a 756 bp open reading frame that codes for a protein with 252 amino acid residues. By northern hybridization, the SOIG mRNA was only expressed in the olfactory epithelium, and not in other tissues. In situ hybridization showed that the expression of SOIG mRNA was observed in the olfactory receptor cells and basal cells of the olfactory epithelium. This suggests that SOIG may have specific and important roles in the olfactory system. Further, in order to clarify the function of these genes, change of expression level in several stages of salmon’s life history will be analyzed using real time PCR.
IDENTIFICATION OF AN OLFACTORY IMPRINTING-RELATED GENE IN SALMON

H. Hino¹, T. Iwai², M. Yamashita² and H. Ueda³
E-Mail: h-hlool@fsc.hokudai.ac.jp

¹Laboratory of Aquatic Ecosystem Conservation, Graduate School of Fisheries Sciences, Hokkaido University, Sapporo, Hokkaido; ²Laboratory of Molecular and Cellular Interactions, Graduate School of Science, Hokkaido University, Sapporo, Hokkaido; ³Laboratory of Aquatic Ecosystem Conservation, Field Science Center for Northern Biosphere, Hokkaido University, Sapporo, Hokkaido, Japan

Session: OlfP9

Abstract: Anadromous salmonids are well known for accurate homing migrations guided by an imprinted memory of their natal stream. Since Hasler and his co-workers proposed the olfactory hypothesis on salmon homing in the 1950’s, many behavioral and electrophysiological studies have indicated important functions of the olfactory system (olfactory epithelium, olfactory nerve, and olfactory bulb) in salmon. We attempted to identify olfactory imprinting-related genes of lacustrine sockeye salmon (Oncorhynchus nerka) by a subtractive hybridization technique of representational difference analysis (cDNA-RDA) using olfactory system of 1- (smolt stage) and 3-year-old fish (feeding migration stage). We obtained a partial clone from a subtractive cDNA library of 1-year-old fish (SOIG; Sockeye salmon Olfactory system Imprinting related Gene). The SOIG contains a 756 bp open reading frame that codes for a protein with 252 amino acid residues. By northern hybridization, the SOIG mRNA was only expressed in the olfactory epithelium, and not in other tissues. In situ hybridization showed that the expression of SOIG mRNA was observed in the olfactory receptor cells and basal cells of the olfactory epithelium. This suggests that SOIG may have specific and important roles in the olfactory system. Further, in order to clarify the function of these genes, change of expression level in several stages of salmon’s life history will be analyzed using real time PCR.

TISSUE SPECIFIC EXPRESSION OF GROWTH HORMONE TRANSGENES IN ATLANTIC SALMON (Salmo salar)

Rod S. Hobbs¹, Trina Kirby² and Garth L. Fletcher¹
E-Mail: rhobbs@mun.ca

¹Ocean Sciences Centre, Memorial University of Newfoundland, Canada; ²Department of Biology, Memorial University of Newfoundland, Canada

Session: GenP2

Abstract: Transgenic Atlantic salmon (Salmo salar) were created with a chimeric growth hormone (GH) gene construct consisting of a Chinook salmon (Oncorhynchus tshawytscha) GH cDNA regulated by an ocean pout (Macrozoarces americanus) antifreeze protein (AFP) gene promoter. This construct integrated into the salmon genome as a single functional copy that had been reorganized so that the first 1600 base pairs (bp) of the ocean pout 5’ promoter region was located downstream of the 3’ flanking region. These transgenic salmon grow at significantly faster rates than non-transgenics. The functional capacity of the truncated promoter was analyzed by ligation to a luciferase reporter gene and examined in a transient expression assay by transfection into three cell lines. Although the truncated promoter was less active than the full length promoter it was fully capable of driving expression of the luciferase gene. The ability of the promoter to drive expression of the GH transgene in vivo was determined by examining salmon tissues for the presence of transgene GH mRNA using Northern blotting and reverse transcription polymerase chain reaction (RT-PCR) procedures. RT-PCR analyses revealed that the GH transgene was expressed in most body tissues, suggesting that the AFP promoter lacked tissue specific elements. However, northern analysis indicated that the only tissues exhibiting significant levels of transgene GH expression were the spleen and pituitary. Research supported by NSERC, AquaNet and USDA.

MIGRATION PATHS FOR JUVENILE SOUTHERN BLUEFIN TUNA: ESTIMATING DETECTION RATES OF CROSS-SHELF ARRAYS

A.J. Hobday¹
E-Mail: Alistair.Hobday@csiro.au

¹CSIRO Marine and Atmospheric Research, Hobart, Australia; ²School of Zoology, University of Tasmania, Australia

Session: TelO18

Abstract: Acoustic monitoring technology allows investigation of movement and residence on a scale suitable for both small scale habitat usage and large scale migration studies. Cross-shelf arrays of listening stations have been used in southern Australia for five years to estimate the cross-shelf location of southern bluefin tuna migration paths. A trade-off exists between the array coverage in a cross-shelf line and the number of lines and tags that can be utilized, such that non-overlapping arrays have been deployed in this study. Statistical correction is then made to estimate the total fish movement across a “leaky” set of curtains. Assumptions about the detection range and shape of the detection envelope influence the
estimates of the proportion of fish crossing a line of listening stations. An individual-based simulation model is used to demonstrate the influence of changing assumptions on the estimates produced. The implications for the estimated migration path for juvenile southern bluefin tuna are demonstrated. Funded by CSIRO Marine Research, Japan-Australia Recruitment Monitoring Program.

**BIPHASIC INTERACTIONS: MECHANISM OF SYNERGISM AND ANTAGONISM OF RETENE TOXICITY BY “ALPHA-NAPHTHOFLAVONE**

P.V. Hodson, P. Quereshi, J. Scott and R.S Brown

E-Mail: hodsonp@biology.queensu.ca

Queens University, Kingston, Canada

**Session:** ImpO7

**Abstract:** Embryos and larvae of fish exposed to alkyl-substituted PAH such as retene (7-isopropyl-1-methylphenanthrene) develop blue sac disease (BSD). This is a syndrome characterized by edema, haemorrhaging, deformities, and induction of cytochrome P450 (CYP1A) enzymes when PAH bind to the arylhydrocarbon receptor (AhR) protein. To determine if retene's toxicity is due to parent retene, or to a metabolite following retene oxygenation by CYP1A enzymes, larval trout were co-exposed to graded concentrations of retene and to alpha-napthoflavone (ANF). ANF also causes CYP1A induction but is a potent antagonist of CYP1A enzyme activity. If parent retene is the toxic form, inhibition of CYP1A activity should enhance toxicity by preventing oxygenation of retene to non-toxic metabolites. If the metabolites are the toxic forms, CYP1A inhibition should antagonize toxicity. At low and non-toxic exposure concentrations, ANF potentiated retene toxicity with dramatic increases in the rates of BSD and mortality. HPLC analyses of tissue and bile demonstrated increased numbers and concentrations of di-hydroxy-metabolites, but decreased numbers and concentrations of mono-hydroxy derivatives. At higher concentrations of ANF, the toxicity of retene was completely eliminated, suggesting that the toxic form was a mono-oxygenated derivative. This was confirmed by tissue analyses demonstrating that parent retene predominated when toxicity was absent. This may be the first reported case of both potentiation and antagonism by the same compound. It also demonstrates the difficulty of predicting the toxicity of complex mixtures of hydrocarbons that have different interactions with AhR and CYP1A proteins. Funded by the Natural Sciences and Engineering Research Council of Canada

**HISTOLOGICAL AND IMMUNOHISTOCHEMICAL CHARACTERIZATION OF ADENOHYPOPHYSEAL CELLS IN *Salminus hilarii***

R. M. Honji1*, R. H. Nóbrega2, M. I. Borella3 and R. G. Moreira4

E-Mail: honjjip@usp.br

1Instituto de Biociências – USP; 2Instituto de Biociências – UNESP; 3Instituto de Ciências Biomédicas – USP; 4Núcleo de Ciências Ambientais - UMC

**Session:** IntP3

**Abstract:** Tabarana, *Salminus hilarii* (Characiformes) is a reophilic species with ecological importance. Nowadays it has been affected by pollution and dams in the upper reaches of the Tietê River (São Paulo, Brazil). Studies on adenohypophyseal cells, especially gonadotropics, can provide useful information for understanding endocrine control mechanisms of this species. Pituitaries from sexually mature animals (natural environment and captivity) were dissected, fixed in Bouin and embedded in paraffin. Sections (5 mm) were prepared and stained with Mallory's Trichrome and periodic acid-Schiff (PAS). For immunohistochemical reactions, sections were immunostained according to SABC method (streptavidin-biotin-peroxidase complex), using the following salmon antisera: growth hormone (GH), prolactin hormone (PRL), somatolactin hormone (SL), b luteinizing hormone (bLH) and b follicle stimulating hormone (bFSH). The adenohypophysis was divided in pars distalis (PD) (subdivided in rostral PD (RPD) and proximal PD (PPD) and pars intermedia (PI). RPD: PRL cells are small, eosinophilic and PAS negative cells organized in a cordonal arrangement; PPD: FSH and LH cells are PAS positive, basophilic and vacuolized cells; they are more immunostained by salmon LH than by FSH antisera. GH cells are PAS negative eosinophilic cells surrounding neurohypophysis branches and blood vessels, PI: SL cells are PAS positive and also can be find in some PPD areas. The adenohypophysis of tabarana is divided in pars distalis (rostral and proximal) and pars intermedia, with specific cell types distribution. The obtained data will supply information on producing hormone cells and their topography for future researches in this specie. Financial support: FAPESP and CNPq.
IMPACT OF PHENOL EXPOSURE ON PROTEIN AND CARBOHYDRATE METABOLISM OF MATRINXÃ (Brycon cephalus)

T.S.F. Hori, I.M. Avilez, L. A. K. Inoue and G. Moraes
E-Mail: gil@power.ufscar.br
Lab. Adaptive Biochemistry, Federal University of Sao Carlos, Brazil

Session: ImpO28
Abstract: Water pollution has become an increasing problem in last few years. Many types of chemicals, known as xenobiotics, are dumped in water systems by anthropogenic activities. Among these are phenols, which are common in wood processing, paint and pesticide industries. Phenolic compounds are known to cause many disturbances on fishes such as immunosuppression, genotoxic and carcinogenic effects. Moreover, it can alter significantly fish metabolism. These alterations can cause many organismal changes like growth, fertility and even survival reduction. The objective of this work was to access the metabolic effects of environmental phenol (2.0 mg/l) in matrinxã in order to have a better understanding of the organismal effects of this pollutant. This was achieved through aspartate amino transferase (ASAT), lactate dehydrogenase (LDH), alanine amino transferase (ALAT), and malate dehydrogenase (MDH) assay plus some key metabolites quantification. The exposure to phenol caused alterations in carbohydrate and protein metabolism. Our results suggest a shift from carbohydrate to protein catabolism as energy source. This change was more intense in the liver, perhaps caused by the synthesis of molecules implicated in detoxification processes. This alteration could account for the reduced growth observed in fish exposed to phenol and indicates the importance of the water quality either in the wild or in rearing systems. This work was supported by the Brazil Research Agencies: FAPESP and CNPq.

ENDOCRINE, METABOLIC AND CELLULAR STRESS RESPONSES OF MATRINXÃ (Brycon cephalus) EXPOSED TO PHENOL

T.S.F. Hori1, L.O.B. Afonso2, S.C. Johnson2, G.K. Iwama3 and G. Moraes1
E-Mail: tiago.hori@gmail.com
1Lab. Bioquímica Adaptativa, Universidade Federal de Sao Carlos, SP, Brazil; 2Institute for Marine Biosciences - National Research Council of Canada, NS, Canada; 3Acadia University, NS, Canada

Session: MolO12
Abstract: Industrial wastes may contain chemicals such as phenols, which can impact the physiology of fish. We studied the effects of phenol exposure on the metabolic, endocrine and cellular stress responses of matrinxã. Fish were exposed to phenol (0, 0.2 and 2.0 ppm) for 96 hours and subsequently subjected to a 30 second handling stress. Plasma cortisol and glucose, and gill and liver hsp70 levels were determined before exposure, 96 h after exposure and at 1, 6, 12 and 24 hours after stress (HAS). Exposure to these concentrations of phenol did not result in elevated levels of plasma cortisol or glucose at 96 h. Exposure followed by handling, significantly increased plasma glucose and cortisol in the 0 and 2.0 ppm groups. Cortisol levels in these groups declined to resting levels by 6 and 24 HAS, respectively. Glucose returned to resting levels at 12 HAS in both groups. The 0.2 ppm group did not have a glucose or cortisol response. Gill hsp70 levels did not change due to phenol exposure. In the 2.0 ppm group gill hsp70 levels declined after stress. At 96 h liver hsp70 levels were lower in all groups. Stress caused no additional changes in liver hsp70. Our results demonstrate that low levels of phenol can modify the stress response. This work was funded by FAPESP/CNPq (Brazil) NRC-CNRC (Canada).

ELECTRORETINOGRAPHIC ASSESSMENT OF VISUAL FUNCTION IN SIX COMMERCIALY AND RECREATIONALLY IMPORTANT ESTUARINE FISHES

A.Z. Horodysky, R.W. Brill, J.A. Musick and R.J. Latour
E-Mail: andrij@vims.edu
Dept. Fisheries Sci., Virginia Inst. Mar. Sci., College of William and Mary, USA

Session: AdvO19
Abstract: Little is known about how differences in visual function reflect the lifestyles and feeding strategies of estuarine fishes. We therefore assessed day and night spectral sensitivities (color vision), light sensitivities, and flicker fusion frequencies (FFF: speed of vision) of six Chesapeake Bay fishes: striped bass (Morone saxatilis), weakfish (Cynoscion regalis), spotted seatrout (Cynoscion nebulosus), red drum (Sciaenops ocellatus), Atlantic croaker (Micropogonias undulatus), and spot (Leiostomus xanthurus) using electroretinography (ERG). Subjects were presented light stimuli covering the spectral range from UV (300 nm) to the near infrared (800 nm) and six orders of magnitude of light intensity via a custom-designed computer-controlled system. Responses were corrected for equal quantal energy at each wavelength. Study animals demonstrated peak sensitivity between 450-575 nm, though retinograms showed strong species-specific differences. Weakfish responded to short wavelength UV light, while striped bass responded to the longer (red) wavelengths. Intensity-response and FFF experiments also revealed species-specific differences in dynamic range and speed of vision. The visual systems of these sympatric fishes thus appear to have evolved different functional
characteristics that are reflective of their specific niches within the estuarine environment. Visual ecology bears important implications for predator-prey interactions, estimating prey encounter probabilities, and ultimately understanding community-level trophic interactions. Funded by Recreational Fishing Advisory Board, Virginia Marine Resources Council.

PRESSURE WAVE AND PARTICLE VELOCITY CONTRIBUTIONS TO THE AUDITORY ABILITIES OF SCIAENID FISHES
A.Z. Horodysky1, R.W. Brill1, J.A. Musick1, M.L. Fine2 and R.J. Latour1
E-Mail: andrij@vims.edu

Session: AdvP3
Abstract: Sciaenid fishes are important models of fish sound production, but investigations into their auditory abilities are fairly recent. We performed auditory brainstem response (ABR) experiments using a hydrophone, a geophone, and a novel active echo-cancellation algorithm to assess the pressure and particle velocity thresholds in various sciaenids, including: weakfish (Cynoscion regalis), spotted seatrout (Cynoscion nebulosus), red drum (Sciaenops ocellatus), Atlantic croaker (Micropogonias undulatus), spot (Leiostomus xanthurus), and northern kingfish (Menticirrhus saxatilis). We used a white noise signal to characterize the echo properties of the experimental chamber, and a proprietary computer algorithm to calculate the specific waveforms needed to actively echo-cancel the noise. Consequently, we were able to present subjects with pure 10 ms tone bursts in 100 Hz steps from 100 Hz to 1.2 kHz in the absence of an anechoic chamber. At each frequency, sound pressure levels (SPL) were successively attenuated in 5-dB steps until recognizable and repeatable ABR waveforms were no longer recorded. All species responded well to low frequency stimuli (100-300 Hz). Although peak sensitivities ranged between 300-500 Hz in all species, particle velocity and pressure audiograms exhibited strong species-specific differences. Overall, weakfish and northern kingfish had the lowest and spot the highest auditory thresholds. The auditory abilities of most species are within the range of other hearing generalists and demonstrate peak sensitivity to the dominant frequencies in their vocalizations.

THE STRESS RESPONSE OF JUVENILE HADDOCK (Melanogrammus aeglefinus) EXPOSED TO LONG-TERM STRESS
S. Hosoya1,4, S. C. Johnson1, A.K. Gamperl2, G. K. Iwama3, A. Hino4 and L.O.B. Afonso1
E-Mail: Luis.Afonso@nrc-cnrc.gc.ca
1Institute for Marine Biosciences, National Research Council, Canada; 2Ocean Sciences Centre, Memorial Univ. of Newfoundland, Canada; 3Acadia University, Wolfville, Canada; 4Graduate School of Agricultural and Life Sciences, The Univ. of Tokyo

Session: MolO11
Abstract: Although the stress response has been extensively investigated in fish, little is known about the effects of a long-term stress. We examined the changes in free and total plasma cortisol, plasma glucose, gill hsp70 levels, and growth in haddock subjected to a daily handling stress (15 seconds out of water) over a period of 4 weeks. Four weeks prior handling, fish were randomly assigned to the control and stressed groups (4 replicates each). There were no significant differences in any of these parameters between groups prior to the initiation of the stress. Free and total plasma cortisol levels increased significantly in the stressed group during the second week (3 ng/ml in control vs. 32 ng/ml in stressed). However, the percentage of free cortisol was already significantly elevated by the first week (control 17 % and stressed 55 %) and remained high during the second week (control 35 % and stressed 65 %). At 3 and 4 weeks both free and total cortisol declined in stressed fish to levels that were not significantly different from the controls. Long-term stress had a suppressive effect on growth, with control and stressed fish growing by 32% and 18%, respectively, over the 4 weeks. Plasma glucose and gill hsp70 levels did not change throughout the experiment. Although this study indicates that plasma glucose and tissue hsp70 levels are not useful indicators of long-term stress in haddock, our data suggests that the ratio of free:total cortisol is a sensitive index of stress. This work was funded by Aquanet AP-35 and the National Research Council of Canada.
**ASPECTS OF FEEDING AND REPRODUCTIVE BIOLOGY OF DAMSELL FISH (*Abudefduf sexatillis* POMACENTRIDAe) IN THE PERSIAN GULF**

H. Hosseinzadeh Sahafi  
E-Mail: h_hosseinzadeh@yahoo.com  
No. 297, Fatemi Ave., Iranian Fisheries Research Institute, Tehran, IRAN

**Session:** TroP1  
**Abstract:** There are several kinds of ornamental fishes existing in the Persian Gulf as a well known temperate zone. *Abudefduf sexatillis* is one of the most dominant species in this area. Research was conducted during 1999-2001 to determined biological aspects of feeding (Food preference, Gastro somatic index) and reproduction (Gonadosomatic index, Hepatosomatic index, Condition factor, Length at first maturity, LM50, Sex ratio and Microscopic gonadal stages). Monthly samples were taken from different size classes by using under water purse sinning. Results showed that *Abudefduf sexatillis* has a prothandrous hermaphrodite reproductive pattern. The sex ratio was different during the year but overall sex ratio was 1(M):1.4(F). Fluctuations in gonadosomatic index showed that the spawning peak took place between March and July with short spawning in September. The Hepatosomatic index increased during January and mid–February. Size at first maturity was 72mm for females and 65mm for males. LM50 was 86mm. According to female microscopic evaluations *Abudefduf sexatillis* has 6 gonadal stages and the gastrosomatic index varied from 2 to 6 with peaks in September and October. Seaweed and macro algae are main groups of food preference. The relationship between the parameters are discussed.

**FIN EROSION FOUND IN UK FARMED RAINBOW TROUT (*Oncorhynchus mykiss*)**

I. Hoyle1, B. Oidtmann2, T. Ellis2, J. Turnbull3, B. North3, J. Nikolaidis3 and T.G. Knowles1  
E-Mail: Imogen.Hoyle@bristol.ac.uk  
1Dept of Clinical Veterinary Sci, Univ of Bristol, UK; 2CEFAS Lab, Weymouth UK; 3Dept of Aquaculture, Univ of Stirling, UK

**Session:** WelO13  
**Abstract:** This study aimed to field test a novel system for macroscopic assessment of fin damage and to gain a representative perspective of the type and distribution of fin erosion suffered by farmed rainbow trout throughout the UK. We sampled 60 fish from two units on 40 commercial farms producing rainbow trout for both the table and restocking markets selected randomly, and distributed throughout the UK. Sampling on farms was stratified to ensure that data were collected from recently introduced fish (<30g) and fish which had been on the farm for several months (150-300g). Fin length was assessed for all the rayed fins by measuring the length of the longest fin ray. Fin sizes were also scored using a photographic classification chart with 6 categories detailing erosion of all rayed fins from intact (0) to complete loss (5). A detailed representation of the fins was also recorded, i.e. the number of splits, presence of blood, inflammation, scoring and regeneration. Water quality data were recorded (ammonia, clarity, DO, alkalinity and pH) as well as husbandry conditions and history of the sampled batches. A total of 4200 fish were sampled, and analysis of the dataset is on-going. We have found a wide variety in the prevalence and severity of fin erosion throughout the UK. All farms involved suffered some degree of fin erosion ranging from a dorsal fin score of 1 to 4.35 and a pectoral fin score of 1 to 4.80 on average. The results should enable the identification of potential risk factors for fin erosion. Funded by Defra, and supported by the British Trout Association.

**CHANGES IN HORMONE AND ION CONCENTRATIONS IN PLASMA OF SPAWNING AND SENESCING SOCKEYE SALMON (*Oncorhynchus nerka*)**

K.A. Hruska1, S.G. Hinch1,2, M.C. Healey2 and A.P. Farrell3  
E-Mail: hruskak@interchange.ubc.ca  
1Dept. of Forest Sci, Univ. of British Columbia, Canada; 2Institute for Resources, Environment and Sustainability, Univ. of British Columbia, Canada; 3Dept. of Zool., Univ. of British Columbia, Canada

**Session:** AdvO6  
**Abstract:** With non-destructive bio-sampling and behavioural observations, we examined the physiological changes associated with spawning and senescence in sockeye salmon (*Oncorhynchus nerka*). Gill biopsies and blood samples were taken from sockeye salmon as they arrived at the Weaver Creek Spawning Channel, BC and again from the same fish as they became moribund. Samples were analyzed to determine concentrations of several hormones (i.e., ethinylestradiol, testosterone, and 11-ketotestosterone), ions (i.e., Na⁺, Cl⁻, K⁺, lactate, and glucose), osmolality, and gill Na⁺/K⁺-ATPase activity. Fish were alive on the spawning grounds for an average of 5 days (range: 2-9 days), during which time there was a significant decline in osmolality (P<0.001 for females; P<0.01 for males) and Na⁺, Cl⁻, and hormone concentrations (P<0.001). Plasma lactate levels increased by 10 times in males and females (P<0.001), K⁺ concentrations in males nearly
doubled (P<0.01), indicating a stress effect. Changes in lactate concentrations indicated that a few individuals were particularly inefficient in energy use and/or significantly stressed during spawning. We used behavioural observations to correlate physiological changes of individual fish with indices of their social reproductive success and have begun to identify some of the mechanisms causing the programmed senescence in Pacific salmon. Funded by NSERC.

EFFECTS OF LIPIDS ON FATTY ACID COMPOSITION AND STEAROYL-COA DESATURASE EXPRESSION IN TILAPIA UNDER COLD SHOCK
S. L. Hsieh¹, Y. T. Hsu¹, C. Y. Hu¹ and T. J. Hsieh²
E-Mail: slhsieh@ntu.edu.tw
¹Department of Nutrition and Health Science, Fooyin University, Kaohsiung 831, Taiwan; ²Basic Medical Science Education Center, Fooyin University, Kaohsiung 831, Taiwan

Session: MolP4
Abstract: Tilapia is an economically important cultured teleost in many countries, but mass mortality has often been reported when the severe cold current approaches. To improve survival under cold, effects of diets with different dietary lipids on cold tolerance of tilapia were investigated: three diets contained 12% fish oil, 12% palmitoleic oil and 12% coconut oil, respectively, and the other diet mixed fish oil (7%) and corn oil (5%). The results showed that during cold shock, proportions of saturated fatty acids decreased steadily and significantly for all diets, but proportions of monounsaturated fatty acids increased oppositely. Proportions of polyenoic fatty acids increased initially and maintained stably for mixed, fish oil, and coconut oil diets, but they didn’t increase significantly until day 4 for palmitoleic oil diet. The enzymatic activity of stearoyl-CoA desaturase (SCD) was lowest at day 0 and then gradually increased for all diets. At any time point, the enzymatic activity of SCD was highest in mixed and coconut oil diets, followed by palmitoleic oil diet, and lowest in oil diet. The expression of SCD mRNA increased steadily for all diets, but increased more substantially for mixed diet. At day 6, the expression was highest in mixed diet, followed by coconut oil diet, and lowest in palmitoleic and fish oil diets. These results evidenced that dietary lipids strongly affect fatty acid composition and SCD expression in tilapia under cold shock, and thus affect cold tolerance of tilapia. This research was supported by the National Science Council, Taiwan (grant No. NSC94-2313-B-242-002).

OLFACTORY SENSITIVITY TO CALCIUM AND SODIUM IS MEDIATED BY DIFFERENT MECHANISMS IN THE GOLDFISH
P.C. Hubbard, C. Haond and A.V.M. Canário
E-Mail: phubbard@ualg.pt
CCMar, Universidade do Algarve, Portugal

Session: OlfO3
Abstract: Growing evidence suggests that teleosts have olfactory sensitivity to changes in environmental inorganic cations, mainly calcium and sodium. The current study investigated whether the olfactory sensitivity to Ca²⁺ and Na⁺ is mediated by the same mechanism in the goldfish (Carassius auratus, a freshwater teleost). The olfactory responses, as assessed by the electro-encephalogram (EEG) from the olfactory bulb, to changes in external [Ca²⁺] and [Na⁺] were recorded in the absence and presence of increasing concentrations of the other ion. Low concentrations of Na⁺ (0 - 1.0 mM) had no significant effects on the olfactory response to changes in [Ca²⁺] in terms of EC50, Imax or Hill co-efficient (n=8). A relatively high concentration of Na⁺ (10 mM) significantly reduced the Imax and increased the EC50. 100 mM Na⁺ reduced the olfactory response to Ca²⁺ to undetectable levels. Conversely, low concentration of Ca²⁺ (0.1 and 1.0 mM) significantly attenuated the olfactory response to changes in environmental [Na⁺], reducing the amplitude of response and increasing the threshold of detection. However, a high concentration of Ca²⁺ (10 mM) failed to attenuate the olfactory response to Na⁺ completely. Taken together, these results suggest that, at normal environmental concentrations of these ions, Ca²⁺ and Na⁺ are detected by distinct and separate cellular mechanisms. However, there seems to be a degree of overlap between the two mechanisms. The exact mechanisms involved, and their biological roles, remain to be established. Funded by Fundação de Ciência e de Tecnologia, Portugal (POCI/BIA-BCM/55467/2004).

A ROLE FOR BILE ACIDS IN INTER-SPECIFIC COMMUNICATION IN TELEOSTS?
Mar Huertas, J. Cerdà, A.V.M. Canario and P.C. Hubbard
E-Mail: mar.huertas@hotmail.com
CCMar, Universidade do Algarve, Portugal

Session: OlfP5
Abstract: Fish have high olfactory sensitivity to bile acids. With a few notable exceptions, the biological role of this sensitivity is unclear. The current study attempted to establish whether olfactory sensitivity to bile acids is confined to intra-
specific chemical communication or whether it may also be involved in inter-specific communication. The olfactory sensitivity of eel (*Anguilla anguilla*), goldfish (*Carassius auratus*) and tilapia (*Oreochromis mossambicus*) to a range of bile acids (cholic acid, lithocholic acid, taurolithocholic acid, chenodeoxycholic acid, taurocholic acid, taurochenodeoxycholic acid, 5α-cyprinol, 5α-cyprinol sulphate, 5α-secmol, 5α-secmol sulphate), bile fluids from six fish species (tilapia, goldfish, gilthead seabream, sole, flounder and eel) and TLC (thin-layer chromatography) fractions of bile from male and female goldfish, tilapia and eel was assessed by the electro-olfactogram (EOG). In general, C27 bile acids were more potent odorants than C24, and conjugated bile acids more potent than the free forms; the biggest responses were recorded for 5α-cyprinol sulphate and taurochenodeoxycholic acid. Fish detected bile fluids from all other species diluted down to 1:10⁷, the responses to eel bile fluid being significantly larger. Sensitivity to bile TLC fractions suggests that eels, goldfish and tilapia can discriminate bile of different species and the sex of the donor. Taken together, these results suggest that fish have a broad sensitivity to many different bile acids, not just those produced by the same, or related, species. It is therefore possible that olfaction of bile acids is involved in inter-specific interactions (e.g. predator/prey detection) and not just intra-specific chemical communication. Funded by Reference Center in Aquaculture (Spain) and Fundação para a Ciência e a Tecnologia (Portugal; POCI/BIA-BDE/55463/2004).

**GENE EXPRESSION PROFILES OF COMMON CARP, CYPRINUS CARPIO, DURING STARVATION AND HYPOXIA REFLECT DIFFERENCES IN STRESS-INDUCED HYPOMETABOLISM**

C. C. Y. Hung¹, A. R. Cossins², A. Y. Gracey³ and D. J. Randall¹

E-Mail: carrie hung2@yahoo.com

¹Department of Biology and Chemistry, City University of Hong Kong, Hong Kong PRC; ²School of Biological Sciences, University of Liverpool, Liverpool, United Kingdom; ³Department of Biological Sciences, University of Southern California, USA

**Session:** ProO2

**Abstract:** There are many similarities in the responses of animals to hypoxia and starvation such as depressed metabolism, reduced locomotion and impaired reproductive ability. We hypothesized that there are similarities in the gene expression profile during starvation and hypoxia, in both cases directed towards energy conservation. Common carp (*Cyprinus carpio*), a hypoxia-tolerant fish, is able to survive prolonged periods of food deprivation. Fish were exposed to prolonged (six weeks) hypoxia or starvation and gene expression profile showed that carp kidney genes respond to starvation much faster than liver and that many genes involved in ATP generating pathways (glycolysis, TCA cycle, and oxidative phosphorylation); as well as ATP-consuming pathways (ubiquitin-proteasome degradation pathway, protein biosynthesis) were down-regulated. However, changes in liver gene expression of starved fish were minimal. Unlike starvation, carp liver and kidney responded to hypoxia similarly and more acutely. Anaerobic respiration genes and some gluconeogenic genes were induced during hypoxia, whereas expressions of genes involved in other metabolic pathways were virtually all suppressed. The degree of induction or suppression of these genes declined or leveled off with prolonged hypoxia. Uncoupling protein 1 (UCP1) which limits free radicals production by mitochondria, was greatly enhanced during hypoxia in carp, whereas other antioxidant genes were suppressed. The gradual return of gene expression profiles to the control state in the presence of long term hypoxia probably reflects the attainment of homeostasis. Our results show that although both starvation and hypoxia result in a general reduction in metabolism, responses at the gene level are not similar.

**CLONING AND EXPRESSION OF AMMONIA TRANSPORTERS IN THE MANGROVE KILLFISH (RIVULUS MARMORATUS)**

C. C. Y. Hung¹, C. M. Wood² and P. A. Wright¹

E-Mail: carrie hung2@yahoo.com

¹Department of Integrative Biology, University of Guelph, Guelph, Ontario; ²Department of Biology, McMaster University, Hamilton, Ontario, Canada

**Session:** IonO21

**Abstract:** Mangrove killifish, *Rivulus marmoratus*, is able to live in extreme conditions including hypo- and hypersalinity, hypoxia, prolonged air-exposure, high external hydrogen sulphide and ammonia. Previous study from our group showed that prolonged exposure of *R. marmoratus* to high external ammonia did not elevate tissue ammonia level, nor did it alter urea excretion rate. Therefore, we hypothesize that killifish is able to excrete ammonia actively during hyperammonia via ammonia transporter rhesus glycoprotein RhCG. We have cloned several full-length cDNA sequences of killifish which show high sequence similarities to the mammalian homologs. Reverse transcription-PCR was used to determine expression among various tissues and real-time qPCR to quantify the expression level of RhCG in control and ammonia exposed fish gills.
THE DNA BARCODE OF LIFE INITIATIVE: WHAT CAN FISHBOL OFFER FISH BIOLOGISTS?
I. Hunt von Herbing1, R. Hanner2 and D. E. Schindel3
E-Mail: ihuntvon@nsf.gov
1SMS, U.Maine, & NSF, US; 2 Dept. of Integ. Biol., Univ. of Guelph, Canada; 3 CBOL, National Museum of Natural History, Smithsonian Institution, US.

Session: AdvO11
Abstract: Derived from authoritatively identified voucher specimens held in reference collections, the Fish Barcode of Life Initiative (FISH-BOL) is a global campaign to assemble a standardised reference sequence library that will enable rapid, accurate and cost-effective identification of all fish species. Although there exist some 30,000 described species of fishes, since the launch of FISH-BOL in June 2005, over 1200 species have been successfully barcoded. The barcode consists of a 648 base-pair sequence derived from the 5' end of the mitochondrial cytochrome c oxidase subunit I gene (COI). This region typically exhibits lower levels of within species variation than the observed levels of divergence between species. It is flanked by highly conserved sequence motifs that support universal primer design, making it an appropriate marker for use in molecular diagnostics. Barcoding has the potential to become a standard tool in taxonomic research, and to improve the consistency of species definitions. DNA Barcodes can extend taxonomic identification to all life history stages, dimorphic sexes, damaged specimens, gut contents and feces. By improving fish taxonomy and providing a way for non-taxonomists to identify fish (especially larval fish), barcoding can add a new generation of data to improve fishery management around the globe (e.g. monitoring both regulated and invasive species). With a comprehensive reference sequence library, future development of handheld barcoding devices will enable rapid identification of fish (and fish products) in the field. FishBOL represents the first effort to assemble a global sequence library for such a diverse group of organisms.

GENETIC DIFFERENCES IN ATLANTIC COD REACTION NORMS:
LINKING INDIVIDUAL AND POPULATION RESPONSES TO THE ENVIRONMENT
J.A. Hutchings1, D.P. Swain2, V. Puvanendran3, S. Rowe4 and J.A. Brown2
E-Mail: Jeff. Hutchings@Dal.Ca
1Dept Biology, Dalhousie Univ., Halifax, Canada; 2Dept Fisheries & Oceans, Moncton, Canada; 3Ocean Sciences Centre, Memorial Univ. Newfoundland, St. John’s, Canada; 4Dept Fisheries & Oceans, Dartmouth, Canada

Session: FroO7
Abstract: Common-garden experiments were undertaken to disentangle the genetic and environmental contributions to population differences in larval growth, larval survival, and phenotypic plasticity for growth and survival in Atlantic cod. Adults were captured immediately prior to spawning from 4 regions of the Northwest Atlantic: Southwest Nova Scotia (NAFO division 4X); Southern Gulf of St. Lawrence (division 4T); Placentia Bay, Newfoundland (division 3Ps); and Bonavista Bay, Newfoundland (division 3L). Groups of 40-70 adults were allowed to spawn undisturbed, producing egg batches that were transferred to a controlled environment prior to hatching. Offspring were reared at 2 levels of food and at 2 temperatures. Size at, and survival to, 43 days post-hatch differed significantly among populations, with growth generally increasing with latitude, as predicted by the counter-gradient selection hypothesis. Reaction norms, which describe the way in which genotypes alter their phenotype along an environmental gradient, also differed among populations, providing evidence of a genetic basis to plasticity. Importantly, genetic differences in fitness-related traits were evident at spatial scales at which genetic variation at selectively neutral loci detected no population structure. Genetic differences in traits directly linked to reproductive success are consistent with the hypothesis of adaptation to environmental conditions at comparatively small scales in Atlantic cod. Funded by NSERC.

STRESS CONDITION IN RUSSIAN PIKEPERCHES
Asiful Islam
E-Mail: asifuli@yahoo.com
Harvard University Medical School, Boston MA 02114, USA

Session: FroO32
Abstract: The destabilization of the ecosystem of Russian Kuibyshev water reservoir influences its ichthio-fauna. Analysis of length-age relationships of Stizostedion lucioperca showed that the decreasing tendency of adult fish persisted in the reservoir. The average length, weight and age of S. lucioperca were 33.20 ± 1.75 cm, 420.35 ± 34.54 g and 4.5 ± 1.3 y during 2000-2004, which were decreasing in comparison to previous 2-3 decades. The same condition persisted with S. volgense i.e. the average length, weight and age were 25.30 ± 2.30 cm, 233.10 ± 8.14 g and 3.2 ± 1.3 y. The natural spawning efficiencies of these species in the study period were higher than in the 1970’s and 1980’s. The water level fluctuations did not influence on the spawning of Percids. Temperature sustains a great role in the spawning of these species. There was a correlation between the number of S. volgense fry and fingerlings to the biomass of zooplankton (r +
ECOTOXICOLOGICAL EFFECTS OF SELENIUM BIOACCUMULATION IN NORTHERN PIKE (Esox lucius)

D.M. Janz\textsuperscript{1}, J.M. Muscatello\textsuperscript{2}, P.M. Bennett\textsuperscript{2} and J.M. Kelly\textsuperscript{2}

E-Mail: david.janz@usask.ca

\textsuperscript{1}Veterinary Biomedical Sciences; \textsuperscript{2}Toxicology Centre, University of Saskatchewan, Canada

Session: ImpO10

Abstract: Due to the bioaccumulative nature of selenium through aquatic food webs and potential adverse effects on fish populations, there is currently much focus and debate regarding the ecotoxicology of this element. In this study we investigated two key aspects of fish population dynamics, namely reproductive capacity of adults and overyearling recruitment success, in northern pike inhabiting lakes within a metal mining effluent exposure gradient in northern Saskatchewan, Canada. We observed significant positive relationships between egg selenium concentrations and the frequencies of characteristic selenium-induced larval deformities. Calculation of EC\textsubscript{20} values suggests that pike are 2-3 times less sensitive to bioaccumulated selenium than warm water centrarchids and cyprinids, and of similar sensitivity to cold water salmonids. To investigate the overwinter survival potential of overyearling pike within this system, we collected fish just before ice-on (early October) and just after ice-off (early June), and measured indices of growth (length, weight, muscle RNA:DNA ratio, muscle protein) and bioenergetics (total body lipids, total body triglycerides, liver triglycerides). We observed consistently higher lipid and triglyceride levels in pike collected from exposure lakes compared to reference, and no depletion of lipids when comparing spring to fall values within lakes. Interestingly, there were no differences in length, weight or condition factor among pike collected from exposure and reference lakes, indicating that the enhanced energy stores were not being allocated to growth. Overall, our results indicate direct and indirect effects of metal mining discharge on northern pike. Funded by NSERC, Cameco Corporation and Areva.

IMPACTS OF THE ORGANOPHOSPHATE MALATHION ON OLFACTORY BEHAVIORS AND ACHE ACTIVITY IN STRIPED BASS (M. saxatilis)

H. E. Jarrard, K. Stem and B. Metcalf

E-Mail: hjarrard2@washcoll.edu

Dept. of Biology, Washington College, Chestertown, MD 21620

Session: OlfO12

Abstract: A growing number of studies have demonstrated that exposure of fish to sub-lethal concentrations of organophosphate (OP) pesticides has the potential to impair olfactory-based behaviors. Numerous questions relating to the risk that such acetylcholinesterase (AChE)–inhibiting compounds may have for wild fish remain, including minimum dose and exposure durations causing behavioral impairment, associated AChE inhibition in relevant tissues, and underlying physiological mechanism(s) linking AChE-inhibition to olfactory impairment. In an ongoing effort to address these questions, we describe a behavioral paradigm in which striped bass (M. saxatilis) in a preference/avoidance trough are acclimated, then observed before and after (10 min each period) the addition of a either a food-associated odor (pellet extract) or water (control). Digitized video recordings were then analyzed using Ethovision (Noldus Technologies) for Preference/Avoidance (% Time in Scented vs. Non-scented Ends), Mean Swimming Velocity, and Tortuosity of Path (Mean Turn Angle). Groups examined were fish exposed for 4 hours to malathion at 0 X, 0.25X, 0.5X, and 1X the 96hr LC\textsubscript{50} (0, 60, 120, or 240 \(\mu\)g/L malathion). Results indicate that instantaneous changes in behavior due to odor introduction (increased turning into stimulus) progressively disappear with higher pesticide exposures. In a parallel study after similar exposures, AChE activity in olfactory rosette, olfactory bulb, brain, and liver were all significantly reduced. Putative physiological mechanisms responsible for impairment include peripheral impairment of sensory function due to mucus hyper-secretion via cholinergic goblet cells in the olfactory epithelium. HEJ support: WAC Faculty Enhancement.
THE COST OF CATCHING UP: INCREASED MORTALITY FOLLOWING STRUCTURAL GROWTH COMPENSATION IN THE WILD
J.I. Johnsson and T. Bohlin
E-Mail: jorgen.johnsson@zool.gu.se
Department of Zoology, Animal Ecology, Göteborg University, Sweden

Session: FroO15

Abstract: Laboratory and observational studies suggest that many animals are capable of compensatory growth after periods of feeding restriction. However, few field experiments have demonstrated structural growth compensation in the wild and even less is known about the costs associated with such compensation. Here we addressed the hypotheses that (1) food restriction can induce structural compensatory growth in free-living animal populations, (2) that compensation is proportional to the level of body size retardation, and (3) that compensation induces mortality costs. To test these, wild brown trout yearlings were brought to the lab, subjected to four levels of food deprivation (including a control), released back into the native stream, and recaptured after one, five and ten months. Brown trout fully restored condition and partially restored mass within a month, whereas compensation in structure (i.e. body length) was not evident until after five months, supporting hypothesis 1. As the level of growth compensation was similar among the three deprived groups, hypothesis 2 was not supported and the results suggest that compensating individuals tend to restore innate growth trajectories rather than reaching an absolute body size threshold. A final recapture after winter revealed delayed mortality, apparently induced by the compensatory response in the deprived groups, which is consistent with hypothesis 3. To our knowledge this is the first field experiment demonstrating structural compensatory growth and associated costs in a wild animal population. The mechanisms underlying these results and their implications will be discussed. Funded by FORMAS.

TEN THINGS TO DO WITH A DEAD FISH – HERE IS NUMBER ELEVEN – RECORD ITS BLOOD PRESSURE!
David R Jones
E-Mail: jones@zoology.ubc.ca
Zoology Animal Care, 6199 South Campus Road, UBC, Vancouver, V6T 1W5 CANADA

Session: CarO7

Abstract: Bony fishes have a modified blood vessel between the heart and aorta, the bulbus arteriosus, which has unique mechanical properties. These properties can be used to determine blood pressure in the living animal from recordings made after it is dead. Recording physiology of the living animal after death defines “necrophysiology” which was the only approach to circulatory physiology before the advent of the scientific revolution and William Harvey’s magnum opus on the circulation of the blood published in 1628. Necrophysiology has not been without its successes however, such as the Arab scholar Ibnul-Nafiess’ (1208-1288) discovery of the lung circulation and now, three quarters of a millennium later, in determining blood pressure of all the world’s fishes. Funded by NSERC.

SWIMMING PERFORMANCE IN EXERCISE CONDITIONED, CULTURED DELTA SMELT.
G. J. Jones¹, J.B. Miranda¹, B. Bridges¹, R. Churchwell² and J.J. Cech, Jr. ¹
E-Mail: jjcech@ucdavis.edu

¹Department of Wildlife, Fish, and Conservation Biology, and Center for Aquatic Biology and Aquaculture, University of California, Davis CA USA; ²Division of Environmental Services, California Department of Water Resources, Sacramento, CA USA

Session: LinO15

Abstract: Information on the comparative swimming performance of wild and cultured fish of the same species and body size is often lacking. Such information can be of use when considering cultured fish as performance surrogates for wild fish that might be difficult to obtain or that represent a population of either steeply declining or dramatically low numbers (e.g., endangered). Because cultured fish are not subjected to the same selective forces as those in wild populations and because exercise conditioning (swim endurance training during rearing) has been shown to improve swimming performance in several cultured, as well as wild, fishes, exercise conditioning is worth consideration as a culture technique to improve swimming performance in cultured fishes. However, questions remain concerning how closely the swimming performance of cultured (including exercised conditioned) fish match those of wild fish of interest. Because of the interest in the (threatened) delta smelt in the Sacramento – San Joaquin Delta, our objective was to compare the swimming performance (measured as critical swimming velocity, Ucrit) of un-exercised and exercise-conditioned delta smelt. These results could then be compared to a previous study of wild delta smelt swimming performance. After pilot studies over the 2003 – 2004 period established an acceptable exercise conditioning regime, fish were exercise conditioned for 45 d and Ucrit was measured in a Brett-type, recirculating swim chamber. Funded by the California Dept. of Water Resources.
EFFECTS OF XENOBIOTICS ON ESTROGEN (E2) METABOLISM IN LAKE TROUT (Salvelinus namaycush)

G.F. Jurgella¹, A. Marwah², J. Malison¹, R. Peterson³ and T. P. Barry¹
E-Mail: tpbarry@wisc.edu
¹Dept. Anim. Sci., ²Dept. Biochem., ³School of Pharmacy, University of Wisconsin-Madison, USA

Session: ImpO40
Abstract: Experiments were conducted to (1) elucidate the biochemical pathways of E2 metabolism in the lake trout kidney and liver, and (2) test the hypothesis that specific xenobiotics and endogenous steroids inhibit E2 metabolism by these tissues. Kidney and liver tissue fragments from immature lake trout were incubated in vitro in the presence of radiolabelled E2 plus various xenobiotics or steroids. E2 metabolites were identified by LC/MS, and quantified by LSC. A major metabolite produced by both tissues was an unidentified hydroxylated estrogen metabolite (E2-OH) that was not estriol. Both tissues produce estradiol-17-glucuronide (E2-17-G), estradiol-17-sulfate (E2-17-S), and estradiol-3-glucuronide (E2-3-G). The following xenobiotics inhibited the production of water-soluble E2 metabolites by both the kidney and liver: 4,4’-(OH)2-3,3’,5,5’-tetrachlorobiphenyl, bisphenol A, tetrabromobisphenol A, tetrachlorobisphenol A, tribromophenol, trichlorophenol, and pentachlorophenol. The alkylphenols, 4-n-nonylphenol and 4-octylphenol, and 2,2’,4,4’-tetrabromodiphenyl ether had no significant effect on E2 metabolism by either tissue. Testosterone and 17a,20b-dihydroxy-4-pregnen-3-one inhibited the production of conjugated E2 metabolites by both the kidney and liver. Cortisol and 11-ketotestosterone inhibited E2 metabolism by the liver only. The results suggest that certain estrogenic xenobiotics may inhibit the phase II conjugation of E2 by the kidney and liver of lake trout. Some of the known biological effects of these compounds are likely mediated, at least partially, by this mechanism of action. Funded by Wisconsin Sea Grant.

DIURNAL NITROGEN EXCRETION RHYTHM OF THE UREOGENIC GOBIID FISH (Mugilogobius abei)

M. Kajimura¹,², K. Iwata¹, H. Hatai¹, M. Takahashi¹ and C. M. Wood²
E-Mail: kajimur@mcmaster.ca
¹Dept. of Edu., Wakayama Univ., Japan; ²Dept. of Biol. McMaster Univ., Canada

Session: TroO4
Abstract: Many organisms exhibit physiological and/or behavioral changes with a diurnal rhythm. This research was performed in order to study the direct relationship between daily periodicity of nitrogen metabolism and locomotor activities in the subtropical ureogenic gobiid fish Mugilogobius abei. Urea and ammonia excretion in 20% seawater (pH 7.6-7.9, 21-25 °C) were measured under a constant photoperiod of LD 12:12 and constant darkness (DD) using a continuous sampling apparatus. Daily variation of urea contents in body and enzyme activities related to urea synthesis were measured using colorimetric methods. Locomotor activity was recorded with a time-lapse videotape recorder and a CCD camera under LD 12:12. Urea excretion of all fish examined under LD 12:12 showed daily periodic changes, while some showed a free-running rhythm under DD. Due to the daily variations in urea excretion, urea contents in tissues changed periodically, whereas enzyme activities related to urea synthesis did not change significantly. The index of urea permeability as determined by changes in body urea contents after 2-h immersion in 25 mM urea solution was high during the peak of daily variation in urea excretion. Locomotor activity and urea excretion showed clear daily variations under LD 12:12, both of which were diurnal. These results suggest that periodic urea excretion was controlled by a circadian clock and mediated by periodic enhancement of permeability for urea at excretion sites. We are currently measuring the diurnal changes of the expression of urea transporter mRNA. Supported by a JSPS grant to MK and an NSERC Discovery to CMW.

COMPLEX DIAGNOSIS OF AEROMONAS INFECTION OF CARPS (Cyprinus carpio) IN POND FARMS IN UKRAINE.

I.G.Kalynovska¹,², M.G.Nakonechna¹, N.G.Sorokina² and I.Semenchukova²
E-Mail: iryna_kalynovska@yahoo.com
¹Dept.of Histol.,Cytol. and Embryol., ²Dept. of Epizoot., National Agricultural Univ., Kyiv; ³Dept. of Pathomorphol., Central State Lab. of Vet.Med., Kyiv, Ukraine

Session: DisP6
Abstract: Motile Aeromonad infection in fish is one of the dangerous bacterial infections, registered in ponds in Ukraine. It causes significant financial losses both due to the great mortality of fish and their defective rejection. The purpose of the study was to isolate and identify the agent of disease in separate pond farms, investigate the contamination of clinically healthy and diseased fish by Aeromonads and reproduce disease on healthy fish to study the pathomorphology. Thirty examples of live carp were collected from the private pond farms of the Kyiv region. Fifteen carp showed clinical symptoms typical of Aeromonas infection (skin and fins hyperemia, hemorrhages of different sizes on the skin, distended abdomens, scale and eye protrusions). The others were conditionally healthy. To solve the task we adopted Ukraine microbiological and pathomorphological methods of investigation. Obtained results revealed: 1) the causative agent of carp
disease in the investigated pond was *Aeromonas hydrophila*; 2) in diseased carp the agent was isolated from intestine and abdominal fluid (100% fish examined), kidney (93.33%), spleen (86.67%), liver (66.67%), muscle (60%), blood (46.67%) and heart (26.67%), in conditionally healthy – from all mentioned organs (except heart) but with less frequency; 3) the lesions in experimentally inoculated carp included inflammation of serous membranes, hemorrhagic fluid in abdomen, edema of all internal organs, dystrophy of the liver, kidney and inflammation of intestinal mucosa; microscopic findings include blood congestion, swelling and necrobiotic foci in muscle, liver, kidney, enteritis. Funded by National Agricultural University

**INDIVIDUALITY OF LEARNING IN SMALL SCHOOLS OF THE COMMON CARP (Cyprino carpio)**

I.Karplus¹, B. Zion², S. Yair¹ and A. Barki¹  
E-Mail: Karplus@agri.gov.il  
¹Aquaculture Research Unit, Agricultural Research Organization, Bet-Dagan, Israel; ²Institute of Agricultural Engineering, Agricultural Research Organization, Bet-Dagan, Israel  

**Session:** FroO10  
**Abstract:** Individual learning was studied in small groups of the common carp (*Cyprino carpio*). Groups consisting of 8 individually tagged carp were conditioned to associate a blue blinking light with food pellets. The training paradigm consisted of 20 sec. of signaling without food, 30 sec. signaling with food and 10 sec. signaling without food. Non-trained carp usually avoid a blinking light. Differences in the ability to associate a blue blinking light with food were found both between and within groups. Some groups learned to approach food immediately after signaling was stopped while other groups learned to approach the lights prior to food administration. In the later groups, some individuals avoided the blinking lights through the entire training sessions while other individuals learned rather rapidly to approach the lights. The physiological and behavioral profiles of fish were analyzed prior to training in order to determine reliable predictors for performance during learning. Funded by the Chief Scientist of the Israeli Ministry of Agriculture and Rural Development.

**RAINBOW TROUT HOMOLOG OF SLC26A1 ANION EXCHANGER INVOLVED IN RENAL SULFATE EXCRETION**

F. Katoh¹, M. Tresguerres¹, K.M. Lee², T. Kaneko², K. Aida² and G.G. Goss¹  
E-Mail: fumikatoh27@yahoo.co.jp  
¹Dept. of Bio. Sci., Univ. of Alberta, Canada; ²Dept. of Aquatic Bioscience, Univ. of Tokyo, Japan  

**Session:** IonO19  
**Abstract:** The kidney plays an important role in ion regulation in both freshwater and seawater fish. However, ion transport mechanisms in the teleost kidney are poorly understood, especially at the molecular level. The SLC26A is a family of recently discovered highly versatile anion exchangers. Some of the family members have been reported to be located in mammalian kidney, and specifically involved in sulfate, chloride, or bicarbonate transport. We have cloned a kidney specific SLC26A sulfate/anion exchanger from rainbow trout (*Oncorhynchus mykiss*) that is homologous to the mammalian SLC26A1 (Sat-1). Excretion of excess plasma sulfate concentration after Na₂SO₄ injection corresponded to significantly higher expression of the cloned SLC26A1 mRNA. Detailed morphological observation of rainbow trout renal tubules was also performed by light microscopy and transmission electron microscopy. According to the structure of brush border and tubular system in the cytoplasm, renal tubules of rainbow trout were classified into proximal tubule first and second (PI and PII) segments, and distal tubules. *In situ* hybridization revealed that SLC26A1 anion exchanger mRNA is specifically localized in the PI segment of kidneys from both seawater and freshwater adapted rainbow trout. Using immunocytochemistry, Na⁺, K⁺-ATPase and vacuolar type H⁺-ATPase were co-localized to the same cells and distributed in the basolateral and the apical membranes, respectively, of the cells where the SLC26A1 mRNA expressed. These findings suggest that the cloned kidney-specific SLC26A1 is located in kidney proximal tubules and is involved in excretion of excess plasma sulfate in rainbow trout. Funded by NSERC to GGG, JSPS and Alberta Ingenuity to FK and Donald Ross Scholarship and Izaak Walton Killam Memorial Scholarship to MT.
GREEN STURGEON BLOOD-OXYGEN EQUILIBRIA:
THE EFFECTS OF CARBON DIOXIDE AND TEMPERATURE
R.C. Kaufman1,2, A.G. Houck2 and J.J. Cech, Jr. 2,3
E-Mail: jjcech@ucdavis.edu
1Pharmacology and Toxicology Graduate Group; 2Wildlife, Fish, and Conservation Biology; 3Center for Aquatic Biology
and Aquaculture, Univ. of California Davis

Session: IntP5
Abstract: Green sturgeon (Acipenser medirostris) is an anadromous fish of special concern found only along the Pacific
coasts of Asia and North America. Blood-oxygen equilibria data are used to gain insight into the physiological adaptations
and potential environmental limits of fishes. The effects of temperature and carbon dioxide on blood-oxygen equilibria are
well studied in teleost fishes but less is known in chondrostean fishes. In vitro measurement of the effect of temperature
and carbon dioxide on blood-oxygen affinity and equilibrium curve shape yielded the following data for the respective
temperature treatments (11, 15, 19, and 24 °C): half-saturation values (P50’s, kPa, a measure of affinity) 1.26, 1.44, 1.63,
1.69 for low-PCO2 treatments and 2.08, 2.41, 2.74, 2.94 for high-PCO2 treatments; Bohr factors -0.322, -0.327, -0.366,
-0.536; and non-bicarbonate buffer values (slykes) –6, -3, -5, -8. Temperature sensitivities (DH, kJ × mol O2 -1) between
these respective temperatures were -34.20, -15.24, -6.74 for low-PCO2 treatments and -20.05, -27.00, and -11.55 for the
high-PCO2 treatments. These data suggest that juvenile green sturgeon may tolerate moderate environmental hypoxia,
moderate aerobic activity, low to moderate hypercapnia, and moderate temperature changes in their environments.
Financial support provided by: Calif. Bay-Delta Authority, Anadromous Fish Restoration Prog. (of the U.S. Fish &
Wildlife Service and the U.S. Bureau of Reclamation), CALFED, the UC Agricultural Experiment Station and a UC Davis
Pharmacology and Toxicology Graduate Group/John Muir Institute of the Environment fellowship.

STRESS AND CONSEQUENCES IN THE URBAN OCEAN
–STUDIES ON MARINE FISHES OF THE SOUTHERN CALIFORNIA BIGHT
K. M. Kelley1, J. A. Reyes1, J. E. Kalman1,2, A. W. Hamilton1, M. M. Galima1, K. Sak1, C. G. Lowe1 and J. L. Armstrong2
E-Mail: kmkelley@csulb.edu
1Environmental Endocrinology Lab, Dept. of Biological Sciences, California State University, Long Beach, Long Beach,
CA 90840; 2Environmental Assessment Division, Orange County Sanitation District (OCSD), Fountain Valley, CA, 92708
Session: MolO22
Abstract: The urban ocean environment presents a variety of stressors to marine wildlife, from disturbances such as direct
contact with humans (e.g., catch & release) to environmental contamination (e.g. from stormwater or sanitation district
outfalls). As in all vertebrates, fishes respond to environmental stressors via a highly integrated neuroendocrine system
(hypothalamo-pituitary-interrenal (HPI) axis) that results in production of the steroid, cortisol. Depending on the nature of
the stressor(s) presented to a fish, and the species under consideration, plasma cortisol levels may increase >200-fold (e.g.,
with capture and captivity) and remain elevated if the stressor(s) persists. Secondary physiological impacts of the cortisol
response include impairment of the HPI axis itself, disruption of the growth endocrine system, and inhibited defense
mechanisms, particularly under situations of chronic stress. The regulation and observed dysregulation of stress responses
in urban ocean fish will be discussed in terms of underlying steriodogenic mechanisms and potential impacts on other
physiological systems. Support in part by Southern California Sea Grant & California Sea Grant College Programs.

PRISMATIC DENTINE IN THE AUSTRALIAN LUNGFISH (Neoceratodus forsteri)
A. Kemp and J.C. Barry
E-Mail: a.kemp@uq.edu.au
University of Queensland, St. Lucia, Queensland 4072, Australia
Session: BonO8
Abstract: Biogenic apatite in the tooth plates of the Australian lungfish (Neoceratodus forsteri) was assessed for potential
in the design of new biomaterials. Methods used included scanning electron microscopy of fresh fracture surfaces of tooth
plates, and micromotted sections of undecalcified tooth plates to reveal crystal structure in high resolution transmission
electron microscopy. Circumdenteonal dentine is based on a dense mass of collagen fibrils, some circumferential and
lining the denteon, and others parallel and radial to the denteon wall. Collagen is retained in the mature tissue, which is
mineralised with slender, elongate crystals of calcium hydroxyapatite, oriented along the collagen fibrils associated with
their formation. Interdenteonal dentine, which surrounds the denteons and the circumdenteonal dentine, contains sparse,
slender collagen fibrils, parallel to cell processes within the dentine. Mineralisation of this dentine is initiated within the
collagen molecules, and the apatite crystals so formed are also aligned with the cell processes. Proliferation of apatite
crystals occurs around the cell process, within a second matrix, of unknown composition, and crystals grow from cuboidal
blocks into long flat hexagonal crystals. Mature interdenteonal dentine consists of prisms of large crystals, each arranged
around a cell process enclosed within the dentine. Circumdenteonal dentine may function as a mineral store for metabolism. However, the heavily mineralised prisms of interdenteonal dentine provide mechanical strength for a tooth plate that is exposed to heavy wear during life. The complex structure of interdenteonal dentine has potential for the design of new biomaterials. This research was funded by the Australian Research Council.

**DO ALTERED CORTISOL DYNAMICS PLAY A ROLE IN THE MULTIFACETED TOXICITIES OF OIL EXPOSURE IN TELEOSTS?**

C. Kennedy¹* and A. Farrell²

E-Mail: c.kennedy@sfu.ca

¹Dept. Biological Sciences, Simon Fraser Univ., Canada; ²Faculty of Land and Food Systems, and Department of Zoology, University of BC, Canada.

**Session:** ImpO12

**Abstract:** The multifaceted acute and chronic toxicities presented by organisms exposed to petroleum hydrocarbons presents a unique challenge in assessing sublethal toxicity with performance indicators that rely on the optimum functioning and integration of several key physiological systems, any or all of which may be targets for toxicity. The stress response, swimming performance and recovery, and immune system performance of juvenile Pacific herring (*Clupea harengus pallasi*) were determined following exposure to the water-soluble fraction (WSF) of North Slope crude oil for over 8 weeks. Mean (±SE) total polycyclic aromatic hydrocarbon (TPAH) concentrations at the beginning of exposures were: 0.2±0.1 (control), 9.6±2.5 (low), 40.7±6.9 (medium), and 120.2±11.4 (high) µg/l. The results of this study clearly show that hydrocarbon exposure (at TPAH concentrations as low as 41 µg/L) can: 1) cause, and subsequently inhibit, the interrenally-mediated organismal stress response, 2) reduce the swimming ability of fish and their ability to recovery from exhaustive exercise, and 3) affect the susceptibility of herring to the pathogen *Vibrio anguillarum*. The time course and magnitude of effects following acute and chronic hydrocarbon exposure suggest that altered cortisol dynamics play an important central mechanistic role in all of the observed sublethal toxic effects. Funded by the Exxon Valdez Oil Spill Trustee Council through contracts with the Alaska Department of Fish and Game.

**THE ECOTOXICOLOGY OF A POLLUTED NILOTIC DRAINAGE CANAL**

Elsayed A. Khallaf

E-Mail: ekhallaf@yahoo.com

Faculty of Science, Minufiya University, Shebeen Alkoom 32511, Egypt

**Session:** ImpO39

**Abstract:** This is a review paper for a comprehensive study to evaluate the response of aquatic populations to environmental pollution in a Nilotic drainage canal in the Egyptian Delta published in a number of papers by the author and his coworkers. The variation of physicochemical parameters, pesticides and heavy metal pollution in the polluted Atalaf Drainage Canal water (ADC, one of the Nile drainage system of canals) and the relationships among them, as well as variations in phyto- and zooplankton were found to be significantly correlating, and were attributed to occurrence of pollution in ADC. Protozoa's, cyclops, nematodes and oligochaets have conspicuously increased and thus can be used as pollution indicators. The variation of the protozoan organisms, as a major element in the zooplankton, was found to be in favor of Ciliophora followed by Mastigophora (Phytomastigophorea) and then Sarcodina. The variation of pollutants in water and in fish tissues (of the most abundant *Oreochromis niloticus*) were also investigated. Many of the studied pesticides and heavy metal pollutants observed in the ADC water found their way to the fish organs. Consequently, various biological parameters such as age, growth and reproduction were significantly effected, and were attributed to the effect of eutrophication and pollution in the ADC.
ionizing radiation (0.5 to 5 Gy (60Co)). Clonogenic survival of these cell lines was measured post-irradiation. Bystander effects were measured using the medium transfer technique where harvested culture medium from irradiated cells (ICCM) is placed on unirradiated cells and their survival measured. RTG-2, RTgill-W1 and Zeb-2j cell lines exposed to ICCM demonstrated a bystander effect with cell survival ranging from 84.9% +/- 10.42 to 120.4% +/- 0.46 relative to the control (100%). CHSE-214 cells did not exhibit an effect. The response to ICCM was not dependent on dose to the donor cells and remained constant over the dose range making the contribution of the bystander effect to the total effect of radiation significant at low doses. Results demonstrate that effects due to radiation can occur in fish cells not directly hit and that the response of cells receiving signals from hit cells can be stimulatory or inhibitory depending on the cell type. This may have implications for radiation and environmental protection of aquatic biota as the effects may impact on low dose and low dose rate risk estimates. Funded by Natural Sciences and Engineering Research Council of Canada (NSERC)

PATTERNS OF METABOLIC SCALING IN THREE SPECIES OF TELEOST FISH: EVIDENCE FOR ONTOGENETIC CHANGES IN AEROBIC CAPACITY
S. S. Killen, I. Costa, J. A. Brown and A. K. Gamperl
E-Mail: r24ssk@mun.ca
Ocean Sciences Centre, Memorial University of Newfoundland, Canada

Session: AdvO9
Abstract: Compared to other vertebrate groups, little is known about patterns of metabolic scaling in teleost fish. For example, no single study has examined changes in standard and active metabolism over the entire life history of any fish species. This is surprising, since the limited data available suggests that scaling of standard metabolism in teleost fish may differ substantially from either the 0.67 or 0.75 “scaling laws” that are commonly proposed for endotherms. In this study, we measured standard and active metabolism in three species of teleost fish (ocean pout, Macrozoarces americanus; lumpfish, Cyclopterus lumpus; and short-horn sculpin, Myoxocephalus scorpius) from the larval to the adult life-stages, wet mass covering a range of 4-6 orders of magnitude. Our results indicate that post-larval standard metabolism consistently scales with a mass exponent of 0.82-0.85 (not 0.67 or 0.75, as is extensively discussed with regard to endotherms), thus challenging universal theories of metabolic allometry. We also provide evidence that: 1) the scaling of maximal metabolic rate varies between fish species and may depend on a species’ ‘athleticism’; 2) the relationship between pre- and post-metamorphic metabolic scaling varies greatly, depending on the fish’s developmental trajectory; and 3) the factorial aerobic scope of larval fish is greatly diminished as compared with adults. This latter result suggesting that fish have a reduced ability to multitask physiologically demanding processes early in life. Funded by NSERC grants to AKG and JAB, an NSERC doctoral fellowship, and a grant to AKG from the Canada Foundation for Innovation.

ALTERNATE FORAGING MODES IN YOUNG LUMPFISH (Cyclopterus lumpus): BALANCING FOOD-INTAKE WITH THE ENERGETIC COSTS OF FORAGING
S. S. Killen, J. A. Brown and A. K. Gamperl
E-Mail: r24ssk@mun.ca
Ocean Sciences Centre, Memorial Univ. of Newfoundland, Canada

Session: EarO12
Abstract: Young lumpfish are unique in that they utilize two alternate foraging strategies – they can actively search for prey by swimming, or be "sit-and-wait" predators while adhered to the substrate using their ventral adhesive disk. Given these two feeding modes, we speculated that active foraging is only used when food is scarce to increase encounter rates with prey items. To test this hypothesis, we exposed lumpfish of two size classes to conditions of high (750 Artemia L⁻¹) and low (75 Artemia L⁻¹) prey density. Behavioral observations showed that lumpfish at the low prey density spent about 50% more time actively foraging, and through this strategy, were able to achieve similar levels of food intake. Interestingly, fish at the low prey density displayed significantly lower growth rates, suggesting that the cost of foraging is a considerable-trade-off, and leads to a significant reduction in the conversion of ingested energy to somatic mass. Given this data, we are currently measuring the swimming speed of foraging lumpfish using videography so that the cost of foraging can be estimated from swim-speed vs. O₂ consumption relationships we have determined for young lumpfish of various size ranges. When combined with data on the caloric content of the prey Artemia, this information will allow us to provide some preliminary models of the trade-off between the energy gained and expended while foraging, and thus predict the prey density at which lumpfish should switch between the two foraging modes. Funded by NSERC and the Canada Foundation for Innovation.
REPRODUCTIVE SENSITIVITY OF FEMALE ATLANTIC SALMON TO ELEVATED WATER TEMPERATURE IS HEIGHTENED AT CERTAIN STAGES OF VITELLOGENESIS

H.R. King1,2, N.W. Pankhurst1 and M. Watts2
E-Mail: harry_king@saltas.com.au

1Salmon Enterprises of Tasmania Pty. Ltd. (Saltas); 2School of Aquaculture, Univ. of Tasmania, Australia; 3Fish Endocrinol. Lab., James Cook Univ., Australia

Session: LinO16
Abstract: In order to compare the effects on reproductive performance of short-term or prolonged exposure to elevated temperatures during vitellogenesis, female Atlantic salmon were held at a water temperature of 22 °C for periods of 4 or 6 weeks during the austral summer and autumn. Plasma levels of sex steroids and vitellogenin (Vtg) were monitored and reproductive success was compared to that in groups of fish maintained at 14 or 22 °C for 12 weeks from mid January. Significant endocrine effects were observed within as few as 3 days of the commencement of exposure to 22 °C, when plasma levels of 17b-estradiol (E2) and Vtg were approximately half those observed in fish maintained at 14 °C. The fertility and survival to the eyed stage of ova from fish held at 14 °C exceeded 85% and 70% respectively, whereas ova from fish held at 22 °C for 6 or 12 weeks exhibited significantly reduced fertility (<70% and <45% respectively) and survival (c. 40 and 13% respectively). In spite of significant endocrine effects at all stages, a 4-week exposure to 22 °C only generated significant reductions in egg fertility (<65%) and survival (c. 30%) when it occurred between mid February and mid March. Together, these data confirm that high temperature spikes can affect reproductive success as strongly as more prolonged exposures, and indicate that there is a critical period of reproductive sensitivity to elevated temperature in late February and early March in this stock of Atlantic salmon. Funded by the Australian Research Council, Saltas and the University of Tasmania.

FISH POPULATION RECOVERY FOLLOWING CATASTROPHIC DISTURBANCE: LOCAL VERSUS IMMIGRANT CONTRIBUTIONS

M.T. Kinnison1, D.J. Weese1, P. Bentzen2, D.N. Reznick3 and A.P. Hendry4
E-Mail: michael.kinnison@umit.maine.edu

1Dept. of Biol. Sci., Univ. of Maine, USA; 2Dept. of Biol., Dalhousie Univ., Canada; 3Dept. of Biol., Univ. of California Riverside, USA; 4Redpath Museum and Dept. of Biology, McGill Univ., Canada

Session: FroO21
Abstract: Natural or anthropogenic disturbances may often decimate local fish populations. Two sources could then contribute to subsequent population recovery: (1) the depleted population of locally adapted individuals or (2) immigrants from the surrounding metapopulation. Although locally adapted individuals may often be the ideal genetic source, immigrants from undisturbed areas may increase in relative abundance following a local disturbance. The contributions of these immigrants may be strong, weak, positive or negative with respect to population growth. Catastrophic flooding in 2005 reduced guppy (Poecilia reticulata) populations by 2-3 orders of magnitude in high-predation reaches of the Marianne River, making them exceedingly rare. Upstream populations in low-predation habitats were largely undisturbed and so might serve as a source for recolonization. To assess the possible contributions of adapted local residents versus immigrants to population rebound, we performed two introduction experiments that used (1) low-predation genotypes only (immigrants) or (2) both low- and high-predation genotypes (immigrants and residents). In both experiments, we recorded individual data on fish color, size, shape and behavior, and then monitored relative survival and offspring contributions through time. By doing so we were able to not only address individual and source contributions to recovery, but also how trait variation and selection regulate such contributions. This work was funded by the National Science Foundation (DEB-0235605), USA.

GENETIC ADAPTATION TO CONTAMINANTS; PHYSIOLOGICAL, GENETIC AND FITNESS CONSEQUENCES

P.L. Klerks, L. Xie and N. Giridhar
E-Mail: klerks@louisiana.edu

Department of Biology, University of Louisiana at Lafayette, USA.

Session: ImpO2
Abstract: Fish populations inhabiting contaminated sites may be able to survive there as a consequence of contaminant-adaptation. However, associated changes (e.g. contaminant uptake, fitness costs, loss of genetic variation) may affect the long-term success of adapted populations. We addressed the adaption potential by comparing contaminant-resistance among populations from different sites and by conducting laboratory selection experiments. We then addressed the physiological, genetic and fitness consequences by comparing contaminant accumulation/detoxification, genetic variation at
microsatellite loci, and fitness-related traits between control and contaminant-adapted populations. No evidence of contaminant-adaptation was found in populations of darter gobies (Gobionellus boleosoma) and western mosquitofish (Gambusia affinis) inhabiting contaminated sites. However, laboratory lines of the least killifish (Heterandria formosa) showed a rapid response when selected for an increased resistance to cadmium. Resistance tripled during six generations. Fish from Cd-resistant lines showed a reduced Cd accumulation and an increased binding of Cd to metallothionein. The Cd-resistance had trade-offs (reduced resistance to copper and to heat) and fitness costs (e.g. reduced fecundity). Fish from the selection lines also had lost genetic variation. These results indicate that some fish populations may be able to adapt to environmental contaminants, that this may have consequences for contaminant transfer in the food chain, and that long-term success of adapted populations may be jeopardized by loss of genetic variation, fitness costs and trade-offs. Funded by US Department of Energy, US EPA and Louisiana Board of Regents.

DOES SIZE MATTER? POPULATION STRUCTURE AND SPAWNING STRATEGY IN PIKE
C. M. Knight1,2, R. E. Gozlan1 and M. C. Lucas2
E-Mail: CarolynKnight7@yahoo.co.uk
1Centre for Ecology and Hydrology, Dorset, UK; 2School of Biological and Biomedical Sciences, University of Durham, UK

Session: TelO11
Abstract: Population structure influences habitat use with some individuals more dependent on particular habitats than others. While this reduces the effect of habitat loss on the population as a whole, individuals employing certain strategies may be more susceptible to change. Using radio telemetry on a wide size range of fish (14–101 cm) we found differential use of main river and side channel habitats by different components of a riverine pike (Esox lucius) population. A strong allometric relationship was apparent with home range size increasing as pike age and size increased, particularly in younger/smaller individuals (R2 ≥ 0.54, P ≤ 0.05 in both cases). Individual growth rate (Von Bertalanffy growth constant) was negatively correlated with home range size (R2 = 0.3, P < 0.000). Slower growing individuals, particularly males, made longer excursions and inhabited larger home ranges, than their fast-growing counterparts. As growth performance and home range size were related, spawning behaviour of male pike was investigated. Spawning ditches were sampled by electric fishing in March, June, September and December 2003 to 2005. Small (10-20 cm) mature males already producing milt were found in spawning ditches in December. Through continuous monitoring with PIT telemetry these small males were found to spend longer in spawning ditches than their larger, dominant counterparts. Combination of radio and PIT telemetry provided detailed information at a population scale showing that while river side channels are important spawning grounds for the whole population, the component comprising slow-growing, possibly subdominant, pike is more likely to suffer from their loss. Funded by a Natural Environment Research Council LOCAR grant.

CLEAR AS MUD: ARE CATTLE FEEDLOTS RESPONSIBLE FOR THE DEFMENIZATION OF FEMALE FATHEAD MINNOWS IN THE ELKHORN RIVER?
Alan S. Kolok1, Edward F. Orlando2, Satomi Kohno3 and Louis J. Guillette Jr3
E-Mail: aolok@mail.unomaha.edu
1University of Nebraska at Omaha, Omaha, NE, USA; 2Florida Atlantic University, Fort Pierce, FL, USA; 3University of Florida, Gainesville, FL, USA.

Session: ImpO5
Abstract: The central hypothesis tested in this research was that runoff associated with cattle feedlots was directly responsible for the defeminization of female fathead minnows. In 1999, wild fathead minnows were collected from three locations: a reference site, a site located immediately downstream from a cattle feedlot, and a site receiving drainage from row-crop agricultural fields. Ovarian synthesis of 17-b estradiol and testosterone was quantified, and the E:T synthesis ratio was significantly reduced in fish at treatment sites relative to fish at the reference site. In 2005, caged fathead minnows were deployed at four locations throughout the watershed while a fifth group of fish was held in the laboratory. Fish from the treatment sites were found to have significantly lower levels of the estrogen responsive genes, estrogen receptor a and vitellogenin, than did laboratory fish. Female fathead minnows were found to be defeminized in both studies, however the effect was not directly associated with proximity to cattle feedlots. Contamination in the Elkhorn River appears to be a systemic, rather than a point source, event. Funding for this research was provided by the European Commission (LIG), the USGS (ASK) and the Nebraska Game and Parks Commission (ASK).
INNATE VARIATION IN EYE-PARASITE RESISTANCE, SPLEEN SIZE AND ANTI-PREDATOR BEHAVIOR IN JUVENILE ARCTIC CHARR

R. Kortet1, T. Lautala1, J. Taskinen2 and H. Hirvonen1
E-Mail: rkortet@cc.jyu.fi

1Department of Biological and Environmental Sciences, University of Helsinki, Finland; 2Karelian Institute, Department of Ecology, University of Joensuu, Finland

Session: LinO6
Abstract: Hatchery-reared fish have long been known to have higher mortalities after release to the wild environment, compared to natural fish. Explanations for this include, potentially genetically determined, behavioral and physiological alterations of fish to farming environment and increased vulnerability to predation and parasitism in the wild. We studied fish anti-predator behavior, resistance against Diplostomum sp. eye-flukes (parasite load) and relative spleen size in hatchery-reared juvenile Arctic charr (Salvelinus alpinus), using a half-sib design. Fish size was positively associated with parasite load, but we did not find any relationship between spleen size and parasitism. In the nested MANOVA, both the sires and the dams nested under the sires affected significantly on length-adjusted parasite load as well as anti-predator behavior, like activity. However, the family background did not have any effect on spleen size. Preliminary analyses suggest that the fish from the families suffering higher loads by eye-flukes were behaving more actively in the predator trials than those from the low-parasite-load families. The analyses for the association between MHC and parasitism are in progress. The results indicate that there are inherited differences in resistance against eye-fluke parasites and anti-predator behavior, and that resistance and some behavioral traits are associated with each other at family level. Funded by UH, Nessling Foundation, Ministry of Agriculture and Forestry, and NAF.

ALTERNATIVE PHENOTYPES IN THE VARIABLE ENVIRONMENT: FREQUENCY DYNAMICS IN COHO SALMON (Oncorhynchus kisutch)

Y. Koseki and I. A. Fleming
E-Mail: ykoseki@mun.ca
Ocean Sciences Centre, Memorial Univ. of Newfoundland, Canada

Session: FroO24
Abstract: Individuals often show distinct forms of phenotypes, or ‘alternative phenotypes’, depending on their environmental conditions and/or social status. The dynamics of alternative phenotypes in natural populations have been poorly understood, despite its potential for providing insight into their evolutionary maintenance. Using over 20 years of survey data from Oregon coastal coho salmon populations, we analyzed the spatial and temporal patterns of frequency dynamics of the alternative male life-history phenotypes (age-2 ‘jacks’ and age-3 ‘hooknoses’). Annual fluctuations of the ratio of jack to hooknose males showed spatial synchrony across populations. The jack-hooknose ratio also showed high temporal variation when computed by brood year (cohort), compared to that by return year (breeding group). These spatial and temporal patterns are inconsistent with our previous study on marine survivals of Oregon hatchery populations, suggesting that variation in the relative frequencies of jack and hooknose males is influenced by freshwater rather than marine processes. This freshwater-induced patterning of frequency dynamics implies that there is a constant perturbation of fitness payoffs for alternative phenotypes, which influences the evolutionary stable strategy (ESS) switchpoint between phenotypes. Thus, the ESS switchpoint and resulting equilibrium frequencies of alternative phenotypes may be less stable or elusive. Funded by the Japan Society for the Promotion of Science, the Coastal Oregon Marine Experimental Station and the Natural Sciences and Engineering Council of Canada.

MOLECULAR MECHANISMS OF EARLY MORTALITY SYNDROME (M74) IN BALTIC SALMON

Kristiina A.M. Vuori and Mikko Nikinmaa
E-Mail: kristiina.vuori@utu.fi
Centre of Excellence in Evolutionary Genetics and Physiology, University of Turku, FI-20014 Turku, Finland

Session: ProO11
Abstract: Yolk-sac fry of Baltic salmon suffer from early mortality, M74, which is fluctuating in occurrence. The proximal cause of M74 is unknown. M74-affected fry are characterized by low thiamine content and oxidative stress. To date, the aim of the project has been obtaining explanation of various symptoms of M74 by applying molecular methods i.e. microarray and transcription factor DNA-binding assay. According to our results, M74-fry can be divided into three major groups with early, intermediate or late onset of the mortality. If mortality starts during the first third of the yolk-sac stage, virtually all the responses are compatible with stress, which rapidly leads to the common terminal responses. If death occurs during the second third of the yolk sac stage, the terminal stage is preceded by a decrease in globin gene expression, which leads to internal hypoxia, when the animals grow and shift from skin- to gill-breathing. The progression of disease is also
associated with decreased DNA-binding of transcription factors HIF-1α and AhR and subsequent target protein expression. The group developing M74 slowest appears to compensate for reduced oxygen delivery by downregulation of metabolism, and hence some fry can escape death. In conclusion, the data hitherto gathered suggest that M74 in Baltic salmon yolk-sac fry results from oxidative stresses disturbing developmental expression and function of several different genes. In ongoing studies we will investigate the mechanisms by which oxidative stresses develop in fry and adult salmon, including the possible involvement of the Baltic Sea food web. Funded by Finnish Academy of Science.

PROTEOMIC PHENOTYPING AND FUNCTIONAL GENOMICS OF SHARK (Squalus acanthias) TISSUES

Dietmar Kültz1,2, Jinoo Lee1, Nelly Valkova1 and Mark White1
E-Mail: dkueltz@ucdavis.edu
1University of California-Davis, USA; 2Mount Desert Island Biological Laboratory, Salisbury Cove-ME, USA
Session: ProO12
Abstract: Dogfish sharks were obtained from coastal waters of the North Atlantic and acclimated to 4 foot diameter holding tanks and running seawater for 2 weeks to allow them to overcome stress associated with their capture. They were then sacrificed and six tissues collected: gill epithelium, kidney, rectal gland, intestine, brain, and heart. Tissues were immediately snap-frozen in liquid nitrogen and then stored at -80 C. Tissues were then homogenized, proteins extracted, and proteins separated by two-dimensional gel electrophoresis (2DGE). On average 1500 distinct protein species were resolved on each 2D gel. Tissues from six sharks were processed by 2DGE and all gels analyzed by Delta 2D software (Decodon) as follows: First, a master gel was created representing average spot intensities for the six 2D gels obtained from a particular type of tissue. Master gels of different tissues were then matched into a single Union gel containing all protein spots in each tissue type. Thereafter, each individual 2D gel was compared against the Union gel to identify proteins that are common to different tissues in a statistically significant way (P<0.05, n=6). Many proteins (535) are expressed at high levels in all six tissues. In addition, 1121 proteins are shared between the four osmoregulatory tissues (gill epithelium, kidney, rectal gland, intestine) but not in heart or brain suggesting that the proteomic phenotype reflects tissue function. We tested this possibility by identification of nearly 200 shark proteins that are either commonly expressed in all tissues, specific to osmoregulatory tissues, or specific to only a single tissue. About half of these proteins were successfully identified by MALDI-TOF/TOF mass spectrometry (ABI 4700 proteomics analyzer). We performed bioinformatics analysis using the identified sets of proteins and their tissue expression patterns to obtain insight into pathways and functional processes characteristic of these six shark tissues. This analysis was performed with PANTHER and PATHWAYSTUDIO software. The results of our study illustrate the following: First, proteins can be successfully identified based on peptide mass fingerprinting and de novo peptide sequencing (MS/MS) in primitive fishes. Second, tissue-specific functions can be revealed by proteomic phenotyping and gene ontology/ pathway analysis. Funded by NSF (MCB0244569).

Paternity COLOURATION INFLUENCES SUSCEPTIBILITY TO PARASITE-INDUCED CATARACT
IN ARCTIC CHARR (Salvelinus alpinus L.) YOUNG

H. Kuukka1,2, M. Janhunen1, N. Peuhkuri2, J. Piironen2 and I. Kolari2
E-Mail: hanna.kuukka@helsinki.fi
1Dept. of Biol. and Env. Sciences, University of Helsinki, 2Finnish Game and Fisheries Research Institute, 3Dept. of Biol., University of Joensuu
Session: WelO12
Abstract: Cultivation often results in differentiation of the farmed fish from the original populations. Such changes may reduce individual performance and survival when fish are stocked in wild. For an example, large number of extremely endangered Lake Saimaa Arctic charr young are yearly stocked for conservation purposes in Finland but the success of the stocking has been very poor. One potential cause could be the high parasite-induced cataract prevalence that we have observed in farmed Lake Saimaa Arctic charr. Cataracts reduce vision and ultimately lead to blindness of fish. Breeding colouration in Lake Saimaa Arctic charr males varies greatly. Male sexual ornamentation is likely to indicate high parasite resistance and female fish are expected to favour strongly ornamented males in nature. Such sexual selection is ignored in artificial fertilisations performed in hatcheries. We tested experimentally whether susceptibility to parasite-induced cataract in Arctic charr young depends on paternal breeding colouration. Conforming to our hypothesis, offspring of bright-coloured males were less susceptible to cataract than offspring of paler males. However, there was some indication of reduced growth at the cost of resistance. The study was funded by FGFRI, The Nordic Working Group on Fishery Research (NAF) and Finnish Cultural Foundation.
DIVERGENT STRESS RESPONSIVENESS IN JUVENILE ATLANTIC COD (Gadus morhua)
R. Laing 1, S. Hosoya 1*, S. C. Johnson1, A.K. Gamperl2 and L.O.B. Afonso1
E-Mail: Luis.Afonso@nrc-cnrc.gc.ca

1Institute for Marine Biosciences, National Research Council, Canada; 2Ocean Sciences Centre, Memorial Univ. of Newfoundland, Canada

Session: MolP8
Abstract: The magnitude of the response to stress can vary between individuals of the same species, and is defined as a divergent response. We are determining whether the divergent stress response in Atlantic cod is consistent over time, and whether it is linked with fish growth. Individually tagged juvenile cod (240 g) were placed into 2 tanks (20 fish per tank) and acclimated to experimental conditions for 30 days. At tagging, 4 fish in each tank were assigned to be controls. Handling stress (15 seconds out of the water) was then applied in 32 fish at approximately 30 day intervals for 4 months (November 2005 to February 2006) Fish were sampled 1 hour after the handling stress, and plasma cortisol and glucose levels, hematocrit, and growth parameters were determined. We examined the results by considering the whole data set, and by ranking the fish, based on their initial plasma cortisol levels, as low or high responders. Based on analysis of November and December samples both plasma cortisol and glucose levels increased significantly in the stressed group, although no differences in mass were observed. The interpretation of the results changed, however, when we grouped the individuals as low and high responders. This analysis suggested that high responder fish grow slower than low responders. Furthermore, the percentage of low and high responder fish changed between the two sampling points. We are currently analyzing the samples collected in January and February. This work was funded by AquaNet AP-35 and the National Research Council of Canada.

CA2+-TRANSPORT CATALYSED BY SERCA2 IN RAINBOW TROUT VENTRICLES. COMPARISONS WITH MAMMALS AND ENDOOTHERMIC FISH
Landeira-Fernandez, A.M.1 Alves, C.M. 1, Silva, D. 1 and Block, B.2
E-Mail: landeira@bioqmed.ufrj.br

1Instituto de Bioquímica Médica, CCS/UF RJ, RJ, Brasil; 2Hopkins Marine Station of Stanford University, Pacific Grove, CA, USA

Session: CarO14
Abstract: In mammals the cardiac sarco/endoplasmic reticulum Ca2+-ATPase (SERCA2) plays a major role during cardiac excitation-contraction (E-C) coupling, transporting Ca2+ from the cytosol into the lumen of the sarcoplasmic reticulum (SR) and thus promoting the relaxation of the heart. In the teleosts heart, most of the Ca2+ comes from the extracellular medium rather than intracellular compartments., and the activity of the SERCA2 protein is thought to be less important. However, recently, physiological and biochemistry studies on the cardiovascular performance of tunas, showed that the elevated heart rates of these fish may rely on increased use of intracellular SR Ca2+ stores. More than that, it was also found that bluefin tuna, the species that encounter the coldest water (~2 °C), displayed the highest SERCA activity, when compared with the other tuna species studied. More recently, data from satellite tracking of the salmon shark reveal that they spend winter periods in waters as cold as 2 to 8 °C. Functional assays and protein gels reveal that the expression of the cardiac SERCA2 is enhanced in salmon shark hearts and that is 6 times higher than bluefin tuna and as high as rat ventricles, until the temperature of 25°C. Now we show that vesicles derived from rainbow trout (Salmo gairdneri) ventricles retain a SERCA pump that is able to transport Ca2+ at the expense of ATP hydrolysis. Measurements of Ca2+ transport using 45Ca2+ reveal a similar kinetic pattern as salmon sharks. The ventricle trout SERCA2 has its maximal activity at 25 °C and at this temperature the rate of Ca2+ uptake was practically the same as the rat ventricles. However, at 35 °C, the activity of the trout SERCA2 ventricles became twice lower than rat ventricles, suggesting a different SERCA2 temperature dependence between trout and rat. Taken together these data suggest that higher activity of the SERCA2 at lower temperature may be important for retaining cardiac function at cold temperatures. This work is supported by NSF and FAPERJ.

TAGGING OF BONEFISH TO STUDY POPULATION MOVEMENTS AND DYNAMICS
Michael F. Larkin1, Jerald S. Ault1, Robert Humston2, Jiangang Luo1 and Natalia Zurcher1
E-Mail: mlarkin@rsmas.miami.edu

1University of Miami, Rosenstiel School of Marine and Atmospheric Science, 4600 Rickenbacker Causeway, Miami, Florida 33149, USA; 2Virginia Military Institute, Department of Biology, Lexington, Virginia 24450, USA.

Session: TelO17
Abstract: Bonefish in south Florida support a large recreational fishery that is a significant component of the regional economy. Despite their relevance, there is a paucity of information on key issues in population dynamics to support management decision making. To address these issues, bonefish conventional anchor tag and acoustic telemetry experiments were conducted in south Florida from 1998 to 2005 to determine the stock structure, mortality, growth,
movements, spawning migrations, habitat use, and site fidelity. A total of over 3,800 bonefish were tagged with conventional anchor tags, and over 110 bonefish were recaptured. Fifty-one bonefish were fitted with acoustic transmitters and released in an array of 38 receivers in the northern Florida Keys. The conventional tagging database was used to estimate survivorship, and tag return data was analyzed to estimate growth. Movement results reveal that bonefish display a high degree of site fidelity, however, long distance movements (>30 km to 300 km) were recorded for the large sexually mature bonefish during the months of reproductive activity suggesting directed spawning migrations. Bonefish were tracked moving offshore to the reefs during the reproductive season during the arrival of a frontal system, and this behavior was presumably related to spawning. Schooling behavior was also observed. The bonefish tagging projects provide information on stock structure and population flux which is necessary for the design of spatial management alternatives to ensure the sustainability of the fishery. This research was funded by the National Fish and Wildlife Foundation, National Park Service Cooperative Ecosystems Studies Unit Grant, Bonefish and Tarpon Unlimited, and Friends of the Sanctuary.

IS EARLY SURVIVAL CONNECTED WITH PARENTAL MHC IN ARCTIC CHARR STOCK WITH LOW GENETIC VARIABILITY?
T. Lautala and H. Hirvonen
E-Mail: tiina.lautala@helsinki.fi
Integrative Ecology Unit, P.O. Box 65, FIN-00014 University of Helsinki, Finland.

Session: EarO7
Abstract: Genes of major histocompatibility complex (MHC), affecting mate choice, fertilization success and immunocompetence, are usually very polymorphic. However, among the endangered Arctic charr (*Salvelinus alpinus* L.) population of Lake Saimaa, genetic variability, including MHC, is very low. This is one suggested reason for high mortality among the stock during early life stages. The population is almost completely dependent on hatchery breeding. Differences in inter-family survival cause decrease in the effective population size (Ne), when new parental stocks are produced. In this study, we examined effects of parental MHC-genotypes and -heterozygosity on the survival of eggs. We reared 60 Arctic charr families with a half-sib design (3 replicates) in standard hatchery conditions. Genetic samples were taken from the parental fish. Variability was only found in one MHC-locus with two alleles. Survival of eggs was recorded until hatching. We found significant differences in egg survival between both full-sib and half-sib families. The preliminary results suggest that inter-family variation in survival was not connected with parental genotypes or predicted offspring MHC-heterozygosity. However, there was some evidence of low survival during early development (0-4 weeks from fertilization) among families with low predicted heterozygosity and families sired by MHC-homozygous males. Thus, the effect of MHC on inter-family differences in survival rates of Arctic charr cannot be entirely excluded, although it seems not to be the major determinant for inter-family variation. Funded by Research Funds of UH and Maj and Tor Nessling Foundation.

GLUTATHIONE DYNAMICS IN FISH: METABOLISM, TRANSPORT, AND EFFECTS OF TEMPERATURE
R.A. Leggatt1, C.J. Brauner2, P.M. Schulte2 and G.K. Iwama3
E-Mail: raleggat@interchange.ubc.ca

1Fac. Land and Food Systems, University of British Columbia, Canada; 2Dept. Zoology, University of British Columbia, Canada; 3Dept. Biology, Acadia University, Canada

Session: AdvO8
Abstract: Glutathione (GSH) is an important antioxidant that is involved in many cellular processes. In fish, the role of GSH during toxicant and oxidative stressors is well defined, but little else is known of the metabolism and function of GSH in fish. We examined the mechanisms by which fish tissues metabolize and transport GSH, and the effects of long and short-term environmental changes on GSH dynamics in fish using various in vivo and in vitro models. We identified several unique mechanisms of GSH metabolism and transport in fish. In particular, the total GSH synthesis capacity in several tissues was not matched by the biological supply of amino acid precursors. Consequently, fish may have the potential to rapidly increase GSH levels with increased supply of GSH precursors, without increasing levels of GSH synthesis enzymes. Increasing acclimation temperature increased GSH levels and turnover in vitro, and increased levels and activity of associated enzymes in vivo. However, these changes were not observed during acute temperature change or handling stressors. Artificially increased or decreased GSH levels by exogenous GSH or GSH synthesis blocker respectively did not consistently affect the ability of fish to respond to acute temperature or handling stressors. Fish appear to have flexibility in their GSH system that allows them to increase GSH levels rapidly. This may help them cope with long-term environmental changes such as temperature and pollution, although the same does not appear to be true for short-term perturbations. Funded by NSERC.
GLUTATHIONE DYNAMICS IN GROWTH HORMONE TRANSGENIC FISH: INCREASED FEEDING AND GROWTH ALTERS ANTIOXIDANT LEVELS IN COHO SALMON

R.A. Leggatt¹, R.H. Devlin², C.J. Brauner³ and G.K. Iwama⁴
E-Mail: raleggat@interchange.ubc.ca
¹Fac. Land and Food Systems, UBC, Canada; ²Fisheries and Oceans Canada, Canada; ³Dept. Zoology, UBC, Canada; ⁴Dept. Biology, Acadia University, Canada

Session: GenP5

Abstract: Insertion of a growth hormone transgene in fish results in accelerated growth, and increased feeding and metabolic rates. However, the physiological consequences of these changes are not fully understood. We examined the effects of the transgene and feeding levels on the glutathione (GSH) antioxidant system in five groups of coho salmon: transgenic fish fed to satiation (TF), control fish fed to satiation (CF), transgenic fish fed at control levels (TR), and control and transgenic fish starved for 1 month (CS and TS). GSH levels increased in various tissues of TF versus CF fish, likely due to both increased GSH from the diet and increased synthesis capacity. This coincided with increased ability to breakdown dietary GSH into transportable amino acids within the intestine of TF. TF fish also had higher activity of GSH reductase (GR), the enzyme responsible for maintaining GSH in its reduced form. Alterations in GSH dynamics in transgenic fish were primarily due to increased feeding and not the transgene, as TR did not differ from CF, and levels were generally similar between CS and TS. However, TS had greater GR activity and lower oxidized GSH than CS, indicating transgenic fish were better able to combat starvation associated oxidative stress. Altered GSH dynamics in transgenic fish may help them cope with increased metabolism from accelerated growth. The effects of the growth hormone transgene on GSH dynamics were due to increased feeding levels, and not a direct effect of the transgene. Funded by the Canadian Regulatory System for Biotechnology and NSERC.

JUVENILE COASTER BROOK TROUT MOVEMENTS AS DETERMINED BY RADIOFREQUENCY IDENTIFICATION (RFID) TELEMETRY ON THE SOUTH SHORE OF LAKE SUPERIOR

E-Mail: jileonar@nmu.edu
Department of Biology, Northern Michigan University, Marquette, MI, USA

Session: TelO8

Abstract: Coaster brook trout (Salvelinus fontinalis), native to Lake Superior although drastically reduced in numbers, are currently the subject of a restoration effort. In 2003, we began assessing stocked and wild brook trout in Pictured Rocks National Lakeshore using RFID that detects 23mm PIT tags using stationary antennas. The antennas were placed at the mouths of three rivers and over the past three years we have tagged approximately 2500 brook trout in the area. Results show that most of the tagged fish, primarily juveniles, are stream resident; approximately 5-7% of tagged brook trout were detected at our antennas. Results were similar for stocked and wild fish. Those fish that did move out of their natal stream ranged in size from 100mm (our minimum size) to 400mm, with most in the 150mm size class at tagging. Movements were more common in the Hurricane R. than in the Mosquito R. or Seven Mile Cr. In all three rivers, some movements out of the rivers occurred throughout the year with peaks in the autumn that typically included larger individuals. A small proportion of the fish have also been detected at different rivers, raising the issues of straying and home stream identification. Our results provide initial information on timing of juvenile coaster movements and demonstrate that our study streams are producing wild brook trout expressing the coaster phenotype. These results bring into question the utility of stocking hatchery produced coasters into these systems and question our current definition of a coaster. Funded by the National Park Service, National Fish and Wildlife Foundation, Trout Unlimited, and NMU.

A MORPHOMETRIC AND PHYSIOLOGICAL COMPARISON OF RESIDENT AND COASTER STRAINS OF BROOK TROUT IN A FIELD SETTING

J.B.K. Leonard¹ and A. Sreenivasan²
E-Mail: Jileonar@nmu.edu
¹Biology Department, Northern Michigan University, Marquette, MI; ²School of Fisheries, University of Alaska-Fairbanks, Juneau, AK, USA

Session: IntO10

Abstract: Lake Superior’s coaster brook trout (Salvelinus fontinalis) are thought to be distinct from local brook trout that remain resident in streams throughout their lives. However, there is little to distinguish these morphotypes as juvenile fish when they share stream habitat, nor are the physiological mechanisms supporting life history differences clear in this species. We compared bioenergetic indicators, morphological variables, and smolting characters in a field “common garden” situation for age 1+ and 2+ trout of the same cohort in the Mosquito River, MI, USA using a monthly sampling scheme from May – Dec. The coaster strain originated from Tobin Harbor (TH; Isle Royale, MI) while the resident strain
were wild Pictured Rocks trout (PR). TH displayed elevated metabolic enzyme levels including white muscle pyruvate kinase and lactate dehydrogenase. There was no difference in thyroid hormones nor in Na⁺K⁺ATPase. There were significant differences in morphology assessed by principle components, largely related to fin shape, between the two strains with TH displaying characteristics associated with a more pelagic life history. Our results suggest that modest measurable differences occur in both physiology and morphology between TH and PR strain juvenile fish by age 1+ suggesting that these strains, which display marked life history differences, are expressing physiological differences prior to their potential outmigration from their natal stream. Funded by the National Park Service, NMU, and Trout Unlimited.

MECHANISMS MAINTAINING BODY SIZE VARIATION IN STREAM SALMONIDS

B.H. Letcher¹ and K.H. Nislow²
E-Mail: bletcher@forwild.umass.edu

¹Conte Anadromous Fish Research Center, Turners Falls, MA, USA; ²US Forest Service Northern Experiment Research Station, Amherst, MA USA.

Session: FroO13
Abstract: Stream salmonids exhibit tremendous body size variation within a cohort. We examined the relative effects of factors that could influence size distributions in the wild using a multi-year dataset of tagged individuals. We examined the factors emergence date, family, life history expression, and size-dependent emigration and mortality. Body size and even life history expression were directly related to emergence or stocking date. Compared to later fish, early fish stayed large and were more likely to smolt as 2+ fish. Body sizes (and life history expression) also varied with family membership, with family differences explaining about 20% of the variation in body size. There were strong family-dependent life history tradeoffs that help to clarify the relationships among life histories. Also, life history explained about 30% of the variation in body size. Wide size distributions could not be explained by growth depensation as there was strong seasonal growth autocorrelation. Size-dependent emigration reduced the size variation seasonally, with larger fish emigrating from the study area in the fall. Size-dependent survival was occasionally strong, but seasonal variation in direction of selection was sufficient to have little consistent effect on size distributions. Wide size distributions in our study system result from heritable growth differences that vary with life history expression and are maintained by inconsistent selection on body size. Funded by the Conte lab and the US Forest Service Northern Experimental Research Station.

EFFECTS OF TEMPERATURE ON ATLANTIC COD MORPHOMETRIC PARAMETERS AND TISSUE METABOLITES AND ENZYMES

H.M. Levesque¹, J. Bondy², C. Short³, J. Ballantyne², W.R. Driedzic³ and T.W. Moon¹
E-Mail: aleve057@uottawa.ca

¹Dept. of Biol., Univ. of Ottawa, Canada; ²Ocean Sciences Centre, Memorial Univ. of Newfoundland, Canada; ³Dept. of Biol., Univ. of Guelph, Canada

Session: NorO2
Abstract: Age 1+ to age 3+ Atlantic cod (Gadus morhua) were held at constant (~9 °C) (CST) or ambient (ABT) ocean temperatures (Newfoundland) from December 2000 to June 2002 under natural photoperiod. Body parameters, tissue metabolites and enzymes activities were assessed over this period. Both groups increased body mass and length with a significantly greater increase for the CST-group at all sampling dates. Both groups demonstrated a growth phase from August to October 2001, while only the ABT-group showed a compensatory growth phase from May to July 2001. Tissue metabolites demonstrated seasonal patterns consistent with photoperiod. Principal component analysis was used to reduce tissue enzymes to Factors, which were used to investigate the effects of temperature on cod physiology. Liver Factor I (LFI) and muscle Factor III (MFIII) were significantly correlated with cod mass and length. Only LFI was correlated with tissue metabolites. Significant differences between thermal groups were only observed for MFIII in June 2002. This study demonstrates that photoperiod and physiological cycles are more important than temperature in determining liver and muscle metabolites and enzyme activities. Temperature affected quantitatively the amounts of tissue metabolites, implicating temperature changes food conversion efficiencies. Most liver enzymes measured are better indicators of fish growth than muscle enzymes. Liver protein is the parameter that best correlates with body mass and length. Funded by AquaNet and NSERC Canada.
MYOGENESIS AND MUSCLE METABOLISM IN ATLANTIC SALMON (SALMO SALAR) MADE TRANSGENIC FOR GROWTH HORMONE
H.M. Levesque¹, M. Shears², G. Fletcher² and T.W. Moon¹
E-Mail: aleve057@uottawa.ca
¹Dept. of Biol., Univ. of Ottawa, Canada; ²Ocean Sciences Centre, Memorial Univ. of Newfoundland, Canada

Session: GenO5

Abstract: Tissues from Atlantic salmon (Salmo salar) made transgenic for growth hormone (GH) and from non-transgenic salmon were collected for enzyme estimates and mRNA analyses at 4 and 7 months of age. White muscle (WM) myosatellite cells were isolated for proliferation assays using bromodeoxyuridine (BrdU) incorporation. Myosatellite cell proliferation was higher in cells from GH-transgenic salmon compared with cells from non-transgenic salmon at 4 months and from non-transgenic salmon of the same mass. However, MyoD I and myogenin mRNA contents were higher in myosatellite cells isolated from non-transgenic fish after 6 days of plating. In WM, MyoD I mRNA was higher in transgenic salmon at 4 months indicating a higher proliferation capacity in this tissue. White muscle myogenin mRNA content varied with fish size and was lower in transgenic fish at 4 months, indicating a lower differentiation capacity. In red muscle (RM), MyoD II mRNA was lower and myogenin was higher in GH-transgenic fish at 7 months compared with non-transgenic salmon at 7 months. However, RM myogenic factor expression was not different between transgenic and non-transgenic fish of the same size. Enzymes activities in WM and intestine were correlated with fish body mass. This study demonstrates that myogenic factors and myosatellite cell proliferation are affected by the ectopic GH-transgene, whereas some metabolic parameters are more affected by fish size indicating that, at some point GH-transgenic animal are physiologically closer to older non-transgenic salmon. Funded by AquaNet Canada, AquaBounty and NSERC Canada.

BIOCHEMICAL AND PHYSIOLOGICAL RESPONSES TO HYPOXIA IN AN AMAZONIAN CICHLID, (Astronotus ocellatus)
J.M. Lewis¹, I. Costa¹, A.L. Val², V.M.F. Almeida-Val², A.K. Gamperl¹ and W.R. Driedzic¹
E-Mail: jmlewis@mun.ca
¹Ocean Sciences Centre, Memorial University of Newfoundland, Canada; ²Laboratory of Ecophysiology and Molecular Evolution, INPA, Brazil

Session: TroO7

Abstract: Amazonian cichlids, such as Astronotus ocellatus, rely on metabolic depression to survive the hypoxic várzea environment. The objective of this study was to explore the contribution of protein synthesis to whole animal metabolic depression during hypoxia and recovery from hypoxic stress in A. ocellatus. Oxygen consumption, as an indicator of routine metabolic rate (RMR) and rates of in vivo protein synthesis, measured by the incorporation of 3H-phenylalanine into various tissues, were determined under normoxia, hypoxia (three hours at 10% dissolved O2) and post-hypoxia recovery. RMR was depressed by approximately 60% during hypoxia. This decrease in whole animal metabolism was accompanied by a 50-60% decrease in protein synthesis rates in liver, heart and gill; suggesting the reduction of protein synthesis during hypoxia is tightly linked to metabolic depression at the whole animal level. The exception to this was brain, in which rates were depressed by 30%, which is not unexpected, as A. ocellatus remains active during hypoxia. One hour post-hypoxia, RMR were increased to 220% of normoxic rates after which they returned to normoxic levels. No hyperactivation of protein synthesis was observed and the time taken for protein synthesis rates to return to normoxic levels was tissue specific. These results suggest an acute hypoxia exposure of three hours is substantial enough for A. ocellatus to accumulate an oxygen debt but not a debt in protein synthesis. Funded by NSERC, CNPq and FAPEAM.

COMPARISON OF HABITAT USE BY JUVENILE WHITE HAKE (Urophycis tenuis) AND GREENLAND COD (Gadus ogac) AS AFFECTED BY A PREDATOR
C.W. Lewis¹, R.S. Gregory², I.A. Fleming¹ and J.A. Brown¹
E-Mail: lewisc@pcglabs.mun.ca
¹Ocean Sciences Centre, Memorial Univ. of Newfoundland, St. John’s, Newfoundland; ²Department of Fisheries and Oceans, Newfoundland, Canada

Session: AdvO14

Abstract: Seine surveys in Newman Sound in Terra Nova National Park, Newfoundland, have shown evidence that the abundance of juvenile white hake (Urophycis tenuis) in this area has been increasing since 1996. Through the past decade, density of juveniles of endangered Atlantic cod (Gadus morhua) in coastal nurseries has been negatively correlated with juvenile white hake density. We undertook a laboratory study to investigate anti-predator behaviours and habitat preference of wild juvenile white hake and Greenland cod (G. ogac). We also determined the potential for habitat competition between the two species before, during, and after exposure to a predator (age 3+ Atlantic cod). Habitat preference was determined by dividing the bottom of two experimental arenas (2 x 2 x 0.5 m) into thirds and covering these with cobble,
sand, or artificial eelgrass. Time spent aggregating (schooling or shoaling) increased in both species during predator exposure, but more so for juvenile cod. We observed higher frequency of aggression by juvenile hake than cod. The habitat preferred for both species was eelgrass (*Zostera marina*), which was consistent with field observations of inshore nursery habitats. Eelgrass is also the preferred nursery habitat of juvenile Atlantic cod along the Newfoundland coast. Interactions with white hake may be limiting cod recovery. Funded by NSERC and Fisheries and Oceans Canada.

**GROWTH HORMONE AND INSULIN-LIKE GROWTH FACTOR GENE EXPRESSION IN EARLY EMBRYOS OF RAINBOW TROUT (Oncorhynchus mykiss) REARED AT TWO TEMPERATURES**

M. Li*, J. Greenaway, J. Raine, J. Petrik, A. Hahnel and J. Leatherland  
E-Mail: mao@uoguelph.ca  
Dept. of Biomedical Sciences, University of Guelph, Canada.

**Session:** EarP3  
**Abstract:** Rainbow trout embryo development is strongly influenced by temperature, and within certain limits, the overall rates of development of trout reared at different temperatures are similar when age is calculated as degree-days (days x °C). In this study we used real time RT-PCR to examine the pattern of the expression of genes encoding for GH and IGF, and their receptors in rainbow trout embryos prior to the appearance of the somatotropic (GH-IGF) axis. Embryos were reared at either 8.5 °C or 6.0 °C to determine if there were compensatory changes in the development of the GH-IGF axis in response to altered developmental rates of the embryos. The study demonstrated the expression of GH1, GH2, IGF-1 and IGF-2 genes, and their receptor (GHR1, GHR2, IGF-RIa and IGF-RIb) genes prior to the appearance of immunoreactive GH in the pituitary gland, suggesting a role for these hormones in early development. The rates of expression for all genes increased markedly with embryo age, with no evidence of compensation related to the different developmental rates of embryos reared at the two temperatures. Funded by NSERC and OMAF.

**EXPRESSION AND REGULATION OF CA$^{2+}$ TRANSPORTERS AND CA$^{2+}$ UPTAKE IN ZEBRAFISH**

B.K. Liao¹, T.C. Pan,¹ A.N. Deng², J.C. Shiao¹, S.C. Chen¹, M.Y. Chou² and P.P. Hwang¹,²  
E-Mail: phwang@gate.sinica.edu.tw  
¹Inst. of Cellular and Organismic Biol., Academia Sinica, Taiwan; ²Instit. of Fish. Sci., National Taiwan Univ., Taiwan  
**Session:** IonO20  
**Abstract:** The present work aimed to study the role of ECaC (epithelial calcium channel), NCX (sodium/calcium exchanger) and PMCA (plasma membrane calcium ATPase) in the Ca$^{2+}$ uptake mechanism in zebrafish (Danio rerio). In silico approach was used to predict the ECaC, NCX and PMCA isoforms in zebrafish using ENSEMBLE and NCBI database. By RT-PCR, one ECaC, five NCX (NCX1, 2, 3, 4a and 4b) and six PMCA (PMC1a, 1b, 2a, 2b, 3b and 4a) were found to express in zebrafish gills. The zECaC was expressed in the skin covering the yolk sac of embryos at 24 h post-fertilization (hpf). The expression expanded to cover the skin of the entire yolk sac following embryonic development and began to occur in the gill filaments at 96 hpf. In correspondence to the profile of ECaC expression, the Ca$^{2+}$ influx and content began to increase at 36~72 hpf. Knockdown of the zECaC with morpholino injection was found to cause a severe decline in larval Ca$^{2+}$ influx and content, demonstrating the role of the zECaC in Ca$^{2+}$ uptake function. Acclimation to low-Ca$^{2+}$ (0.02 mM) fresh water caused an upregulation in zECaC mRNA expression, but never showed significant effect on the expressions of the zNCX and zPMCA isoforms. Co-localization of zECaC mRNA and the Na$^{+}$/K$^{+}$-ATPase α subunit indicated that only a portion of the mitochondria-rich cells expressed zECaC mRNA. These results suggest that the zECaC plays a key role in Ca$^{2+}$ absorption mechanisms of fish. Funded by NSC and Academia Sinica, Taiwan.

**TRANSMITTER EFFECTS: CONSIDERATIONS FOR TELEMETRY STUDIES**

T. L. Liedtke, I. N. Duran and C. D. Smith  
E-Mail: Theresa_Liedtke@usgs.gov  
U.S. Geological Survey, Columbia River Research Laboratory Cook, Washington, USA  
**Session:** TelO28  
**Abstract:** Implicit in the conduct of telemetry studies is the assumption that the transmitter has negligible effects, and therefore findings from the tagged population can be extrapolated to the untagged population. Fish telemetry studies typically evaluate transmitter effects by comparing mortality, tag loss, swimming performance, buoyancy compensation, and predator avoidance ability of tagged fish relative to untagged controls. We present findings from one study and make recommendations on study design and performance metrics for future evaluations. We measured the buoyancy compensation and critical swimming speeds (Ucrit) of juvenile sockeye salmon (*Oncorhyncus nerka*) to test for effects of implanted radio transmitters (14.5 x 6.3 x 4.5 mm, 0.65 g in air). The transmitter weight to body weight ratio of test fish ranged from 1.5 to 6.5%. The Ucrit of tagged fish and untagged controls was measured 1 and 5 d after transmitter
implantation using a ramped protocol in a Blazka-style respirometer. There were no significant \( \text{Ucrit} \) differences between tagged and control fish after 1 d (4.4 BL/s) or 5 d (4.3 BL/s). Buoyancy compensation was determined in a pressure chamber by measuring the pressure reduction at which fish were neutrally buoyant before and after tagging. Tagged fish retained an average of 83\% of their initial buoyancy immediately after implantation, and untagged controls retained 99\%. By 6h after implantation (given access to air), the buoyancy of tagged fish was not significantly different from controls. These findings suggest that the transmitter had limited effects on the fish. We recommend using a full range of performance measures to evaluate transmitter effects. Funded by The US Army Corps of Engineers.

FOUR DIMENSIONAL IMAGING OF GFP-TRANSGENIC ZEBRAFISH (Danio rerio) EMBRYOS UNDERGOING CADMIUM TREATMENT
A. C. C. Lin and S. H. Cheng
E-Mail: cclin@cityu.edu.hk
Department of Biology and Chemistry, City University of Hong Kong, 83 Tat Chee Avenue, Hong Kong

Session: FisO9

Abstract: Over the past few years, many zebrafish transgenic lines have been generated with the Green Fluorescent Protein (GFP) for easy visualization of the transgenes. With these transgenic lines, we can observe accurately the temporal and spatial expression of the transgene. With the increasing popularity of using zebrafish embryos as model organisms to study the toxicity of anthropogenic substances, we investigated whether the exposure to toxicants will affect the dynamics of organ formation. To achieve this goal, we developed four dimensional (4D) imaging which studied the changes of the three dimensional (3D) measurements of a target organ over a duration of time. Different imaging systems for obtaining 3D data from in vivo specimens have been developed but they usually involved large and expensive machines and sophisticated computer programmes. We report here an experimental set up using a simple inverted compound microscope and a commercially available bioimaging software to detect the 4 dimensional changes of the shh:GFP expression in transgenic zebrafish embryos. We used this 4D system to study the effect of cadmium on the shh transgene expression. In untreated zebrafish embryos, the 3-D volume of shh could first be detected at about 9 hours post-fertilization (hpf), increased steadily in the next 7 hours, peaked at about 17 hpf and decreased in the next 4 hours. In cadmium exposed embryos showing severe malformations, there was a significant decrease in shh:GFP expression volume and a delay in peak expression of the transgene. Our system demonstrated that the dynamics of organ formation could be affected by exposure to toxicants. Funded by the Research Grants Council of Hong Kong Project # CityU 1109/01M.

NSAIDS IMPACT ZEBRAFISH (Danio rerio) OVARIAN FUNCTION
A. Lister and G. Van Der Kraak
E-Mail: alister@uoguelph.ca
Dept. of Integrative Biology, Univ. of Guelph, Canada

Session: ImpP6

Abstract: The detection of non-steroidal anti-inflammatory drugs (NSAIDs) in surface waters led us to investigate the potential impact of these drugs on ovarian function in zebrafish. NSAIDs are designed to reduce prostaglandin (PG) production by inhibiting cyclooxygenase (COX) enzymes. PG are involved in the regulation of several reproductive processes in fish, including ovulation. We showed that exposure of groups of zebrafish to 100 mg/L indomethacin (INDO) produces significantly fewer eggs and reduces whole-body levels of PGE2 compared with fish exposed to 1 mg/L INDO or solvent control. In order to investigate further the mechanism(s) by which NSAIDs impact ovulation in zebrafish, we exposed groups of breeding fish to 100 mg/L of INDO, diclofenac, or aspirin for 7 days and measured ovarian levels of (1) PGF2a and 17a,20b-P by EIA, and (2) mRNA expression of enzymes involved in the mobilization or conversion of arachidonic acid to PGs by Real-Time PCR. Our results show that INDO and diclofenac reduced the levels of PGF2a, while none of the treatments affected the levels of the maturation-inducing steroid, 17a,20b-P. INDO and diclofenac also tended to reduce the levels of mRNA of the genes PGE synthase, cytosolic phospholipase A2, COX-2, and to a lesser extent, COX-1. Currently, we are analyzing the livers of the fish to determine whether these NSAIDs impacted mRNA levels of the metabolizing enzymes, CYP1A1 and CYP3A65. Our zebrafish short-term exposure regime is a convenient method to investigate contaminant-induced reproductive impairments (i.e., egg production) and allows for detailed analyses of possible mechanisms of action. This work has been funded by The Salamander Foundation, OGS, and NSERC.
THE GYNOGENESIS OF CRUCIAN CARP USING THE SPERM OF BLUNT SNOUT BREAM
Shaojun Liu, Yuandong Sun, Zhun Zhang, Jiaming Shen and Jingpeng Yan Yun Liu
E-Mail: lsj@hunnu.edu.cn
Key Laboratory of Protein Chemistry and Fish Developmental Biology of State Education, College of Life Sciences, Changsha, 410081, China

Session: LinO9
Abstract: In catalog, the crucian carp and blunt snout bream belong to different subfamilies. The red crucian carp (Carassius auratus red var.) and Japanese crucian carp (Carassius auratus cuvieri) both with 100 chromosomes belonged to Cyprininae subfamily. The blunt snout bream (Semicossyphus pulcher) with 48 chromosomes belonged to Cultrinae subfamily. In chromosome number, appearance, and feeding habit, blunt snout bream is quite different from red crucian carp and Japanese crucian carp. In the present study, the eggs of red crucian carp and Japanese crucian carp which were activated by the UV-treated sperm of the blunt snout bream, and then were cold-shocked, successfully developed into diploid gynogenetic progeny with 100 chromosomes. The duration of UV-treatment was 30-40 minutes and the duration of the cold-shock was 35-45 minutes at the water temperature of 4°C. The appearance of gynogenetic progeny of red crucian carp with the red body color was similar to the red crucian carp, and the appearance of gynogenetic progeny of Japanese crucian carp with the silver body color was similar to the Japanese crucian carp. Both the Japanese crucian carp and red crucian carp were used to as the diploid maternals to produce the triploids by mating them with the males of the tetraploid hybrids of red crucian carp × common carp. So the gynogenesis of red crucian carp and Japanese crucian carp had biological significance in both basic research and the practical application. On the other hand, we made the distant crosses: red crucian carp × blunt snout bream, Japanese crucian carp × blunt snout bream. The results indicated when the blunt snout bream performed as the paternal, and red crucian carp, Japanese crucian carp acted as the maternal, respectively, a great number of living offspring were produced. But in the reversal crosses in which the blunt snout bream acted as the maternal, and the other two kinds of crucian carp acted as the paternal respectively, there was no living progeny. In the crosses of red crucian carp (♀) × blunt snout bream (♂), both the tetraploid and hybrids were found. The tetraploid possessed 148 chromosomes forming four sets of chromosomes, two from the maternal-red crucian carp and two from the paternal-blunt snout bream. The tetraploids were grey in body color and had one pair of barbells. However, the triploid hybrids possessed 124 chromosomes making up three sets of chromosomes, two from the maternal-red crucian carp and one from the paternal-blunt snout bream, and they were black in body color and had no barbells. In the crosses of Japanese crucian carp (♀) × blunt snout bream (♂), only the triploids were found, no tetraploid being observed. The triploids had 124 chromosomes forming three sets of chromosomes, two from the maternal-Japanese crucian carp or tetraploid hybrids, one from the paternal-blunt snout bream. The triploid hybrids of Japanese crucian carp (♀) × blunt snout bream (♂) were silver in body color and had no barbells. We could distinguish the gynogenetic offspring from the real hybrids by examining their appearance, body color, and chromosomal number. The formation of both of the gynogenetic progeny and the tetraploid and triploid hybrid progeny had important significances in both the basic research and fish ploidy-manipulation breeding.

EXTERNAL MORPHOLOGY AND SEX STEROIDS AS INDICATORS OF GONAD STATE
IN CALIFORNIA SHEEPHEAD (Semicossyphus pulcher)
Kerri A. Loke, Michael A. Sundberg, Kelly A. Young and Christopher G. Lowe
E-Mail: kloke@usa.net
California State University Long Beach, Long Beach California

Session: AdvO5
Abstract: California sheephead are commercially valuable, protogynous hermaphrodites whose external morphology changes as they transition. We determined the reliability of using external morphology and sex steroid concentrations to predict gonad state and sought to find morphometric measures to make sex determination in the field more accurate. Thirty sheephead were collected from June to August at Santa Catalina Island. External morphology was documented and gonads and blood samples were collected. A histological assessment of gonadal tissue was used to determine whether fish were immature, female, transitional or male, and if gonads were functional. Transitional fish were found during the breeding season. Morphometric data showed morphology cannot be accurately used to sex sheephead. Testosterone (T) and estradiol (E2) concentrations, determined by radioimmunoassays on blood plasma were correlated to gonadal sex. E2 concentrations were not detected among immature nor transitional fish; however, E2 was detected in active males. Breeding female sheephead had the highest levels of E2. T concentrations were observed in all sexes caught during summer and did not differ among immature, female, and transitional fish; however, there was a 4.4-fold increase in males as compared to other groups. Therefore, steroid concentrations during the breeding season may be used to determine sexual state. These data suggest that fishing pressure may have resulted in skewed sex ratios and sex change during the breeding season, which could reduce overall reproductive output. Supported by California Dept. of Fish & Game 07304905.
FROM LISTS OF PROTEINS TO FUNCTIONAL SETS: PROTEOMICS IN ZEBRAFISH AND SUNFISH

Richard Londraville1, Peter Niewiarowski1, Sarah Edmonds1, David Jury1, Suma Kaveti2 and Michael Kinter2

E-Mail: Londraville@uakron.edu

1University of Akron, Dept. of Biology USA; 2Cleveland Clinic Foundation, USA

Session: ProO13

Abstract: We are pursuing basic physiological questions in fishes by using proteomics as a hypothesis-generating step. To date we have examined effects of high-calorie diet on zebrafish (Danio rerio) liver proteome, and effects of parasitism (black spot) on bluegill sunfish (Lepomis macrochirus) plasma proteome. We resolved 400-700 bands per gel in the zebrafish experiments, and 350-500 bands in bluegill. In both cases, the number of bands detected was significantly reduced in the treatment (high calorie, parasitized) vs. control (normal calorie, non-parasitized) groups. Homologous bands were compared across gels and treatments to assess relative differences in protein expression. Bands of interest were excised and submitted to mass spectrometry analyses for identification (trypsin digestion, ESI-LC-MS/MS (ITD), CID, MALDI-TOF). To date, >50 proteins have been identified per experiment. Among the proteins that change the greatest with diet (zebrafish liver) are enzymes of intermediary metabolism, fat-storage proteins, and antioxidant proteins. In bluegill, proteins that are differentially expressed with parasitism are consistent with the acute phase response (APR) of the initial innate immune response. We are now using the Gene Ontology (GO) database to assign differentially expressed proteins to known functions, with the goal of divining a ‘big picture’ response of the proteome (similar to genome studies). Funded by Univ. Akron.

EFFECTIVENESS OF VR ACOUSTIC RECEIVERS IN MONITORING MOVEMENTS OF FISHES IN DIFFERENT MARINE HABITATS

C.G. Lowe1, K. Anthony1, L. Bellquist1, E. Jarvis1, T. Mason1, D. Topping2, J. Vaudo3 and J. Caselle4

E-Mail: clowe@csulb.edu


Session: TelO22

Abstract: Vemco VR acoustic receivers have been used to quantify movement patterns, home range, and site fidelity of marine fishes in a wide variety of habitats; however, varying abiotic conditions (temp, depth, geology) and the number of tagged fish within the area can significantly influence the effectiveness of these receivers in detecting tagged individuals. We use several techniques to quantify the effectiveness of different VR arrays used in shoreline surfzones, kelp beds, and offshore oil platforms. VR receivers in shallow (<2 m depth) surfzone habitats were able to detect an avg. 68% of signals emitted to an avg. max. distance of 275 m. Max. detection distance of different receivers varied with increased tidal height. VR receivers in kelp bed habitats where additional tagged individuals were present showed a significant decrease in detection frequency (26-54%) within a 50 m range. Mean detection rates decreased linearly with increase distance away from receivers between 17 and 165 m. However, detection ranges varied considerably among receivers depending on the depth of the tag and receiver location. Detection rates decreased significantly with increased number of tagged individuals at offshore oil platforms. These results indicate that calibration methods must be used to determine functional ranges and detection probabilities of VR receivers in each application. More active species show lower detection rates. Failure to calibrate an array could result in misinterpretation of degree of site fidelity, movement patterns, and behavioral interactions. Supported in part by California Sea Grant #s NA86RG0054 and NA06RG042, and Minerals Management Service Coop. Agreement # 1435-01-04-CA-34196.

THE EFFECT OF ENVIRONMENTAL LEVELS OF PESTICIDES ON SALMONID FECUNDITY AND EMBRYO DEVELOPMENT

N. Lower and A. Moore

E-Mail: nicola.lower@cefas.co.uk

CEFAS, Lowestoft Laboratory, UK

Session: ImpP8

Abstract: The decline in wild stocks of Atlantic salmon (Salmo salar L.) throughout the NE Atlantic has been attributed to a variety of factors operating in both the freshwater and marine environments. Salmon are exposed to a suite of contaminants during sensitive periods in their life cycle and previous studies have shown that exposure to low levels of pesticides disrupts pheromonal-mediated spawning. The aim of these studies was to investigate the impact of the pesticide atrazine on adult female fecundity, and the sheep-dip pesticides cypermethrin and diazinon on the early-life cycle stages of the salmon. Ripe adult female salmonids were exposed to water-borne atrazine for 5 days, after which time the eggs were fertilised and subsequent survival was monitored. In a separate study, exposure of eggs and milt to low levels of cypermethrin and diazinon during fertilisation significantly affected both the number of fry that emerged and the timing of
that emergence. There was a reduction in the survival of the fry, as well as a higher incidence of fry deformities following insecticide exposure. Histopathological analysis of fry exposed to the insecticides during fertilisation showed malformed notocords and myotomes of the spinal cord. These results may have significant implications for the successful reproduction of salmon in contaminated waters, and may affect recruitment back to the population. This work is funded by the UK Government Department of Environment, Food and Rural Affairs.

THE EFFECT OF CODED WIRE TAGGING ON STRESS LEVELS AND SEAWATER SURVIVAL IN ATLANTIC SALMON SMOLTS (Salmo salar L.)
N. Lower1, W.D. Riley1, T. Ellis2 and A. Moore1
E-Mail: n.j.lower@cefas.co.uk
1CEFAS, Lowestoft Laboratory, UK; 2CEFAS, Weymouth Laboratory, UK

Session: WelP3
Abstract: The decline in salmon stocks in the NE Atlantic has been partly attributed to poor natural survival in the marine environment. Coded wire tags (CWT) implanted into the nasal cartilage of salmon smolts are one of the assessment techniques used to obtain estimates of return rates at a number of rivers. However, the procedure of handling, anaesthesia and tagging of both wild and hatchery fish has been suggested to have a negative effect on their welfare and subsequent survival. A non-invasive method of measuring cortisol levels in water was used to assess the effect of a routine tagging procedure on stress levels in smolts. Cortisol release rates were calculated for individual smolts subjected to handling, with and with anaesthetic; and for CWT insertion, with and without the removal of the adipose fin. Recovery was monitored in freshwater for 4 days and in saltwater for 3 days. At the end of the experimental period, all smolts were physiologically adapted to the saline conditions. Cortisol release rates into the water were affected by the handling procedures. Cortisol release had returned to baseline levels by the end of the study however, and levels of plasma cortisol at the end of the study also showed no significant difference between treatment groups. Measuring cortisol in water is a practical indicator of stress levels in fish and should be applied to those tagging techniques routinely used as tools for population assessments. This work is funded by the UK Government Department of Environment, Food and Rural Affairs.

REAL-TIME RT-PCR QUANTIFICATION OF BRAIN CORTICOTROPHIN-RELEASING FACTOR mRNA IN RAINBOW TROUT (Oncorhynchus mykiss) AND ATLANTIC SALMON (Salmo salar)
S.L.Ludke1, N.W.Pankhurst1 and R.E.Peter2
E-Mail: Shilo.Ludke@jcu.edu.au
1Fish Endocrinology Laboratory, James Cook University, Townsville Australia; 2School of Biological Sciences, University of Alberta, Canada.

Session: MolP1
Abstract: To investigate corticotrophin’s (CRF) regulatory role in short term stress and feeding regimes we developed a quantitative real time PCR assay, using the Corbett Rotor-Gene for expression analysis in several brain regions. The full length sequence of Trout CRF has been sequenced and the reference gene β-actin for trout and salmon were cloned and partially sequenced to confirm amplicon identity. Salmon CRF and EFIA sequences are anticipated shortly. The cDNA obtained through mRNA extraction from adult rainbow trout and juvenile Atlantic salmon brains yielded CRF and β-actin amplicon sizes of 123bp and 134bp (salmon); 123bp and 81bp (trout). Trout CRF sequence analysis shows between 60-66% homology with various CRF sequences including goldfish Carassius auratus and white sucker Catostomus commersoni. The distribution pattern of CRF expression in trout brain is comparable with CRF expression determined using Northern blotting techniques, showing the expression hierarchy peaks in the telencephalon and hypothalamus and then gradually declines through the hindbrain/cerebellum, optic tectum and pituitary. Whilst salmon expression data is still under investigation, preliminary rainbow trout data suggests that CRF may not instigate the suppression of feeding during acute stress. Funding for this study was provided through the Australian Research Council Industry Linkage Program.

EFFECT OF HYPOXIA, HEART RATE AND ADENOSINE ON IN VIVO GLUCOSE UPTAKE IN A HYPOGLYCEMIC FISH, Myxocheilus scorpius
T.J. MacCormack and W.R. Driedzic
E-Mail: tmacc@mun.ca
Ocean Sciences Centre, Memorial Univ. of Newfoundland, Canada

Session: HypO8
Abstract: The majority of teleost fish have a limited capacity for glucose homeostasis and the regulatory mechanisms controlling in vivo carbohydrate utilization in fish are poorly understood. In this context, cardiovascular parameters and tissue glucose uptake rates were measured in the sculpin (Myxocheilus scorpius) under a number of treatment conditions.
Sculpin exhibit a bradycardia under hypoxia and maintain whole animal glucose turnover and glucose uptake rates in heart, brain, gill, spleen, and white muscle. Atropine eliminated the bradycardia and tended to increase myocardial glucose uptake. Injecting atropine-treated fish with the adenosine receptor inhibitor 8-(p-sulfophenyl)theophylline (8SPT) lead to a further, significant increase in heart glucose uptake to levels 5-fold higher than untreated hypoxic fish. Glucose uptake is the rate-limiting step in utilization in most tissues. The majority of intracellular glucose is unphosphorylated, suggesting that hexokinase is important in the control of the tissue glucose gradient. White muscle accumulates glucose under normoxia to twice the levels in plasma suggesting the presence glucogenic pathways. Unique muscle glucose handling may contribute to the poor capacity of some fish to defend glucose homeostasis. Hypoxic adenosine accumulation was absent, even in animals treated with atropine. Cardiac adenosine levels in sculpin do not appear closely linked to oxygen supply or myocardial work load. 8SPT did not affect cardiovascular parameters in atropine-treated sculpins exposed to hypoxia. The data indicate a limited role for adenosine in this species. Funded by NSERC and The Canadian Foundation for Innovation.

ENERGY DYNAMICS OF JUVENILE CHINOOK SALMON DURING EMIGRATION FROM FRESHWATER TO THE COASTAL OCEAN

R. B. MacFarlane
E-Mail: Bruce.MacFarlane@noaa.gov
Fisheries Ecology Division, Southwest Fisheries Science Center, NMFS, Santa Cruz, CA, USA.

Session: FroO3
Abstract: Losses due to nodavirus (NNV) disease are one of the main impediments to the successful culturing of many marine fish species. The virus can cause 100% mortality in larvae; however, empirical evidence suggests that NNV is carried within the juveniles and adults without obvious clinical signs. The goal of this study is to examine the role of elevated temperature in NNV disease in Atlantic cod. Two hundred cod (20-30g), from a population suspected to be carriers of NNV, were evenly stocked in 10 tanks. Five tanks were held at ambient seawater (4-6°C) and five at 17°C. Fish in 4 tanks at each temperature (total 160 fish) were injected i.p. with 10⁵ TCID₅₀ ml⁻¹ NNV. One tank at each temperature (total 40 fish) was injected with culture medium only. Fish were monitored for disease and samples for RT-PCR were obtained over a 21 day period. Although high proportions (>60%) of both the control and challenged groups tested positive for NNV there were no signs of disease in control groups or challenged groups held at ambient temperature. Thirty nine percent of the challenged fish held at 17°C showed signs of disease. Our results show that cod can be carriers of NNV and that elevated temperature can cause overt disease. We are presently determining whether there is a relationship between temperature, presence of virus and the expression of immune-related genes known to be important in viral diseases.

VARIATION IN EGG SIZE IN PACIFIC SALMON

D. D. MacKinlay
E-Mail: mackinlay@sfu.ca
Fisheries & Oceans Canada, 401 Burrard St. Vancouver BC V6C 3S4 Canada, Dept. Biological Sciences, Simon Fraser Univ., Canada

Session: EarO2
Abstract: Eggs of Pacific salmon vary considerably in size dependent on the species, stock, age-class, maternal parent size and rearing history. Egg sizes range from less than 0.07 g (for small sockeye salmon eggs) to greater than 0.7 grams (for large Chinook salmon eggs). Eggs from the same female are very similar in size (coefficient of variation ~ 5%) but different females from the same stock (even ones of similar body size) can have very different sized eggs. On the contrary, the germinal disk of salmon eggs (the disk of protoplasm floating on a sea of yolk that contains the genetic material and forms the original cells of the developing embryo) is much less variable in size (0.7-1.3 mm in diameter) and similar in size for all species. Therefore, the embryo starts at about the same size in all salmon but reaches different sizes dependent on how much yolk is present. There must be a feedback mechanism that informs the developing embryo that all of its organs must be completed at a smaller size if the yolk supply is smaller. The variation in egg size for Pacific salmon is likely an adaptive response to an unpredictable and volatile environment, allowing the species to survive under a variety of environmental conditions.
DEVELOPMENT, STANDARDIZATION AND VALIDATION OF MUMMICHOG (Fundulus heteroclitus) BIOASSAYS TO DETERMINE EFFECTS OF ENDOCRINE DISRUPTING SUBSTANCES

D.L. MacLatchy1, R.E.M. Peters1, S.C. Courtenay2 and G.J. Van Der Kraak3

1Department of Biology and Canadian Rivers Institute, University of New Brunswick, Saint John, NB; 2Fisheries and Oceans Canada, Moncton, NB and CRI, UNB Fredericton, NB; 3Department of Integrative Biology, University of Guelph, Guelph, ON, Canada

Session: ImpO11

Abstract: We have been developing bioassays in the estuarine mummichog (Fundulus heteroclitus) to identify the effects of endocrine-disrupting substances. The bioassays have been validated by exposures to 17α-ethynyl estradiol (EE2), an environmentally-relevant estrogen. We have exposed pre-spawning, reproducing, and developing fish to environmentally-relevant concentrations (0, 0.1, 1, 10 and 100 ng/L) of EE2 in a 24-hour static daily renewal system. Adult reproductive status is assessed by steroid hormone levels, in vitro gonadal steroid production, fecundity (cumulative egg production) and relative organ sizes. Eggs are monitored for important developmental endpoints (viability, time to hatch, and length at hatch). Critical juvenile endpoints (survival, growth rate, and developmental abnormalities) are monitored during maturation. EE2 alters reproductive endocrine status and lowers cumulative hatch at higher concentrations. Hatching success is not different among the groups. The embryos exposed to the highest EE2 concentration hatch sooner and are larger at hatch. At 100 ng/L EE2, secondary sexual characteristics and gonadal development are altered, with the fish showing predominately female characteristics. Overall, the bioassay has identified endpoints sensitive to estrogen exposure as well as the sensitivity of this species to estrogenic effects. Supported by NSERC and TSRI and CWN.

PHYSIOLOGICAL SUBSTRATES FOR SYNAPTIC MEMORY IN THE OLFATORY SYSTEM OF THE ATLANTIC SALMON (Salmo salar)

Nikki K MacLeod1, John C. Curtis1 and John D. Armstrong2

1Centre for Integrative Physiology, University of Edinburgh, Edinburgh, Scotland; 2Freshwater Laboratory, Fisheries Research Service, Pitlochry, Scotland.

Session: OlfO8

Abstract: Inspired by the studies of Nevitt and Dittman demonstrating the extraordinary ability of individual salmon olfactory receptor cells to “tune” their biochemistry and physiology to specific odours at the time of parr-smolt transformation (PST), we have undertaken to look for downstream changes in the neural circuits of the olfactory bulb. We are addressing the capacity of synapses in the fish olfactory bulb to undergo alterations in efficacy following the application of conditioning stimuli in the hope that this will provide clues on how the unconditional memories induced in the receptor cells during PST are transformed into permanent neural memories that can be recalled during homing to guide the fish to their natal streams. Initial experiments are investigating the field potentials evoked in the olfactory bulb by stimulation of the olfactory nerve. The complex wave-form is generated by a series of sequential synaptic events in bulbar neurones. Our first results have revealed that the field potential generated by activation of the olfactory nerve-mitral cell synapses within the glomeruli can be conditioned by particular patterns and rates of afferent impulses to show both short and long-term changes in synaptic efficacy. These changes are similar to those reported extensively for other neural systems such as the rodent hippocampus but require very different conditioning stimulus protocols. Surprisingly, to date, changes in synaptic plasticity of the primary olfactory nerve evoked response, which include Post Tetanic Potentiation, Short Term Potentiation and Long Term Potentiation appear not been reported for the olfactory bulb of any other species.

BEHAVIORAL STUDY ON UPSTREAM MIGRATION OF CHUM SALMON IN THE SHIBETSU RIVER

Y. Makiguchi1, H. Nii2, K. Nakao2 and H. Ueda1

1Division of Environmental Science Development, Graduate School of Environmental Science, Hokkaido University, North 9 West 9, Kita-ku, Sapporo, Hokkaido 060-0809; 2Hokkaido Farming Fisheries Promotion Corporation, North 3 West 7, Chuo-ku, Sapporo, Hokkaido 060-0003; 3Laboratory of Aquatic Ecosystem Conservation, Field Science Center for Northern Biosphere, Hokkaido University, North 9 West 9, Kita-ku, Sapporo, Hokkaido 060-0809, Japan

Session: TelP6

Abstract: The channelization of river for flood control and water utilization has caused the disappearance of biodiversity of river environment. To restore the river environment, a segment of the Shibetsu River in northern Japan was reconstructed to create previous meandering condition in 2002. In 2005, we used electromyogram (EMG) telemetry and depth/temperature (DT) loggers to investigate the upstream migration behavior of adult chum salmon (Oncorhynchus keta). We estimated the relationships between EMG values and swimming speed of twelve adult chum salmon using the
swimming chamber, and then released in 7.25 km point from the estuary and tracked using a radio receiver (SRX_400). After tracking, we measure the river depth where the fish swam and the current speed using a current meter. Further, we used another ten chum salmon to measure critical swimming speed (Ucrit) in swimming chamber. Mean value of swimming speed and ground speed of tracked chum salmon were not significantly different between the channelized and reconstructed segment. However, the fish often held to swim at the site of artificial fallen trees in reconstructed segment. Water velocities exceeding Ucrit were measured in the segment. We suggest that holding behavior is important as rest during upstream migration to the spawning ground. Further, we observed holding behavior of a couple of chum salmon in the reconstructed segment. Habitats for holding place for salmon in the river may be important since they can await the arrival of other salmon to improve their reproductive success.

THE PHYSIOLOGICAL CHANGES INDUCED BY OTTER-TRAWL CAPTURE IN THE SPINY DOGFISH (Squalus acanthias)
J.W. Mandelman and M.A Farrington
E-Mail: jmandelman@neaq.org
Research Department, New England Aquarium, Boston, MA, USA.

Session: CapO4
Abstract: Heavily discarded as bycatch in commercial otter-trawl fisheries, Northwest Atlantic (NWA) spiny dogfish (Squalus acanthias) have reportedly experienced major population declines in recent years. Yet, the physiological effects of capture by mobile fishing gear as they pertain to the ultimate fate of discarded bycatch remain mostly unstudied in fishes and have yet to be addressed in this species or other elasmobranchs. To assess the responses of dogfish to otter-trawling capture, blood physiology from individuals landed in 45-60 minute tows (n = 183) and by a far less rigorous (2-3 minute) hook-and-line method (n = 79) were compared. Subsequent to sample processing, assays for key blood constituents were conducted in-situ (ISTAT clinical analyzers; readings for hematocrit) and in the laboratory (spectrophotometry; NOVA blood chemistry analyses). With the exception of plasma protein, (dogfish-size-adjusted) values from all parameters (whole-blood hematocrit; sera electrolytes (Na+, Cl-, K+); metabolites (whole-blood lactate anion, serum glucose and BUN); whole-blood vascular pH and gases (pO2, pCO2)) were markedly different (P < .001) as a function of capture-method and considerably more disturbed following trawl-capture. When applying accompanying findings alluding to low short- (72-hour) and longer-term (30-day) post-trawl mortality, the species appears quite able to cope with and recover from the physiological disruptions elicited by otter-trawling. Funding for all components of this study was supplied by a NOAA/NMFS Saltonstall-Kennedy grant and the New England Aquarium’s Research Department.

EFFECT OF GROWTH HORMONE TREATMENT ON GROWTH AND PUBERTY IN YELLOWTAIL FLONDER (Limanda ferruginea)
A.J. Manning, M.P.M. Burton and L.W. Crim
E-Mail: amanning@munalum.ca
Ocean Sciences Centre, Memorial Univ. of Newfoundland

Session: LinP2
Abstract: The positive relationship between growth rate and age at first maturation has been well documented for fishes. This correlation was explored in cultured yellowtail flounder by artificially stimulating growth rate. It was hypothesized that growth hormone (GH) treatment accelerates pubertal onset either by direct actions of GH and somatomedins, or indirectly through the metabolic state of fast growth. Immature females were treated with a slow-release formulation of recombinant bovine GH (Posilac®, Monsanto). Posilac® treated animals grew significantly larger than oil-injected controls after only 2-3 months of treatment. Samples at six months post-injection showed a mixture of immature and early pubertal females in both treated and control groups. No histological or endocrine evidence of accelerated maturation was seen among treated fish. A second sample made five months later demonstrated that overall ovarian development was slower in the treated group. Individual pubertal development was either indistinguishable from control females (n=3) or delayed (early vitellogenesis, n=4, or immature, n=1). Control females, in contrast, were in a pubertal state with only one out of eight females still in an early pubertal stage. These results show that artificially accelerated growth by GH does not promote pubertal onset or accelerate development. No direct effect of GH treatment is suggested given the individual variation in ovarian development. Delayed pubertal onset in some treated females is likely due to a GH induced utilization of energy reserves for growth that limited energy available for maturation. Funding was provided by CCFI and NSERC. Posilac® was donated by Monsanto.
VOLUME REGULATION IN TELEOST CHLORIDE SECRETING CELLS
INVOLVES SITE SPECIFIC TYROSINE PHOSPHORYLATION OF FOCAL ADHESION KINASE
Marshall*, W.S., Main, H. and Cozzi, R.R.F.
E-Mail: bmarshal@stfx.ca
Department of Biology, St. Francis Xavier University, Antigonish, Nova Scotia, CANADA
Session: IonO18
Abstract: Chloride cells in opercular membranes of euryhaline teleosts such as the killifish Fundulus heteroclitus are osmosensitive, in that hypotonic shock shuts off NaCl secretion while hypertonic shock stimulates NaCl secretion. The response is via phosphorylation/dephosphorylation of sodium, potassium, 2 chloride cotransporter (NKCC) in the basolateral membrane. We showed that a protein kinase cascade terminating in a protein phosphatase mediated hypotonic responses, including Src kinase (cSrc), extracellular signal regulated kinase 1 (ERK1), focal adhesion kinase (FAK), cJun N terminal kinase (JNK), protein kinase C (PKC), ste20 related proline rich stress kinase (SPAK), oxidative response gene (OSR1) and myosin light chain kinase (MLCK). FAK is a tyrosine kinase with multiple phosphorylation sites that colocalises with NKCC and integrin at the basolateral membrane, as detected by immunofluorescence. Further, hypotonic shock and clonidine rapidly dephosphorylate p-Y407-FAK, seen by immunoblot and immunofluorescence, implicating FAK in the osmosensitivity of chloride cells. Surprisingly, FAK phosphorylated at other sites (p-Y576 and p-Y861) is instead distributed in the intercellular tight junctions (Y861) and the apical membrane (Y576) and is not osmosensitive. Meanwhile, Y397 and Y577 are not phosphorylated in control or osmotic stress conditions. Thus FAK tyrosine phosphorylation is specifically site directed toward multiple functions in this epithelial system, only one of which (Y407) that is osmosensitive. Supported by NSERC Canada, CFI and ACOA.

AUTOTROPHIC CARBON SOURCES FOR PARACHEIRODON AXELRODI (OSTEICHTHYES, CHARACIDAE) IN THE MIDDLE RIO NEGRO BASIN, CENTRAL AMAZON, BRAZIL
Bruce G. Marshall, Bruce R. Forsberg, Mario J.F. Thomé-Souza
E-Mail: bruce@inpa.gov.br
Coordenação de Pesquisas em Ecologia, Instituto Nacional de Pesquisas da Amazônia, Manaus, AM, Brazil
Session: TroO2
Abstract: The cardinal is the most abundant species of the Brazilian ornamental fish trade, constituting more than 80% of the ornamental fish collected in the middle Rio Negro. Stable isotope analyses were used to identify the autotrophic carbon sources and trophic position for the cardinal in relation to the plant groups at the base of its foodchain. Periphyton, phytoplankton, tree and plant leaves and cardinals were collected in stream habitats, flooded forests and interfluvial swamps (campos) during peak flood, falling water and low water periods. δ¹⁵N values of the cardinal in relation to the plants at the base of the food chain indicated a trophic position of omnivore. Values of δ¹³C for the plants ranged from -43.1 to -26.4‰, with averages of -37.6, -32.6, -30.4 and -29.4‰ for periphyton, phytoplankton, flooded-forest leaves and campo leaves, respectively. The δ¹³C values for the cardinal ranged from –35.7 to -27.9‰, with an average of -31.4‰. Relative contributions of plants to fish carbon were estimated in two different stable isotope mixing models. A three source two isotope mixing model determined that the average relative contribution of periphyton was 28.3%, with values of 3.2% and 68.4% for phytoplankton and tree/shrub leaves, respectively. A two end-member mixing model produced a similar result for periphyton of 29%; however, seasonal variation was encountered throughout the hydrological cycle. The cardinals least enriched in ¹³C were encountered in November during the falling water period, indicating that they had perhaps recently migrated down from interfluvial campos where periphytic algae production is significant. Considering that algal production has been reported to be less than 1% of total primary production in the Rio Negro, these results could suggest some evidence of selective herbivory in the cardinal’s food chain. Funding sources: CNPq and LBA/NASA.

FOREVER YOUNG: DEVELOPMENTAL STAGING OF CALIFORNIA GRUNION IN NORMAL AND EXTENDED INCUBATION
K. Martin, J. Flannery, C. Moravek, A. Walker, and S. Bolan
E-Mail: kmartin@pepperdine.edu
Pepperdine University, Malibu, CA
Session: EarO9
Abstract: Embryos of beach-spawning California grunion Leuresthes tenuis (Atherinopsidae) incubate in damp sand above the tide line until triggered to hatch when waves wash them free. If not swept out by a syzygy tide series, the embryos extend incubation for as long as yolk energy resources persist, up to three times longer than the primary time required to reach hatching competence. At whatever time hatching is triggered, larval life begins. While the embryos are encapsulated within the clear chorion, they are alert and respond to stimuli. They maintain a high metabolic rate and can hatch within seconds once the environmental trigger presents. Thus the extended incubation period does not involve cryptobiosis or
arrested metabolism. We developed a staging series for the normal incubation period to hatching competence, approximately 10 days at 20°C. Then we hatched out embryos after different intervals in an extended incubation period, for up to 25 additional days. We photographed and measured the hatchlings initially and for four weeks of larval growth. At hatching, all hatchlings look similar. Those that hatched later were slightly larger and had more heavily pigmented melanophores but otherwise resembled primary hatchlings. Growth rates for the larvae fed ad libitum were similar no matter how late they began larval life, and all were approximately the same size within 21 days post hatch, no matter how many days they incubated. Unlike some terrestrially incubating amphibian embryos that advance in developmental stage while delaying hatching, grunion embryos appear to maintain steady metabolism but dramatically slow the progress of aging while waiting for the right trigger to enter into their next stage of life in the aquatic habitat. Primary funding is provided by California Sea Grant College NA04OAR4170038, the National Fish and Wildlife Foundation, and the US National Oceanic and Atmospheric Administration.

**IMPROVED TRANSGENIC TILAPIA FOR ACCELERATE GROWTH**

Rebeca Martinez, Yamila Carpio, Julio Cesar Rodriguez¹, Fidel Herrera, Antonio Morales, Reynold Morales, Zoila Abad², Eulogio Pimentel² and Mario Pablo Estrada

E-Mail: rebeca.martinez@cigb.edu.cu

Biotechnology in Aquatic Organism Department. CIGB. P.O. Box 6162, Havana 10600, Cuba. ¹Instituto de Endocrinología, MINSAP Zapata y C, Habana, Cuba ²CIGB, Camaguey, Cuba

**Session:** GenO7

**Abstract:** The genetic modification of aquatic organisms has become an important tool to improve the productivity of aquaculture and mariculture. We have obtained a transgenic tilapia line with accelerated growth which is capable of express the growth hormone in different tissues. Experiments were performed to evaluate the behavior of transgenic tilapia in comparison to wild tilapia as a way to assess the environmental impact of introducing transgenic tilapia into Cuban aquaculture. Studies were also conducted to evaluate, according to the principle of substantial equivalence, the safety of consuming transgenic tilapia as food also an experiment has been conducted to evaluate the composition of nutritionally and physiologically important molecules in transgenic tilapia compared with non-transgenic tilapia and their impact in the mammalian gut. The results obtained up to now, at least under the conditions found in Cuba, have shown no environmental implications for the introduction of this transgenic tilapia line and the safety in the consumption of tilG-transgenic tilapia as an alternative-feeding source for humans. It is know GH interacts with other hormones, and we would like to study the T3/T4 serum levels in transgenic fish to compare with non transgenic ones, by the other hand as it has been demonstrated exogenous GH plays an important role in the development, maintenance and function of the immune system, has been interesting compare the levels of NO production in the serum of transgenic and non transgenic animals. The results obtained let us to assert that this line is also a wonderful model to follow the GH action in diverse systems of the organism. Finally in order to obtain monosexual populations of heterozygote transgenic tilapia as a way to keep contained the transgenic strain fifteen homozygote males transgenic tilapia, were bred with forty five pseudo females and a manual sexing were carried out with offspring, given 89.7% of male heterozygote transgenic descendents.

**PRODUCTION OF ALL-FEMALE ATLANTIC HALIBUT FOR COMMERCIAL AQUACULTURE**

D. J. Martin-Robichaud, T.J. Benfey and M. Reith

E-Mail: martin-robindchaudd@mar.dfo-mpo.gc.ca

Fisheries and Oceans Canada, Biological Station, 531 Brandy Cove Road, St. Andrews, New Brunswick, E5B 2L9

**Session:** LinO7

**Abstract:** Immediate economic gains can be achieved by producing all-female Atlantic halibut populations for commercial aquaculture production. Female Atlantic halibut can grow twice as fast as males in their first 3 years, and males reach maturity prior to reaching a market size of 3-5 kg. Techniques to produce all-female Atlantic halibut populations will be summarized. Gynogenetic halibut produced using irradiated homologous sperm and pressure treatment to restore diploidy resulted in 100% females. Since gynogens contain only maternal chromosomes, this confirmed that Atlantic halibut females are homogametic (XX). Therefore, indirect feminization strategies similar to those used to produce all-female salmonid populations can be used to produce all-female halibut stocks for aquaculture. Direct hormonal sex reversal using androgens administered via feed to 30 mm FL juveniles for 45 d resulted in 100% phenotypic males. A subsample of these males was reared to maturity and all males produced viable sperm. Half of these phenotypic males are expected to be genetic females able to produce all-female stocks when crossed with normal females. Offspring from each male that was subjected to androgen treatments must be sexed to confirm which males are actually genetic females. Two out of 4 males evaluated in 2005 produced all-female offspring. Industry will be evaluating the genetic sex of further androgen treated males this year and building up a broodstock capable of producing all-female stocks for commercial production.
INDIVIDUAL VARIATION IN GROWTH OF AFRICAN CATFISH (*Clarias gariepinus*): A SEARCH FOR EXPLANATORY FACTORS
E-Mail: catarina.martins@wur.nl
Aquaculture and Fisheries Group, Wageningen University, Netherlands

**Session:** LinO13  
**Abstract:** Among farmed animals, fish exhibit the largest individual variation in growth. For the aquaculture industry, this growth variation has important consequences: it increases food wastages and thus the waste production of a farm; it may stimulate cannibalism/aggression and decrease welfare and product quality. This 4-years project aimed to understand the underlying factors responsible for the individual variation in growth of African catfish. Six experiments were performed using both individually and grouped housed juveniles. Individual differences in growth, feed intake, feed efficiency, feeding behaviour and stress response were quantified and their relationships established. In contrast to what is generally accepted for most fish species, the results of this project suggest that in catfish the individual variation in growth is not the result of marked dominance-subordinance relationships. Instead, genetic-based differences in feed intake, feed efficiency, feeding behaviour and stress response seem to play a role in explaining the growth variation. Individual differences in feed intake and feed efficiency contributed ± 85 and 15% to explain differences in growth. Feeding behaviour and stress responsiveness were related to feed efficiency: the most efficient individuals were both fast eaters and low stress responders. In practical terms, one may question the use of grading in this species as grading is done under the assumption that it disrupts an existing social hierarchy. Furthermore, the results of this thesis provide information which can be used in selection programmes for this species. Funded by the Foundation for Science and Technology, Portugal.

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THE EFFECT OF HYPOXIA ON GILL MORPHOLOGY AND IONOREGULATORY STATUS IN LAKE QINGHAI NAKED CARP (*Gymnocypris przewalskii*)
E-Mail: kuperman@sunstroke.sdsu.edu/
¹Department of Biology, San Diego State University, ²Department of Zoology, University of British Columbia, ³Department of Biology, McMaster University, ⁴Department of Biology, University of Waterloo, ⁵Department of Biology, Queen’s University, ⁶Department of Biology, University of Northern British Columbia, ⁷Department of Biotechnology, Zhejiang University.

**Session:** HypP4  
**Abstract:** The high altitude naked carp from Lake Qinghai was exposed to 24h acute hypoxia (0.3mg/L) followed by 12h recovery, with no mortality. During exposure to hypoxia, ‘wavy-convex’ mitochondria rich cells (MRC’s) of the gill filaments were transformed into “shallow-basin” cells within 12h, and MRC’s consisted predominantly of the a-subtype containing extensively developed mitochondria, tubular reticulum, and tubulo-vesicular system. Extensive mucus production and deposition on the filaments was observed during exposure to hypoxia. This may be part of a general stress response in fish, but may also play a role in ion exchange and water balance. In the lamellae, alterations included a gradual expansion of the functional respiratory surface (> 50%) combined with a reduction in the epithelial water-blood diffusion distance (<50%). These changes were initiated within 4h and almost complete within 12h. The changes were reversible, showing signs of recovery 12h following return to normoxia. The increase of caspase activity in gills occurred at 12h hypoxia exposure indicating possible involvement of apoptosis in the gill filament alteration. The large increase in lamellar surface area and reduction in diffusion distance presumably enhances gas transfer during hypoxia (especially in the presence of increased mucous production) but comes with an osmoregulatory cost, as both plasma [Na⁺] and [Cl⁻] levels were significantly reduced by 10% within 12h of hypoxia. Funded by NSERC, Canada and the Chinese National Science Foundation (30128016).

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CHARACTERIZATION AND EXPRESSION USING Q-RT-PCR OF GENES RELATED TO SEX DIFFERENTIATION IN ATLANTIC HALIBUT
M. P. Matsuoka* and M. Reith
E-Mail: makoto.matsuoka@nrc.ca
National Research Council, Institute for Marine Biosciences, Canada

**Session:** ProO9  
**Abstract:** Atlantic halibut aquaculture would benefit from the development of all-female lines, since females grow faster and reach a larger size than males. Determining the period when gonad development occurs would define the critical time when hormonal or environmental treatments should be applied to influence sex ratios. To understand sex differentiation at the molecular level, we have characterized steroid hormone biosynthesis genes, including ovary- and brain-type aromatase
and 11β-hydroxylase, which catalyze key steps in the synthesis of 17β-estradiol and 11-ketotestosterone, respectively. We have also investigated their expression during the period of sex differentiation in juveniles, as well as in various adult tissues, using Q-RT-PCR and have detected their expression in fish as small as 16 mm, which is earlier than when gonadal differentiation (GD) is detectable by histology (32 mm). In addition, partial cDNA sequences were obtained for steroid hormone receptor genes, steroidogenic enzyme genes including 17α-hydroxylase/C17, 21 lyase, 3β-hydroxysteroid dehydrogenase (HSD), 11β-HSD, 17β-HSD, and genes related to GD including three SRY-like box containing genes, sox-3, sox-5 and sox-9, anti-Mullerian hormone, steroidogenic factor 1, Wilms' tumor 1, and doublesex and mab-3 related transcription factor 1 (Dmrt1). We present the expression of these genes in various adult tissues and developing juveniles and relate them to aspects of sex specificity and GD. This study is a part of the Pleurogene project funded by Genome Canada/Genoma España.

WATER QUALITY REGULATES FISH COMMUNITY STRUCTURE IN A COLUMBIA RIVER RESERVOIR
E-Mail: alec_maule@usgs.gov
USGS, Columbia River Research Lab. Cook, WA. 1USGS, Klamath Falls OR; 2Ideal Health, Hood River OR; 3Idaho Department of Fish & Game, ID USA

Session: FroO30
Abstract: We examined year-class strength and growth of resident fish in Lake Rufus Woods, an impoundment of the upper Columbia River, to see if years of high total dissolved gas supersaturation (TDGS) or water temperature corresponded to years of poor growth of individuals or populations. Fish ages and year-classes were determined by counting the annual growth rings (annuli) in scales from four species collected in 1999. Incremental scale growth and fork length at capture were used to back-calculate length-at-age. General linear models and multiple range tests were used to look for differences in growth due to fish age and year-to-year environmental variability. All species had differences in incremental scale growth based on the age of the fish. Only walleye Stizostedion vitreum vitreum had differences in scale growth based on the environment with growth in 1996 (when TDGS was relatively high) greater than 1998 (when TDGS was relatively low). Year-classes of predatory fish (northern pikeminnow Ptychocheilus oregonensis, rainbow trout Oncorhynchus mykiss, and walleye) correlated positively with years of high TDGS (i.e., 1996, 1997) when year-classes of a prey fish (longnose sucker Catostomus catostomus) were weakest. Longnose sucker year-class strength correlated positively with temperature, and was poorest when that of the predators was greatest. These results suggest that predator-prey relations and, thus, community structure may be regulated by water quality. Funded by USGS and US Bureau of Reclamation.

METABOLIC COSTS OF FEEDING AND GROWTH IN ATLANTIC COD (Gadus morhua) LARVAE USING MICROCALORIMETRY
A. McCollum1, J. Geubtner1 and I. Hunt von Herbing1
E-Mail: ihuntvon@nsf.gov
1School of Marine Sciences, U. Maine, USA

Session: EarO10
Abstract: The energetic costs associated with growth as recorded by an increase in the total metabolic rate after feeding in cod larvae, were measured from hatching to 4 wks post-hatch at 10 °C. An increase in metabolic rate after feeding, or Specific Dynamic Action (SDA), is usually measured as an increase in oxygen consumption after feeding. In this study, SDA was measured as differences in the total heat output (THO) (aerobic+anaerobic metabolism) between unfed and fed larvae using a very sensitive thermal activity monitor (TAM), or microcalorimeter. Unfed THO increased with development from 2.14 mW at first-feeding to 23.72 mW at 4 weeks post-hatch. Increases of THO occurred within the first 2 h after feeding with rotifers (Brachionus sp.) and Artemia, remained high for up to 10 h and was significantly higher in fed than in unfed larvae. THO of unfed larvae increased more than 3 times from 16.56 mW at first-feeding (4 days post-hatch) to 47.84 mW at 4 weeks post-hatch. Estimates of SDA rose from 14.42 mW to 24.12 mW, representing a 1.67 factor increase over the duration of the study. Results show that 4 day old cod larvae exhibit some SDA and that the amount increases with size and age. That SDA remained elevated for many hours after feeding and increased with development, suggests that cod larvae allocate a large part of their energy budget to growth and for a long period of time after feeding in order to meet the demands of high growth rates.
ARE WE MISSING A MINERALOCORTICOID IN FISH? EFFECTS OF CORTICOIDS AND RECEPTOR INHIBITORS ON ION REGULATION IN ATLANTIC SALMON
S.D. McCormick1, M.F. O’Dea1, A.M. Moeckel1 and J.M. Shrimpton2
E-Mail: mccormick@umext.umass.edu

1USGS, Conte Anadromous Fish Research Center, Turners Falls, MA USA  1Organismic and Evolutionary Biology Program, University of Massachusetts, Amherst, MA USA; 2 Biology Program, Univ. of Northern British Columbia, Prince George, BC, Canada

Session: IonO10
Abstract: It has long been held that cortisol, acting through a single receptor, carries out both glucocorticoid and mineralocorticoid actions in teleost fish. The recent finding that fish express a gene with high sequence similarity to the mammalian mineralocorticoid receptor, suggests the possibility that a hormone other than cortisol carries out some mineralocorticoid functions in fish. To test for this possibility, we examined the ability of cortisol, 11-deoxycorticosterone (DOC) and aldosterone to increase salinity tolerance in Atlantic salmon. In vivo cortisol treatment for 6 to 12 days that resulted in increased physiological levels of cortisol also resulted in increased gill Na,K-ATPase (NKA) activity and improved salinity tolerance (lower plasma chloride after a 24 h seawater challenge). Administration of DOC and aldosterone did not increase either NKA activity or salinity tolerance. Data on the impact of cortisol, DOC and aldosterone on gill NKA alpha1a and alpha1b, GR and MR mRNA will be presented. RU486 effectively blocked the ability of cortisol to increase NKA activity and salinity tolerance, but spironolactone was only partially effective. Neither RU486 or spironolactone blocked changes in gill NKA activity or plasma chloride 6 days after transfer of fish from fresh water to seawater or from seawater to fresh water. The results provide support that cortisol, and not DOC or aldosterone, regulates salinity tolerance in salmonids, but do not rule out a role for DOC or aldosterone in other osmoregulatory or physiological actions

THE IMPACT OF CORTISOL ON TOADFISH GLUTAMINE SYNTHETASE AND UREA TRANSPORTER (TUT) MRNA EXPRESSION AND ACTIVITY
M. D. McDonald and P. J. Walsh
E-Mail: dmcdonald@rsmas.miami.edu
RSMAS, University of Miami, Miami, Fl. USA

Session: MolO8
Abstract: The gulf toadfish, Opsanus beta, has a fully functional ornithine urea cycle and is consequently able to produce and excrete predominantly urea, rather than ammonia, during times of stress. The toadfish also has a specialized urea excretion mechanism, namely, when the toadfish is ureotelic, urea is not excreted continuously across the gill, instead it builds up within the plasma and is excreted in distinct pulses once or twice daily. The glucocorticoid, cortisol, is highly implicated in the regulation of both urea production and excretion in toadfish. By quantitative PCR analysis, the impact of endogenous and exogenously loaded cortisol on the mRNA expression of tUT and the toadfish isoforms of glutamine synthetase, an important accessory enzyme for the ornithine urea cycle and the production of urea, was analyzed. Furthermore, changes in mRNA expression of these genes were compared to the activity of the proteins in vivo. An elevation of cortisol as a result of environmental stress results in an increase in the activity of glutamine synthetase. In addition, cortisol appears to affect the toadfish urea transporter (tUT); mRNA expression of tUT is upregulated when toadfish are naturally stressed or exogenously loaded with cortisol yet these conditions appear to inhibit tUT activation. This research has been funded by NSERC Canada, NSF (# IOB0455904) and a NIEHS Marine and Freshwater Biomedical Sciences Center Grant (#ES05705).

SEAWATER ACCLIMATION IN TILAPIA (Oreochromis mossambicus): ROLE OF CORTISOL
A. McGuire1, A. Takemura2 and M.M. Vijayan1
E-Mail: amcguire@uwaterloo.ca
1Department of Biology, University of Waterloo, Waterloo, Ontario, Canada; 2Sesoko Station, Tropical Biosphere Research Project, University of the Ryukyus, Okinawa, Japan

Session: IonP6
Abstract: Euryhaline teleosts use ion extrusion mechanisms to maintain ionic and osmotic homeostasis in environments varying from fresh water (FW) to seawater (SW). Although, Mozambique tilapia (Oreochromis mossambicus) is a euryhaline species, it can not survive during acclimation to full-strength SW (32 ppt). However, it can survive in SW after a pre-acclimation in 20% brackish water for 24 h. The pre-acclimation process allows tilapia to develop the osmoregulatory mechanisms crucial for SW survival. Therefore, the objective of this study was to examine if cortisol is playing a role in this pre-acclimation process necessary for SW residence. Mozambique tilapia in FW were injected with either vehicle (coco butter) or vehicle containing cortisol (50 mg/kg) and allowed to recover for 48 h. Groups of six fish
were then transferred to SW (32 ppt), while another six fish remained in FW and the fish were sampled 6 h post-transfer. Cortisol treatment significantly decreased gill metabolic capacity in the SW group. Gill Na\(\text{K}^+\)-ATPase activity significantly increased in SW tilapia; however cortisol injection attenuated this response. Despite changes in gill metabolism, cortisol treatment did not affect plasma ion levels in SW fish, indicating efficient ion regulation. Gill glucocorticoid receptor mRNA was significantly up regulated in SW fish, but this response was not modified by cortisol treatment. Overall, cortisol signaling may be playing a key role in the gill metabolic adjustments essential for SW acclimation in tilapia. Funded by NSERC discovery, NSERC PGS-M and 21st Century COE program.

**THE EFFECT OF WATER HARDNESS, ALKALINITY, PH, AND DISSOLVED ORGANIC MATTER ON THE OLFACTORIAL NEUROTOXICITY OF COPPER IN JUVENILE SALMON**

J.K. McIntyre\(^1\), D.H. Baldwin\(^2\), J.P. Meador\(^2\), D.A. Beauchamp\(^1\) and N.L. Scholz\(^2\)

E-Mail: jmcintyr@u.washington.edu

\(^1\)School of Aquatic and Fishery Sciences, Univ. Washington, USA; \(^2\)Northwest Fisheries Science Center, NOAA, USA

**Session:** OlfO10

**Abstract:** Copper is a ubiquitous contaminant in urban stormwater and is present at levels that could detrimentally impact juvenile salmon in the Pacific Northwest (PNW), USA. Dissolved copper concentrations in stormwater often reach levels that are known to impact olfaction and olfactory-mediated behaviours in salmon under laboratory conditions. A wealth of literature, integrated into the Biotic Ligand Model, shows that water quality affects the toxicity of copper at the fish gill. Does water quality affect the toxicity of copper at the olfactory epithelium? To answer this question, we exposed juvenile coho salmon (*Oncorhynchus kisutch*) to artificial waters of variable hardness (0.2-1.6 mM Ca), alkalinity (0.2-3.2 mM HCO\(_3\)-), DOC (0-5 mg/L), and pH (7.5 vs 8.5). Electro-olfactograms were used to quantify the olfactory response before and after a 30-min exposure to 20 \(\mu\)g/L Cu. At the end of the copper exposure in the lowest-ion water, relative olfactory response was reduced by 80-90%. Relative olfactory response was weakly correlated with hardness and alkalinity, but correlated strongly with DOC concentration. Olfactory toxicity was independent of pH. Ionic copper measurements and copper speciation modeling showed that copper bound to carbonates were bioavailable to the salmon olfactory epithelium. Our results suggest that hardness, alkalinity, and pH in natural waters of the PNW are not protective against the neurotoxic effects of copper, whereas DOC may have significant protective effects if present at sufficiently high levels. Funding was provided by the NOAA Coastal Storms Program.

**NERVOUS AND HUMORAL CONTROL OF CARDIAC PERFORMANCE IN THE WINTER FLOUNDER (P. americanus)**

P.C. Mendonça, A.K. Gamperl

E-Mail: mendonca@mun.ca

Ocean Sciences Centre, Memorial Univ. of Newfoundland, Canada

**Session:** CarO8

**Abstract:** Previous studies have suggested that adrenergic cardiac innervation is absent in flatfish, and thus that adrenergic control of heart function in this taxa is primarily via circulating catecholamines. However, data on neurohormonal control of flatfish cardiac function is scarce, and has never been directly studied in vivo. Thus, we: 1) injected neural and humoral antagonists to determine the contribution of autonomic innervation and circulating catecholamines to the control of resting cardiac function; 2) measured pre- and post-stress (90 sec. chase to exhaustion) catecholamine levels; and 3) performed catecholamine dose-response curves for cardiovascular function based on the results of experiment #2. The cholinergic contribution to resting flounder heart function was comparable to other teleosts (resting tonus 26%), and the lack of an effect of bretylium injection confirmed the absence of adrenergic innervation. Surprisingly, however, we also failed to find evidence that circulating catecholamines support resting cardiac function in this species using \(\beta_1\) and \(\beta_2\)-adrenergic blockers. We found that flounder have a diminished post-stress catecholamine levels (Adren., 21 nM; Noradren., 14 nM) as compared with other teleosts, but that this muted stress response does not affect the ability of circulating catecholamines to stimulate cardiac function. For example, maximal increases in cardiac function (e.g. cardiac output by 30%) were achieved at catecholamine doses lower than would result in max. post-stress in vivo levels. This suggests that the flounder heart has a higher affinity and/or density of \(\beta\)-adrenoreceptors. Studies are underway to test this hypothesis. Funded by NSERC and a Foundation for Science and Technology doctoral fellowship (Portugal).
ASSESSMENT OF THE PH EFFECTS ON COPPER TOXICITY ON TAMBAQUI (*Colossoma macropomum* CUVIER, 1818)

Menezes, A. C .L.¹, Aride, P. H.² and Val, A. L.¹
E-Mail: dalval@inpa.gov.br

²Laboratory of Ecophysiology and Molecular Evolution, National Institute of Research in the Amazon–INPA (Brazil); ¹Nilton Lins University – UniNilton Lins (Brazil)

Session: ImpP4

Abstract: Copper is considered an essential trace element to organisms; however, in high concentrations this element can be toxic to organisms. Copper toxicity is high at low pH, because in acidic water, there is an increase in copper availability, increasing the lethality. High copper concentrations in the black waters of the Amazon can be highly toxic as this water is poor in ions and acidic. The aim of this study was to determine the copper toxicity for the tropical fish species *Colossoma macropomum* in pH 4 and 8 and to assess the biocorcentration and the effects of copper exposition on physiological parameters and swimming performance of the animals. Lethal concentration in 96 hours (LC50) in pH 4 was estimated as 2.68mgCu/L; however, it was not possible to estimate this value at pH 8. Thereby, the experiments to analyse the physiological effects of copper were conducted with the value estimated at pH 4. The effects of DOC were assessed using 5mg/L. Tambaqui presented changes in hematology, plasma ions, plasma metabolites. Copper is also genotoxic to tambaqui. However, the exposure does not cause changes in the activity of GST and CAT. An increase of copper levels in gills and liver was observed in exposed animals. Sublethal concentrations of copper were enough to affect the physiological parameters, suggesting metabolic and ionic disturbances that can be attributed to copper. Presence of organic matter did not reduce the toxic effects of copper on the exposed animals. (CNPq, FAPEAM, ICA).

MECHANISMS OF DELAYED MORTALITY IN JUVENILE SALMONIDS MIGRATING DOWNSTREAM IN THE COLUMBIA RIVER

M.G. Mesa, S.C. Lupes, J.D. Hotchkiss and A.G. Maule
E-Mail: matt_mesa@usgs.gov

U.S. Geological Survey, Western Fisheries Research Center, Columbia River Research Laboratory, USA

Session: MolO14

Abstract: The Pacific Northwest is experiencing declines of many stocks of anadromous salmonids. One factor contributing to this decline in the Columbia River Basin is delayed mortality of juvenile fish after they have passed the last dam (Bonneville) and entered the estuary. Delayed mortality refers to mortality of fish that occurs in the estuary or ocean that is related to their earlier experiences in the hydrosystem. We sampled juvenile spring Chinook salmon *Oncorhynchus tshawytscha* that had been transported downriver in barges and those that migrated in-river to determine whether physiological dysfunction contributes significantly to delayed mortality. We collected blood and gill tissue from groups of fish to measure levels of thyroxine (T4), cortisol, and sodium-potassium ATPase. Also, we removed the liver and determined the status of various physiological systems using a targeted salmonid cDNA microarray. Plasma levels of cortisol and T4 were significantly higher in fish that migrated in-river compared to those that were barged. Gill ATPase activities, however, were low and did not differ between groups. As of this writing, we are still processing data from our microarray assays, but will present results on patterns of gene expression in barged and run-of-river fish. Collectively, our results will provide valuable insight into the physiological status of fish before they leave Bonneville Dam, would be useful for predicting the fate of fish as they continue their migration, and could be used to develop testable hypotheses about the physiological basis of delayed mortality. Funded by the U. S. Army Corps of Engineers.

HOW DOES RATE OF DEVELOPMENT AFFECT FUTURE VIABILITY?

N.B. Metcalfe
E-Mail: n.metcalfe@bio.gla.ac.uk

Div. Of Environmental & Evolutionary Biology, Univ. of Glasgow, UK

Session: PleO2

Abstract: There are many benefits of being large: larger individuals can begin breeding earlier, and can also reduce the time spent in the most vulnerable stages of the life cycle. Fish that are large for their age also have a competitive advantage, which may increase their access to food, so allowing them to grow even faster. However, the benefits of a large size need to be balanced against the costs of achieving it: there is increasing evidence that rapid growth is costly in both the short and long term. The immediate costs of a strategy of rapid growth (and hence greater food requirement) are fairly obvious, but the longer-term consequences are more surprising. In this talk I will summarise the experimental evidence from a range of species that indicates how rapid growth and accelerated development can influence the resulting adult phenotype. I will show how there can be long-term effects on physiology (e.g. lipid accumulation, initiation of sexual maturation), swimming
performance (both burst and sustained) and behaviour (dominance interactions). I will also present experimental evidence that alternating periods of reduced and accelerated growth can affect lifespan. However, it is also clear that these effects are not necessarily ubiquitous: species (and populations within species) appear to differ in both their capacity for rapid growth and in the extent to which this acceleration of development can have adverse effects later in life. I will therefore consider how selection pressures have shaped developmental patterns in fish such that growth trajectories are optimised to maximise the net benefits.

**HOW IMPORTANT IS DIADROMY AND VARIABLE LIFE HISTORIES FOR AUSTRALIAN COASTAL RIVERINE FISH COMMUNITIES?**

Nathan Miles and Ron West
E-Mail: ngm96@uow.edu.au

School of Earth and Environmental Sciences, University of Wollongong, Australia

**Session:** TroO1

**Abstract:** Diadromous fish species are a frequent but poorly understood component of coastal riverine fish communities in Australia. This study examined diadromous and riverine fish assemblages in selected coastal streams of eastern Australia. A variety of fishing gear was used at 47 sites in 17 catchments, and captured 13269 fish from 31 species, dominated in number by freshwater fishes (10252 fish, 8 species), when compared with introduced (1570 fish, 3 species), marine (777 fish, 10 species) and diadromous fishes (670 fish, 10 species). Diadromous fish were of significantly larger sizes when compared to other groups in the assemblages ($P<0.0001$). Multivariate analysis (MDS and ANOSIM) significantly delineated fish communities based on: geographical location ($P<0.001$), river size ($P<0.001$), rivers ($P<0.001$), sites ($P=0.030$) and estuary type ($P=0.028$). SIMPER revealed that *Retropinna semoni*, *Gambusia holbrooki*, *Mugil cephalus*, *Philypnodon grandiceps*, *Galaxias maculatus*, *Gobiomorphus australis*, *Macquaria novemaculeata* and *Potamalosa richmondia* were species which often contributed to differences in these fish communities. Multiple regression analyses indicated that distance from the source, depth, woody debris, substrate coarseness, substrate heterogeneity and temperature were key environmental factors determining fish distribution and abundance. The high diversity of diadromous species highlights their importance in coastal streams of eastern Australia and indicates the critical need for information on the biology of this poorly studied group. Funded by NSW Fisheries Scientific Committee and Australian Society for Fish Biology.

**THE HUMAN PHARMACEUTICAL GEMFIBROZIL CHALLENGES THE ANTIOXIDANT DEFENSE SYSTEM IN GOLDFISH (Carassius auratus)**

C. Mimeault, V. L. Trudeau, and T. W. Moon
E-Mail: cmimeaul@science.uottawa.ca

Centre for Advanced Research in Environmental Genomics, Biology Department, University of Ottawa, Ontario, Canada

**Session:** ImpO22

**Abstract:** The lipid regulator gemfibrozil (GEM) is one of many human pharmaceuticals found in the aquatic environment. In this study, we address the potential of an environmentally relevant waterborne concentration of GEM (1.5 mg/L) to induce oxidative stress in goldfish liver and if this process may be linked to peroxisome proliferation. We also investigate the autoregulation of the peroxisome proliferator-activated receptors (PPARs) as a potential index of exposure. Three PPAR subtypes (a, b, and g) were amplified from goldfish liver cDNA. Environmentally relevant concentration of GEM (1.5 mg/L) for 14 and 28 days significantly increased hepatic PPARa mRNA levels (p=0.023) after 14 and 28 days. Antioxidant enzyme activities were determined by spectrophotometric assays. GEM exposure significantly induced the antioxidant defence enzymes catalase (p<0.001), glutathione peroxidase (p<0.001) and glutathione-s-transferase (p=0.006) but not acyl-coA oxidase or glutathione reductase (p=0.152). As GEM exposure failed to increase levels of thiobarbituric reactive substances (TBARS), we conclude that a sub-chronic exposure to GEM challenges the antioxidant status of the goldfish without leading to oxidative damage. This ACO-independent induction of the antioxidant defence system implicates an alternative action of GEM possibly through a cytochrome P-450 mechanism. This study adds further evidence of sub-chronic effects of pharmaceuticals in the environment on non-target species. Funded by NSERC Canada.
DIFFERENTIAL GENE EXPRESSION IN RAINBOW TROUT (Oncorhynchus mykiss) LIVER IN RESPONSE TO HANDLING STRESS
T.S. Momoda¹, L. Gerwick², C.J. Bayne¹ and C.B. Schreck
E-Mail: tracey.momoda@oregonstate.edu
¹Oregon Cooperative Fish and Wildlife Research Unit, U.S.G.S., Department of Fisheries and Wildlife, Oregon State University, USA; ²Center for Marine Biotechnology & Biomedicine, University of California, San Diego, USA;

Session: MoI02
Abstract: We used an oligonucleotide microarray specific for Oncorhynchus mykiss, to identify differentially expressed genes in response to stress. We conducted replicate experiments at two different times using two different sets of fish. In both experiments, fish exposed to a three-hour stressor were compared to fish exposed to no stress. Plasma cortisol was used to document the physiological stress response of the fish. In the microarray analysis, we used pooled RNA from liver and normalized expression to a pooled reference RNA made from stressed and unstressed fish. For technical replication of the array, we performed ‘dye swap’ experiments. Real-time PCR (qPCR) was used to validate microarray findings of candidate genes, using the pools of RNA. We also used qPCR to obtain expression data of candidate genes for the individual fish in order to observe the natural variation of expression. The microarray identified many genes to have differential expression after three hours of stress. Twenty-five genes were differentially expressed in the first experiment and 14 genes in the second experiment. Of these, five genes gave similar results between experiments, suggesting that they are robust indicators of stress. These genes are major histocompatibility complex class I, JunB, glucose 6-phosphatase, rat p8 (ubiquitous stress protein) and tumor necrosis factor decoy receptor. Funded by USACE, WRAC and OCFWRU.

EFFECTS OF ACID/ALUMINUM ON ATLANTIC SALMON PARR AND SMOLT PHYSIOLOGY; WHY ARE SMOLTS MORE SENSITIVE?
M.Y. Monette and S.D. McCormick
E-Mail: mym@forwild.umass.edu
Graduate Program in Organismic and Evolutionary Biology, Univ. of Mass., Amherst, MA; USGS, Conte Anadromous Fish Research Center, Turners Falls, MA

Session: IonO15
Abstract: Acid rain coupled with elevated aluminum (Al) is a potential cause of Atlantic salmon decline in many North American rivers. Smolts are highly sensitive to acid/Al (AA), yet the mechanisms underlying this sensitivity are unknown. Our goals were: to confirm that smolts are more sensitive to AA than parr, and to determine the mechanism(s) underlying increased sensitivity. In the lab, parr and smolts were exposed to either control or AA water, and sampled after 2 and 6 d. In AA smolts, plasma Cl⁻ decreased 11 % and plasma glucose increased 3-fold after 6 d, however, in parr plasma Cl⁻ and glucose were unaffected. Gill Na⁺,K⁺-ATPase activity (NKA) and hematocrit of both lifestages were unaffected by AA. Gill Al increased > 7-fold after 2 and 6 d of treatment in both lifestages. After 6 d, parr gill Al was 2-fold > than smolts. In the field, caged parr and smolts were placed in either a reference (RS) or an AA impacted stream (AAS) and sampled after 2 and 6 d. Plasma Cl⁻ decreased 8.3 % in AAS parr and 27 % in smolts after 2 d. After 6 d, plasma Cl⁻ in AAS parr continued to decline, but partially recovered in AAS smolts. Plasma glucose increased 2.7- and 2.2-fold in AAS parr and smolts, respectively, and remained elevated after 6 d. Gill NKA decreased 45 % in both AAS parr and smolts after 6 d. Gill Al increased > 8-fold after 2 and 6 d of treatment in both lifestages. After 6 d, parr gill Al was 2-fold > than smolts. Our results confirm that smolt ion regulation is more sensitive to AA than that of parr, yet neither decreased gill NKA nor elevated gill Al appear to be the mechanism of increased smolt sensitivity. Funded by USGS and SICB GIAR.

GENETIC AND ENVIRONMENTAL EFFECTS ON THE SIZE OF HEART AND GILLS IN ARCTIC CHARR (Salvelinus alpinus)
M.A Montañez Ruiz¹,², H. Thorarensen¹, R. Ginés Ruiz² and J.M.A López²
E-Mail: helgi@holar.is
¹Hólar University College, Hóulum í Hjaltadal, 551 Sauðárkrókur, Iceland; ²Department of Animal Production, University of Las Palmas de Gran Canaria, Trasmontaña s/n, E-35416 Arucas, Las Palmas, Spain

Session: CarP6
Abstract: The relative heart size of many species of fish is plastic and depends on factors such as environmental temperature, sex, maturity, activity level and routine oxygen consumption. Less is know about the plasticity of gill size. The aim of this study was to evaluate the significance of environmental (temperature) and genetic factors on the size of the cardio-respiratory organs in Arctic charr. Fish from two different strains, were reared for one year at 5, 10 and 15 °C, and heart and gill sizes were measured at the end of the experiment. The fish were individually tagged and came from several full-sib families, thus allowing estimation of genetic effects on heart and gill mass. Temperature had a significant effect on
relative heart and gill mass. The hearts of fish reared at 15 °C were comparatively larger than the hearts of fish reared at 5 °C. This is different from what is observed in temperate species, such as rainbow trout, where relative heart size increases at lower temperatures. Moreover, the gills of fish reared at low temperature were larger than those of fish reared at higher temperatures. Genetic effects on heart mass were also observed. There were significant differences in the relative heart and gill mass of the two strains. The estimated heritability for heart and gill mass were 0.20±0.03 and 0.30±0.03 respectively and comparable with those for growth and with those for growth in Arctic charr. Funded by CRAFT.

**FISH SWIMMING IN PHARMACEUTICALS – IS THERE A PROBLEM?**
T.W. Moon, C. Mimeault, C. Cameron, C. Estey, V. Marlatt, and V.L. Trudeau
E-Mail: tmoon@uottawa.ca

Dept. of Biol. and Centre for Adv. Res. in Environ. Genomics, Univ. of Ottawa, Canada

**Session:** ImpO4
**Abstract:** Analyses of surface waters from across North America and Europe report the presence of a wide variety of pharmaceuticals and personal care products (PPCP). These are anthropogenically derived from waste water treatment plant (WWTP) effluents, and from agricultural field run-off as a result of the spreading of biosolids from WWTP and agricultural wastes. As analytical techniques improve, the variety of products found is increasing, so even though each compound may be at ng or μg/l concentrations the total exposure of aquatic species continues to rise. Drugs in particular are developed against specific cellular receptors and these receptors are highly conserved across at least vertebrates, so predictably drugs affecting humans will also affect fish. Unfortunately, the impact of these agents on the physiology of aquatic species is only now being studied. This paper will examine cholesterol/lipid regulators and in particular the fibrate class of drugs and their impact on two model fish species, the goldfish (*Carassius auratus*) and the rainbow trout (*Oncorhynchus mykiss*). As peroxisome proliferators fibrate drugs activate nuclear receptors called peroxisome proliferator-activated receptors (PPAR) which heterodimerize with the retinoid X receptor (RXR) to activate gene transcription. Gemfibrozil, a fibrate drug used in the treatment of hyperlipidemia is consistently found in environmental water samples in the range of 1 to 20 μg/L. This drug at environmental levels bioconcentrates in goldfish, modifies plasma lipids, PPAR expression and the reproductive and stress axes. In addition we are beginning to examine interactions between fibrate and statin drugs and how these impact the physiology of both goldfish and trout. We are developing in vivo and in vitro models to better understand these complex interactions. Our studies demonstrate that although the biochemical effects of pharmaceuticals in fish may be subtle, longer term physiological consequences may be significantly greater. Funded by NSERC Discovery and Strategic Grants.

**GLUCOKINASE (GK) AND HEXOKINASE (HK) EXPRESSION AND ACTIVITIES IN RAINBOW TROUT TISSUES: CHANGES WITH FOOD DEPRIVATION AND RE-FEEDING**
T.W. Moon¹, S. Polakoff², X. Chen¹, S. Sangiao-Alvarellos² and J.L. Soengas²
E-Mail: tmoon@uottawa.ca

¹Dept. of Biol., Univ. of Ottawa, Canada; ²Dept. de Biooxia Funcional e Ciencias da Saúde, Univ. de Vigo, Spain

**Session:** LinO1
**Abstract:** Rainbow trout (*Oncorhynchus mykiss*) were fed, fasted for 14 days and re-fed for 7 days. Tissues GK and HK-I expression and activities were assessed. Two different HK-I cDNAs were identified in different tissues; GK mRNA was identified only in liver and 4 brain regions. GK expression was significantly altered by feeding conditions especially in liver and hypothalamus where food deprivation decreased and re-feeding increased expression; these changes reflected activity changes and changes to tissue glycogen levels. Food deprivation generally decreased tissue glucose phosphorylating capacity; in some cases this decrease was attributed to HK (liver, kidney, gills, intestine and heart) and in others to GK (liver, hindbrain, kidney). Re-feeding trout resulted in hyperglycemia, increased glucose phosphorylating capacity and generally increased glycogen levels. Interestingly, reduced capacity appears to be more attributable to changes HK whereas increased capacity to GK which fits with the different Km values of the GK and HK enzymes. Our results also implicate the hypothalamus as a glucosensor in trout as suggested in mammals, though a possible role for other brain regions like hindbrain could not be excluded. Thus, even though the rainbow trout utilizes glucose poorly, none of the parameters tested here relate to this inability to utilize glucose. This implies that this species could adjust to a higher carbohydrate diet assuming that the proper carbohydrate is added to the diet. Funded by the Ministerio de Ciencia y Tecnologia and FEDER, Xunta de Galicia and NSERC Canada.

VIIth International Congress on the Biology of Fish – Program Guide – Page 158
Abstract: Growth Hormone Transgenic (GHT) Atlantic salmon exhibit many characteristics that distinguish them from non-transgenic conspecifics; principally differences in growth, metabolic rate, and behaviour. However, the relationship between this observed pleiotropy and ontogeny is poorly understood. An increased metabolic rate may explain the decreases in time to emergence observed in GHT coho salmon (O. kisutch) and provide insight into potential behavioural and ecological consequences later in life. To examine this we sampled individuals from 8 hemizygous families throughout hatching and emergence to determine the effect of GH transgenesis on developmental rate. Complimentary routine metabolic rate measurements were also made on 6 fish from six of these families at the eyed-egg (400-430 degree days) and alevin (550-600 degree days) life history stages. Our findings begin to identify the extent of GHT-induced pleiotropic effects and how they may affect selection during early ontogeny and interactions with non-transgenic conspecifics. Redd emergence is a critical period of survival in stream-dwelling salmonids, where individuals must quickly become proficient foragers in a competitor-saturated environment. While, early emergence can increase predator-induced mortality, positive trade-offs such as first access to profitable feeding territories may occur. Increased metabolic demands can also influence requirements for oxygen during incubation and food intake following emergence, thereby affecting activity, aggression and territorial dominance. Funded by a USDA-CSREES Biotechnology Risk Assessment Grant, NSERC and CFI grants.

CYCLIC POPULATION DYNAMICS OF PINK SALMON (Oncorhynchus gorbuscha) IN THE BERING SEA
E-Mail: moritak@affrc.go.jp
Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Japan

Session: FroP2
Abstract: Pink salmon (Oncorhynchus gorbuscha) have a 2-year life cycle, and virtually all individuals mature at 2 years of age. Pink salmon abundance often oscillates biennially, wherein significant differences in abundance persist between odd- and even-numbered years. However, a comprehensive understanding of the mechanism underlying this oscillation is lacking. We examined factors affecting the dynamics of pink salmon in the Bering Sea (55 –59 N, 175 W –175 E) from 1973 to 2005 using high-seas salmon monitoring data from Japanese research vessels. Abundance dominated in odd-numbered years during the study period, and year-to-year differences were as great as 10-fold. The population growth rate of pink salmon was negatively correlated with their abundance and positively correlated with body weight (i.e., fecundity) of the parental stock. However, a parametric bootstrap likelihood ratio test did not identify significant density dependence. The body weight of pink salmon was negatively correlated with the abundance of sympatric chum salmon (O. keta), which mature at 2 –7 years, but was not correlated with their own abundance. Chum salmon abundance (particularly immature fish) also oscillated biennially, with dominance in even-numbered years, and the body weight of pink salmon was significantly smaller in even-numbered years than in odd-numbered years. The maturation rate of chum salmon was negatively correlated with the abundance of pink salmon in the previous year, and was significantly smaller in even-numbered years than in odd-numbered years. Our results suggest that interaction with chum salmon may be a factor generating the biennial oscillation in pink salmon abundance.

SEX-BIASED DISPERSAL AND GROWTH IN SABLEFISH (Anoplopoma fimbria) IN THE NORTH PACIFIC
Shoko H. Morita, Kentaro Morita and Akira Nishimura
E-Mail: shokoh@affrc.go.jp
Hokkaido National Fisheries Research Institute, Fisheries Research Agency, Japan

Session: FroP3
Abstract: Sex-biased dispersal and growth is common in animals, but it is not clear which proximate factors affect sex-biased growth. In this study, we reveal sex-biased dispersal and growth of sablefish (Anoplopoma fimbria) using tagging data. Tagging programs were conducted by teams from Japan and the United States. From 1980 to 1984, 58918 sablefish were captured and tagged with anchor tags, and between 1980 and 1993, 3318 sablefish were recaptured in the Bering Sea and the northeastern Pacific. The average fork lengths were 62.5 cm (males) and 68.6 cm (females), the average time to recapture was 4.5 years (maximum 13 years), and the average movement distance (maximum 3987 km) were 712 km (males) and 877 km (females). An analysis of variance identified significant effects of sex on growth increments and movement distance; females grew larger and moved longer distances than males. We calculated the standardized growth increment that accounted for the effects of elapsed time, seasonality, and fork length at release using a von Bertalanffy
growth model. The standardized growth increment significantly increased with distance moved per elapsed time. However, the relationships between distance moved per elapsed time and the standardized growth increment differed significantly between sexes; females grew faster than males at a given movement distance. We suggest that female-biased dispersal may be a factor generating female-biased growth in sablefish.

**K⁺-INDEPENDENT MOTILITY INITIATION IN CHUM SALMON SPERM TREATED WITH GLYCEROL**

M. Morita¹, M. Fujinoki², A. Takemura¹ and M. Okuno³

E-Mail: moritamasaya@hotmail.com

¹Sesoko Station, Tropical Biosphere Research Center, Univ. of the Ryukyus, Japan; ²Dept. of Physiol., Dokkyo Univ. School of Medicine, Japan; ³Dept. of Biol., Graduate School of Arts and Sciences, Univ. of Tokyo, Japan

**Session:** AdvO10

**Abstract:** Sperm of salmonid fishes are quiescent in the presence of millimolar concentrations of extracellular K⁺, but motility initiation occurs when sperm are suspended in K⁺-free medium. In this study, glycerol (CH₂OHCHOHCH₂OH) treatment in the presence of K⁺ on intact sperm induced the initiation of motility even though a large amount of K⁺ was present. Another organic alcohol erythritol (CH₂OH(CHOH)₂CH₂OH) also showed similar effect but ethylene glycol (CH₂OHCH₂OH) did not initiate sperm motility. Furthermore, this glycerol-treated sperm showed motility without subsequent addition of ATP and cAMP. An uncoupler of electron-transport chain in mitochondria for ATP synthesis, CCCP, suppressed motility of glycerol-treated sperm, suggesting that ATP synthesis for dynein to slide microtubules occurred in glycerol-treated sperm. The amount of intracellular cAMP ([cAMP]ᵢ) did not increase in glycerol-treated sperm on motility activation, but a protein kinase A (PKA) inhibitor, H-89, inhibited glycerol-treated sperm motility. In addition, phosphorylation of protein associated with motility initiation also occurred in glycerol treated-sperm, suggesting that the glycerol treatment induces activation of PKA without the increase in [cAMP]. Taken together, it can be concluded that organic alcohol, glycerol and erythritol induce phosphorylation for motility initiation bypassing the increase in [cAMP]ᵢ as a result of a decrease in extracellular K⁺. Funded by 21st Century COE program of the University of the Ryukyus, Japan.

**STRUCTURES AND TISSUE DISTRIBUTIONS OF GROWTH HORMONE AND INSULIN-LIKE GROWTH FACTOR-I RECEPTORS IN SALMON**

S. Moriyama

E-Mail: morisuke@kitasato-u.ac.jp

Lab. Mol. Endocrinol., School of Fisheries Sciences, Kitasato Univ., Sanriku, Iwate 022-0101, Japan

**Session:** FisO14

**Abstract:** The growth hormone (GH) and insulin-like growth factor-I (IGF-I) endocrine axis plays a major role in the growth regulation in teleosts as in other vertebrates. The biological actions of these hormones are initiated upon binding to their specific receptors in target tissues. In an attempt to understand growth regulation in salmon, we identified the structures of salmon GH and IGF-I receptors by PCR and examined the tissue distributions of their mRNA expressions by RT-PCR. The salmon GH receptor, which belongs to the cytokine receptor family, shares common characteristic features with known GH receptors of teleosts and mammals, including the five cysteine residues and a YGEFS motif in the extracellular domain, a single transmembrane region, and proline-rich Box1 and Box2 in the intracellular domain. The salmon GH receptor mRNA level was higher in the liver than in all other tissues examined. On the other hand, the salmon IGF-I receptor, which belongs to the tyrosine kinase receptor family, contains a cysteine-rich domain in the alpha-subunit, and the conserved transmembrane and tyrosine kinase domains in the beta-subunit, the same as in other teleosts and mammals. The salmon IGF-I receptor mRNA signals were detected in a wide range of tissues including heart, gills, muscle, stomach kidney, intestine, and gonads. These results indicate that in salmon, the GH-IGF-I axis is not only important in growth regulation but may also be involved in the regulation of ionic and osmotic balance, metabolism, immunity, and reproduction, the same as in other teleosts.

**WOULD RECREATIONAL FISHING SELECTIVELY TARGET THE FASTEST GROWING COD (Gadus morhua) IN THE GILBERT BAY, LABRADOR, MPA?**

C. Morris¹ and J. M. Green²

E-Mail: Morrisc@dfo-mpo.gc.ca

¹Dept. of Fisheries and Oceans, St. John’s, Canada; ²Dept. of Biol., Memorial Univ. St. John’s, Canada

**Session:** FroP1

**Abstract:** Mark recapture sampling by hook and line is used to monitor the Atlantic cod (Gadus morhua) population in the recently designated MPA in Gilbert Bay, southern Labrador. Every year since 1998, approximately 600 cod have been
MULTIPLE STRESSOR EFFECTS OF RADIATION AND METALS IN RAINBOW TROUT
C. Mothersill, D. Oughton, B. Salbu, J. Denbeigh and C.B. Seymour
E-Mail: mothers@mcmaster.ca

Session: BioO2

Abstract: These experiments were designed to look at the cellular effects in key organs in rainbow trout after exposure in vivo to radiation, and subtoxic levels of aluminum (Al) and cadmium (Cd) alone or in combination. Animals were exposed to doses which, used alone, were just below the threshold for detecting an effect. Rainbow trout (25G) were exposed to cobalt 60 Gamma rays in water containing Cd, Al or Cd+Al. Three fish per group were sacrificed after 1 hr and the liver, pronephros, fin and gill was dissected. Small explants of each tissue were set up. After 2 days, the culture medium was harvest and filtered then placed on a reporter cell line for determination of stress signal activity. We determined lamprey recovery time after release and passage success using an extensive network of fixed-site receivers. We then evaluated these metrics as functions of: 1) the transmitter size relative to the lamprey weight (% weight) and girth (% girth), 2) lamprey length, 3) the migration year, and 4) the release date. We also compared lamprey that had been anesthetized using either tricaine methanesulfonate (MS222 fish) or eugenol (clove oil fish). There were no significant effects of anesthetic treatment; however, clove oil fish recovered faster and had higher passage success than MS222 fish.

The most parsimonious logistic regression model of lamprey passage success did not include any two-way interaction terms and the only significant main effects were release date (positively correlated) and % weight (negatively correlated). Similarly, the best model of recovery time included only the % girth term (positively correlated). There was strong collinearity (0.86) between % weight and % girth so it was impossible to separate these effects. We speculate that tag diameter was more likely to have affected lamprey performance than tag weight because no transmitters used in this study exceeded 0.9% of lamprey body weight. In this retrospective, tag effects were not detectable until over 800 lamprey were analyzed. Thus, experiments that test for tag effects with low sample sizes may be misleading.
RESPONSE OF CHOLECYSTOKININ AND PEPTIDE Y TO NUTRIENT FACTORS IN YELLOWTAIL (Seriola quinqueradiata)
K. Murashita1,2, H. Fukada1 and T. Masumoto1
E-Mail: pochiq52@yahoo.co.jp
1Faculty of Agriculture, Kochi Univ.; 2National Research Institute of Aquaculture, Fisheries Research Agency, Japan
Session: LinP3
Abstract: In mammals, it is well known that the hormones cholecystokinin (CCK) and neuropeptide Y (NPY)-related peptide regulate the pancreatic enzyme secretion through stimulation and inhibition functions respectively. However, in fish, the relations between CCK and peptide Y (PY, belongs to NPY-related peptide) synthesis in the digestive tract by nutrient factors has not been examined, and the mechanism of digestive enzyme secretion by CCK and PY are poorly understood. Therefore, in this study through the administration of PBS (control), starch (carbohydrate), casein (protein), olein (fatty acid) and tri-olein (triglyceride) to yellowtail (Seriola quinqueradiata), the mRNA levels of CCK, PY and the pancreatic digestive enzymes (lipase, trypsin and amylase) in the digestive tract were examined. Synthesis of pancreatic digestive enzymes increased in the casein-, olein- and tri-olein-administrated fish while in those fish starch-administrated no effect was observed. In addition, gene expression of CCK and PY showed inverse pattern in the casein-, olein- and tri-olein-administered fish (CCK increased while PY decreased) whereas starch-administrated fish were not stimulated. Results suggest that in yellowtail, protein and fat stimulated the pancreatic enzymes secretion mediated by CCK and PY, and the two hormones (CCK and PY) controlled antagonistically this secretion. Research was totally granted by the Laboratory of Fish Nutrition, Faculty of Agriculture, Kochi University.

EVALUATION OF REFERENCE GENES FOR QUANTITATIVE PCR ANALYSES IN CHANNEL CATFISH TISSUES UNDER VARYING PHYSIOLOGICAL CONDITIONS
C.A. Murdock1, B.C. Small2*, A.L. Bilodeau2, B.C. Peterson2 and G.C. Waldbieser2
E-Mail: bsmall@ars.usda.gov
1Bio. Depart., Jacksonville State Univ., USA; 2Catfish Genetics Research Unit, ARS-USDA, USA
Session: FisO6
Abstract: Real-time RT-PCR represents an efficient method for measuring mRNA levels in a given sample, and its use is increasingly popular in physiological studies of fish, including channel catfish. Normalization of expression data to an internal standard is critical for useful comparisons of expression levels between individual samples. In this study, a total of seven reference genes were investigated for channel catfish. Specifically, 18S rRNA (18S), α tubulin (TUBA), β actin (ACTB), β-2-microglobulin (B2M), elongation factor 1 α (EEF1A), glyceraldehyde-3-phosphate dehydrogenase (GAPDH), and a RNA polymerase II subunit (POLR2B) were evaluated. Basal expression levels of all seven reference genes were determined for 15 tissues. Data revealed that 18S expression showed the least amount of variation between these 15 tissues, followed by TUBA, ACTB, B2M, POLR2B, GAPDH and EEF1A. Additionally, analyses of these seven reference genes, under different physiological conditions, were conducted in tissues within the growth, stress, and reproductive axes. For example, changes in expression were investigated in the hypothalamo-pituitary-interrenal axis in response to low water stress. All reference gene/tissue combinations were found to be suitable for normalization within the stress axis, except for POLR2B within the head kidney. Collectively, the results of these studies suggest that no single reference gene is optimal across tissue types and physiological conditions. Therefore, the choice of an internal standard(s) for normalization should be determined based on the tissues of interests and experimental conditions.

ECOFISH: A TOOL FOR INSTRUCTION IN FISH ECOPHYSIOLOGY
W.H. Neill
E-Mail: w-neill@tamu.edu
Dept. Wildlife & Fisheries Sci., Texas A&M Univ., USA; Texas Parks & Wildlife Dept., USA.
Session: FisO5
Abstract: EcoFish is a virtual fish that lives only in the systems-modeling program STELLA™. The core of EcoFish is the research-based simulation model Ecophys.Fish (Neill et al., Rev. Fish. Sci. 12:233-288, 2004), which implements F.E.J. Fry’s “physiological classification of environment” and his concept of “metabolic scope for activity.” Surrounding that core is a body of algorithms that enables simulation of a series of classical exercises in fish biology: EcoFish eats and evacuates its stomach; consumes oxygen from a routine respirometer, exhibiting respiratory independence/dependence in the process; acclimates to changes in temperature and dissolved oxygen (DO); resists potentially lethal effects of exposure to high and low temperature, low DO, ammonia, and copper; has a core temperature reflecting dynamic balance between rates of metabolic heat production and heat exchange with the surrounding water; behaviorally enviroregulates in gradients of temperature and DO; and, grows in response to temporally varying environment and food resources. EcoFish, unlike its research predecessor, is stochastic; and, EcoFish incorporates provision for generating the experimental treatments to be
imposed in the various exercises. Realistic outputs compare favorably with “ground truth” from experiments with real fish, both in terms of central tendency and variation. EcoFish is a cohesive framework designed to accommodate substitution of its present components (convenient place-holders, in many instances) with alternatives reflecting better information or ideas. This presentation is designed both to introduce and demonstrate EcoFish to scientist-educators responsible for training the next generation of fish biologists, and to invite collaboration in improving this tool. Funded by Texas A& M University.

ECOPHYSIOLOGICALLY BASED CALCULATIONS OF THE CONTRIBUTION FROM RELEASED HATCHERY FISH TO THE SPORT FISHERY FOR RED DRUM (Sciaenops ocellatus) IN COASTAL WATERS OF TEXAS (USA)

W.H. Neill¹ and R.R. Vega²

E-Mail: w-neill@tamu.edu

¹Dept. Wildlife & Fisheries Sci., Texas A&M Univ., USA; ²Texas Parks & Wildlife Dept., USA.

Session: FroO31

Abstract: Since 1981, almost half of a billion hatchery-produced red drum juveniles have been released into Texas coastal waters for enhancement of the wild stock. During that quarter-century, apparent abundance of this highly valued sport- and food-fish has increased, from historic lows recorded in the 1970s. But, the production and release of hatchery fish has been concurrent with bans on commercial fishing and on entanglement netting, and with a series of mild winters, all of which also may have facilitated stock recovery. Thus, the question: Has the release of hatchery fish been effective? We sought to explore this issue quantitatively. We began with application of our ecophysiological model (Rev. Fish. Sci. 12:233-288, 2004) to simulate red drum growth and forage consumption, then incorporated empirical estimates of natural mortality as a function of fish size, and ended with time-series analysis of stocking rates and seine-sampling estimates of juvenile abundance in Texas bays, from 1981 to 2005. We presumed wild and hatchery fish have equal rates of mortality at size, once 0.5-g hatchery fish have suffered 70 % die-off during the first two days post-release. We computed numbers of hatchery-reared fish needed to complement each wild year-class on a forage-impact basis, as they survived and grew to the minimum slot-limit for recreational harvest in Texas (TL = 20 in. = 504 mm). On this basis, 13 % of red drum reaching the slot limit in Texas waters since 1981 have been hatchery fish; 21 %, since 1991. Since 1981, the number of red drum stocked has been 85 % of the optimum number, on a median annual basis; and, 61 % on a total basis. Funded by TPWD.

POPULATION LEVEL DIFFERENCES IN ENDURANCE BUT NOT SPRINT PERFORMANCE ARE DUE TO PHENOTYPIC PLASTICITY IN A CYPRINID


E-Mail: jnelson@towson.edu

Department of Biological Sciences, Towson University, Towson Md, USA

Session: FroO27

Abstract: Urbanization produces streams with reduced base flow but increased flow during storm events. Endurance swimming performance in blacknose dace (Rhinichthys atratulus) from rural environments depended upon base flow of the stream they were collected from, but animals collected from urbanized streams performed better than predicted from that relationship. Population-level differences in endurance performance were stable across generations of fish spanning four years. Sprint swimming performances also showed population-level differences that correlated significantly with stream flow characteristics. Population-level differences in sprint swimming performance were stable in fish collected nine months apart. Laboratory acclimation of fish from different populations to static flow conditions caused homogenization of endurance swimming performance around values representative of fish from low-flow streams. Sprint swimming performances did not homogenize under static-flow conditions. These results suggest that endurance swimming performance in blacknose dace is phenotypically plastic and fish from high-flow environments are better trained. Conversely, population level differences in sprint swimming performance are genetic or ontogenetic in nature or do not "de-train" in the laboratory because of behavioral interactions. Funded by National Science Foundation (IBN-0216974) and Towson University.
STRESS RESPONSE DURING AND AFTER CONFINEMENT IN 17 ALPHA HYDROXYLASE DEFICIENT COMMON CARP (Cyprinus carpio L.)

M.A. Nematollahi 1, H. van Pelt 2 and H. Komen 2
E-Mail: Mohammadali.Nematollahi@wur.nl

1Aquaculture and Fisheries Group, 2Animal Breeding and Genetics Group, Dept. of Animal Sciences, Wageningen Univ., The Netherlands

Session: LinO21

Abstract: The aim of study was to analyze the stress response in normal (STD) and in 17α-hydroxylase (CYP17) deficient common carp. Fish were raised for 6 months and subjected to a net confinement stressor for 3 hours, followed by a recovery period of 24 hrs. Fish were sampled at t0 (control, unstressed), 5 min, 20 min, 1 hour and 3 hours net confinement, and after 1 hour, 3 hours and 22 hours of recovery. At every time point, blood was collected to determine cortisol, corticosterone, glucose, lactate and FFA levels (5 fish per strain). Fish and head kidney were weighted before and after dissection respectively to determine head kidney somatic Index (HKSI). Morphometric analysis of head kidney tissues indicated that the head kidney somatic index was significantly larger in CYP17-fish (0.076±0.021) compared with STD fish (0.045±0.015). There were significant differences in cortisol, corticosterone and lactate between the two strains. Cortisol values (ng/ml) according to the ordered time points were; 20.0, 56.7, 80.3, 90.7, 133.2, 156.7, 117.6, 33.3, in CYP17 fish and 6.5, 443.3, 449.4, 558.6, 292.6, 123.9, 5.2, 5.9 in STD fish. Corticosterone values (ng/ml) were; 532, 894, 2381, 1412, 2854, 3217, 2936, 1168 in CYP17 fish, and 0.48, 0.82, 1.45, 1.16, 1.22, 1.02, 2.38, 1.83 in STD fish. The values for Lactate (mM) were; 1.76, 4.5, 1.61, 1.6, 1.11, 1.5, 2.1, 3.6 in CYP17 fish and 2.7, 6.2, 4.2, 2.7, 1.6, 2.4, 3.1, 2.1 in STD fish. There was no significant difference in Glucose and FFA values between both strains. Results support the conclusion that the reduced capacity of CYP17 fish to produce cortisol is caused by a deficiency in 17α-hydroxylase activity. A reduced cortisol output leads to increased stimulation of adrenals by ACTH, resulting in increased outputs of corticosterone. It is not clear whether corticosterone exerts any biological activity in carp. This research is funded by Ministry of Sciences, Research and Technology of Islamic Republic of Iran

SELECTIVE BREEDING OF ATLANTIC SALMON (Salmo salar) AFFECTS GROWTH HORMONE ACTION ON GROWTH

E-Mail: lena.neregard@zool.gu.se

1Dept Zool, Göteborg University, Göteborg, Sweden; 2Norwegian Inst Nature Res, Trondheim, Norway; 3Fisheries and Oceans Canada, West Vancouver, Canada; 4Ocean Sci Centre, Memorial Univ Newfoundland, Canada

Session: GenO3

Abstract: The AquaGen strain of Atlantic salmon has been selectively bred for several generations to improve performance in aquaculture. The growth potential of AquaGen salmon was compared with its wild progenitor strain from River Namsen, and a wild strain from River Imsa. Parr were implanted with growth hormone (GH) or placebo and growth was monitored for three months, after which tissue samples were collected. GH increased growth in all three strains. Of the control fish, the AquaGen strain grew to the largest size, while when treated with GH, both the wild strains grew to a larger size than the AquaGen fish. All strains had highest condition factor (CF) in October, with controls having higher CF than GH-treated fish. Among the strains, the CF of AquaGen fish was the highest. In all three strains, GH increased body silvering, which may be an indirect consequence of increased growth as silvering and body size are positively correlated. GH was found to have strain-specific effects on plasma levels of insulin-like growth factor I (IGF-I), only elevating IGF-I levels in the Namsen salmon. No major differences were detected in GH-receptor or IGF-I gene expression in gill, muscle and liver. The results indicate that while the breeding selection has resulted in elevated growth of the AquaGen strain, some GH-inducible growth potential has been lost in the process. Financed by NFR (The FUGE program) and FORMAS.

EFFECTS OF WATER TEMPERATURE ON MOLECULAR AND PHENOTYPIC GENDER DEVELOPMENT IN ATLANTIC HALIBUT

S. van Nes and Ø. Andersen
E-Mail: solveig.van-nes@akvaforsk.no

AKVAFORSK Institute of Aquaculture Res., Norwegian Univ.of Life Sci., As, Norway

Session: LinO8

Abstract: Female Atlantic halibut display faster somatic growth and reach a larger ultimate size than males. Therefore, enhanced female ratios would have economical advantages for halibut production. Water temperature during early developmental stages has been shown to influence the direction of phenotypic gender development in lower vertebrates. Hence, a better understanding of the mechanisms behind gender development and the impact of temperature is of great importance for practical applications in halibut aquaculture. The aromatase (CYP19) and estrogen receptor (ESR) play
important roles in the process of gender development of lower vertebrates, including teleosts. We cloned two genetic distinct forms of halibut CYP19, and found a sexual dimorphic expression pattern of the ovary-type (CYP19A) in gonads of adult halibut. Real-time PCR revealed that both enzymes are highly expressed prior to any histological ovarian differentiation, and that molecular sex differentiation seems to be initiated in brain prior to gonads. A temperature experiment was conducted to examine effects of temperature on phenotypic sex and transcription rates of the cyp19 and esr genes. Real-time PCR showed a positive correlation between the transcription level of cyp19a and ovarian phenotype, as the gene expression increased with increasing female incidence in the lowest temperature treatment. The proportion of females never exceeded 50%, indicating that the female is the labile gender. Whereas temperature treatment is not likely suitable for direct feminization in halibut, the possibility for high-temperature production of XX-neomales for broodstock to obtain all-female offspring by crossing with XX-females is suggested. Funded by the Norwegian Research Council.

PHARMACOKINETICS OF MORPHINE IN FISH: WINTER FLOUNDER AND SEAWATER-ACCLIMATED RAINBOW TROUT
N. Newby¹, P. Mendonça², K. Gamperl² and Don Stevens¹
E-Mail: dstevens@uoguelph.ca

¹University of Guelph, Ontario, Canada N1G 2W1; ²Ocean Sciences Centre, Memorial University of Newfoundland, St. John's, NF, Canada A1C 5S7

Session: WelO7

Abstract: We made a single intraperitoneal injection of morphine sulfate (40 mg/kg) into winter flounder and seawater acclimated rainbow trout at 10°C and then followed its disposition by measuring the change in plasma morphine concentration for 100 hours using a morphine specific ELISA. Disposition also was followed for 6 hours after a single IV injection of 7.5 mg morphine sulfate in winter flounder. The disposition was slower in flounder than in trout even though the fish were held at the same temperature. The present study is the first comprehensive pharmacokinetic analysis for any analgesic in an ectotherm, and our results show that: 1) significant intra-specific variation exists between fishes: and 2) the disposition of morphine in fish is approximately one order of magnitude slower than it is in mammals. These differences may be due in part to mass specific differences in cardiac output. Funded by NSERC

WHAT CONSTITUTES A “PAINFUL” PROCEDURE IN FISH?
Nathalie C Newby, Tom Binder and E. Don Stevens
E-Mail: nnewby@uoguelph.ca
Dept of Integrative Biology. Univ of Guelph, Canada

Session: WelP1

Abstract: Our experiments focus on three aspects of the use of analgesics in fish: 1) pharmacokinetics (the time course of changes in a drug concentration), 2) pharmacodynamics (the time course of the drug action), and 3) what procedures might require analgesics. The topic of this presentation falls into the later category. PIT (passive integrative transponder) tagging in juvenile rainbow trout (Oncorhynchus mykiss) did not negatively impact feeding behaviour. PIT tagging is a commonly used procedure to identify fish. Previous studies have shown it does not affect survival or growth rate. However, there is little research concerning the acute effects of PIT tagging. Our purpose was to study the acute effects of PIT tagging on feeding behaviour. Treatment groups consisted of a control group and a PIT tagged group. The first experiment consisted of timing the latency to resumed feeding prior to and after the treatment day in fish that were trained to feed with a light cue. In the second experiment, the amount of food ingested was recorded prior to and after the treatment day in fish fed to satiation. There were no significant differences between control and PIT tagged groups (p= 0.08 for the latency to resumed feeding and p= 0.71 for the amount of food eaten). PIT tagging did not affect the latency to resumed feeding of or the amount of food consumed by juvenile rainbow trout. We conclude that PIT tagging does not constitute a procedure so “painful” that an analgesic is required. (Funded by NSERC).

DIRECT EFFECT OF CORTISOL ON MELATONIN PRODUCTION IN THE PINEAL ORGAN OF TILAPIA (Oreochromis mossambicus)
Y. Nikaido¹*, N. Aluru², A. McGuire², M.M. Vijayan² and A. Takemura¹
E-Mail: simplesimon56@hotmail.com

¹Tropical Biosphere Research Center, University of the Ryukyus, Japan; ²Department of Biology, University of Waterloo, Canada

Session: MolP3

Abstract: Light information perceived by photoreceptive cells in the pineal organ is expressed as fluctuation of circulating melatonin, which plays an important role in a variety of physiological functions concerning daily rhythm. It is well
established that light is the most potent environmental cue to regulate melatonin synthesis in the pineal organ. However, it is not fully understood what kind of endogenous factors are related to the regulation of melatonin synthesis in this organ. The aim of the present study was to examine the involvement of cortisol in melatonin synthesis in the pineal organ of tilapia, Oreochromis mossambicus. Melatonin content in the blood circulation measured with time-resolved immunofluoroassay clearly showed daily variations with a decrease during daytime and an increase during nighttime. Plasma levels of cortisol, which was measured with enzyme-linked immunosorbent assay, also had daily variations with an increase toward early morning. Real-time PCR analysis revealed that a glucocorticoid receptor (GR) gene was expressed in the pineal organ and fluctuated at relatively low levels during daytime. The pineal organ was cultured with cortisol at physiological levels (10 ng/ml) resulting in relatively high production of melatonin in the medium, whereas addition of cortisol to the medium at stress levels (100 ng/ml) suppressed melatonin production. These results suggest that cortisol is directly involved in pineal melatonin production, which is affected by levels of stress. Funded by the 21st Century COE program of the University of the Ryukyus, Japan.

THE PROCESSING OF ODORANT INFORMATION FROM THE OLFATORY ORGAN THROUGH TO FOREBRAIN

Alexander A. Nikonov and John Caprio
E-Mail: jcap@lsu.edu
Dept. of Biol. Sci., LSU, Baton Rouge, LA 70803 USA

Session: OlfO6

Abstract: We are studying how odors are processed in the olfactory system of the channel catfish (Ictalurus punctatus). In vivo electrophysiological recordings of single olfactory receptor (ORN), bulbar (OB) and forebrain (FB) neurons to amino acids were performed. Neurons (Group 1) were identified at all three anatomical levels that were highly selective for either neutral (e.g L-Met) or basic (e.g. L-Arg) amino acids. In addition, novel FB neurons were identified that were excited by both neutral and basic amino acids, unit types never observed at either ORN or OB levels. Further, neurons (Group II) of broader specificity (Group II) were observed at all three anatomical levels. Dose-response functions to amino acid odorants were also similar across all three neural levels studied; estimated thresholds were \(\leq 10^{-8}M\). At both OB and FB levels, a chemotopic organization was indicated whereby amino acid and nucleotide (i.e. feeding stimuli) information is processed in lateral regions, whereas bile salt (i.e. social stimuli) information is processed in medial regions. For some units in the FB, new response properties emerged, as the FB is the first center where odors serving a common behavioral (i.e. food function) converge. "New" unit types not previously encountered at lower olfactory levels, but seen in the FB include amino acid units that are excited by both neutral (Met) and basic (Arg) amino acids and units excited by both amino acids and nucleotides. FB units were never observed that were excited by both food- and socially-related odorants. Funded by NSF (IBN-0314970) and NIH (DC-03792).

LEARNING CAPACITIES OF ATLANTIC COD (Gadus morhua)

J. Nilsson¹, T. S. Kristiansen¹, J. E. Fosseidengen¹, A. Fernö² and R. van den Bos³
E-Mail: jonatan.nilsson@imr.no
¹Institute of Marine Research, Austevoll, Norway; ²Dept. of Biology, Univ. of Bergen, Norway; ³Dept. of Animals, Science & Society, Utrecht University, Netherlands

Session: WelO4

Abstract: In order to investigate the basic learning capacities of Atlantic cod we conducted classical conditioning experiments on groups of cod, where a light signal (CS) in the feeding area was paired with a food reward (US). The CS and the US either overlapped (delay conditioning) or were separated (trace conditioning) in time with 20, 60 or 120 s for different groups, 2 replicate groups for each treatment. In the control groups the CS and the US were not paired. At the end of the experiment (52 trials) the percentage of fish that occupied the feeding area during the CS was similar as to the US in all delay, 20 s and 60 s trace groups and in one of the 120 s trace groups, but not in the control groups. The fish remained in the feeding area during the trace in the 20 s and 60 s trace groups, but not in the 120 s trace groups. For the delay, 20 s, 60 s and one of the 120 s trace groups more fish occupied the feeding area during the CS than during baseline in almost all trials from trial 2 on, indicating that these groups detected the CS-US relationship after few trials. After the end of the conditioning experiments the delay groups and the 20 s trace groups were transferred to other tanks for 87 and 69 days, respectively, and were thereafter returned to the learning tanks and given the same CS as in the conditioning experiments 6 times with 2 hours interval without reward. In all groups the response to the CS were always higher than baseline. Cod are thus capable of associate 2 events even when they are separated by a 2 minutes interval, and can remember an association between 2 events for at least 3 months. Funded by the Research Council of Norway.
EEG RESPONSES TO NON-PAINFUL AND PUTATIVE PAINFUL STIMULI IN THE ATLANTIC SALMON (*Salmo salar*)

J. Nordgreen¹, T.E. Horsberg¹, B. Ranheim¹ and A.C.N. Chen²

E-Mail: janicke.nordgreen@veths.no

¹Norwegian School of Veterinary Science, Norway. ²Capital University of Medical Sciences, Beijing.

Session: WelO8

Abstract: The question of whether fish has the ability to feel pain or not has been central in the rapidly growing research field concerned with fish welfare. An important issue in the debate has been whether motoric responses to noxious stimuli in fish are merely reflex responses or reflecting processing within higher brain centers that might underlie awareness of pain. As a starting point for answering this question it is important to know whether stimuli validated as pain-inducing in humans reach the fish brain, and whether the responses they may elicit differ from responses following stimuli validated as non-pain inducing in humans. We recorded the somatosensory evoked potentials (SEP) in the salmon telencephalon and mesencephalon following four intensities of galvanic stimulation to the tail (amplifier and stimulator from ANT, Cephalon) given with an interstimulus interval of 2 sec. The SEP was registered by means of intracerebrally placed silver-silver chloride electrodes. The stimulation intensities were 2 mA, 5 mA, 10 mA and 20 mA. Each subject received 60 stimulations at each intensity. The salmon were kept under etomidate anesthesia throughout the procedure. The SEPs for each condition were averaged and the mean amplitude of the SEP and the latency to onset were calculated. Preliminary results show that the galvanic stimulation elicits a SEP in both brain sites investigated and that the characteristics of the response depend on the stimulus strength. This work was funded by the Norwegian Research Council and The Norwegian School of Veterinary Science.

LDH-A EXPRESSION IN OSCAR (*Astronotus crassipinis*) INDUCED BY ANOXIA AND HYPOXIA

S.R. Nozawa¹, R.M. Araújo², M.S. Ferreira-Nozawa¹, A.R. Chipari-Gomes², A.L. Val² and V.M.F. Almeida-Val²

E-Mail: snozawa@niltonlins.br

¹Centro Universitário Nilton Lins; ²Laboratório de Ecologia e Evolução Molecular (LEEM) INPA, Manaus, Amazonas, Brazil

Session: TroP4

Abstract: The muscle form of Lactate dehydrogenase (LDH-A) is one of the glycolitic enzymes that are regulated during hypoxia. However, in vivo studies that corroborate these observations are scarce. Oscar (*Astronotus spp*) are known in the current literature to be anoxia tolerant and to sustain 6 h. anoxia based on metabolic suppression and anaerobic activation. The increase in hypoxia tolerance in these species is also followed by an increase in anaerobic capacity. A. crassipinis were exposed to hypoxia and anoxia in a respirometer chamber (n=5 for each size). The pO2 was lowered stepwise to 40, 20 and 0% air saturation by reducing the aeration of the cell water over 1 h. and 15 min. Total RNA was extracted from white muscle with Trizol (Invitrogen). Quantification and integrity of the RNA were evaluated by agarose gel electrophoresis and staining with ethidium bromide. Results of RT-PCR analysis showed the same increase (p<0.05) in LDH-A gene expression both in and anoxia and 40% hypoxia. The quantification of LDH gene expression in hypoxia and anoxia resulted in a duplication of the values expressed in control animals. In another set of experiments we have analysed enzyme absolute levels, investigating in vitro activities in total LDH of skeletal muscle of the same species. Enzyme levels followed the same trends, increasing their activities in low oxygen levels. We conclude that hypoxia tolerance mechanisms of A. crassipinis are based, in part, on LDH-A regulation, which is the result of a refined oxygen sensing system. Funded by: FAPEAM & CNPq.

TRIALS AND TRIBULATIONS OF DETERMINING THE TEMPERATURE PREFERENCE OF FISH

R. O’Keefe and T.J. Benfey

E-Mail: okeefe@unb.ca

Dept. of Biology, Univ. of New Brunswick, Canada

Session: Lin012

Abstract: Preferred temperatures for fish have traditionally been determined using either horizontal or vertical gradients. Such systems allow no control of environmental factors, such as current (horizontal gradient) or light intensity and water pressure (vertical gradient), that influence location choice in thermal gradients. A novel device controlling for abiotic factors was constructed using a central tank (12X12X7 cm) connected to 4 surrounding tanks of the same size by 2.5 cm PVC pipes to allow free passage among tanks. The outer tanks received water of the same (control) or different (experimental) temperatures. Fish of similar size were individually placed in each of 12 replicate systems and their locations recorded at random times over 4 days between 9 AM and 5 PM. This procedure was conducted for wild and domestic strains of brook trout (*Salvelinus fontinalis*) and Arctic charr (*S. alpinus*). A bias in tank selection in the controls...
suggested some other environmental factor was influencing movement of the fish. This led to the development of a
horizontal gradient (4 replicates 180X20 cm) with the addition of upwelling to eliminate the influence of current on choice
of location. The movements of brook trout were video taped for 6 hours/day for 5 days and their locations determined from
the videos every 5 minutes. Control trials (no temperature gradient) suggest fish were choosing a location based on
unknown cues. How fish behave when placed in a temperature gradient is still under investigation and these results will be
presented at the conference. Funded by NSERC.

LOCAL ADAPTATION TO HYPOXIA IN THE THREE-SPINED STICKLEBACK (Gasterosteus aculeatus)
O'Connor, E. A. 1, Pottinger, T.G 2, Cossins, A.R. 1 and L.U. Sneddon
E-Mail: eao@liv.ac.uk

1Biosciences, University of Liverpool, UK; 2CEH, University of Lancaster, UK

Session: HypO5
Abstract: Geographically isolated populations are exposed to different environmental conditions which may give rise to
local adaptation within species. Oxygen availability has a major impact upon species distributions and populations exposed
to hypoxia may have evolved specific adaptations. This study tests the hypothesis that exposure to hypoxia generates
behavioural and physiological adaptations using populations of the three-spined stickleback. Fish from different habitat
types, lotic and lentic, were held under hypoxia or normoxia as a control. Costly behaviours, aggression and foraging, were
recorded before and during hypoxia to determine dominance relationships. L-lactate and cortisol assays were performed on
whole body homogenates to measure dependency on anaerobic respiration and stress response. Microsatellite analysis was
also conducted to determine the genetic distance between populations and to correlate phenotypic responses to these
distances. Dominance relationships of lotic populations were profoundly disrupted by hypoxia. Lotic fish also had higher
levels of L-lactate under hypoxia compared with lentic fish. Cortisol was not significantly elevated by hypoxia in fish from
either habitat. Populations from highly oxygenated lotic environments showed a more dramatic response to hypoxia than
populations from lentic habitats which regularly experience low oxygen. Current work is focusing on lab-bred progeny
from these environments reared under either periodic hypoxia or constant normoxia. Testing the progeny’s response to
hypoxia will establish if hypoxia tolerance is genetically fixed or is a phenotypically plastic response induced by exposure
to low oxygen levels. Funded by NERC & CEH.

GROWTH AND SURVIVAL OF LARVAL CAPELIN IN ICELANDIC WATERS
IN RESPONSE TO ENVIRONMENTAL FORCING
A. H. Olafsdottir and J. T. Anderson
E-Mail: anna.olafsdottir@mi.mun.ca
Ocean Sciences Centre, Memorial Univ. of Newfoundland, Canada

Session: EarO11
Abstract: Recruitment of the Icelandic capelin stock is highly variable. We investigated the effects of larval growth and
survival on year class size at recruitment. We reconstructed daily growth histories of two year classes of capelin (Mallotus
villosus) larvae from hatch until approximately 4 months old. The larvae were collected over the continental shelf around
Iceland in August 2001 and 2002. Growth estimated from both size-at-age and daily increment width models showed faster
growth of the 2001 year class (0.37 mm d⁻¹, 2.1 μm d⁻¹) compared to 2002 (0.28 mm d⁻¹, 1.9 μm d⁻¹). Environmental
conditions on the capelin nursing ground were better in 2001, both higher temperature and more zooplankton. Daily
increment width models demonstrated a common growth trajectory both within and among year classes with the 2001 year
class growing significantly faster after the age of approximately 20 days. Growth was not density dependent as the 2001
year class had both greater growth rate and higher abundance in August and spawning stock biomass was similar in both
years. Year-class strength in Icelandic capelin is in part determined during the first four months of life. We conclude that
the growth and survival of larval, juvenile and adult capelin are all determined by environmental forcing of Atlantic and
Arctic waters that relate directly to zooplankton prey availability operating at approximately decadal scales. On an inter-
annual basis undetermined proximate factors appear to be more important. Funded by Memorial Univ. of Newfoundland,
The Icelandic Research Fund for Graduate Students, The Federation of Icelandic Fishing Vessel Owners and the Icelandic
Ministry of Fisheries.
PHYSIOLOGICAL RESPONSES OF TAMBAQUI (*Colossoma macropomum*) FED DIET SUPPLEMENTED WITH CAMU-CAMU (*Myrciaria dubia*)

A.M. Oliveira and A.L. Val  
E-Mail: alzira@inpa.gov.br  
National Institute for Research in the Amazon, Manaus, Brazil

**Session**: TroP5  
**Abstract**: During their evolution the fish of the Amazon developed the ability to feed fruits and seeds from floodplain areas. Tambaqui (*Colossoma macropomum*) is considered to be the major and the largest frugivorous characiform of the Amazon basin. More than one hundred types of fruits are regularly consumed by tambaqui and among of them is camu-camu (*Myrciaria dubia*), a fruit containing 3,133.06mg/100g wet pulp of ascorbic acid. The goal of this work was to assess the physiological responses of tambaqui, after feeding supplemented diet with camu-camu. The experimental diet had a significant effect on the physiology of tambaqui, enabling the animal to better face stress, in particular, those related to exercise and hypoxia exposure. Funded by CNPq and FAPEAM.

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PHYLOGENY OF THE CARDIAC Na⁺/Ca²⁺ EXCHANGER

C. On, C.R. Marshall and G.F. Tibbits  
E-Mail: tibbits@sfu.ca  
Cardiac Membrane Research Lab., Simon Fraser University, Canada

**Session**: CarO16  
**Abstract**: The Na⁺-Ca²⁺ exchanger (NCX) is a member of the cation:Ca²⁺ antiporter (CaCA) family and plays a key role in maintaining cellular Ca²⁺ homeostasis in a variety of cell types. NCX is present in a diverse group of organisms and exhibits high overall identity across species. To date, three separate genes – NCX1, NCX2, NCX3 – have been identified in mammals. NCX1 is expressed in high levels in ventricular tissue of all species examined to date. However, phylogenetic analysis of the exchanger has been hindered by the lack of non-mammalian NCX sequences. In this study, we expand and diversify the list of NCX sequences by identifying NCX homologs from whole genome sequences accessible through Ensembl Genome Browser. We identified and annotated 13 new NCX sequences, including four from zebrafish, four from Japanese pufferfish, two from chicken, and one each from honeybee, mosquito and chimpanzee. Examination of NCX gene structure, together with construction of phylogenetic trees, provided novel insights into the molecular evolution of the NCX gene family. A detailed analysis of the cardiac NCX structure function relationship in a variety of fish species will be discussed in the context of these data. Funded by NSERC, CFI and CRC.

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GENE EXPRESSION IN CAGED FISH AS A FIRST-TIER INDICATOR OF CONTAMINANT EXPOSURE

J.T. Oris¹, A.P. Roberts¹, W.H. Clements², W. Stubblefield³ and G.A. Burton⁴  
E-Mail: orisjt@muohio.edu  
¹Miami University (OH); ²Colorado State University; ³Oregon State University; ⁴Wright State University

**Session**: ImpO3  
**Abstract**: The primary objective of this research was to implement a biomarker-based method of exposure assessment using caged fish and real time reverse-transcriptase polymerase chain reaction (rtRT-PCR) measurements of gene expression. Primers were developed for the CYP1A1, metallothionein, and vitellogenin genes in trout and salmon. Each of these genes has been shown to respond specifically to planar aromatic compounds, heavy metals, and environmental estrogens, respectively. Juvenile fish were placed in cages and exposed in situ at reference and contaminated sites on the Cache la Poudre River (CO), the Arkansas River (CO), the St. John River (NB), two urban creeks near Dayton, OH, and in a marine system in Prince Willaim Sound, AK. Quantitative gene expression was determined using rRT-PCR. Biomarker expression profiles were obtained that demonstrated differences in CYP1A1, metallothionein, and vitellogenin mRNA production unique to each site, indicating that specific types of compounds were bioavailable and present in sufficient concentrations to elicit transcriptional responses in the organism. These findings support the use of a biomarker-based approach to exposure identification and assessment.
THE EFFECTS OF CHRONIC IMMUNE STIMULATION ON MUSCLE GROWTH IN RAINBOW TROUT

K. Overturf1, W. Sealy2 and K. Johansen1

E-Mail: kennetho@uidaho.edu

1USDA-ARS, Hagerman Fish Culture Experiment Station, Hagerman, ID USA; 2University of Idaho, Hagerman Fish Culture Experiment Station, Hagerman, ID, USA

Session: FisO7

Abstract: Successful production of aquaculture species depends on efficient growth with low susceptibility to disease. Therefore, selection programs have focused on rapid growth combined with disease resistance. However, chronic immune stimulation diminishes muscle growth (a syndrome referred to as cachexia), and decreases growth efficiency in production animals, including rainbow trout. In mammals, recent results show that increased levels of pro-inflammatory cytokines, such as those seen during an immune assault, specifically target myosin and MyoD and inhibit muscle growth. This suggests that increased disease resistance in fish, a desired trait for production, may actually decrease the growth of muscle, the main aquacultural commodity. To test this possibility, a rainbow trout model of cachexia was developed and characterized. A six-week study was conducted in which rainbow trout were chronically immune stimulated by repeated injections of LPS. Growth indices were monitored, and whole body and muscle proximate analyses, real-time PCR, and immunohistochemistry were conducted to examine the resulting cachectic phenotype. Muscle ratio was decreased in fish chronically immunostimulated, however expression levels of MyoD2 and myosin were not decreased compared to fish that were not immunostimulated, indicating that while muscle accretion was altered, the mechanism by which it occurred was somewhat different than that characterized in mammals. Microarray analysis was used to compare gene expression in fish that had been chronically immunostimulated versus those that had not to identify possible alternative mechanisms of cachexia in fish.

THE EFFECT OF ACUTE HYPOXIA ON HUMBUG DAMSEL (Dascyllus aruanus) EMBRYOS

P.M. Pankhurst and L. Regtop

E-Mail: Tish.Pankhurst@jcu.edu.au

School of Marine Biology and Aquaculture, James Cook University, Townsville, Australia

Session: HypP3

Abstract: Humbug damsels Dascyllus aruanus (Pomacentridae) form polygynous social groupings using the interstices of branching corals for both shelter and egg laying. Eggs are laid in masses amongst coral branches where they are protected by the male until hatching occurs 2.5 days later. On the reef, embryos can be exposed to acute hypoxic conditions around dawn when the night-time respiratory demand of reef organisms has depleted the oxygen produced by primary producers during the previous day. In the laboratory, at a temperature of 27°C and salinity of 32 ppt, we exposed humbug damsel embryos 8, 25 and 35 hours post-fertilization (hpf) to acute hypoxic conditions of 0.35 ppm and 1.85 ppm DO, and near-oxygen saturated sea water (0.5 ppm = control treatment), for durations of 15, 30, 60 and 90 minutes. Embryos were then returned to normoxic conditions until 63 hpf, one hour after hatching had commenced in control groups, at which time all embryos and hatchlings were sampled. Hatching rate and larval length was significantly reduced while yolk volume was significantly larger than controls when embryos 8hpf were subjected to acute hypoxic conditions of 0.3 ppm DO for 60 and 90 minutes and 1.8 ppm DO for 90 minutes. Hatching rate, larval length and yolk volumes were not significantly different when embryos of 25 and 35 hpf were exposed to acute hypoxic conditions for any of the hypoxic treatment durations. This indicates that humbug damsel embryos are robust in relation to acute hypoxic challenge, but that exposure of early stage embryos to acute hypoxia extended embryonic duration, whereas older embryos appeared to be able to compensate for acute hypoxic exposure for short periods.

RELATIONSHIP BETWEEN STRESS, CORTICOTROPIN-RELEASING FACTOR MRNA, PLASMA GHERLIN AND CORTISOL LEVELS, AND FEEDING RESPONSES IN RAINBOW TROUT (Oncorhynchus mykiss) AND ATLANTIC SALMON (Salmo salar)

N.W. Pankhurst1, H.R. King2, S.L. Ludke1 and R.E. Peter3

E-Mail: Ned.Pankhurst@jcu.edu.au

1Fish Endocrinology Laboratory, James Cook University, Townsville Australia; 2Salmon Enterprises of Tasmania, Australia; 3School of Biological Sciences, University of Alberta, Canada

Session: MolO7

Abstract: Sexually immature rainbow trout and Atlantic salmon were exposed to a variety of short term stress and feeding regimes to examine the relationship between feeding, stress, brain corticotrophin mRNA and plasma ghrelin levels and other stress parameters. Plasma ghrelin levels showed an increase 24 h after a single feed in trout but not salmon, and were depressed in stressed fish in association with increases in plasma lactate, glucose and cortisol. There was also a transitory depression in feeding in association with stress. Expression of CRF mRNA was unchanging through the period of stress
and recovery in both species. In salmon, the intensity of the responses to stress was strongly stage dependent. Parr and post-smolts generally showed smaller elevations in plasma cortisol than fish close to, or undergoing smoltification, and the stress-induced depression of feeding activity was most marked around the time of smoltification. Similarly, stress-related depression of plasma ghrelin levels was strongest in fish just before smoltification. The results of the present study confirm that feeding in rainbow trout and Atlantic salmon is suppressed by acute stress but also that the effect varies with developmental stage. Ghrelin appears as in other fishes to be modulated by feeding status, to have an orexigenic role, and to be reduced by stress. CRF mRNA data suggest that changes of expression of CRF may not be involved in short term suppression of feeding by stress.

DEMYSTIFYING STURGEON – REMOTE TELEMETRY PROVIDES INSIGHT INTO THE DAILY LIFE OF WHITE STURGEON IN THE LOWER COLUMBIA RIVER
Michael J. Parsley and Nicholas D. Popoff
E-Mail: michael_parsley@usgs.gov
U.S. Geological Survey, Western Fisheries Research Center, Columbia River Research Laboratory, 5501A Cook-Underwood Road, Cook, WA 98605
Session: TelO10
Abstract: A year-long deployment of a radio-acoustic positioning array in the lower Columbia River provided information on the movements of white sturgeon Acipenser transmontanus at intervals as short as 1 minute. Fish appeared to move continuously. Depth profiles confirmed the hypothesis that fish move shallowest at night and mixed-model ANOVA revealed that rates of movement were greater at night than during daylight. Localized movements over time by individuals and return to previously occupied areas after seasonal migrations indicated a high degree of site fidelity for some individuals. Dispersal over short to medium time periods to adjacent areas by some individuals provided an opportunity for discovery of additional habitats. Kernel density estimation was an effective method of describing the reaction of tagged sturgeon to river channel maintenance dredging operations, and showed mixed results of fish moving towards and away from the disturbance.

WATER AND ION BALANCE IN THE AFRICAN LUNGFISH PROTOPTERUS DOLLOI AND PROTOPTERUS ANNECTANS
M. Patel, A. Ip., M. Wilkie and C.M. Wood
E-Mail:patelm6@mcmaster.ca
McMaster University, Dept. of Biology. ON Canada
Session: TroO5
Abstract: Water balance and ion regulation are essential for lungfish to maintain osmoregulation. African lungfish have characteristically underdeveloped gills compared to freshwater teleosts. The gills are thought to play an important role in CO₂ and ionic exchange while in aquatic conditions. The gills of the Protopterus annectans contain both α and β chloride cells, however the skin contains only α chloride cells (Sturla et al., 2001). These α chloride cells are the putative sites for Cl⁻ absorption as well as Ca²⁺ uptake. To establish the site of ion uptake and water exchange in the Protopterus dolloi and Protopterus annectans, various divided chamber experiments are being carried out. In aquatic conditions, diffusive water exchange rates are similar in the Protopterus dolloi and Protopterus annectans. The major site of water efflux is the gill. However, the reduced gill areas result in lower water exchange rates compared to freshwater teleost fish. Ion regulation studies show the importance of diet in the regulation of Na⁺ and Cl⁻. During feeding Na⁺ and Cl⁻ are absorbed from the food and homeostasis is maintained through the excretion of these ions to their surrounding water. However, feeding does not seem to alter Ca²⁺ uptake. There is a constant rate of extraction of Ca²⁺ from the water. However, compared to most freshwater teleost fish, ion exchange rates are much lower. (Supported by NSERC Discovery Grant to Dr. Chris M. Wood) Reference: Sturla, M., Masini, M.A., Prato, P., Grattarola, C., Uva, B. 2001. Mitochondria Rich Cells in Gills and Skin of an African Lungfish Protopterus annectans. Cell Tissue Res. 303:351-358.
TESTING GENE FLOW FROM GROWTH-ENHANCED TRANSGENIC MEDAKA (Oryzias latipes)
IN CONFINED EXPERIMENTAL SYSTEMS
K. M. Paulson¹ and A. R. Kapuscinski²
E-Mail: kmp@umn.edu

¹Conservation Biology Graduate Program, University of Minnesota - Twin Cities, Saint Paul, MN, USA; ²Institute for
Social, Economic, and Ecological Sustainability & Department of Fisheries, Wildlife, and Conservation Biology,
University of Minnesota - Twin Cities, Saint Paul, MN, USA

Session: GenO10
Abstract: Predicting the likelihood and consequences of transgene flow from genetically modified fish to a wild population
of conspecifics would aid scientists, policymakers, and the public to assess the risk of farming transgenic fish. We are
testing the reliability of one methodology for predicting transgene flow, the "net fitness" model. Our study is among the
first to use real transgenic fish (growth-enhanced medaka, Oryzias latipes) to investigate the robustness of this
methodology. First, fitness component data, such as fecundity, fertility, age at sexual maturity, mating advantage, juvenile
viability and adult viability, were collected on transgenic and non-transgenic fish. Second, populations of non-transgenic
medaka were “invaded” by small numbers of transgenic medaka in a semi-natural setting (mesocosms) to test the model's
predictions of gene flow and its consequences. Using RT-PCR, we have confirmed that the transgene is being expressed in
this line of medaka; however, size varies considerably in both transgenic and non-transgenic individuals. Likewise, fitness
component measurements are characterized by their variability, and gene flow was not consistent across mesocosm
replicates. A new experimental system aims to provide some ecologically relevant variables (predation and food limitation)
in addition to more replicates. Funding provided by a US Department of Agriculture Biotechnology Risk Assessment
Grant, a US National Science Foundation Graduate Research Fellowship (KMP) and a Pew Marine Conservation
Fellowship (ARK).

NEVER MEASURE CRITICAL SPEED AGAIN: GAIT TRANSITION AS AN ALTERNATE ESTIMATOR
OF MAXIMUM AEROBIC CAPACITY IN FISH
S. J. Peake
E-Mail: speake@unb.ca
Canadian Rivers Institute, Univ. of New Brunswick, Fredericton, Canada.

Session: NorO6
Abstract: The highest swimming speed that can be attained using energy supplied from aerobic metabolic pathways is
almost universally estimated by measuring critical swimming speed (or Ucrit). Although the protocol is straightforward, it
is relatively time consuming, the endpoint of the test is subjective, and the data can be highly variable and poorly correlated
to morphological and physiological parameters. In this study, a specially designed flume was developed to determine if the
swimming speed at which fish transition from a steady locomotory gait (powered by red muscle) to unsteady, white muscle
supported swimming can be used as an alternative estimator of maximum sustained speed. Results indicate that the highest
speed that juvenile brook trout (Salvelinus fontinalis) could maintain using a steady gait accurately estimated critical
swimming speed. Furthermore, data could be collected very quickly, required no subjective input from the investigator, and
accurately described the relationship between maximum aerobic capacity and fish size, with much less unexplained
variation than in the Ucrit data. Gait transition speeds also produced the same estimate of Ucrit, regardless of whether fish
moved through the flume voluntarily or were forced to swim. Finally, it was determined that gait transition speed can only
be estimated in a respirometer if ground speed during the test is monitored. It is concluded that this new protocol can be
used as an alternative to the critical speed test, to estimate maximum sustained speed and investigate the impacts of various
stressors on aerobic capacity. Funded by NSERC and the Canadian Foundation for Innovation.

HORMONE-INDUCED SPAWNING OF THE PACIFIC RED SNAPPER (Lutjanus peru) WITH LHRH-A
E-Mail: silviedumas@hotmail.com
Instituto Politécnico Nacional. México

Session: AdvO4
Abstract: Induced gonadal maturation under laboratory conditions has been reported for L. peru, but hormone induction
still have to be used for spawning. In this study, we evaluate LHRHa injections in the induction of ovulation and
spermatiation in wild caught broodstock. Females with mean oocyte diameter of ~ 0.400 mm were induced to ovulation
following two injections of LHRHa separated by 24h, at different doses (25, 50, and 100 µg/kg). Number of spawned
females, time to ovulation and relative fecundity were evaluated. Males were induced by a single injection of LHRHa of 25
and 50 µg/kg. Sperm motility (viability), sperm cell concentration and spermatocrit were evaluated. The eggs and sperm
were obtained by manual stripping. Females treated with the 100 µg/kg died before the second injection. Spawns were
obtained $47.5 \pm 5.6$ h after the first injection in 86% of the injected females (50$\mu$g/kg) and $47.3 \pm 2.2$ h in 83% (25$\mu$g/kg). The average relative fecundity was $57 \times 10^3$ eggs/kg and $70 \times 10^3$ eggs/kg (50 and 25 $\mu$g/kg LHRHa respectively). In males no significant difference was observed between doses ($p > 0.05$) for viability (89.2b $\pm$ 3.7 %), cell concentration ($48.3 \pm 56.2 \times 10^7$ cells) and spermatocrit (93.4 $\pm$ 5.5 %) from sperm samples taken 30 hours after the injection. These results suggest that injections of 25 $\mu$g/kg and 50 $\mu$g/kg can successfully induce ovulation and spermiation in wild caught Pacific red snapper, however, for economic reasons, we recommend the use of the smaller concentration. Supported by CONACYT-SAGARPA, SIP, PIFI, and COFAA-IPN, México.

CRYOPRESERVATION AND REFRIGERATION STORAGE
OF THE PACIFIC RED SNAPPER (Lutjanus peru) SPERM
V. Pelcastre, S. Dumas*, L. Corral, I. Zavala-Leal, M. Contreras-Olguín and R. Peña
E-Mail: silviedumas@hotmail.com
Unidad Piloto de Maricultivos, CICIMAR-IPN. La Paz, B.C.S. Mexico

Session: EarP7
Abstract: Sexual maturity have been obtained in captive Pacific red snapper but hormone induction still have to be used for spawning. This procedure is stressfull for the fish and the use of stored sperm could reduce the need to collect males at the same time as females. The objective of this study was to develop protocols for the storage of sperm by refrigeration (4 ºC for 24, 48, and 72h) or cryopreservation (liquid nitrogen vapors for 5, 10, or 15 min.). Hank’s balanced salt solution without calcium (200 $\mu$M) (HBSS) and whole powdered milk solution were used as extender. Dimethyl sulfoxide (DMSO 5, 10, 15%) and glycerol (5, 10, 15%) were used as cryoprotectants. Sperm was diluted (1:1) with different combinations of extenders and cryoprotectants to test their toxicity. Toxicity and the effect of storage duration were evaluated by the sperm motility after activation. The less toxic solution was DMSO 10%+HBSS (67%). It was used for the cryopreservation. After 2 months in liquid nitrogen, no difference was observed for the exposition time to nitrogen vapors. The motility decreased at 25 %. In refrigeration, the HBSS extender without antibiotics give the best result (81%). No significant difference ($p>0.05$) was observed when compared to the control (undiluted sperm) at 24 and 48 h. At 24 h, the motility observed with the other combinations was significantly lower than that observed in the control. These results suggest that HBSS (200 $\mu$M) can be used as extender and DMSO (10%) as cryoprotectant in the storage of the Pacific red snapper sperm. Fertilization success still need to be evaluated. Supported by CONACYT-SAGARPA, SIP, PIFI, and COFAA-IPN, México.

CHRONIC SWIM TRAINING INFLUENCES THE DEVELOPMENT
OF THE CARDIOVASCULAR SYSTEM IN ZEBRAFISH
B. Pelster
E-Mail: bernd.pelster@uibk.ac.at
Department of Zoology, University of Innsbruck and Center of Molecular Biosciences, Innsbruck, Austria

Session: CarO2
Abstract: Chronic muscular activity typically elicits characteristic adaptations in the cardio - respiratory systems and in cellular metabolism, as well documented in adult vertebrates. In the present study we tested the idea that the early development of the cardiovascular system is characterized by developmental plasticity, and that larval stages of zebrafish forced to swim in a swim tunnel show adaptations in the cardiovascular system. Chronic exposure of zebrafish larvae to a water current inducing an increase in swimming activity, did not cause any adaptations in cardiac activity until 32 days post fertilization (dpf). Nevertheless, critical PO2 in trained animals was reduced, indicating an improvement of the oxygen transport system in these larvae. In the muscle tissue an increase in mitochondrial density especially in red and intermediate muscle cells was observed. At 32 dpf an increase in capillary density of the segmental muscle tissue as well as of the tail fin was detected in trained larvae. Analysis of the expression of VEGF121 and VEGF165 by real time PCR revealed an increase especially in the expression of VEGF165 during early developmental stages. In later stages, however, long term activity resulted in a decrease in the expression of VEGF. Supported by the Austrian Science Foundation (FWF P14976)

RESETTLEMENT OF AUTOCHTHONOUS BROWN TROUT IN ALPINE STREAMS
B. Pelster¹, N. Medgyesi¹, R. Lackner¹, A. Riedl², A. Meraner², S. Baric², J. Dalla²
bernd.pelster@uibk.ac.at
¹Department of Zoology, University of Innsbruck, Austria; ²Research Centre for Agriculture and Forestry Laimburg, Italy

Session: FroP4
Abstract: During an extensive search for autochthonous brown trout in Tyrol, Salzburg and Carinthia seven populations carrying exclusively Danubian haplotypes were found on the basis of mitochondrial DNA sequencing and microsatellite
analysis. The basis for stocking experiments was a successful reproduction of the population from the Anraser See and Gossenkoellesee at the Institute of Zoology (University of Innsbruck). A twenty seven month lasting field experiment with reared offspring revealed high recapture and good growth rates for a high mountain, but not for a lowland brook. We conclude that reared fish from relic brown trout populations are well adapted to the rough Alpine environments and are thus the ideal fish for restocking remote areas. Supported by the Interreg IIIA programme and the government of Tyrol (TROUTEXAMINVEST).

TEMPERATURE EFFECTS ON THE EMBRYONIC DEVELOPMENT OF THE PACIFIC RED SNAPPER (*Lutjanus peru*)
R. Peña, S. Dumas, M. Contreras-Olguin, I. Zavala-Leaf and V. Pelcastre
E-Mail: blacklarvae@hotmail.com
Unidad Piloto de Maricultivos, CICIMAR-IPN. La Paz, B.C.S. Mexico

Session: EarP4
Abstract: The Pacific red snapper is a species with high potential for cultivation in the Pacific Coast of Mexico. An adequate incubation temperature will help to increase hatching rate and optimize the rearing temperature during larval culture. We evaluated the effect of incubation temperature on the embryonic development, time to hatching and hatching success in the Pacific red snapper (*Lutjanus peru*). Viable gametes were obtained by induced spawning using LHRH-a intramuscular injection. After artificial fertilization, zygotes were incubated at 26, 28 and 30 °C. Random samples were taken at regular intervals until the blastula stage was reached and then were taken hourly. Time from fertilization to every developmental stage and until first hatch, 50 % hatching and 100 % hatching was recorded in every sample. Eighteen developmental stages were observed during the incubation period regardless of the incubation temperature. The time from fertilization to 50 % hatching decreased from 24 h to 21 h and 20 h at 26, 28 and 30 °C, respectively. The time period from first hatching to 100% hatching was 3 h at any incubation temperature. The hatching percentage showed no significant differences at 26, 28 and 30 °C (83.6, 82.4 and 79.7 %, respectively). These results suggest that incubation of the Pacific red snapper in culture conditions is possible at temperatures ranging from 26 to 30 °C. This project was supported by CONACYT-SAGARPA, SIP, PIFI, and COFAA-IPN, México.

DEVELOPMENT AND DISTRIBUTION OF INTESTINAL ENZYMATIC ACTIVITY IN *PARALABRAX MACULATOFASCIATUS* LARVAE
R. Peña1, S. Dumas1 and C. Rodríguez-Jaramillo2
E-Mail: blacklarvae@hotmail.com
1Unidad Piloto de Maricultivos, CICIMAR-IPN, La Paz, B.C.S. Mexico; 2Laboratorio de Histología, CIBNOR, La Paz, B.C.S. Mexico

Session: LinO2
Abstract: We described the development and distribution of the intestinal enzymatic activity of aminopeptidase M, dipeptidyl aminopeptidase IV, non-specific esterase, alcaline phosphatase and acid phosphatase, using enzymohistochemical techniques, in the spotted sand bass larvae under culture conditions. Larvae were fed from first feeding (day 2) to day 4, with rotifers *Brachionus plicatilis*, Selco™ (Artemia systems, Ghent, Belgium)-enriched rotifers from days 5 to 15, Artemia nauplii on days 12 and 13, and Selco™-enriched Artemia nauplii from days 14 to 29. Twelve days-old Artemia were offered to the larvae from day 20 until the end of the experiment at day 30. All the digestive enzymes tested showed a positive reaction from first feeding and throughout the studied period. At first feeding, the main site of activity was the mucosa in both intestines. Later in development, enzymatic activity was observed in the liver, kidney and stomach. An increment of the intensity of all enzymatic activities was evident from day 15 and remained constant throughout the studied period, suggesting the onset of the maturation of the digestive tract. From day 20, a positive reaction was recorded in the pyloric caeca for all enzymatic activities tested. Our study confirms the digestive and absorptive functions of the intestines in the spotted sand bass larvae from first feeding. It also brings new insight to establish an early weaning strategy during the larval culture of the spotted sand bass. This project was supported by SEP-CONACYT, SIP, PIFI, and COFAA-IPN, México.
HABITAT USE AND MOVEMENT BY FISH IN A RESERVOIR AND COMPENSATORY FLUVIAL HABITAT
BEFORE AND AFTER CONSTRUCTION OF A HYDROELECTRIC DEVELOPMENT

Pennell, C.J.1, B. Sellars2, D.A. Scruton1 and L.M.N. Ollerhead1
E-Mail: pennellc@dfo-mpo.gc.ca

1Fisheries and Oceans Canada, St. John's, NL A1C 5X1; 2Newfoundland and Labrador Hydro, St. John’s, NL A1B 4K7
Canada

Session: TelO5

Abstract: Development of the Granite Canal Hydroelectric Development in insular Newfoundland, Canada, resulted in destruction of 450 units (100 m²) of fluvial habitat and a ‘state of the art’ artificial river was constructed to compensate for habitat losses. A telemetry study was undertaken to examine habitat use and movement, by landlocked Atlantic salmon (ouananiche, _Salmo salar_) and brook trout (_Salvelinus fontinalis_) in an existing reservoir and newly constructed compensatory fluvial habitat, before and after development. In fall 2002, 45 salmon were captured, radio transmitters implanted, and fish released near their point of capture. In fall 2003, 35 ouananiche and 10 brook trout were tagged, released and tracked in a similar fashion. Fish position was monitored using a combination of fixed stations and helicopter tracking flights, permitting a continuous 2 + year study encompassing pre-construction, opening of the compensatory habitat (fall of 2003), and one post project spawning cycle. Initial movement of fish in 2002 confirmed fish were staging for migration and use of historical spawning areas. Fish then moved off of spawning grounds distributing to over-wintering areas. Fish remained largely stationary and widely distributed over winter during the ice covered period (winter 2003). In fall 2003, several salmon entered Compensation Creek, while a few were attracted to the hydro plant tailrace before moving to Compensation Creek. Brook trout tagged in fall 2003 did not spend any significant time in Compensation Creek in 2003 and 60% migrated to a neighbouring pond during fall 2003. These studies demonstrate the initial response to the hydroelectric development and attraction to and use of the compensatory habitat.

ENVIRONMENTAL BLUE LIGHT AND BIOCHEMICAL STRESS IN THE NILE TILAPIA

E.M. Pereira-da-Silva1, M.P. De Melo1, G.L. Volpato2,3,*, L.D. Peres1, S.M.P. Pugine1, R.H.F. Oliveira1, A.A.C. Barone1, and M.B. Del R. Sgambatti1
E-Mail: gilvolp@gmail.com

1FZEA, USP, Pirassununga, SP, Brazil; 2Dept. Physiology, CB, UFRN, Natal, RN, Brazil; 3Dept. Physiology, IBB, Unesp, SP, Brazil

Session: WelP4

Abstract: Effects of environmental blue light on stressed Nile tilapia (_Oreochromis niloticus_) were investigated by assessing red and white muscles for both oxidative stress in terms of antioxidant enzyme activities (catalase and glutathione reductase) and anaerobic metabolism from lactate dehydrogenase activity. After a 14-day period under full spectrum white light (pre-stress), 8 fish (BW = 36.29 ± 4.34 g) were sampled for biochemical analyses and the remainder stressed daily (1 h confinement day-1 for 14 days) and continuously kept for 14 days (stress period) under either (8 fish each): white colour (control; BW = 37.04 ± 2.29 g) or blue colour (test; BW = 35.27 ± 4.04 g). Light intensity was maintained at around 110 Lux throughout the 28 days of the experiment. All the fish gained body weight in the pre-stress period and growth rate was significantly decreased after confinement, irrespective of environmental colour. Considering the biochemical parameters, white muscle catalase was lowered at a similar rate in fish kept under either white or blue light, but in red muscles this activity was significantly reduced (41.03 %) by stress only in fish under white light. White muscle lactate dehydrogenase was unchanged, but it was increased significantly (about 23 %) in red muscles after stress under both colour conditions. Glutathione reductase was not affected at all. These results indicate that the blue spectrum could not prevent the stress-induced weight loss, but rather, it modulated the responses at biochemical levels, suggesting enhanced welfare in this species. Funded by CAPES and CNPq.

THE STRESS AND METABOLIC RESPONSES OF JUVENILE ATLANTIC COD (_Gadus morhua_) TO AN ACUTE THERMAL CHALLENGE

J.C. Pérez-Casanova1, L.O.B. Afonso1,2, S. Currie3, S. Johnson2 and A.K. Gamperl1
E-Mail: jucperea@yahoo.com

1Ocean Sciences Centre, MUN., St. John’s, NL, Canada; 2IMB-NRC, Halifax, NS, Canada; 3Mount Allison Univ. Sackville, NB, Canada

Session: LinO18

Abstract: In Atlantic Canada, cod are often transported from the hatchery to the cage-site at approximately 5-10g. However, these fish may be exposed to high and fluctuating, temperatures if they are stocked into sea-cages in the summer. Since little is known about the thermal tolerance of cod of this size, or what indices are most appropriate for assessing thermal stress in cod, we exposed 10g fish to an acute increase in temperature (2°C h-1 – from 10 to 24°C) and measured
survival, oxygen consumption (MO2), plasma cortisol and glucose, and gill hsp70 levels at 2°C intervals. Although 93% of the fish survived to 24°C, all fish died within 15 min. of this temperature being reached. MO2 gradually increased with temperature, and at 22°C was 2.7x greater than measured for control fish. Plasma cortisol levels showed an exponential increase with temperature, with values reaching ~ 100 and 200 ng ml\(^{-1}\) at 19 and 22°C, respectively. Plasma glucose, however, was not a useful index of sub-lethal stress as levels varied considerably and were only significantly elevated at 22°C. Interestingly, we did not detect changes in constitutive or inducible hsp70 levels at any temperature using either rabbit or salmonid specific antibodies. This latter result supports our previous work, and that of others, suggesting that these proteins in cod are not functionally similar to those expressed in other teleosts. We are now evaluating how 50g cod respond to the same experimental protocol to examine if juvenile size influences our results. This project was supported by funding from NSERC, the AquaNet NCE, the Canadian Centre for Fisheries Innovation, and the Atlantic Innovation Fund.

BRAIN STEREOTAXY AND GENE EXPRESSION: ESSENTIALS TOOLS FOR NEUROENDOCRINOLOGY

Peter, R.E. and Volkoff, H.
E-Mail: dick.peter@ualberta.ca
Department of Biological Sciences, University of Alberta, Edmonton, Alberta T6G 2E9, Canada Department of Biology, Memorial University of Newfoundland, St. John’s, Newfoundland A1B 3X9, Canada

Session: FisO1
Abstract: A stereotaxic technique and atlas of forebrain nuclei were first developed for the goldfish, and subsequently for other several species, including killifish, rainbow trout, Atlantic salmon and Indian catfish. The development of stereotaxic techniques opened the way for neuroendocrine studies involving brain lesioning, brain injections and pellet implantations, as well as mapping of brain peptide and neurotransmitter systems, particularly in the goldfish. Molecular cloning and development of cDNA probes have provided the opportunity to accurately localize sites of synthesis of peptides within the brain and to use gene expression as a tool to investigate the activity of selected brain peptide neuronal systems during such physiological events as ovulation, spawning and feeding. For example, an increase or a decrease in mRNA levels of a neuropeptide can be detected in a brain region such as the hypothalamus within minutes of an event such as brain injection of a peptide ligand or withholding of food at a scheduled feeding time. Based on use of the important tools of brain stereotaxy and gene expression, a model for the regulation of food intake in goldfish has been developed that can serve as the basis for future studies.

IS THE CARDIO-RESPIRATORY SYSTEM OF ATLANTIC COD (\(Gadus morhua\)) A LIMITING FACTOR FOR SURVIVAL IN EXTREME ENVIRONMENTS?

L. Petersen\(^1\), M. Gollock\(^1\), S. Currie\(^2\) and A.K. Gamperl\(^1\)
E-Mail: lene@mun.ca
1Ocean Sciences Centre, Memorial Univ. of Newfoundland, Canada; 2Dept. of Biol., Mount Allison Univ., Canada

Session: NorO7
Abstract: Cod are faced with acute increases in water temperature to near lethal levels at Canadian aquaculture cage-sites, and with severely hypoxic waters in the Gulf of St. Lawrence. Thus, we measured in vivo cardiac function and O\(_2\) consumption (MO\(_2\)), and performed in vitro experiments to examine whether the cod’s cardiorespiratory system may be limiting MO\(_2\) under these conditions. In the first study, we exposed cod to an acute temperature increase (1.75 °C h\(^{-1}\) to CTM) in vivo, and performed in vitro O\(_2\)-Hb binding curves at 8, 20 and 24 °C. Although cardiac output (Q) and heart rate (fH) increased until 2°C prior to the fish’s CTM (22.2 ± 0.2 °C), and in vivo increases in Q and fH were tightly correlated with MO\(_2\), in vitro O\(_2\)-Hb binding curves suggested that blood O\(_2\) carrying capacity may limit MO\(_2\) at the cod’s CTM. In the 2nd series of experiments we studied the effect of chronic hypoxia (6-12 wks at ≤ 45 % sat.) on Ucrit, MO\(_2\) (resting and maximum), and in vivo and in situ cardiac function under both normoxic and hypoxic conditions. These experiments showed that: 1) hypoxic acclimation does not alleviate the negative effects of short-term hypoxic exposure on exercise and metabolic capacity; 2) although max.Q during both normoxia and hypoxia is reduced significantly in hypoxia-acclimated cod, the hearts of these fish recover better following acute hypoxic exposure; and 3) MO\(_2\) was comparable in hypoxic and normoxic-acclimated fish, despite diminished cardiac function in the former. Future studies are planned to examine why cardiac function is limited in hypoxia-acclimated fish, and what adaptation(s) explain the latter result. Funded by NSERC.
FEEDING FREQUENCY, GROWTH, GHRELIN, AND NPY MRNA IN NORRIS AND NWAC103 CHANNEL CATFISH (Ictalurus punctatus)
B.C. Peterson and B.C. Small
E-Mail: bpeterson@ars.usda.gov
USDA-ARS Catfish Genetics Research Unit, Stoneville, MS, USA

Session: AdvO18
Abstract: Fish growth is influenced by feed availability and intake, genetics, environment, and nutrition. Of these factors, feed intake is perhaps the principal factor affecting growth rate of catfish. We examined the effect of feeding frequency on growth performance and abundance of ghrelin and NPY mRNA of juvenile Norris and NWAC103 strains of channel catfish reared under laboratory conditions. Catfish (4.0 ± 0.2 g/fish) were fed to visual satiety at different feeding frequencies (one, two, or three times daily). Specific growth rate and feed intake were higher in fish fed three times daily compared to once and twice daily for both strains. Feed efficiency was reduced in NWAC103 fed three times daily compared to fish fed once or twice while feed efficiency was similar among the Norris treatments. Gastrointestinal (GI) tract index [(weight of GI tract/weight of fish) x 100] decreased in NWAC103 catfish as feeding frequency increased while a similar nonsignificant trend was also observed in Norris catfish. Feeding frequency did not increase abundance of stomach ghrelin or brain NPY mRNA in either strain. Results demonstrate that aquarium reared Norris and NWAC103 catfish fed three times a day consume more feed and gain more weight than catfish fed once or twice a day. The observed decrease in the GI index due to feeding more frequently demonstrates that the size of the GI tract increases, relative to body weight, when catfish are fed only once a day. Feeding catfish under laboratory conditions once a day is similar to twice a day for growth and feed efficiency; however, feeding three times daily increased growth rates for both strains of catfish. Feeding frequency does not appear to affect ghrelin or NPY mRNA expression. Funded by USDA-ARS.

SYNOPTIC VIEWING OF TRAWL NETS AND FISH BEHAVIOUR: INTRODUCING THE ARNE
M. Pol and K. Ford
E-Mail: Mike.Pol@state.ma.us
Massachusetts Division of Marine Fisheries, Massachusetts, USA

Session: CapO1
Abstract: Improving the size or species-selectivity of commercial fishing gears relies on a fundamental understanding of the design and function of the gear and on the behaviour and reaction of marine organisms to the gear. Historically, field observation of fish reaction to otter trawls was conducted with divers and manned towed vehicles, complex camera systems, or simple cameras that provided a limited fixed view. The Division of Marine Fisheries has acquired a Remotely Operated Towed Underwater Vehicle (ROTV) with the goal of advancing our understanding of the fish capture process and simplifying the determination of reaction behaviours and gear performance. The ARNE (Advanced Research tool for Neritic Environments) is a Focus-2 vehicle from MacArtney, Inc. It is towed by a strengthened fiberoptic cable, and has yaw, pitch, and roll control flaps, which allow maneuverability in three dimensions. The ARNE offers a stable, versatile platform for flying sensors in and around fishing gear. It is currently instrumented with low-light and color cameras and a multibeam sonar head. Additional instrumentation, such as a DIDSON acoustic camera or water quality sensor package, is easily added. The ARNE will be used to examine the entire otter trawl capture process from the doors back to the codend. Our goal is to track individual fish with cameras and acoustic gear, allowing the determination of physiological capabilities (e.g. endurances) and behavioral differences between species. Funded by the National Marine Fisheries Service, the Marine Fisheries Institute and the Division of Marine Fisheries.

HOLDING STRESS IN CHINOOK SALMON AT SALVAGE OPERATIONS: EFFECTS ON PLASMA CONSTITUENTS AND SWIMMING PERFORMANCE
D.E. Portz and J.J. Cech, Jr.
E-Mail: deportz@ucdavis.edu
Department of Wildlife, Fish, and Conservation Biology, University of California, Davis, USA

Session: CapO5
Abstract: Several fish species in the Sacramento-San Joaquin Delta, California have declined in abundance, and water diversions are suspected of being one of the primary causes. Operations of south Delta fish salvage facilities require daily collection and holding of fish, and transport back to the Sacramento River. These salvage methods may inadvertently cause harm to entrained fishes. Measuring the acute physiological stress and potential direct and indirect mortality experienced by fishes during the different components of the salvage process is vital to understanding negative impacts associated with fish salvage. We assessed chemo-physiological changes and compromised performance over a functional spectrum in juvenile Chinook salmon (Oncorhynchus tshawytscha) that were exposed to simulated salvage-tank-related stresses. These assessments covered proximate (e.g., blood plasma constituents), performance (e.g., burst swimming), and ecological
measurements (e.g., predator avoidance), in evaluating three treatments (i.e., control, standardized stressor, and oval tank with a screw lift) under 5 different holding durations (4h, 6h, 8h, 12h, 24h). Preliminary results show the value of the functional spectrum approach in identifying stress-related effects of the fish salvage process. Exposure to holding conditions showed no negative effects, however fish removal methods had stress equivalent to 30 second air exposure. Manifested stress is conserved throughout the functional spectrum and can be resolved at each hierarchal level. Compromised swimming performance due to sublethal stresses may increase the susceptibility of these fishes to predators, and exposure to prolonged stressors may decrease fish performance and overall health, adversely affecting population size and sustainability. Research funded by USBR, Mid-Pacific Region.

RESPIRATORY, METABOLIC AND CARDIOVASCULAR RESPONSES OF SALMONIDS TO INFECTION WITH Neoparamoeba spp.

M.D. Powell, M.J. Leef and M. Jones
E-Mail: Mark.Powell@utas.edu.au
School of Aquaculture, University of Tasmania, Australia and Aquafin CRC

Session: DisO5

Abstract: Infections of salmonids with the amphizoic Neoparamoeba spp. results in Amoebic Gill Disease that affects production and survival of primarily Atlantic salmon in commercial culture. The respiratory effects of the disease on salmon appear to be relatively minor and although correlating with the progression and severity of infection, the multifocal nature of AGD lesions on the gill are unlikely to severely affect gas exchange. However, as the disease progresses there is an increase in standard and routine metabolic rate and ultimately a decrease in metabolic scope suggesting an increase in oxygen demand probably reflective of the increased metabolic activity of the gill due to the branchial hyperplasia. Infection of salmon with Neoparamoeba spp. under laboratory conditions results in an increase in systemic vascular resistance that is not seen in the less susceptible rainbow or brown trout. This increase in vascular resistance was partially eased by intravenous administration of sodium nitroprusside or the ACE inhibitor captopril. SNP reduced the vascular hypertension to a greater relative extent in AGD affected fish suggesting whereas captopril had the same anti-hypertensive effect in both AGD affected and control fish. Amoebic gill disease, although presenting primarily in the gills of Atlantic salmon appears to have a more profound and systemic pathology that partially explains the reduced stress tolerance of affected salmon. This work was funded through the Cooperative Research Centre for sustainable finfish aquaculture and the Australian Research Council.

NATRIURETIC PEPTIDE RECEPTOR EXPRESSION AND FUNCTION IN RAINBOW TROUT HEAD KIDNEY LEUCOCYTES – ANOTHER ROLE FOR NATRIURETIC PEPTIDES IN FISH

M.D. Powell¹, H. Macwilliam², S. Nankervis², R. Butler¹ and M-T. Toop²
E-Mail: Mark.Powell@utas.edu.au
¹School of Aquaculture, University of Tasmania, Australia; ²School of Biological and Chemical Sciences, Deakin University, Australia.

Session: DisO4

Abstract: Rainbow trout head kidney leucocytes were isolated and either stored in RNA later (for PCR receptor expression) or were incubated in 96 well microtitre plates and stimulated with agonists and respiratory burst measured. Using oligonucleotide primers specific to rainbow trout natriuretic peptide A and B receptors, sequences were amplified from leucocyte cDNA. Head kidney macrophages were stimulated in vitro with a range of concentrations of trout atrial natriuretic peptide (tANP) or trout c-type natriuretic peptide (tCNP) (10⁻⁴-10⁻⁹ M) or the cGMP analogue 8-bromocyclic guanosine monophosphate and the respiratory burst measured relative to stimulation with PMA and con A. In a second set of experiments, macrophages were stimulated with tCNP or tANP (10⁻⁶ M) in the presence of the cGMP competitive inhibitor 8-bromo-phenyleuthenoguanosine monophosphate resulting in a dose dependent inhibition of respiratory burst. These results suggest that functional natriuretic peptide receptors occur on head kidney macrophages and appear to function through a cGMP mediated second messenger system. This work was funded through the Australian Research Council.

BAROTRAUMA AND RECOVERY IN ROCKFISHES (Sebastes spp.)

A. L. Pribyl¹, S. J. Parker² and C. B. Schreck¹
E-Mail: alena.pribyl@oregonstate.edu
¹Oregon State University, Dept. of Fisheries and Wildlife, Corvallis, OR; ²Oregon Dept. of Fish & Wildlife, Hatfield Marine Science Center, Newport, OR

Session: CapO3

Abstract: Discarded rockfishes (Sebastes spp.) from the Northeast Pacific experience high mortality as bycatch in part due to the effects of “barotrauma,” which is induced from the rapid change in pressure during capture. As a result of
barotrauma, catch and release techniques may not be effective for discarded fish. Field experiments show that it may be possible for rockfish to recover in the short term from barotrauma if quickly recompressed prior to release. However, no work has followed the physiological recovery of rockfish after recompression or determined if it is possible for rockfish to survive such a severe and multifaceted physical stress. In this study, we induced barotrauma in black, blue, and yellowtail rockfish that were acclimated to 3.5 ATM (35 m depth) using hyperbaric chambers. The severity of barotrauma and levels of plasma cortisol were compared among species. Yellowtail rockfish experienced the lowest levels of barotrauma, and blue rockfish appeared to have the highest stress response compared to other species. We also induced barotrauma with subsequent recompression in black rockfish that were acclimated to 3.5 ATM (35 m depth). Following recompression, rockfish were slowly acclimated to surface pressure and transported to 2.4 m diameter tanks for recovery. Tissues (brain, eye, gill, pseudobranch, heart, head kidney, liver, rete mirabile, and gonad) of rockfish were sampled at 2, 14, and 30 days post-recompression to evaluate the cellular-level response during recovery from barotrauma. The heart was most severely affected with tissue emphysemas covering approximately 3% of the tissue, but emphysemas appeared to heal over time. This project is funded by the Coastside Fishing Club, Oregon Department of Fish and Wildlife, and the Hatfield Marine Science Center.

**SEASONAL EXPRESSION PATTERN OF PPARα, PPARγ, ERA AND RXRA IN TISSUES OF THE THICKLIP GREY MULLET (Chelon labrosus)**

D. Raingeard, I. Cancio and M. P. Cajaraville

E-Mail: gcbrasad@lg.ehu.es


Session: ImpP7

Abstract: Marine and estuarine organisms are exposed to xenobiotics that can cause peroxisome proliferation and/or endocrine disruption, both cell responses being modulated by transcription factors belonging to the nuclear receptor (NR) superfamily. In vertebrates, peroxisome proliferators are agonists of peroxisome proliferator-activated receptors (PPARs) that act through dimerization with the retinoid X receptor (RXR). Many xenoestrogens on the other hand act through the estrogen receptor (ER). PCR-based screening of mullet Chelon labrosus cDNA with degenerate primers resulted in the amplification, cloning and sequencing of cDNA fragments encoding different NRs: 1090 bp for PPARα, 1255 bp for PPARγ, 278 bp for RXR, and 578 bp for ERα. In January and June 2005, semi-quantitative RT-PCR was used to characterize the expression pattern of these NRs in different tissues of male, female and juvenile mullets employing 18S-rRNA, β-actin and elongation factor α as housekeeping genes. Expression of both PPARs was highest in liver and lowest in muscle of mature individuals. RXRα expression was homogeneous in all tissues excepting a decrease in adult gill in winter and juvenile brain. ERα predominated in liver and female gonad in spring, while no expression was detected in gill and muscle. The regulation of these genes under exposure to xenobiotics is under study in our lab with the aim of developing new tools to assess the effect of pollutants on fish. Funded: Spanish MEC (REN2002-02982/MAR, VEM2003-20082-CO6-01), Basque Government (ETORTEK-IMPRES) & UPV/EHU (consolidated groups).

**DIFFERENTIAL EXPRESSION OF NUCLEAR RECEPTORS IN THE MULLET (Chelon labrosus) EXPOSED TO PFOS AND TO PRESTIGE-LIKE FUEL OIL**

D. Raingeard, I. Cancio and M. P. Cajaraville

E-Mail: gcbrasad@lg.ehu.es


Session: ImpO24

Abstract: Animals living in coastal waters are exposed to xenobiotics that can cause peroxisome proliferation (PP) and/or endocrine disruption. Peroxisome proliferators are agonists of peroxisome proliferator-activated receptors (PPARs) that upon dimerization with the retinoid X receptor (RXR) induce PP, while many xenoestrogens bind to the estrogen receptor (ER). Fragments of PPARα (AY618315), PPARγ (submitted), RXR (DQ011294) and ERα (DQ011293) were cloned in the thicklip grey mullet Chelon labrosus and their expression pattern studied by semi-quantitative RT-PCR in liver of mullets exposed for 2 and 16 days to perfluorooctanesulfonate (PFOS), a typical mammalian peroxisome proliferator, and to Prestige-like fuel oil (fuel oil no.6); fresh and weathered for 2 months before exposure. 18S-rRNA (AY836368) and elongation-factor α (AY836369) were used as housekeeping genes. After 2 days of exposure to fresh and weathered fuel, PPARα and RXR expression was significantly up-regulated whereas PPARγ expression decreased in the three treatments. No significant effect of PFOS or fuel was noted on ERα expression. Although attenuated, trends were similar after 16 days of exposure except for RXR where expression decreased significantly in weathered fuel with respect to the control. Results indicate the potential of PFOS and fuel oil to cause PP and to alter lipid homeostasis in mullets.
CORTISOL RESPONSE OF ZEBRAFISH: AN INDICATOR OF CROWDING AND HANDLING STRESS

JM Ramsay¹, GW Feist¹, Z Varga², M Westerfield², ML Kent⁴ and CB Schreck¹

E-Mail: jennifer.ramsay@oregonstate.edu

¹Oregon Cooperative Fish & Wildlife Research Unit, Dept. Fisheries & Wildlife, Oregon State University (OSU), Corvallis OR USA; ²Zebrafish International Resource Center (ZIRC), University of Oregon (UO), Eugene OR; ³Institute of Neuroscience, UO; ⁴Center for Fish Disease Research, Dept. Microbiology, OSU

Session: MolO21

Abstract: Environmental stress can adversely affect the health, welfare and fitness of cultured fish species. Better understanding how cultured fishes respond to husbandry stressors aids in improving rearing environment, fitness and production parameters. Despite wide use as a vertebrate research organism, the effects of husbandry stress on zebrafish (Danio rerio) have not been thoroughly investigated. We have demonstrated whole-body cortisol to be a useful indicator of crowding and handling stress in adult zebrafish. Crowding zebrafish for 3 hours or 5 days resulted in a four-fold increase in cortisol compared to fish not crowded. In fasted fish, weight was inversely related to the cortisol response to crowding. Feeding ameliorated crowding-induced increases in cortisol. Severe net stress resulted in a six-fold increase in whole-body cortisol compared to controls (no netting). Following net stress, cortisol increased linearly peaking at 15 minutes post-net stress. A similar rate of decrease in cortisol was observed; at 60 minutes post-net stress cortisol in the net stressed group did not differ from control fish. Better understanding the role of stress-induced elevations in cortisol on zebrafish reproduction and susceptibility to disease may improve management of these husbandry-related problems as well as the consistency of research involving this popular fish model. Funding: National Institutes of Health, OSU, ZIRC, NSERC Postgraduate Fellowship

CHARACTERIZATION OF PCB BIOACCUMULATION IN THE LAKE HARTWELL FOODWEB USING THE AQUATOX MODEL.

B. Rashleigh¹, M.C. Barber¹ and D. Walters²

E-Mail: rashleigh.brenda@epa.gov

¹U.S. Environmental Protection Agency, Athens GA, USA; ²U.S. Environmental Protection Agency, Cincinnati OH, USA

Session: ImpO13

Abstract: PCBs from the Sangamo-Weston Superfund Site near Clemson, South Carolina, USA, were released into the Twelvemile Creek arm of Lake Hartwell until the early 1990s. Monitoring data have shown that while PCB concentration in sediments declined since 1995, PCB concentrations in largemouth bass have remained in the range of 5-10 ppm. The EPA aquatic ecosystem model AQUATOX was applied to this system to better understand food web dynamics and characterize bioaccumulation. The model was parameterized with available flow, nutrients, and TOC data, calibrated with observed fish biomass data, and then initialized with measured PCB values in water (0.05ug/L), sediment (5 ppm), and fish. According to model results, PCB loadings at approximately half the initial conditions were necessary to simulate fish PCB concentrations in the range of observed data over a 5-year period. The model demonstrated that contaminated detritus loaded to the system was incorporated into the food chain through direct consumption and ingestion by benthic organisms. More detrital PCB was consumed than deposited (17% vs. 4%), thereby maintaining the PCB concentrations in fish while the concentrations in the sediment declined. The model can be used to estimate the time needed for PCB concentrations in fish to be reduced to target levels for recovery (>2.0 ppm). Although this work was reviewed by EPA and approved for publication, it may not necessarily reflect official Agency policy.

GROWTH, PROTEIN AND ENERGY UTILIZATION AND GENE EXPRESSION IN TRANSGENIC COHO SALMON (Oncorhynchus kisutch)

P.A. Raven¹, R.H. Devlin² and D.A. Higgs²

E-Mail: ravenp@dfo-mpo.gc.ca

¹Dept. of Zoology, UBC, Canada; ²Fisheries and Oceans Canada, BC

Session: GenO8

Abstract: The increased feeding motivation and extreme growth found in growth hormone (GH) transgenic coho salmon (Oncorhynchus kisutch) raises questions regarding the hormonal changes regulating growth and feed intake. Transgenic and non-transgenic coho were fed diets with 15, 17, 19 and 21 MJ/kg digestible energy for 84 days and analyzed for growth, feed intake and protein utilization. Gene mRNA expression of the major regulators in the GH-axis as well as the appetite hormone, cholecystokinin (CCK), were analyzed in the brain of fish from this experiment and in six brain regions,
muscle and liver of a size-matched comparison of full-ration transgenic, restricted-ration transgenic (pair-fed to non-transgenic) and full-ration non-transgenic fish. Transgenic fish had greater feed intake and growth which were negatively and positively correlated with digestible energy of the diet respectively. Protein use was more efficient in transgenic fish fed the 15 and 17 MJ/kg diets. Gene expression of all hormones did not change between transgenic fish on the different diets. Plasma insulin-like growth factor I (IGF-I) was greater in transgenic fish but did not correlate with weight as in the non-transgenic coho. In the size-matched study, GH and GH receptor expression were generally higher in the transgenic fish and hepatic IGF-I expression followed growth rate irrespective of genotype. There were no conclusive differences in the other hormones. Transgenic fish, with increased growth, feed intake and protein utilization, are consuming to a caloric demand possibly due to increased GH, and IGF-I with little changes to the GH regulating hormones and the CCK satiety signal. Funded by the Canadian Regulatory System for Biotechnology.

HYPOXIA AND REPRODUCTIVE TRADE-OFFS IN AN AFRICAN MOUTH BROODING CICHLID

E.E. Reardon1 and L.J. Chapman1,2
E-Mail: erin.reardon@mail.mcgill.ca

1Biol. Dept., McGill Univ., Canada; 2Wildlife Conservation Society, USA

Session: HypO12
Abstract: Eutrophication and pollution of water bodies, driven by influxes of municipal wastes and fertilizer runoff, has led to decreased levels of dissolved oxygen (DO), or hypoxia, in aquatic ecosystems around the world. Despite the increasingly widespread nature of hypoxia in fresh waters, little is known about reproductive costs of oxygen scarcity for fishes. In this study, we explore the relationship between DO and reproductive traits of a mouth brooding African cichlid Pseudocrenilabrus multicolor. Brooding and non-brooding female P. multicolor were collected from seven sites in Uganda that represented a range of DO concentrations. For each population, we estimated size at maturity and brood quality metrics (e.g., number of eggs, egg volume, egg energy content). In a laboratory growth experiment, we raised F1s from multiple families of two field populations using a split brood design. For brooding females, we quantified the suite of reproductive traits measured for field populations, and we compared metabolic rates of brooding, non-brooding females, and males. In the field, P. multicolor was found to breed successfully in normoxic waters but also under conditions of extreme hypoxia. Field populations from hypoxic sites were characterized by a smaller size at maturity and lower number of young per brood. Although there was no difference in mean egg energy content, broods raised under hypoxia had a smaller size at maturity and produced fewer, larger eggs; indicating a degree of environmentally-induced variation in reproductive traits. These findings provide evidence for an effect of hypoxia on reproductive characters of P. multicolor. The flexibility in life history traits exhibited by this fish may contribute to its widespread distribution and its persistence in the face of environmental change. Funded by: Sigma Xi, ASIH, ACA, MGSF, and NSERC support to LJC.

TRIGGERS AND TARGETS OF OXYGEN-DEPENDENT GENE EXPRESSION IN FISH

B.B. Rees
E-Mail: brees@uno.edu
Dept. Biol. Sci., Univ. New Orleans, USA

Session: PleO5
Abstract: A variety of aquatic habitats are characterized by periods of low dissolved oxygen, and fish display a variety of behavioral, anatomical, and physiological specializations to deal with hypoxia. The purpose of this presentation is to review evidence for molecular responses to hypoxia in fish, with special emphasis on the presence and role of the hypoxia inducible factor (HIF), a dimeric transcription factor implicated in the regulation of oxygen-dependent gene expression in animals. Among fish, at least three different HIF-alpha subunits have been cloned and sequenced, HIF-1 alpha, HIF-2 alpha, and a third form which may represent the fish homolog of HIF-3 alpha. In the killifish Fundulus heteroclitus and F. grandis, there is polymorphism in the nucleotide sequences of the HIF-1 alpha and HIF-3 alpha subunits. The functional role of this polymorphism, if any, is unknown. Data on the expression of HIF-alpha mRNA and protein are limited, but they suggest a broad tissue distribution for HIF-1 alpha protein in salmonids and HIF-2 alpha mRNA in Fundulus heteroclitus. Although there are a variety of potential targets of regulation by HIF, a role in transcriptional regulation has only been demonstrated for a small number of putative targets. On-going and future research should clarify the tissue distribution, oxygen sensitivity, and role of the multiple forms of HIF, as well as characterize their interactions with additional target genes in the molecular response of fish to hypoxia. Supported by the US NSF.
POPULATION VARIATION IN PROTEIN EXPRESSION IN FUNDULUS

B.B. Rees¹, T. Andacht² and D.L. Crawford³
E-Mail: brees@uno.edu

¹Dept. Biol. Sci., Univ. New Orleans, USA; ²Univ. Georgia, USA; ³Univ. Miami, USA

Session: ProO15

Abstract: Previous studies using cDNA microarrays have shown that gene expression in the killifish Fundulus heteroclitus varies among and within populations sampled along the Atlantic coast of North America. Here, we assessed patterns of protein expression in northern and southern populations of F. heteroclitus and a single population of F. grandis (from habitats similar to southern F. heteroclitus). Cardiac proteins were separated by 2-dimensional gel electrophoresis, imaged by fluorescent labeling, and identified by mass spectrometry. The fluorescence intensities of 408 spots were analyzed by ANOVA for among- and within-population variation. About 26% of the protein spots (108) were significantly different among populations and 30% (126) showed significant inter-individual variation within a given population (P < 0.01). After correcting for multiple comparisons, 18 protein spots were significantly different among populations and 42 were significantly different within a given population (P < 1.25 E-04). The results support conclusions based upon cDNA arrays that populations of Fundulus differ in gene expression and that variation within populations is greater than variation among populations. Cluster analysis of fluorescence intensities resulted in three distinct groups, with southern F. heteroclitus being more similar to F. grandis than to northern conspecifics. Using mass spectrometric analyses of trypsin-digested gel spots, we identified several contractile proteins and proteins of intermediary metabolism among the proteins that differed within or among populations. Variation in these proteins will be interpreted in the context of known changes in mRNA abundance and their implications for possible functional variation among populations of Fundulus. Funded by NSF.

VENTILATORY ACCLIMATISATION TO HYPOXIA IN VERTEBRATES

Stephen G. Reid
E-Mail: sgreid@utsc.utoronto.ca

Centre for the Neurobiology of Stress, Department of Life Sciences, University of Toronto at Scarborough, 1265 Military Trail, Toronto, Ontario, M1C 1A4, Canada

Session: HypO1

Abstract: Although exposure to aquatic hypoxia is a common occurrence for many species of fish, particularly tropical and neo-tropical fish, environmental hypoxia (chronic, acute or intermittent) is a relatively rare occurrence for other groups of vertebrates such as mammals, birds, reptiles and amphibians. However, there are a number of situations in which terrestrial air-breathing vertebrates can encounter hypoxic situations. These include ascent to high altitude (i.e., mountain-climbing or high altitude flying), life in underground burrows and, for some reptiles/amphibians, over-wintering underwater in ponds. This talk will review some of the cardiorespiratory responses of non-fish vertebrates to chronic and intermittent hypoxia. For example, the classical ventilatory response to chronic hypoxia in mammalian species is ventilatory acclimatisation to hypoxia (VAH). VAH manifests as an increase in resting ventilation as well as an increase in the responsiveness of the respiratory control systems to further bouts of acute hypoxia. These changes are induced by an increase in sensitivity in the periperal O₂ chemoreceptors and changes in the sensitivity of the central nervous system to afferent input from these chemoreceptors. Our recent studies have revealed that changes in both glutamate and GABA neurotransmission in the brainstem are involved in this later process. Further studies from this laboratory have demonstrated that the responses to chronic hypoxia in amphibians are different from those in mammals, possibly reflecting the different degrees of hypoxia tolerance. NSERC

BEHAVIOUR AND PHYSIOLOGY OF SMALLMOUTH BASS (Micropterus dolomieu) IN AN EXPERIMENTAL FISHWAY

J.E. Reid and S. J. Peake
E-Mail: speake@unb.ca

Canadian Rivers Institute, Univ. of New Brunswick, Fredericton, Canada

Session: AdvO16

Abstract: Swimming physiology of fish has primarily been studied in the laboratory using swim tunnels and respirometers. However, researchers have recently begun to study behaviour, biomechanics, and energetics in turbulent flow, and in raceways that do not confine fish in small spaces. Results of this work suggest that turbulence can impact the energetic costs of movement, and that unconfined fish can attain higher swimming speeds than individuals in swim tunnels. This study was conducted to examine the effects of physical barriers and non-linear flow patterns on passage behaviour and post-exercise physiology of smallmouth bass, for comparison with published data for fish that ascended a raceway with no barriers or turbulence. Muscle and plasma samples were removed from individuals that voluntarily ascended a 20-m inclined (10%) channel that contained either Denil or vertical slot baffles. Physical differences in the baffles created
different physical impediments to straight-line swimming, and different patterns and degrees of turbulence. Results indicate that anaerobic energy use in the present study was elevated relative to that of individuals that faced similar water velocities for similar periods of time while moving through an open channel. Fish that ascended the Denil fishway (which created more turbulence) showed evidence of greater anaerobic energy recruitment than those that moved through the vertical slots, even though ascent times were not significantly different. We therefore conclude that physical barriers and turbulence increase energy demands in swimming fish. Funded by NSERC, the Canadian Foundation for Innovation, and Manitoba Hydro.

**EXPLORING GENE EXPRESSION IN THE BRAIN OF FISH DURING NOCICEPTION USING TRANSCRIPTOMICS**

S.C. Reilly¹, A.R. Cossins¹, J.P. Quinn² and L.U. Sneddon¹

E-Mail: sreilly@liv.ac.uk

¹School of Biological Sciences, University of Liverpool, United Kingdom; ²Physiological Laboratory, University of Liverpool, United Kingdom

**Session:** MolO3

**Abstract:** Nociception is the detection of stimuli that may cause tissue damage and in humans can give rise to pain. Recent studies in fish have demonstrated that a nociceptive stimulus induces a prolonged behavioural response and elevates cortisol levels. Many genes are differentially expressed during nociception and a global overview of this event can be obtained with microarray technology. The present study investigated global transcript profiles in brain regions of two species of fish. Common carp (*Cyprinus carpio*) and rainbow trout (*Oncorhynchus mykiss*) were given a noxious stimulation and subsequently sampled at 1.5, 3 and 6 hours. The brain was carefully dissected and forebrain, midbrain and hindbrain regions were collected. Gene expression in each brain region was examined by comparing the experimental group with controls using a carp cDNA microarray. Several genes that are known to be important in nociception in mammals showed a significant response, for example BDNF. Novel genes were also identified that have not previously been linked to nociception. The majority of responsive genes were found in the forebrain at 1.5 and 3 hours. These times correlate with the performance of anomalous behaviours. The results also indicate that the forebrain is an important brain region for the interpretation of nociceptive stimuli. Three candidate genes and their proteins will be examined using in situ hybridisation and western blotting. This work was funded by BBSRC.

**NA+/K+-ATPASE AND V-ATPASE EXPRESSION IN AMMOCOETE AND METAMORPHIC SEA LAMPREY (*Petromyzon marinus*)**

P.N. Reis-Santos¹,², S.D. McCormick² and J.M. Wilson¹

E-Mail: pnsantos@fc.ul.pt

¹Ecofisiologia-CIIMAR, Porto, Portugal; ²USGS Conte Anadromous Fish Research Center, MA, USA

**Session:** IonP3

**Abstract:** The lamprey *Petromyzon marinus* is an anadromous fish and the larval ammocoetes spend many years in fresh water before metamorphosing and migrating to sea. Metamorphosis involves the radical transformation from a substrate dwelling filter feeder into a free swimming parasitic feeder. During the transformation, lamprey have been found to already have acquired salinity tolerance which is essential for their juvenile and adult marine phase. In the present work we examined the effects of short term salinity acclimation (7d) in ammocoetes, both before and during transformation (larvae: DW,FW,10‰ and transformers:DW,FW,20,25,30, 35‰SW). We measured the expression of key branchial ion transporting proteins (Na⁺/K⁺-ATPase, V-type H⁺ ATPase) as well as a number of relevant blood parameters (Hct, [Na⁺], and [Cl⁻]). Pre-metamorphic larvae had significantly lower plasma [Na⁺] and [Cl⁻] which increased markedly with salinity challenge (10%). In transformers, plasma ions only increased at high salinity (>25‰). Branchial Na⁺/K⁺-ATPase levels were ~10-fold higher in transformer compared to larvae and salinity did not affect expression in either group. However, branchial H⁺ ATPase expression showed a negative correlation with salinity in both groups. Na⁺/K⁺-ATPase immunoreactivity was strongest in transformers and associated with clusters of cells in the interlamellar spaces. V-ATPase (B subunit) immunoreactivity was localized to a separate cell type in a similar pattern as carbonic anhydrase. The results indicate that Na⁺/K⁺-ATPase and salinity tolerance increase in metamorphosing lamprey, and that H⁺ATPase is downregulated by salinity. -PNRS was supported by 7thFLAD-IMAR scholarship to USA.
A GENETIC LINKAGE MAP FOR ATLANTIC HALIBUT (Hippoglossus hippoglossus)
M. Reith1, D. Reid1, C. Smith1, B. Blanchard2 and D.J. Martin-Robichaud3
E-Mail: martin-robichaudd@mar.dfo-mpo.gc.ca
1NRC Institute for Marine Biosciences, Halifax, NS, Canada; 2Scotian Halibut Ltd., Clarks Harbour, NS, Canada; 3Fisheries and Oceans, St. Andrews Biological Station, St. Andrews, NB, Canada
Session: GenP3
Abstract: A moderate density genetic linkage map for Atlantic halibut (Hippoglossus hippoglossus) that was generated using two maternal half-sib families (n=90) has been constructed to map quantitative trait loci (QTL) associated with phenotypic traits. To date, more than 250 microsatellite loci have been placed on the map. These markers have been derived from several sources: ~125 were from an Atlantic halibut genomic library enriched for (GT)n sequences, ~75 were derived from microsatellites in Genbank sequences from other pleuronectid species and >50 were identified in halibut EST sequences. The latter group has resulted in the mapping of specific genes. In addition, more than 350 AFLP markers, generated from 64 combinations of primers, have been mapped. The map consists of 23 linkage groups, in close agreement with the 24 chromosomes in this species. The rate of recombination is slightly higher (1.2:1) in the heterogametic females. Centromere locations are currently being estimated for each linkage group by genotyping selected microsatellites in gynogenetic offspring. Morphometric data were collected for each experimental family to potentially identify QTL associated with pigmentation, body size (length, width, weight) and metamorphosis (eye migration, myotome height). A genetic map and the identification of markers associated with traits of economic importance will allow the Atlantic halibut industry to make significant production gains through marker assisted selection and broodstock enhancement. Funded by DFO ACRDP and Genome Canada/Genoma España.

THE EFFECT OF HYPOXIC AND ANOXIC PRECONDITIONING ON THE BALANCE OF EXCITATORY AND INHIBITORY AMINO ACIDS: NEUROPROTECTIVE ADAPTATIONS OF A TROPICAL ANOXIA TOLERANT REEF SHARK (Hemiscyllium ocellatum)
G.M.C. Renshaw1, J.M. Mulvey2, G. Wise1, B. Garnham1 and G.E. Nilsson3
E-Mail: g.renshaw@griffith.edu.au
1Hypoxia and Ischemia Research Unit, Griffith University, Qld, Australia; 2Medicine, University of Sydney, NSW Australia; 3University of Oslo, Norway
Session: HypO3
Abstract: The reef platform of coral cays can provide an intermittently hypoxic environment that primes its inhabitants to resist the physiological stress caused by hypoxia & reoxygenation. One reef dweller, the epaulette shark can withstand up to 5 hours of anoxia. In order to determine whether the balance of excitatory & inhibitory amino acids changes to a neuroprotective profile in response to diminished oxygen, we examined the effect of experimental hypoxia & anoxia on the levels of amino acids in epaulette shark brain using immunohistochemistry & HPLC. Immunohistochemical studies of brainstem nuclei revealed that there was a heterogenous change in the level of, the inhibitory amino acid, GABA while no change was detected in the level of, the excitatory amino acid. There was a significant increase in the level of GABA in the vagus, a cardiorespiratory centre. The spatial pattern of increased GABA inhibition corresponded to the pattern of decreased neuronal activity in brainstem nuclei as well as observed bradycardia & ventilatory depression. Our HPLC studies showed that while levels of glutamate remained unchanged, the level of GABA, glutamine & taurine were higher than in control tissue. These data suggest that anoxia tolerant adaptations in the phylogenetically older elasmobranch may parallel those reported for teleosts that evolved their hypoxia & anoxia tolerance at temperatures close to freezing. Funded by Sea World Research & Rescue Foundation.

ENDOCRINE DISRUPTION IN FLATFISH OF THE SOUTHERN CALIFORNIA BIGHT
J. A. Reyes1, D. M. Petschauer1, R. K. Hagstrom1, J. L. Armstrong2, A. Dalkey3, K. Sak1 and K. M. Kelley1
E-Mail: jreyes2@csulb.edu
1Environmental Endocrinology Lab, Dept. of Biological Sciences, California State University, Long Beach, Long Beach, CA 90840; 2Environmental Assessment Division, Orange County Sanitation District (OCSD), Fountain Valley, CA, 92708; 3Environmental Monitoring Division, City of Los Angeles Bureau of Sanitation, Los Angeles, CA 90293.
Session: ImpO27
Abstract: Despite the enormous human population affecting southern California’s marine environment, the issue of endocrine disruption in marine wildlife has been virtually unstudied in this region. Our work to date has uncovered clear evidence of endocrine-disrupted states in flatfish living in proximity to wastewater treatment plant (WWTP) outfall locations as compared with fish at more distal sites. Among these are a blunted endocrine stress response (impaired hypothalamo-pituitary-interrenal axis) and reduced levels of the important growth-regulatory peptide, insulin-like growth factor-I (IGF-I). Additionally, in a non-migratory flatfish species (hornyhead turbot, Pleuronichthyes verticalis), blood and
tissue concentrations of 17β-estradiol (E2) are significantly elevated in association with proximity to WWTP outfalls. These observed endocrine alterations will be discussed in terms of underlying steroidogenic mechanisms (for E2 and cortisol), interactions between the endocrine systems under study, and potential impacts of human-derived factors. Support by Southern California Sea Grant College Program.

GENOMIC METHODS AND BEHAVIOR TESTING USED TO ASSESS IMPACT OF ORGANOPHOSPHATE PESTICIDES ON EARLY LIFE STAGE TROUT
M.L. Rise, M. Rise, S.L. Miller and A. Schmoldt
E-Mail: mrise@uwm.edu
Great Lakes WATER Institute, University of Wisconsin-Milwaukee, USA

Session: FisO8
Abstract: We develop tools to study biologically significant impacts of low levels of organophosphate pesticides (OPs) in water, and to resolve molecular mechanisms by which OPs can cause neurological and behavioral defects in vertebrates. OPs are widely used in U.S. and international agriculture. OPs exert their acutely toxic effects by inhibiting acetylcholinesterase, which is critical to the normal functioning of cholinergic synapses. A toxicogenomic approach was used to characterize response of the juvenile rainbow trout transcriptome to 48 hour sub-acute (1-100 ppb) waterborne chlorpyrifos exposure relative to vehicle control. A reference design microarray experiment, using ~3500 gene GRASP cDNA microarrays with Genisphere Array 50 reagents and methods, identified candidate molecular biomarkers of chlorpyrifos exposure. Results were validated using quantitative RT-PCR (QPCR) on individual fish samples. We created a suppression subtractive hybridization (SSH) cDNA library from chlorpyrifos-exposed and control tissues to identify novel trout genes responsive to chlorpyrifos. In addition, we are developing methods for studying changes in behavior that are associated with chlorpyrifos exposure. We employ EthoVision, a video tracking system that enables automatic behavior recognition and analysis of locomotory tracks. Early results demonstrate that fish activity can be evaluated with this software. Behavioral profiling, and functional annotation of chlorpyrifos-responsive genes, will add detail to our understanding of potentially deleterious changes associated with OP exposure in fish, and provide biomarkers for assessing biological impacts of OPs on feral fish populations. Funded by the Shaw Foundation, NIEHS, and the CWS (USDOD) (MLR).

MICROARRAY-BASED GENE EXPRESSION PROFILING OF GH TRANSGENIC COHO SALMON LIVER WITH AND WITHOUT RATION RESTRICTION.
M.L. Rise1, S.E. Douglas2, D. Sakhrami2, J. Williams2, K.V. Ewart2, M. Rise1, W.S. Davidson4, B.F. Koop5 and R.H. Devlin3
E-Mail: mrise@uwm.edu
1Great Lakes WATER Institute, Univ. of Wisconsin-Milwaukee, USA; 2Inst. for Marine Biosciences, NRC, Canada; 3Fisheries and Oceans Canada, West Vancouver; 4Dept. of Molecular Biology and Biochemistry, Simon Fraser Univ., Canada; 5Centre for Biomedical Research, Univ. of Victoria, Canada

Session: GenO4
Abstract: Three groups of salmon were examined: transgenic on full ration (T), transgenic on restricted ration (R), and control nontransgenic (C). Differential gene expression in T, R, and C liver was determined using ~3500 gene (3.5K) and 16K microarrays from GRASP, and R and C samples were compared using a 4K microarray from the IMB. A large number of genes informative in these studies are involved in iron homeostasis, mitochondrial function, carbohydrate metabolism, cellular proliferation, and innate immunity. Cross-platform comparisons identified genes behaving similarly between studies. For example, genes encoding a precerebellin-like protein and complement C3 were down-regulated in R relative to C (R < C) in 2 studies, and hemoglobins a and b were R > C in all 3 studies. Comparisons of informative gene lists within and between studies inferred causes of altered gene expression. A suite of genes including 78 kDa glucose-regulated protein, hemoglobins a and b, and a C-type lectin, were likely induced by transgenesis given their presence in both T > C and R > C gene lists. Changes in the expression of genes involved in maintaining hemoglobin levels in transgenic fish indicate a need for additional hemoglobin, perhaps due to higher metabolic rate required for enhanced growth. Funded by the Shaw Foundation (MLR), the Canadian Biotechnology Strategy Genomics Fund (RHD), and Genome Canada, Genome BC, NRC, and NSERC (BFK).
GENOMIC RESOURCES FOR STUDYING EARLY LIFE STAGE SALMONID HEALTH

M.L. Rise¹, M. Rise¹, D.C. Honeyfield³, R.H. Devlin⁴, C.E. Rexroad⁴, W.S. Davidson⁵ and B.F. Koop⁶

E-Mail: mrise@uwm.edu

¹Great Lakes WATER Institute, University of Wisconsin-Milwaukee, USA; ²Northern Appalachian Research Laboratory, USGS; ³Fisheries and Oceans Canada, West Vancouver; ⁴USDA Agricultural Research Service, National Center for Cool and Cold Water Aquaculture; ⁵Dept. of Molecular Biology and Biochemistry, Simon Fraser Univ.; ⁶Centre for Biomedical Research, Univ. of Victoria, Canada.

Session: ProO5

Abstract: Genomic approaches are being used to study pathological and normal processes in early life stage salmonids. Early Mortality Syndrome (EMS), a disease associated with low egg thiamine levels, causes early life stage mortality and low recruitment of Great Lakes salmonids including lake trout. We use GRASP microarrays, quantitative RT-PCR (QPCR), and suppression subtractive hybridization (SSH) cDNA library construction and characterization, to identify key genes dysregulated in thiamine deficient lake trout eggs and embryos relative to thiamine replete individuals. We hypothesize that the functional annotations of informative genes will point to molecular pathways altered in EMS. Molecular biomarkers of thiamine deficiency will be tested in QPCR-based assays on templates prepared from feral lake trout eggs of various thiamine levels. The knowledge gained from this work may lead to the development of tools for selection of EMS-resistant broodstock. In addition, GRASP microarrays and SSH libraries have been used to study global gene expression changes occurring during normal rainbow trout embryonic development. This work will improve the characterization of embryonic salmonid transcriptomes, paving the way for development of genomic tools tailored to studies involving early life stage salmonids. Funded by the Shaw Foundation (MLR), the Canadian Biotechnology Strategy Genomics Fund (RHD), and Genome Canada (WSD and BFK).

IDENTIFICATION OF MYOSTATIN INTERACTING PROTEINS USING A YEAST-TWO HYBRID APPROACH

S.B. Roberts

E-Mail: sroberts@mbl.edu

Marine Biological Laboratory, Woods Hole, Massachusetts, USA

Session: FisO2

Abstract: Myostatin is a member of the transforming growth factor – β superfamily that has been shown to be a significant regulator of skeletal muscle growth in mammals. To date, clear evidence that myostatin is a potent regulator of muscle growth in fish is lacking. In order to characterize the role myostatin has in salmonid muscle growth, myostatin interacting proteins are being identified using and yeast two-hybrid system. Specifically, proteins that interact with the mature form of myostatin and therefore presumably regulate the proteins biological activity are being targeted. Both experimental and computational approaches are being employed with a rainbow trout muscle cDNA library and select salmonid expressed sequence tags used as ‘prey’ in the two-hybrid system. Several novel genes have been identified that interact with that active form of myostatin. Based on sequence similarity with previously identified proteins, the trout proteins are likely involved in cell cycle activity. In addition, the latency associated peptide (LAP) form of trout myostatin interacts with the mature myostatin peptide. These data indicate that myostatin in trout is regulated by proteins similar to those in higher vertebrates and suggests that myostatin’s mechanism of action is conserved in fish. This research is supported by US Department of Agriculture grant no. 2005-35206-1526.

THE ROLE OF CORTICOSTEROIDS IN PULSATILE UREA EXCRETION

IN THE GULF TOADFISH (Opsanus beta)

T.M.Rodela¹, P.J.Walsh², and K.M.Gilmour¹

E-Mail: trode075@uottawa.ca

¹Department of Biology, University of Ottawa, Canada; ²Rosenstiel School of Marine and Atmospheric Science, University of Miami, USA

Session: AdvO2

Abstract: A cursory examination of the literature quickly reveals that most adult teleosts are obligatory ammonioteles, excreting the majority of their nitrogen waste in the form of ammonia. Occasionally, adverse environmental conditions may impair the movement of ammonia across the excretory surfaces. Gulf toadfish (Opsanus beta) are among a small group of unusual teleosts that excrete urea as their predominant nitrogen end product in response to certain environmental situations. Under conditions of crowding and confinement, fasted toadfish excrete the majority of their nitrogen waste in large, daily, irregular pulses of urea (>90% of total nitrogen) lasting up to 3 hours in duration. Previous studies have demonstrated that plasma cortisol levels fall markedly 2 to 4 hours preceeding a urea pulse event and rise rapidly thereafter. It is now known that this decline in cortisol is a permissive event rather than the actual trigger. Changes in cortisol appear to modulate urea excretion rates by ultimately controlling pulse size rather than pulse frequency. The purpose of this study was to investigate
the mechanisms of corticosteroid action in O. beta. Presently, at least two corticosteroid receptors (CR) have been cloned from O. beta. Investigations are focusing on measuring temporal changes in CR expression will be measured at different phases of the pulse cycle. It appears that the effects of cortisol in O. beta are mediated through glucocorticoid receptors Funded by NSERC.

THE EFFECTS OF COMPETITION ON THE GROWTH OF THREE COHABITING JUVENILE GADIDS; Gadus morhua, Gadus ogac, AND Urophycis tenuis
S.E. Ross and R.S. Gregory
E-Mail: seross@mun.ca
Ocean Science Center, Memorial University of Newfoundland, Canada

Session: NorO1
Abstract: Intra- and interspecific competition may be important factors affecting the growth and survival of juvenile Atlantic cod (Gadus morhua), Greenland cod (G. ogac), and white hake (Urophycis tenuis) in coastal Newfoundland waters. Over the past 10 years white hake densities have been increasing, whereas Atlantic cod densities have been decreasing. The primary nursery habitat of all three species is eelgrass (Zostera marina). Competition between these species may limit the access of cohabitants to space and food resources in their preferred habitat. In eelgrass habitats, juvenile cod show low variance abundances and predictable behaviour, relative to barren habitats where juvenile cod show a high variance in abundance and variable behaviour. This pattern suggests that competitive mechanisms act to limit fish density in eelgrass. Interspecific and intraspecific competition between Atlantic cod, Greenland cod, and white hake may limit the access of cohabitants to space and food resources in their preferred habitat. We used 1.0 m3 enclosures to determine the threshold density for each species in an eelgrass meadow. Juveniles were placed with conspecifics at densities between 1 and 5 fish/m2 for 2 weeks. Interaction effects between species were also determined by placing single juveniles of two species together in enclosures for 2 weeks in the following combinations; Atlantic cod with Greenland Cod, Atlantic cod with hake, Greenland cod with hake, Atlantic cod together, Greenland cod together, and hake together. White hake showed higher survival and growth rate than Atlantic and Greenland cod, and Greenland cod show a higher survival than Atlantic cod. This data suggests that white hake may limit the abundance of juvenile cod in eelgrass. Funded by NSERC, Department of Fisheries and Oceans, and Memorial University of Newfoundland.

CHARACTERIZING CURRENT USE PESTICIDE IMPACTS ON SALMON IN BRITISH COLUMBIA
P.S. Ross1, K. Harris1, K. Tierney2, N. Dangerfield1, M. Woudneh3, T.G. Brown4 and C. Kennedy2
E-Mail: rosspe@pac.dfo-mpo.gc.ca

1Institute of Ocean Sciences, Fisheries and Oceans Canada, Sidney BC, Canada; 2Dept of Biol. Sci., Simon Fraser University, Burnaby BC; 3Axys Analytical Services, Sidney BC; 4Pacific Biological Station, Fisheries and Oceans Canada, Nanaimo BC

Session: ImpO14
Abstract: The widespread use of pesticides to control and eliminate pests, fungi and weeds can present a risk to the health and viability of salmonids. Samples of water, sediment and coho salmon (Oncorhynchus kisutch) smolts were collected from three sites in British Columbia, representing urban (Musqueam River, Vancouver), agricultural (Nathan Creek, Burnaby), and remote (Koeye River, Central BC) areas. Total pesticide concentrations in water were 161 ng L-1 at the agricultural site, 11 ng L-1 at the urban site, and 2.3 ng/L at the remote site. The agricultural site was dominated by the currently used acid extractable herbicides, with these compounds making up 73% of the total in water and 35% in sediments. At the urban site, the banned organochlorine pesticides made up 46% of the total in water and 88% in sediments. At the remote site, fluazifop made up 35% of the total in water, and acid extractable pesticides made up 70% of the total in sediments. Inter-site differences reflected heavy agricultural use of pesticides in the Nathan Creek watershed, legacy contamination in Musqueam Creek, and atmospheric delivery of pesticides to the remote site. In an effort to evaluate the effects of priority current use pesticides on salmon olfaction and behaviour, we conducted a series of single-pesticide dosing experiments using juvenile coho salmon and rainbow trout. Olfaction represents an endpoint of ecological concern since it drives many aspects of imprinting to natal streams, predator avoidance, and feeding in salmonids. The function of trout olfactory neurons and supporting cells was measured using electro-olfactograms (EOGs; nasal trans-epithelial voltage responses). Reductions in EOG responses and olfactory-mediated behaviours in salmon following low level exposures highlight the potential of population-level impacts associated with pesticide use in British Columbia.
HERITABILITY AND CONDITIONAL STRATEGY IN ATLANTIC SALMON (*Salmo salar* L.):
IMPACT ON OFFSPRING METABOLIC CAPACITIES

O. Rossignol, H. Guderley and J. Dodson
E-Mail: orlanerossignol@yahoo.fr
Dépt. Biol., Univ. Laval, Québec, Canada

Session: EarP6

Abstract: Male Atlantic salmon (*Salmo salar* L.) follow a conditional strategy and either become “combatants” that undertake a seaward migration and spend a minimum of one year at sea, or “sneakers” that remain in freshwater and mature as parr. These male reproductive phenotypes suggest marked energy tradeoffs between investment in growth and sexual maturity. The two tactics coexist in a given population and often, on the same spawning site. The choice of tactic is dictated by the capacity of an animal to attain a physiological threshold. The threshold position is strongly determined by the biotic and abiotic environments but it also may be influenced by parental genotype. In this study, we compared offspring fathered by anadromous males with those fathered by mature parr from hatching up to two years old. At hatch and at maximum attainable wet weight (MAWW), we measured different parameters directly related to growth (length, mass, growth rate and protein content). We measured oxygen consumption to determine the routine metabolic rate. Then, we used enzymatic indicators to evaluate the metabolic capacity of the alevins, focusing upon aerobic capacity (cytochrome C oxidase (CCO) and citrate synthase (CS)), glycolytic capacity (lactate dehydrogenase (LDH)) and nitrogen metabolism (glutamate dehydrogenase (GDH)). Funded by C.R.S.N.G. and Québec-Océan.

POPULATION CONSEQUENCES OF INDIVIDUAL VARIABILITY
IN REPRODUCTIVE BEHAVIOUR OF ATLANTIC COD

S. Rowe¹ and J.A. Hutchings²
E-Mail: RoweS@mar.dfo-mpo.gc.ca
¹Fisheries and Oceans Canada, Bedford Institute of Oceanography; ²Department of Biology, Dalhousie University, Canada.

Session: FroO6

Abstract: Census estimates of mature individuals (Nc) may be considerably greater than the number of individuals that contribute genes during reproduction. For broadcast spawning marine fishes, effective population size (Ne) may be 2-5 orders of magnitude lower than Nc because of unusually high variance in individual reproductive success. We tested the hypothesis that variability in reproductive success in Atlantic cod (*Gadus morhua*) is random with respect to morphology, condition, and behaviour. Allowing 4 groups of 52-93 cod from 3 Northwest Atlantic populations to breed undisturbed in a large (684 m³) tank, we quantified individual variation in reproductive success, based on parentage assignment of 8913 offspring. Reproductive success was highly variable with few individuals contributing to most spawning events. Male success was positively associated with body size and aggression. Both females and males achieved their highest success when breeding with larger mates. Our results suggest that intrasexual competition and/or mate choice are constituents of the mating system, and that this can have a significant influence on individual fitness. Consequently, reductions in the mean and variance of body size concomitant with size-selective harvesting may have greater negative consequences for population recovery than previously thought. These findings have important implications for the conservation of marine fishes, particularly those with mating systems similar to Atlantic cod. Funded by NSERC.

GLYCOCONJUGATES SUPERFICIAL IN THE EPITHELIUM OF GILLS OF POECILIA VIVIPARA
UNDER EFFECTS OF WATER SALINITY VARIATIONS

E-Mail: saboias@terra.com.br
Laboratory of Cellular Behavior, Department of Morphology, Institute of Biological Science IV – Federal University of Goiás, 74001-970,Goiânia, GO, Brazil Department of Anatomy, Institute of Biomedical Science, University of Sao Paulo, SP, Brazil Laboratory of Cytochemistry and Immunocytochemistry, Department of Histology and Embryology, Institute of Biology - University of Campinas, 13083-970, Campinas, SP, Brazil

Session: IonP2

Abstract: In the present study was used the carbohydrate cytochemistry as tool for gills mucous cells identification based on their glycoconjugates contents and their possible physiological variations under experimentally induced environmental changes and the protection of surface of epithelium. The gills of guppies living in sea-water (SW) and fresh-water (FW) adapted respectively to lower (0‰) and higher (20‰) salinity concentrations were processed for LR-White, Spurr resin embedding and tissue homogenates for SDS-PAGE and blotting. The sections were stained with eleven biotinylated-lectins, Ruthenium Red (RR) and periodic acid-thiocarbahydrazide-silver proteinate (PA-TCH-SP) cytochemistry. The screening performed with biotinylated lectins distinguished superficial epithelium cover for glycoconjugates layer according to their reaction pattern and showed preferential domains of their distributions in the gill epithelia. The glycoconjugates layer has
qualitative and quantitative affinities differences against the lectins set used when compared among SW and FW fishes submitted to salinity variations in the water. The RR and PA-TCH-PP reactions were seen over the free surface of the gill epithelia and in the pits of chloride cells, being the reaction stronger on the gills of SW fishes. These results showed the commitments of mucous cells response against salinity changes in the water, based on their glycoconjugate secretion. The accuracy of lectins cytochemistry to detect such variations of gills’ mucous cells responses, raise them as useful tool for bio-monitority of fishes or other water living animals regarding influences of composition of water environmental changes. Funded: FUNAPE and CAPES.

**DIETARY ENERGY REQUIREMENT OF TRIPLOID BROOK TROUT (Salvelinus fontinalis)**

Charles F.D. Sacobie¹, Heather A. Mouland¹*, Tillmann J. Benfey¹ and Santosh P. Lall²
E-Mail: charles.sacobie@unb.ca

¹Department of Biology, University of New Brunswick, Canada; ²National Research Council of Canada, Institute for Marine Biosciences, Halifax, Nova Scotia, Canada

Session: LinO4

Abstract: Triploid salmonids are used in aquaculture because they are sterile and are fed commercial diets formulated for diploids, in spite of being quite different in their physiology, such as changes in cell size, number and surface to area volume ratio that arise from increasing chromosome number. An optimal balance of energy is important because an excess or deficiency may result in lower growth rates. If the diet is deficient in non-protein energy, protein will be used for energetic purposes rather than for protein synthesis. Also, if the diet contains an excess of non-protein energy, appetite may be satisfied before a sufficient quantity of protein is ingested to satisfy demand for protein synthesis and growth. In order to assess the dietary energy requirements of triploid brook trout, diets were formulated with 15, 16.5, 18 MJ/kg and fed to both diploid and triploid brook trout in triplicate. Thirty fish per tank were fed to satiation twice daily for a 10-week period and food consumed was recorded daily. The fish were measured initially and every 4 weeks until the end of the experiment and five fish per tank were then randomly collected for whole body proximate composition. It was found that triploids had a significantly lower specific growth rate and protein efficiency ratio, but a higher food conversion ratio. Triploids tended to have a higher moisture and protein content, but lower energy content. The diets had no effect on weight gain and condition factor. The data thus far have shown that triploids do not perform equally to diploids when fed similar diets and therefore triploids may have different dietary requirements. This project was funded by NSERC, in partnership with Cooke Aquaculture, Heritage Salmon, Corey Feed Mills and the Atlantic Salmon Federation.

**MONITORING THE ENVIRONMENTAL ESTROGENICITY USING A TRANSGENIC MEDAKA (Oryzias latipes) HARBORING CHGL-GFP GENE**

M.A. Salam, T. Sawada, T. Ohya and S. Hayashi
E-Mail: salam@yokohama-cu.ac.jp

Grad. School of Integrated Sciences, Yokohama City Univ., Japan

Session: BioP2

Abstract: Estrogenic substances released into the environment have adverse effects on wildlife and human. Previously, we established a transgenic medaka harboring choriogenin L (ChgL)-tagged with green fluorescence protein (GFP) that expressed GFP in the liver in response to estrogen (E2). We determined the appropriate condition for analysis of estrogenicity by changing E2 concentrations, exposure periods and the developmental stages of medaka hatchlings. We observed that the hatchlings at 4 day post hatch (DPH) showed the best condition to expose E2 and measurement of GFP intensity at 9 DPH. Additionally, we optimized the exposure period that exposure from 4 DPH for 5 days period have significant increased in GFP intensity. We used the E2 concentrations of 0, 12.5, 25, 50 and 100 ng/l in which the dose 25 ng/l showed clear increase of GFP intensity at day 6 of exposure period. We also examined the sensitivity of vitellogenin (Vtg) induction by western blot and enzyme-linked immunosorbent assay (ELISA) using whole body homogenates of E2 exposed (0, 12.5, 25, 50 and 100 ng/l) juvenile medaka. Vitellogenin induction as determined by western blot was found in the juvenile medaka those were exposed to 100 ng/l E2. Whereas, Vtg induction was detected by ELISA from the juveniles those were exposed to 12.5 ng/l E2. Thus, these results suggested that ChgL-GFP transgenic medaka could be an easy and handy tool to detect environmental estrogenicity considering the practical concentrations of estrogenic substances in contaminated or waste water. Funded by Japan Society for the Promotion of Science (JSPS).
RELATIONS BETWEEN LARVAL FISH DISTRIBUTION AND GEOSTROPHIC CURRENTS
Laura Sánchez-Velasco1, Carlos Avalos-García1 and Emilio Beier2
E-Mail: lsvelasc@ipn.mx
1 Departamento de Plancton y Ecología Marina, CICIMAR. Ave. Instituto Politécnico Nacional s/n, Col. Playa Palo de Santa Rita CP 23090, La Paz, BCS, México. COFAA-IPN, EDI-IPN; 2 Centro de Investigación Científica y de Educación Superior de Ensenada. Estación La Paz, BCS. Miraflores 334 e/ Mulegé y La Paz. Fracc. Bella Vista, CP 23050, La Paz, BCS.

Session: EarP1
Abstract: Bahía de La Paz is the largest body of water on the western coast of the peninsula of Baja California, and is characterized by its fishery importance. Using hydrographic data and zooplankton samples from for oceanographic cruises during 2001 and 2002, we have study the seasonal variations of the distributions of larval fish assemblages, not only in the interior of the bay but also in the adjacent oceanic area. The Bray-Curtis Dissimilarity Index defined three larval fish assemblages named by their localization and dominant species as: Oceanic, Transitional and Coastal. The seasonal cycle of the spatial distribution of the fish assemblages appears to be related with the interchanges of water, between the bay and the Gulf of California, through the North Mouth (NM). During autumn the geostrophic volume flux through the NM is strong and as a consequence the Oceanic fish assemblages is dominant in the whole area, meanwhile during winter, when the geostrophic volume transport through the NM is weak, the dominant fish assemblages in the interior bay is the Coastal one. Acknowledgments to Instituto Politecnico Nacional and CONACyT.

THE INFLUENCE OF APICAL HYPOOSMOTIC STRESS ON THE EXPRESSION
OF CYTOSKELETAL COMPONENTS IN TROUT GILL EPITHELIAL CELLS
A. M. Sandbichler, M. Egg and B. Pelster
E-Mail: adolf.sandbichler@uibk.ac.at
Institute of Zoology and Center for Molecular Biosciences, University of Innsbruck, Austria

Session: IonP5
Abstract: Trout (Oncorhynchus mykiss) gill epithelial pavement cells grown on permeable filter membranes in biphasic culture reorganize into a high-resistance, double-layered epithelium. After 5 days of symmetrical culture conditions (L15 media apical/L15 media basolateral) the reconstructed epithelia were exposed to 24 hours of asymmetrical culture conditions (freshwater apical/L15 media basolateral) to simulate environmental freshwater adaptation in euryhaline fish gills. Using differential display RT-PCR we were able to identify trout-specific isoforms of claudin and actinin mRNA to be differentially regulated in asymmetrical cultures compared to symmetrical control cultures. The trout claudin sequence is an ortholog of human claudin 4, zebrafish (D. rerio) claudin e and claudin 28b of Takifugu rubripes respectively. The trout actinin sequence belongs to the isoform-4-class of actinins. Immunohistochemical staining with a polyclonal actinin antibody revealed a putative actinin 4 protein to be localized in the lower layer of cells which also contain phalloidin-stained actin stress fibers. The cells in the upper layer facing the “environment” do not show staining for actinin and phalloidin-staining of actin in these cells is restricted to a thin cortical ring. We conclude that freshwater transfer may trigger a cytoskeletal remodelling of pavement cells within the epithelial compound. Funded by the Tyrolean Science Fund.

CONTROL AND FUNCTION OF THE VENOUS CIRCULATION IN FISH
E. Sandblom and M. Axelsson
E-Mail: erik.sandblom@zool.gu.se
Department of Zoology, Göteborg University, Sweden

Session: CarO9
Abstract: While, most current knowledge about cardiovascular control in fish is based on studies of the heart and the systemic and branchial circulations, little is still known about the control of the venous circulation in this group. The venous vasculature serves as a capacious low pressure, high compliance blood volume reservoir. From mammalian studies, it is well recognised that small decreases in venous capacitance increases venous return significantly. Reductions in venous capacitance may also shift blood towards the heart and increase filling pressure and, concomitantly, stroke volume and cardiac output via the Frank-Starling mechanism. As part of our ongoing research programme on cardiovascular control, we have characterised the venous responses for a number of cardiovascular challenges in fish, such as those during exercise and hypoxia and in response to acute changes in temperature and arterial blood pressure (the baroreflex). From these investigations it has become clear that the α-adrenergic system is a central component in the control of venous capacitance in both teleosts and elasmobranchs. In teleosts, both neural and humoral release of catecholamines is important, while elasmobranchs mainly appear to rely on humoral adrenergic control. A synthesis of recent results from our laboratory will be presented and discussed. Funded by the Swedish research council, VR.
A SIMPLE METHOD FOR QUANTIFICATION OF SURGICAL STRESS IN FRESHWATER FISH
Sandblom E., Seth, H., Ståhl K. and Axelsson M
E-Mail: m.axelsson@zool.gu.se
Göteborg University, Department of Zoology / Zoophysiology

Session: CarP4
Abstract: It is well known that different stressors affect the physiology and that this may have implications for the conclusions drawn. One of the first scientists to recognize this was Steven Hales. In his work from 1733 he noted that the heart rate of the horse he used was elevated and his conclusions was that this was due to the pain. Surgical stress is an important factor and it can be divided into acute stress due to anesthesia and post-surgical pain and a more prolonged and diffuse stress due to implanted sensors and other factors. The acute stress can usually be alleviated by proper pre- and post-operative care, while the more prolonged stress may be harder to deal with. It has been shown that heart rate and ventilation are both good indicators of stress and mean average heart rate, or more recently heart rate variability, are useful indicators of post-surgical recovery. The procedures used to measure these variables are both invasive, and so a proper reference is needed. Here we present a simple, low-cost system to non-invasively quantify the effects of an experimental procedure in fish. It is based on a system developed for a water quality testing purposes and consists of two electrodes placed in the experimental chamber and connected to an EEG-type amplifier. The bio-potentials from the fish are transmitted via the water, amplified and filtered. Heart rate and ventilation can be recorded prior to any surgical intervention and used as a reference. A preliminary study has shown that despite mean heart rate and heart rate variability data indicating a good recovery 72 hours after a dorsal aortic cannulation, heart rate in rainbow trout was elevated by approx. 50% compared to before cannulation. Funded by Swedish Research Council.

A BIOCHEMICAL BASIS FOR REDUCTIONS IN WHOLE ANIMAL METABOLIC RATE DURING SALINITY STRESS IN MOZAMBIQUE TILAPIA (Oreochromis mossambicus)
B. A. Sardella and C. J. Brauner
E-Mail: sardella@zoology.ubc.ca
Department of Zoology, University of British Columbia

Session: IonO8
Abstract: Reductions in metabolism during exposure to salinities greater than seawater (SW) have previously been observed in a number of euryhaline fish species, including Mozambique tilapia (Oreochromis mossambicus), and have generally been attributed to reductions in spontaneous activity. In this study, we acclimated tilapia to a range of salinities (FW, 15, 30, 45, 60 and 75 g/l), and measured whole animal oxygen consumption rate (MO2), to correlate with biochemical mechanisms such as ATPase and PEPCK activities in the liver, muscle and brain. We found a 32% reduction in metabolic rate in tilapia acclimated to 60 g/l relative to SW at 14 d. Furthermore, there was a significant negative relationship between MO2 and ambient salinity from 15 to 60 g/l, which highly correlated (r2=0.98) with total liver ATPase activity. Finally the highest MO2 rate was observed at 15 g/l after five days, which correlated with significantly elevated brain Na+, K+-ATPase levels; these data may be indicative of high activity within the pituitary as the animal switches between a hyper- and hypo-osmotic osmoregulatory strategy.

APOPTOSIS IN GILL MITOCHONDRIA RICH CELLS AS A BIOMARKER OF SALINITY STRESS IN CALIFORNIA MOZAMBIQUE TILAPIA (Oreochromis mossambicus X O. urolepsis Hornorum)
BA Sardella1, V. Matey2 and CJ Brauner1
E-Mail: sardella@zoology.ubc.ca
1Department of Zoology, University of British Columbia; 2Department of Biology, San Diego State University

Session: MolP5
Abstract: The California Mozambique tilapia is incredibly tolerant of salinities greater than seawater, and is a model teleost for understanding mechanisms of salinity tolerance. It is also the most abundant fish species in the Salton Sea, a large saline lake (43 g/l) in California which is becoming progressively more saline (0.3 g/l per year). To investigate the use of mitochondria rich cell (MRC) apoptosis as a biomarker of salinity stress, seawater-acclimated (SW) tilapia were exposed to progressive 10 g/l increases in salinity every 5 days, up to a maximum of 95 g/l. From 35 to 55 g/l, no changes in MRC apoptotic levels were observed, however, from 55 to 95 g/l, there was a linear increase in apoptotic cells, peaking at a maximum of 700% of SW values. The increase in MRC apoptosis levels at 65 g/l occurred in the absence of any changes in other sub-lethal salinity stress indicators (i.e. plasma ion levels, gill Na+,K+-ATPase activity, drinking rate) which were not elevated until 75 g/l. At 75g/l +, MRC apoptosis and other sub-lethal salinity stress indicators changed in a qualitatively similar pattern. These data indicate that MRC apoptotic levels may be the most sensitive biomarker of salinity stress, which could be useful in assessing the status of fish in the Salton Sea. This research was supported by the US Bureau of Reclamation and NSERC, Canada.
IMMUNOHISTOCHEMICAL OBSERVATIONS ON COLLAR ENAMEL IN GARS (*Lepisosteus oculatus*)

I. Sasagawa¹, M. Ishiyama², H. Yokosuka², K. Mikami³ and T. Uchida⁴

E-Mail: ichsasgw@ngt.ndu.ac.jp

¹Dept. of Anatomy, ²Histology and ³Microbiology, Nippon Dental Univ., Niigata; ⁴Dept. of Oral Biology, Hiroshima Univ., Hiroshima, Japan

**Session:** BonO6

**Abstract:** Collar enamel, as well as cap enameloid, is found in the jaw teeth of gars. This means that we can observe amelogenesis following cap enameloid formation during tooth development, and may identify clues concerning the origin of enamel in the evolution of vertebrates. It is reported that the organic matrix of collar enamel showed marked mammalian amelogenin immunoreactivity (Ishiyama et al., 1999). The amino acid sequence of amelogenin cDNA was found in not only mammals, but also reptiles and amphibians (Ishiyama et al., 1998; Toyosawa et al., 1998; Wang et al., 2005); in fish, however, there is still no evidence. In this study, light and electron microscopic immunohistochemistry using antibodies specific to the C-terminal, central and N-terminal regions, respectively, of porcine amelogenin (Uchida et al., 1991) was performed to examine the collar enamel matrix in gars, *Lepisosteus oculatus*. The enamel matrix showed intense immunoreactions to the C-terminal and central region-specific antibodies, but not to the N-terminal region-specific antibody. The data suggest that the enamel matrix in gars contains a domain that closely resembles the C-terminal and central regions of porcine amelogenin. Supported in part by a Grant-in-Aid for Scientific Research, 16591844, from the Ministry of Education, Science, Sports and Culture, Japan.

FATTY ACID PROFILES IN AUSTRIAN WILD AND FARMED FISH – A COMPARISON

M. Schreiner

E-Mail: matthias.schreiner@boku.ac.at

BOKU University of Natural Resources and Applied Life Sciences, Department of Food Science and Technology – Division of Food Chemistry, Vienna, Austria

**Session:** AdvP7

**Abstract:** Commercial fish production in Austria is mainly focused on endemic species such as carp, tench, trout and other salmonides such as arctic char. The Alpine climate provides an excellent basis for fish high in long chain omega-3 fatty acids (LCn-3PUFA). The aim of this survey was to assess the the fatty acid status of wild and farmed fish from Austrian waters. The main goal was to find out, whether farmed fish reaches similar omega-3 levels as wild fish. Farmed fish samples were obtained from fish farms in the Austrian regions of Lower Austria and Styria. Wild fish samples were provided from fishermen under supervision of the responsible veterinarian for fish-health in Lower Austria. Samples were vacuum-sealed in plastic bags and frozen until analyzed. Fillets were prepared, lyophilized and subjected to a direct extraction/derivatisation method and subsequently analyzed by gas chromatography. In general, farmed fish showed high contents of LCn-3PUFA (mainly docosahexaenoic acid – C22:6n-3), while wild fish showed elevated intermediate metabolites of essential fatty acids of both, omega-3 and omega-6 pathways. Especially the high content of C22:5n-6 should be mentioned. The high content of DHA in farmed fish could be related to sources of marine lipids in the commercial fish diet, since ceteoleic acid (C22:1n-11), which is a fatty acid typical for the marine food chain, was found at high levels in all farmed salmonides. The strictly extensiv keeping of carp was reflected by the absence of C22:1n-11. Highest levels of LCn-3PUFA were found in farmed charr, wich contained more than 1 g LCn-3PUFA in 100 g of filet.

THE EVOLUTION OF NA⁺/K⁺ ATPASE ISOFORMS IN SALMONIDS

P.M. Schulte and A.C. Dalziel

E-Mail: pschulte@zoology.ubc.ca

Dept. of Zoology, The University of British Columbia, Canada.

**Session:** IonO6

**Abstract:** We have previously identified five isoforms of the alpha subunit of Na⁺/K⁺ ATPase alpha-isoforms in rainbow trout. Two of these isoforms (which we named alpha1a and alpha1b) were differentially expressed following seawater transfer. Transfer from freshwater to 40% and 80% seawater decreased gill Na⁺/K⁺ATPase alpha1a mRNA, while transfer from freshwater to 80% seawater caused a transient increase in Na⁺/K⁺ATPase alpha1b mRNA. This switching between Na⁺/K⁺ATPase gene duplicates in trout gills following salinity transfer suggested the possibility that the whole genome duplication in the lineage leading to the salmonids could have played a role in the evolution of anadromy in this group. To test this hypothesis, we have sequenced Na⁺/K⁺ATPase isoforms from representatives of the major salmonid taxa, and from sister taxa that lack the whole-genome duplication. All salmonids (including the basal whitefish and grayling) expressed both alpha1a and alpha1b. In fact, phylogenetic analysis revealed the presence of both isoforms in the Northern Pike (*Esox lucius*), a diploid species. This result suggests that alpha1a and alpha1b arose before the salmonid whole genome duplication. Funded by NSERC.
FROM MOLECULES TO BEHAVIOR:
AN INTEGRATED APPROACH TO STUDYING THERMAL ADAPTATION IN FISH
P. Schulte.
E-Mail: p.schulte@zoology.ubc.ca
Dept. of Zoology, The University of British Columbia, Canada

Session: PleO6
Abstract: In order to understand the mechanisms that underlie the adaptation of animals to their environment, ecological and evolutionary physiologists must consider processes that occur over a variety of spatial and temporal scales, often at multiple levels of biological organization. Using intertidal and estuarine fish, my research group is investigating the relationship between phenotypic plasticity within a species (a response to short-term environmental change) and adaptive variation between species (a process that occurs over evolutionary time). By integrating processes at multiple levels of biological organization (from genes to populations), and across these differing temporal scales we hope to provide insights into the mechanistic basis for ecological phenomena such as species distributions. In this talk, I will highlight some recent results on the genomic organization, regulation, and function of heat shock proteins in several species of fish and demonstrate how this variation relates to differences in whole-organism performance and behaviour.

MILESTONES AND FLEXIBILITY IN EARLY DEVELOPMENT
OF THE CARDIO-RESPIRATORY SYSTEM OF THE MODEL ANIMAL ZEBRAFISH (Danio rerio)
ANALYSED WITH NON-INVASIVE COMPUTER ASSISTED IMAGE ANALYSIS
T. Schwerte
E-Mail: thorsten.schwerte@uibk.ac.at
Leopold-Franzens University Innsbruck, Austria

Session: PleO3
Abstract: Independent of species, the cardiovascular system is the first functioning component of the developing vertebrate embryos. Cardiovascular and respiratory responses to environmental, genetic and epigenetic perturbations have been examined in detail to understand the relationships between cardio-respiratory performance, haematopoiesis and vasculogenesis in embryonic or larval stages of the popular model animal zebrafish. Young zebrafish (5-7 mm body length) obtain sufficient amounts of oxygen via bulk diffusion during the first days of their development until 10 days post fertilization (dpf). This permits to study genetic mutants even with extreme defective phenotypes affecting the cardio-respiratory system. Physiological characterization of mutants and experimentally influenced animals (training, hypoxia, microsurgery and pharmacology) enabled us to depict milestones and flexibility in early development of the cardio-respiratory system in this animal. Sympatho-vagal control of heart rate appeared around 12 dpf, ventilation as well as heart rate became sensitive to hypoxic stimulation as early as 4 dpf. Specific receptors always seem to appear long before the connected regulation systems are working. Although genetic factors are often dominant the animals show high flexibility in most of the cardio-respiratory parameters like vascular patterning, cardiac performance, blood cell concentration, and ventilation rate. Funded by “Fonds zur Förderung der wissenschaftlichen Forschung” to Dr. T. Schwerte (FWF 16272-B06) and the University of Innsbruck (N17/P 2005 III. Tranche, Aktion D. Swarovski 2004)

AIRBORNE CONTAMINANTS AND THE AFFECT ON FISH IN WESTERN U.S. NATIONAL PARKS
A.R. Schwindt¹, C.B. Schreck²,³, L. Ackerman³, J.M. Ramsay³, S. Simonich⁴,⁵ and M.L. Kent¹
E-Mail: schwinda@onid.orst.edu
¹Department of Microbiology; ²Oregon Cooperative Fish and Wildlife Research Unit, US Geological Survey-BRD;
³Department of Fisheries and Wildlife; ⁴Department of Chemistry; ⁵Department of Environmental and Molecular Toxicology, Oregon State University, Corvallis, OR 97331 USA

Session: ImpO38
Abstract: Organic contaminants and some metals are known to accumulate in alpine and arctic aquatic ecosystems, precisely the areas characterized by many western U.S. National Parks. Some of these pollutants have been correlated to endocrine and pathological changes in fishes in other locations. To address these issues, the Western Airborne Contaminants Assessment Project was initiated to assess the levels and potential effects of contaminants in mountain and arctic biota. Fishes were captured in 2003-2005, from 12 total lakes in 8 national parks to be analyzed for contaminants, health, and abnormalities which may be evidence of contaminant exposure. PAHs, PCBs, PDBEs, mercury and other metals, pesticides, herbicides, and fungicides have been found in the Parks, including fishes. Upon capture, each fish was examined macroscopically for gross abnormalities. Otoliths were used to age the fishes, which ranged from 1 to 41 years. Plasma vitellogenin, a biomarker for xenoestrogens, was identified in some male fishes and, examination of gonad histology indicated the presence of intersex fishes. We are also examining correlations between macrophage aggregates (spleen, liver and kidney) and anthropogenic contaminants in these fish. Our results suggest that anthropogenic activities
likely occurring outside National Park boundaries may affect park biota, similar to highly impacted areas. Funded by the NPS, EPA, USFS, USGS, OSU, and UW.

IONOREGULATION AND BEHAVIOUR OF NON-NATIVE ZANDER (Sander lucioperca) IN SALINE WATERS: DISPERSAL IMPLICATIONS
D. M. Scott, R.W. Wilson and J. A. Brown
E-Mail: d.m.scott@exeter.ac.uk
School of Biosciences, Univ. of Exeter, UK

Session: IonO7
Abstract: Zander (pikeperch) (Sander lucioperca) is a large piscivore first introduced into UK lakes for sporting purposes. Subsequent translocation and natural dispersion has led to its establishment in several freshwater systems with some populations being present near the tidal limits of several estuaries. Although originally considered strictly freshwater, we have now shown that zander can tolerate high salinities and possesses some hypo-osmoregulatory capacity including the ability to increase drinking rates in saline waters. To understand the potential for zander to utilise brackish waters for dispersal, we have analysed behavioural responses alongside assessment of osmo(iono)regulatory status and stress following exposure to (a) 12 h simulated tidal cycle rising to 30.0 psu (810 mOsmol kg-1) and (b) chronic salinity exposures, increasing every 2 days by 4.3 psu to a maximum of 21.6 psu (583 mOsmol kg-1). Both regimes caused significant osmotic and ionic disturbances and increased plasma cortisol, with chronic exposures being more stressful than the tidal cycle. In freshwater, zander are relatively inactive in daylight hours, but during the tidal cycle increased daytime activity, including vertical movements within the water column, occurred at < 14.0 psu. During chronic exposures, a similar threshold salinity for increased daytime swimming activity was observed, but changes in nocturnal activity occurred at lower salinities (< 4.3 psu). Changes in swimming activity may represent avoidance responses to stressful salinity regimes, but in the wild the increased vertical movements could locate lower haloclines and/or aid in dispersal to new freshwater systems. This work was supported by the Natural Environment Research Council, UK (NE/B502436).

USE OF TELEMETRY TO ASSESS DOWNSTREAM FISH PASSAGE OF ATLANTIC SALMON (Salmo salar) SMOLT AND KELT AT A SURFACE SPILL BYPASS SYSTEM AT A HYDRO FACILITY
Scruton, D.A., C.J. Pennell, C.E. Bourgeois, R.F. Goosney and K.D. Clarke
E-Mail: scrutond@dfo-mpo.gc.ca
Fisheries and Oceans Canada, Science Branch, 80 East White Hills Road, P.O. Box 5667, St. John's, NL A1C 5X1 Canada
Session: TelO2
Abstract: In 2002/3, the Bishops Falls hydroelectric facility, Exploits River, Newfoundland, Canada, underwent extensive refurbishing including installation of a ‘retrofitted’ fish bypass system. The effectiveness of system has been assessed during the downstream run of wild Atlantic salmon smolt and kelt in 2003, 2004, and 2005 using radio telemetry. Fish bypass efficiency for smolt in 2003, 2004 and 2005 was 63%, 72%, and 60%, respectively, and for kelt in 2004 and 2005 was 92% and 81%. There was no significant difference (P<0.05) in passage effectiveness or turbine entrainment of fish between in-river and forebay releases. Downstream evaluation of overall fish passage survival indicated 45% and 46% of turbine passed smolt survived indicating overall project survival of 85% and 88 % in 2004 and 2005, respectively. Conversely, no turbine passed kelt were detected suggesting 100% turbine mortality. In all 3 years the time spent in the forebay by turbine passed fish was significantly greater than for bypassed fish. Few fish migrated during daylight hours and peak passage (> 75%) was during the hours of 18:00 and 01:00. These results will assist in further refinement of the bypass operation to optimize survival. Funding: NRCan’s Panel for Energy Research and Development and Abitibi Consolidated Company of Canada.

ENERGY METABOLISM OF EUROPEAN EEL (Anguilla anguilla) UNDER PRESSURE
P. Sébert1, A. Vettier1, A. Amérand1, A. Péqueux2 and C. Moisan1
E-Mail: philippe.sebert@univ-brest.fr
1Unité Haute Pression et Métabolisme,EA 3879, UFR Médecine, CS 93837, 29238 Brest cedex3, France ; 2Laboratoire de Physiologie, Université de Liège, 4020, Belgique

Session: IntO2
Abstract: Due to its particular life cycle, the European eel must migrate from Europe presumably to the Sargasso sea which represents a 6000km trip at depth and without feeding. Before this migration, the eel must metamorphose from yellow stage to the silver stage which represents several morphological, physiological and metabolic changes. Experiments, including measurements of mitochondrial respiration, at pressures up to 101 ATA (1000m depth) on yellow eels have shown that aerobic metabolism is impaired by pressure effects on mitochondrial membranes (mainly a decrease in
membrane fluidity). However, after several weeks under pressure, eel is able to acclimatize in such a way that oxidative phosphorylation efficiency is improved. This is made possible by adjustments of the activities of the respiratory chain enzymes complexes leading to a decrease in electrons leak concomitantly with the restoration of membrane fluidity. Similar experiments performed with silver eels (the migrating stage) show that in contrast, pressure has few effects on energy production system. Several experimental facts let to conclude that silver eel is really pre-adapted to high pressure (for example, by increasing membrane fluidity before migration) in order to limit energy cost of adaptation during the migration, sparing energy stores for swimming and reproduction which are obliged activities for the species. Funded by EC contract EELREP N Q5RS-2001-01836.

VARIATION IN THE STANDARD METABOLIC RATE BETWEEN AND AMONG THE THREE ATLANTIC SALMON (Salmo salar) STOCKS
E. Seppänen1, H. Huuskonen2 and J. Piironen3
E-Mail: eila.seppanen@rktl.fi

1Finnish Game and Fisheries Research Institute, Laasalantie 9, FIN-58175 Enonkoski, Finland, 2Karelian Institute, Dept. of Ecol., Univ. of Joensuu, P.O. Box 111, FIN-80101 Joensuu, Finland, 3Finnish Game and Fisheries Research Institute, Yliopistonkatu 6, FIN-80100 Joensuu, Finland

Session: EarP2
Abstract: Standard metabolic rate (SMR) represents a measure of the minimum rate of metabolism in the absence of muscular activity, food consumption and its subsequent processing. Studies on differences in SMR between fish populations are rare. We examined oxygen consumption of three Atlantic salmon (Salmo salar) stocks: the non-anadromous Saimaa stock (fresh water) and the anadromous River Neva (brackish water) and River Teno stocks (brackish water and full-strength seawater, respectively). Measurements were conducted by an automated, computerized intermittent-flow respirometer. The study fish were reared under similar experimental conditions starting from the egg stage. The experiments were done both on population and individual level. We analysed SMR of 35 individuals from each stock. There were wide size and temperature ranges (1·2 – 90·0 g, 4 – 7 °C). Our results show that SMR differed between the stocks. We will continue our studies with these three salmon stocks by examining also variation in growth, behaviour, morphology and genetics between the stocks to find out how they will correlate with SMR. Funded by Finnish Game and Fisheries Research Institute and Karelian Institute, Department of Ecology, University of Joensuu.

THE ANAL GLAND OF MALE BLENNY Salaria pavo: STRUCTURE AND FUNCTION
R.M. Serrano1,2, E.N. Barata1,2, P.C. Hubbard2, P. Guerreiro3, M.A. Birkett3, J.A. Picket3, O. Lopes1, J. Araújo1 and A.V.M. Canário2
E-Mail: rserrano@ualg.pt

1University of Évora, Portugal; 2CCMar, Faro, Portugal; 3Rothamsted Research, Harpenden, UK

Session: OlfO16
Abstract: In the breeding season, male S. pavo develop anal glands (AGs) on the anal fin, which produce and/or release pheromone(s) that attract mature females; the chemical nature of these putative pheromones is unknown. The current study investigated the ultrastructure and differentiation of the AGs using light and electron microscopy, and the behavioural effects and olfactory potency of chromatographic fractions of anal gland secretions in females. The epithelium of the AGs contains cells that undergo cyclic differentiation into secretory clusters during the breeding season and degenerate in late Summer/Autumn. Histochemistry studies suggested that these produce neutral glycoproteins. Macerated glands, and water conditioned by males with fully developed glands, attracted mature females. However, immature females were not attracted. Electro-olfactogram recordings combined with chromatographic techniques showed that females have olfactory sensitivity to odorants secreted to the water by AGs. The chemical nature of these depends on the stage of differentiation; hydrophilic odorants secreted by fully developed glands are absent in partially developed glands, excision of partially developed anal glands did not affect the olfactory potency of water conditioned by males, and water conditioned by males with partially developed glands elicited smaller olfactory responses than those with fully developed glands. Together, these results suggest that the AGs release a multi-component message which specifically attracts females in reproductive condition. Funded by FCT (Portugal) and CRUP/British Council.
COMMUNICATION OF RADIATION-INDUCED STRESS OR BYSTANDER SIGNALS BETWEEN FISH IN VIVO

CB Seymour, R Smith, C Bucking, A O’Neill, N Aghihotri, M Kilemade and Carmel Mothersill

Dept of Medical Physics and Applied Radiation Sciences, McMaster University, Hamilton, Ontario, L8S 4K1 Canada

Session: ImpO19

Abstract: Radiation-induced bystander effects, resulting in the appearance of radiation damage or induction of typical radiation responses in unirradiated cells and tissues are now an established consequence of exposure to low doses of ionizing radiation. However little work has been done in vivo or in species other than humans or mice. Here we report data suggesting that whole fish irradiated to 0.5Gy total body dose can signal other unexposed fish and cause induction of radiation effects – increased levels of apoptosis, cell death and expression of cellular proteins associated with radiation response (cmyc, bcl-2, HSP70). Rainbow trout were exposed then returned to their tanks and paired with unirradiated fish for two hrs, in other cases, unirradiated fish were placed in water which had been used to hold irradiated fish for 2 hrs. Sham irradiated fish and absolute control fish were also examined. At the end of the two hr period, fish were killed by a blow to the head and dissected. Five organs were removed from each fish and cultured using an established explant technique. After 2 days, the culture medium was harvested and used in a reporter assay to determine whether a bystander effect had been induced. The explants were cultured on for a further 7 days then fixed for assay of radiation response proteins. There were differences in response of different organs with the gill and fin showing the most pronounced response. The results suggest that communication signals leading to a typical radiation response can be passed between fish and seem to involve secretion of a chemical messenger into the water. The data may indicate a possible mechanism for coordination of population level responses to stressors.

BIOMECHANICAL DESIGN OF AEROBIC MUSCLE IN TUNAS AND LAMNID SHARKS

R. E. Shadwick

Dept. of Zoology, Univ. of British Columbia, Canada

Session: MusO8

Abstract: Tunas and sharks in the family Lamnidae have remarkably similar anatomical and physiological specializations for the continuous locomotion that is essential for their pelagic predatory lifestyle. One feature recently investigated is the elongated tendon systems in both groups that allow endothermic aerobic muscle fibres, concentrated mid-body and close to the backbone, to project their contractile effort to power the lunate caudal fin rather than causing curvature and lateral motion in the mid-body region. This is a marked departure from the body design of ectothermic fishes in which contractions of superficial aerobic fibres are tightly coupled to local body bending. An additional feature of interest is performance enhancement of the lateral muscle in relation to endothermy. Previous work on yellowfin tuna indicated that the additional power produced by the heated muscle likely extends the speed range for aerobic swimming (J. Altringham and B. Block, J. Exp. Biol. 200:2617, 1997). In the mako shark (Isurus oxyrinchus) contractile properties are likewise enhanced at elevated body temperature (>25°C), but at the expense of performance at low temperatures (15°C), compared to the ectothermic Leopard shark (Triakis semifasciata). In cold-water (4-10°C) salmon sharks (Lamna ditropis) the adaptation for aerobic muscle to power sustained swimming at elevated temperatures (up to 26°C) is so extreme that these fibres cannot function at ambient water temperature, and are ineffectual even if warmed by 10°C above ambient. Burst swimming powered by the white muscle mass is like enhanced by the conductive heating of these fibres due to their proximity to the central vascular heat exchanger. Funded by NSF and NSERC.

Implantable Dinner Bells? Acoustic Properties of a VEMCO V9 Coded Transmitter

M. A. Shane, A. E. Bowles and S. L. Denes

Hubbs-SeaWorld Research Institute, San Diego, California, USA

Session: TelO27

Abstract: Ultrasonic acoustic transmitters ('tags') are being used to study movement, site fidelity, and home range in fish and invertebrates in the marine environment. Results from these studies are also being used to address questions about marine reserves, protected areas, and essential habitats. However no published data exist describing the acoustic properties of these tags and their potential to be detected by predators. To obtain empirical data on the level and frequency range of the tags, we measured a series of pings from five VEMCO V9-2L-R04K coded transmitters. Initial recorded measurements were made in a 7.6 m diameter concrete circular tank filled with seawater to a depth of 0.9 m. Two hydrophones, positioned 1 m from the transmitter, and high speed data acquisition equipment were used to make recordings on the sides.
and ends of each transmitter. Pings had a peak frequency of 69 kHz, but the spectrum had a marked 'shoulder' on the low end, with substantial energy down to around 50 kHz. A faint click was produced every time a ping was actuated, ranging from 400 Hz to 20 kHz. Our results suggest that the transmitters will be audible to sensitive phocids (e.g., harbor seals) and delphinid cetaceans at ranges great enough to enable them to find tagged individuals. At close range, clicks will be audible to pinnipeds, cetaceans, and some fishes. Pinger-equipped fishes and invertebrates may therefore be more detectable to predators. If marine mammals learn to associate ping sounds with a meal, mortality rates estimated from tagging data will be artificially elevated. Funded by San Diego County Fish and Wildlife Advisory Commission and the Hubbs-SeaWorld Research Institute.

HYPOXIA AFFECTS SEX DIFFERENTIATION AND DEVELOPMENT, LEADING TO A MALE-DOMINATED POPULATION IN ZEBRAFISH (*Danio rerio*)

Eva H.H. Shang, Richard M.K. Yu and Rudolf S. S. Wu*

E-Mail: bhrswu@cityu.edu.hk
Centre for Coastal Pollution and Conservation, City University of Hong Kong, 83 Tat Chee Avenue, Kowloon, Hong Kong SAR, China

Session: HypO10
Abstract: Hypoxia is affecting thousands of km² of water, and has caused declines in fish populations and major changes in aquatic communities worldwide. For the first time, we report that hypoxia can affect sex differentiation and sex development of fish, leading to a male-biased population in the F1 generation (74.4±1.7% males in the hypoxic groups vs 61.9±1.6% males in the normoxic groups, n=5; p<0.05, Chi-square test). The increase in males was associated with down-regulations of various genes controlling the synthesis of sex hormones (i.e. 3β-HSD, CYP11A, CYP19A and CYP19B) and an increase in the testosterone/estradiol ratio. The male-dominated populations caused by hypoxia will have reduced reproductive success, thereby threaten the sustainability of natural fish populations. Funded by the University Grants Committee of the Hong Kong Special Administrative Region, China (Project No. AoE/P-04/04)

AGE-DETERMINATION AND BACK-CALCULATION OF LENGTH OF PIKE (*Esox lucius* L.) BY USE OF THE METAPTERYGOID BONE; A VERIFICATION BY MARK-RECAPTURE

C.M. Sharma, R. Borgstrom.
E-Mail: chhatra.sharma@umb.no
Department of Ecology and Natural Resource Management, Norwegian University of Life Sciences, P.O. Box 5003, NO-1432 Aas, Norway.

Session: AdvO17
Abstract: The validity of the metapterygoid bone of pike (*Esox lucius* L.) for age determination and back-calculation of length was evaluated by using tagged pikes recaptured after one to three years. The study was conducted in the eutrophic Lake Årungen in southeastern Norway. A regression equation for the relationship between pike length and metapterygoid length was estimated, and no significant deviations between the back-calculated and expected length at tagging were found for pikes recaptured one to three years after tagging, confirming that 1) the checks are formed annually, and 2) that no false checks appeared. Accordingly, the checks represent true "winter zones", and the metapterygoid is well suited for age determination and back-calculation of pike length. We would like to acknowledge Ås municipality, Norway, for its financial support as a part of their long-term management strategy.

INVESTIGATION OF DE NOVO CHOLESTEROL BIOSYNTHETIC CAPACITY IN THE GONADS OF GOLDFISH (*Carassius auratus*) EXPOSED TO BETA-SITOSTEROL

R.L. Sharpe¹, M. Drolet² and D.L. MacLatchy¹
E-Mail: rainie.sharpe@unb.ca
¹Canadian Rivers Institute; ²Dept. of Chemistry, Univ. of New Brunswick (Saint John), Canada

Session: AdvP8
Abstract: Total and intra-mitochondrial gonadal cholesterol concentrations are decreased in fish exposed to the phytoestrogen β-sitosterol (β-sit). The present study examined the potential for β-sit to disrupt de novo cholesterol synthesis in the gonads of goldfish exposed to 200 mg/g β-sit and 10 mg/g 17β-estradiol (E2; estrogenic control) by intra-peritoneal Silastic® implants for 21-days. The de novo cholesterol synthetic capacity was estimated by incubating gonadal tissue with 14C-acetate for a period of 18 hours, followed by chloroform/methanol lipid extraction. Lipids were separated using thin layer chromatography (TLC) and total radioactivity in each lipid class was determined. Plasma testosterone (T) and gonadosomatic index (GSI) were also measured. Plasma T was significantly reduced in male β-sit-treated fish compared to control and E2-treated fish (p<0.001). 14C-Acetate incorporation towards cholesterol and cholesterol esters was not
significantly different between treatment groups for both male and female fish. Incorporation towards triglycerides (TG) and free fatty acids (FFA) was higher than expected in both sexes, with FFA incorporation significantly greater in male control fish than either β-sit or E2 treatments (p=0.005). These results indicate gonadal de novo cholesterol biosynthetic capacity is not disrupted by β-sit or E2 treatment in early recrudescing male or female goldfish. The research was funded by the Natural Sciences and Engineering Research Council (NSERC) Discovery Grant program (D.L. MacLatchy).

**BETA-SITOSTEROL ALTERS GONADAL STERIOIDOGENIC ACUTE REGULATORY PROTEIN (STAR) EXPRESSION IN GOLDFISH** *(Carassius auratus)*

R.L. Sharpe¹, W. Woodhouse², T.W. Moon², V. Trudeau² and D.L. MacLatchy¹

E-Mail: rainie.sharpe@unb.ca

¹Canadian Rivers Institute, Univ. of New Brunswick (Saint John), Canada; ²Center for Advanced Research in Env. Genomics, Univ. of Ottawa, Canada

**Session:** ImpO29

**Abstract:** Fish exposed to β-sitosterol (β-sit) have decreased circulating hormone and cholesterol concentrations, and reduced intra-mitochondrial cholesterol pools in the gonads. The current study examined the potential for β-sit to alter abundance of a key cholesterol transport protein, steridoigogenic acute regulatory (StAR) protein, which delivers cholesterol to the first and rate-limiting steridoigogenic enzyme P450 side chain cleavage (P450scc) inside the mitochondria. Plasma testosterone (T) and lipids (cholesterol, high-density and low-density lipoproteins (HDL, LDL) and triglycerides) were also measured. Goldfish were exposed to 200 mg/g β-sit (pure or as a phytosterol mixture) and 10 mg/g 17β-estradiol (E2; estrogenic control) by intra-peritoneal Silastic® implants for 21-days or for five-months. Plasma T was significantly decreased in male fish exposed to the phytosterol mixture following the long-term exposure (p<0.001). Male fish had significantly lower HDL as compared to control fish (p<0.025) following the long-term exposure, with a corresponding increase in LDL. StAR transcript levels were reduced after exposure for five months in male β-sit fish (p=0.05) and E2-treated female fish (p=0.049). This is the first study to demonstrate that β-sit has the capacity to alter gonadal StAR transcript abundance and to limit cholesterol availability to the steridoigogenic pathway. The research was funded by the Natural Sciences and Engineering Research Council (NSERC) Discovery Grant program (D.L. MacLatchy; T.W. Moon) and the Canadian Water Network (D.L. MacLatchy; P.I. K. Munkittrick).

**STABLE ISOTOPE AND TELEMETRY EVIDENCE FOR PARTIAL MIGRATION IN NEWFOUNDLAND COD** *(Gadus morhua)*

G.D. Sherwood¹, M.J.S. Windle² and G.A. Rose²

E-Mail: gsherwood@gmri.org

¹Gulf of Maine Research Institute, USA; ²Memorial Univ. of Newfoundland, Canada

**Session:** TelO13

**Abstract:** Though partial migration (within-population adoption of either resident or migrant behaviour) has been studied extensively in anadromous fishes (e.g. salmonids), very little information exists on this phenomenon in oceanodromous species. Here, we provide evidence for two distinct behavioural types of Atlantic cod (Gadus morhua) that differ in their inter-spawning movement patterns and habitat use. Our analysis is based on a stable carbon isotope (d13C) characterization of habitat use and feeding history, coupled with radio telemetry-based and fishery return approximations of movement patterns of a single spawning population of cod during and between two adjacent spawning events (2002 – 2003) at the Bar Haven spawning grounds in Placentia Bay, Newfoundland. During spawning periods (April), cod displayed a wide range of d13C signatures characteristic of the entire range of feeding types found in Newfoundland waters (both pelagic and benthic). Following spawning (June), only those cod with signatures typical of benthic feeding were either relocated or recaptured in the general vicinity (within 10 km radius) of the spawning grounds. Cod with more pelagic signatures were either not found near the spawning grounds or were found at greater distances (~ 100 km) following spawning. Our isotope and tagging results suggest the coexistence of both migrant and resident types (i.e. partial migration) within a single spawning population of Atlantic cod and raise questions regarding the relative frequency of these types. Funded by NSERC and the Industrial Chair in Fisheries Conservation.
CARDIAC MYOCYTE MORPHOLOGY FROM PELAGIC FISH SPECIES
H.A. Shiels¹, M. Musyl² and R. W. Brill³
E-Mail: holly.shiels@manchester.ac.uk

¹The University of Manchester, UK, ²The University of Hawaii, USA, ³Virginia Institute of Marine Science, USA

Session: CarP2

Abstract: The shape and intracellular organization of the cardiac myocyte has important implications for excitation-contraction coupling. We isolated atrial and ventricular myocytes from a number of pelagic fish species using enzymatic digestion. Myocytes from yellowfin tuna (Thunnus albacares), skipjack tuna (Katsuwonus pelnis), bigeye tuna (Thunnus obesus) and Mahimahi (Corypheana hippurus) were isolated at sea, and fixed in 4% formalin for later imaging. Some cells were plated onto slides and labelled with the lipophilic dye Di-8-ANEPPS or FITC-conjugated dextran to allow visualisation of the cell membrane when examined through a confocal microscope. Z-stack profiles were used to measure cell length, width and depth and to calculate volume. Sarcolemmal membrane labelling reveal the presence of a transverse-axial tubular system in some but not all myocytes studied. These results are discussed in relation to their potential role in excitation-contraction coupling. We thank the staff and crew of the NOAA ship Oscar Elton Sette and the University of Manchester for supporting this research.

IONOREGULATORY CHANGES IN MATURING SOCKEYE SALMON (Oncorhynchus nerka) DURING OCEAN AND RIVER MIGRATION
J.M. Shrimpton¹, D.A. Patterson², J.G. Richards³, S.J. Cooke⁴, P.M. Schulte⁵, S.G. Hinch⁵ and A.P. Farrell²
E-Mail: shrimptm@unbc.ca

¹Biology Program, Univ of Northern British Columbia, Prince George, BC; ²Fisheries and Oceans Canada, Science Branch, Burnaby, BC; ³Dept of Zoology, Univ of British Columbia, Vancouver, BC; ⁴Dept of Biology, Carleton Univ, Ottawa ON; ⁵Dept of Forest Sciences, Univ of British Columbia, Vancouver, BC.

Session: IonO5

Abstract: We present data on changes in ionoregulatory physiology of maturing, migratory adult sockeye salmon. Fraser River sockeye were intercepted in the ocean as far away as the Queen Charlotte Islands (~850 km from the Fraser River) and during freshwater migration to the spawning grounds; for some populations a distance of over 700 km. Sockeye showed a decline in gill Na⁺,K⁺-ATPase activity as they migrated in seawater toward the mouth of the Fraser River and up river to spawning grounds. Gill Na⁺,K⁺-ATPase activity of fish arriving at the spawning grounds was significantly lower than values from fish captured before entry into fresh water. Plasma osmolality and chloride also showed significant decreases from seawater values during the freshwater migration to spawning areas. Movement from seawater to fresh water increased mRNA expression of a freshwater specific Na⁺,K⁺-ATPase isoform (a1a) while having no effect on the seawater specific isoform (a1b). Funded by an NSERC Strategic Grant.

BEHOLD A PALE FISH: LIFE WITHOUT OXYGEN-BINDING PROTEINS IN THE ANTARCTIC ICEFISHES
Bruce D. Sidell
E-Mail: BSidell@maine.edu

School of Marine Sciences, University of Maine, Orono, Maine, USA

Session: PleO4

Abstract: Antarctic icefishes (Family Channichthyidae) have long captured the imaginations of comparative cardiovascular physiologists because of the lack of circulating hemoglobin (Hb) in their blood. More recent recognition that the intracellular oxygen-binding protein, myoglobin (Mb), is expressed in hearts of only 10 of the 16 known species in this family has further focused attention upon how these unusual animals are able to supply adequate amounts of oxygen to aerobic tissues and has prompted a series of even more wide-ranging questions, including: How and when did losses of expression of these important oxygen-binding proteins occur? Were losses of their expression of adaptive value? If “yes”, what advantages were conferred; if “no”, why have the traits persisted in populations of these animals? How have the suites of physiological characteristics that appear to be aimed at compensating for losses of these proteins arisen? Recent findings point to a series of provocative explanations. Most evidence now suggests that losses of both Hb and Mb did not confer advantage to the animals. Nearly all of the hallmark traits of channichthyids may be a result of high levels of nitric oxide (NO), a condition that one would expect in the absence of Hb and Mb because of their usual roles in the chemical degradation of NO. If correct, this would imply that many of the now genetically fixed physiological characteristics of channichthyids may have originated through homeostatic mechanisms very rapidly after the original mutations that caused loss of Hb and Mb expression. Supported through grants from the US National Science Foundation’s Office of Polar Programs, most recently grants OPP 01-25890 and ANT 04-37887.
IMPACT OF POND MANAGEMENT ON SURVIVAL, GROWTH AND YIELD OF TAMBAQUI (Colossoma macropomum)

C. R. Silva1 and L. C. Gomes2*
E-Mail: levy@cpaa.embrapa.br
1 Escola Batista do Amazonas, Brazil; 2Embrapa Amazônia Ocidental, Brazil

Session: LinP8

Abstract: Tambaqui Colossoma macropomum is the main fish species raised in Amazon, and the actual rearing system included regular pond fertilization. Therefore the objective of this work was to evaluate impact of pond management on fish feed, growth, yield and survival during tambaqui production. Fish were distributed in nine 600-m2 earth ponds at a density of 0.5 fish/m² (300 fish/pond), during 210 days. Three different pond management were applied: limed and fertilized (LimFer), limed (Lim), and non management (Nat). Fish were fed with a commercial feed containing 28% crude protein twice a day. Monthly, 20% of fish (60 per pond) were captured, anesthetized with benzocaine (100 mg/L), and weighted and measured. At the end of the experiment, the following parameters were evaluated: survival (%), production per area (kg/ha), weight gain (WG = final weight – initial weight) and feed conversion rate (FCR = feed consumption/weight gain). Survival ranged between 92 and 94% without significantly difference among treatments. Weight gain is greater than 1kg on fish reared in Lim and LimFer ponds. Yield in the Lim ponds were 5332 ± 339 kg/ha and in the Nat ponds were 4325 ± 738 kg/ha. There were no significant differences in fish growth and feed conversion rate among treatments. Pond fertilization is a dispensable management during tambaqui juvenile production, since growth and yield were similar than in limed pond. Funded by International Foundation For Science.

CARDIAC REMODELING IN RAINBOW TROUT SIGNIFICANTLY INCREASES THE CORONARY VASCULAR VOLUME AND IMPROVES IN VIVO CARDIAC FUNCTIONING

Danielle L. Simonot and A. P. Farrell
E-Mail: farrellt@interchange.ubc.ca
Dept. of Zool., Univ. of British Columbia, Canada

Session: CarO5

Abstract: Cardiac remodeling was studied in rainbow trout (Oncorhynchus mykiss Walbaum) using chronic, chemically-induced anemia. Radioisotope tracer analysis of coronary vascular volume found that a 37% increase in relative ventricular mass (rVM) doubled the volume of the coronary circulation. In vivo measurements of maximum cardiorespiratory performance in rainbow trout with a 27% higher rVM yielded a significantly increased maximum cardiac output (Q) and stroke volume of 60%. However, the acute effect of anemia on routine Q did not appear to be proportional to the Hct. Rather, the primary response may have been to decrease the venous oxygen content (Cvo2) rather than increasing Q, and only at a threshold Cvo2 was a significant increase in Q observed. A preliminary reliance on existing venous oxygen stores could be energetically conservative until the heart is remodeled.

MONITORING THE EFFECTS OF WATER MANAGEMENT PRACTICES ON ESTUARINE ELASMOBRANCHES

C.A. Simpfendorfer and M.R. Heupel
E-Mail: colins@mote.org
Center for Shark Research, Mote Marine Laboratory, USA

Session: TelO20

Abstract: A network of acoustic receivers was deployed within the Caloosahatchee River in southwest Florida to monitor the movements and residency patterns of estuarine elasmobranch species. The acoustic network covered approximately 28 km of the river from the tidally influenced mouth upstream to predominantly freshwater habitats. Since 2003, 36 juvenile bull sharks (Carcharhinus leucas) and seven smalltooth sawfish (Pristis pectinata) have been monitored within this system. Individuals were fitted with acoustic transmitters with a battery life of approximately 18 months and have been monitored for periods of up to 15 months. The location of each individual within the array was calculated once per hour for the duration of residence using an algorithm based on averaged detections by each station in the network. These data were compared to physical factors within the estuary to determine if changes in water parameters affected animal movements or locations. Examination of animal location and movement data revealed strong correlations between salinity variation and movement patterns of both sharks and sawfish. Data from a simple hydrographic models provided interpolated data that were used in habitat selectivity analyses and to build habitat selection models. The results of these analyses were used to investigate how water management practices in the Caloosahatchee River influence use of this estuary by resident elasmobranch species. Funded by National Marine Fisheries Service and South Florida Water Management District.
TISSUE SPECIFIC CHANGES IN THE PROTEOME OF RAINBOW TROUT (Oncorhynchus mykiss) ARISING FROM X-RADIATION AND BYSTANDER EFFECT EXPOSURE

R. W. Smith*, C. P. Bucking1, M. Kilemade2, A. O’Neill3, C. Mothersill1 and C. Seymour3
E-Mail: rsmith@mcmaster.ca

1Department of Biology, McMaster University, Canada; 2Juravinski Cancer Centre, Canada; 3Department of Radiation Sciences, McMaster University, Canada

Session: ImpO20

Abstract: It is generally accepted that the severity of response to direct radiation is correlated with the size of the exposure dose. However at the very lowest exposures there is still debate regarding whether the effects are beneficial or detrimental. In addition to the actual radiation dose the phenomena of the bystander effect has been reported. This describes the response of cells adjacent to the cell directly receiving the radiation dose but which themselves were not irradiated. The bystander effect is therefore transmitted by an intercellular signal resulting in growth alteration to the recipient cell. This has been observed in mice and in vitro with the human cell line HPV-G being accepted as a bystander effect reporter model. Recently we have found evidence that the bystander effect occurs in vivo in rainbow trout. Media from cell explants from the gill, skin and adipose fin of non-irradiated fish held in proximity to directly X-rayed fish, or from non-irradiated fish held in water which had previously held X-rayed fish, all caused a 50 – 55% reduction in HPV-G colony formation, whilst media from spleen explants resulted in a 25% increase. This study builds on this result by describing the changes in the proteomes of these tissues. Here we will describe tissue specific proteome changes in directly irradiated fish and fish exhibiting the bystander effect; the aim being to differentiate direct and indirect radiation effects and identify proteins which may be involved in the generation and/or transmission of the bystander effect phenomena. Funded by NSERC.

CARDIAC MITOCHONDRIA AS A MAJOR TARGET OF DECAVANADATE

S.S. Soares1, M. Aureliano1, J. Coucelo1 and C. Gutiérrez-Merino2
E-Mail: sssoares@ualg.pt

1CCMAR, Faculty of Marine and Environmental Sciences, University of Algarve, Portugal; 2Dept. Biochemistry and Molecular Biology, Faculty of Sciences, University of Extremadura, Spain

Session: ImpO33

Abstract: Vanadium (V) is a heavy metal with increased environmental circulation, resulting from various anthropogenic activities and it is of great concern due to its toxicity and accumulative behaviour at specific target organs. Recent studies have focused on the involvement of this metal in cardiac oxidative damage and suggest that this organ shows a great vulnerability to V intoxication. However, the contribution of different vanadate oligomers to the toxicological effects mediated by V is still unclear. In the present study, we further explored the oxidative stress responses induced by an acute exposure to a sub-lethal concentration of two V solutions (metavanadate and decavanadate) administrated intravenously, on the cardiac muscle of Sparus aurata (gilthead seabream). In vivo studies suggested that an acute exposure to different vanadate oligomeric species promotes different V distributions, in blood and heart of S. aurata. Furthermore, cardiac mitochondria seem to be a target of V accumulation. It was also concluded that, both vanadate solutions affects the mitochondrial functional integrity: inducing membrane depolarization (IC50 <1 mM or 10 mM, for decavanadate and metavanadate, respectively); inhibiting mitochondrial oxygen consumption (with a concomitant decrease of ROS production); and, leading to an altered redox steady-state of cytochrome b. These studies reveal cardiac mitochondria as a model to oxidative stress evaluation induced by different vanadate oligomers, at a subcellular level. SSS was supported by a Foundation for Science and Technology (Portugal) doctoral fellowship (SFRH/BD/8615/2002). Project POCTI/38191/QUI/2001.

ECOTOXICOLOGICAL RISK ASSESSMENT IN AQUATIC SYSTEMS: FISHING IN UNCERTAIN WATERS

K R Solomon
E-Mail: ksolomon@uoguelph.ca

Centre for Toxicology, 2120 Bovey Building, Gordon Street, University of Guelph, Guelph, ON N1G 2W1, Canada

Session: ImpO16

Abstract: Ecotoxicological risk assessment and the consideration of uncertainty have evolved significantly in the last 10 years. As is the case with all risk assessments, the results are dependent on the risk hypotheses that are tested in the assessment. It is now recognized that a clear statement of the risk hypotheses and the conceptual model in which they are tested is critical to obtaining a useful answer to a risk question. These new methods are advances beyond the traditional hazard quotient (HQ) approaches with nominal uncertainty factors and incorporate probabilistic approaches to characterize both exposures and toxicity. Probabilistic ecological risk assessment (PERA) allows variability and uncertainty in exposure values and toxicity measures to be estimated and to be taken into consideration in the risk assessment and decision making. Greater understanding of both direct and indirect effects of substances in the environment is now possible with tests that incorporate field components with multiple trophic levels and food chain links. However, these new techniques express

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risks is different ways to the traditional HQ and this presents challenges to the risk communicator and risk manager. In
addition, ecological and biological information must to be integrated into the explanation of the risks and their relevance to
the ecosystem. This presentation will illustrate these new procedures and their application in aquatic systems with
examples of from pesticides and pharmaceuticals as well and suggest methods for communicating risks to decision makers.
Funded by the CNTC.

A MIXTURE OF NOVEL SULFATED STEROIDS FUNCTIONS AS A POTENT MIGRATORY PHEROMONE
FOR THE SEA LAMPREY (Petromyzon marinus)
P.W. Sorensen1, J.M. Fine1, V. Dvornikovs2, C.S. Jeffrey2, F. Shao2, J. Wang2, L.A. Vrieze1,
K.R. Anderson1 and T.R. Hoye2
E-Mail: soren003@umn.edu
1Dept. Fisheries, Wildlife Conservation Biology, University of Minnesota; 2Dept. Chemistry, University of Minnesota,
USA.

Session: OlfO14
Abstract: The sea lamprey is an ancient and parasitic fish with an enormously developed olfactory system and an
anadromous life history. Here, we report the discovery and structure elucidation of a multi-component steroidal pheromone
that is released by stream-dwelling larval lamprey and which guides adults to spawning streams. Milligram quantities of
this pheromone were isolated from 8000 liters of larval holding water using XAD resin and purified using HPLC-mass
spectrometry while olfactory activity was ascertained EOG recording. Behavioral activity was further confirmed using a
two-choice maze. The most important component was found to attract migratory lamprey at a concentration of 10^-13Molar
and to contain two sulfates and an unprecedented a 1-(3-aminopropyl)pyrrolidin-2-one unit. Its structure is related to
squalamine, an antibiotic produced by sharks. The second component is a new 28-carbon steroid with two sulfates and is
only slightly less potent. The third is petromyzonol sulfate, a known lamprey-specific bile acid. The potency of the
individual compounds is enhanced when they are presented as a mixture and can account for the natural activity of stream
water. This mixture is the first migratory pheromone identified in a vertebrate. Funded by: Great Lakes Fishery
Commission, N.I.H., Minnesota Agricultural Experiment Station

BIOCHEMICAL AND MOLECULAR TECHNIQUES AND APPROACHES IN ESTABLISHING
THE NEUROENDOCRINE REGULATION (HPG AXIS) OF REPRODUCTION
IN ANCIENT FISH, LAMPREY (Petromyzon marinus)
Stacia A. Sower
E-Mail: sasower@cisunix.unh.edu
Department of Biochemistry and Molecular Biology, Univ. New Hampshire, USA

Session: FisO10
Abstract: The research in my laboratory focuses on comparative molecular and biochemical neuroendocrinology and
molecular evolution of fish brain, pituitary hormones and their respective receptors. Lampreys are exciting to study since
they are one of two living representatives of the oldest extant lineage of vertebrates. My students, collaborators and I have
helped to establish the lamprey as a model organism for neuroendocrinological studies using a variety of biochemical,
molecular and physiological techniques. Our investigations have led to the advancement of lamprey neuroendocrinology by
the discovery of the primary structures of gonadotropin-releasing hormones (GnRH-I and –III) by protein purification, the
corresponding GnRH cDNAs and GnRH receptor by molecular cloning. We have mapped the expression of GnRHs, its
receptor by in situ hybridization, RT-PCR and immunocytochemistry. We have used confocal microscopy to determine the
expression of GnRH and gamma-aminobutyric acid (GABA). We have determined the cDNA of lamprey GTH beta by
expressed sequence tag analysis of the pituitary and determined its expression by real-time PCR. We have determined the
cDNA of a glycoprotein (gonadotropin-like) receptor by using a PRINTS GLYHORMONER glycoprotein hormone
receptor fingerprint in degenerate primer design. A transient cell culture system was established to examine the function of
the receptors including truncation studies. Ongoing research includes the use of peptidomics and 2D gel electrophoresis.
This research is funded by National Science Foundation Grant # 0421923.
DO THE ELECTRIC ORGAN DISCHARGES OF BLACK GHOST KNIFE FISH (Apteronotus albifrons) SERVE AS INDICATORS FOR THE FISH’S WELFARE STATUS?

Anne Spiess1,2,*, Dr. Toby Carter1 and Prof Donald Broom2
E-Mail: a.spiess@anglia.ac.uk
1Environmental Sciences Research Centre, Anglia Ruskin University, East Road, Cambridge, CB1 1PT; 2Centre for Animal Welfare & Anthrozoology, Department of Veterinary Medicine, University of Cambridge, CB4 0ES

Session: WelO3

Abstract: Weakly electric fish use self-produced electric organ discharges (EODs) for communication and navigation. EODs are the result of a compound action potential of all electrocytes in the electric organ. The EOD characteristics are species-specific, in some species sexually dimorphic and often individually distinct. Wave type weakly electric fish produce EODs that are quasi-sinusoidal and continuous. Under constant conditions the EOD characteristics of wave type species are extremely stable over time. Social and environmental changes can have modulating effects on EOD characteristics such as for example frequency or amplitude. The changes in EOD characteristics are likely to be the result of changes in the levels of circulating plasma hormones which directly influence the electrocytes’ tissue. Plasma hormone levels are known to change in response to stressors. In addition changes in, for example, plasma cortisol levels have been shown to affect the discharge behaviour of some weakly electric fish of the genus Apteronotus. The EODs of black ghost knife fish (A. albifrons) were investigated in the present study. Individual EODs were recorded under constant conditions and after the fish had been subjected to normal aquarium husbandry practices, which may be expected to stress the fish. We observed changes in EOD characteristics as a response to these potential stressors, linked to changes in the level of cortisol metabolites in the water containing the fish, indicating that measuring changes in the characteristics of the EOD of the black ghost knife fish may be a reliable tool for assessing the welfare status of the fish. The project is funded by Anglia Ruskin University, Cambridge, UK.

MALE CRUCIAN CARP (Carassius carassius) ENDOCRINE AND MILT RESPONSES TO OVULATORY FEMALES IN NATURAL CONDITIONS

N. Stacey1 and K.H. Olsén2
E-Mail: norm.stacey@ualberta.ca
1Dept. of Biol. Sci., Univ. of Alberta, Canada; 2Södertörn Univ. College, Huddinge, Sweden

Session: OlfP3

Abstract: In laboratory studies, ovulatory goldfish (Carassius auratus) release a steroid pheromone that rapidly increases male LH, in turn increasing milt volume at spawning. We sought to determine if this pheromonal priming effect 1) occurs in natural conditions in a wild congener, crucian carp (C. carassius) and 2) is sensitive to heterospecific influence. During the spawning season, carp were trapped in a pond near Uppsala, Sweden, and held separately by sex in net pens. Adding untreated, nonovulatory carp to male pens did not affect male LH or milt for the following 17 h. However, adding GnRH (Ovaprim™)-injected females increased male LH at all sample times (5, 9, 13 and 17 h) and increased milt at all but the first sample. Males also increased LH and milt after addition of female carp injected with the goldfish pheromonal steroid 4-pregnen-17,20β-diol-3-one (17,20βP), suggesting that response to GnRH-injected females was due, at least in part, to a pheromonal steroid. The pheromonal priming response of male carp appears relatively insensitive to heterospecific influence because: male carp do not respond to GnRH-injected sympatric cyprinids (rudd, Scardinius erythrophthalmus; white bream, Blicca bjoerkna); their response to GnRH-injected conspecifics is not affected by the presence of these heterospecifics. Crucian carp appear to employ the same preovulatory steroidal pheromone as goldfish, and should be an ideal cyprinid in which to study pheromonally-mediated phenomena in natural conditions. Funded by Carl Tryggers Foundation for Scientific Research (KHO), and NSERC (NES).

STUDY OF ICHTHYOPLANKTON IN THE MOUTH ZONE OF PARANAPANEMA RIVER INTO JURUMIRIM RESERVOIR, SP, BRAZIL

Suiberto1 M. R., Henry1 R. and Bialetzki2 A.
E-Mail: mrs@ibb.unesp.br
1Dep. de Zoologia, Inst. de Biociências, Univ. Estadual Paulista (UNESP), Botucatu, SP, Brasil; 2Nupélia/Univ. Estadual de Maringá (UEM), Maringá, PR, Brasil

Session: TroP7

Abstract: This study aimed to determine spatial and temporal distribution of fish eggs and larvae in the mouth zone of the Paranapanema river into Jurumirim Reservoir, as well as to assess the relationships of these with environmental variables. Samples were taken in the Paranapanema river and in in two marginal lakes (Camargo and Coqueiral), between February 2003 and January 2004. During this period the eggs (2.05 eggs/10m3) were more abundant than larvae (0.69 larvae/10m3), mainly in the Paranapanema river. Not only eggs but also larvae showed highest density in the hottest months of this year,
February for eggs (17.83 eggs/10 m³) and November for larvae (2.48 larvae/10 m³). In the Paranapanema river *Pimelodus maculatus* larvae were the most abundant, mainly in February. It seems the Paranapanema river was used as a hatching site for this species. In the Coqueiral lake *Hoplias aff. malabaricus* larvae had the greatest density, in December (0.61 larvae/10 m³), while in the Coqueiral lake *Apareiodon* spp. was most abundant, with highest density in November (0.68 larvae/10 m³). It seems that the lentic environment was used as a development site for larvae of these species. The greatest densities, not only to eggs but also to larvae, occurred in the months coincided with reproductive period the principal fish community. Support: FAPESP (Processes 02/111130-8 e 97/04999-8).

**DRIFT OF FISHES LARVAE IN THE MOUTH ZONE OF PARANAPANEMA RIVER INTO JURUMIRIM RESERVOIR, SP, BRAZIL**

Suiberto, M.R.\(^1\), Henry, R.\(^1\) and Bialetzki, A.\(^2\)
E-Mail: mrs@ibb.unesp.br

\(^1\)Dep. de Zoologia, Inst. de Biociências, Univ. Estadual Paulista (UNESP), Botucatu, SP, Brasil; \(^2\)Nupélia/Univ. Estadual de Maringá (UEM), Maringá, PR, Brasil

**Session:** TroP8

**Abstract:** The study of fish eggs and larvae is important because it allows to verify how they are using the environment for their development. The aim of this work was to analyze drift patterns of fish larvae. The sampling was done from 5-19 January 5th to 19th 2004, in the main channel of the Paranapanema river and in two marginal lakes (Camargo and Coqueiral), using a conic-cylindrical plankton net in the afternoons and nights. The relationship between larvae densities and environmental variables was investigated using Spearman’s correlation. Principal species found were *Pimelodus maculatus*, *Hoplias aff. malabaricus*, *Serrasalmus maculatus* and *Serrapinnus notomelas*. The correlations showed that the largest captures of *P. maculatus* happens when the environmental presented low temperature values, pH and level fluviometric, while electrical conductivity negatively influenced the capture of *S. maculatus*. Two of vertical distribution patterns were observed for the larvae. In the first, larvae of *P. maculatus* were more abundant during the day; in the second larvae of *H. aff. malabaricus*, *S. maculatus* and *S. notomelas*, were more prevalent during the night. These different vertical migration patterns can be related to these two groups, since they explore different food resource and avoid different groups of visual predators. Support: FAPESP (Processes 02/111130-8 e 97/04999-8).

**INTERRELATED REGULATION OF STRESS, BRAIN MONOAMINES, CORTISOL & BEHAVIOR**

Cliff H Summers\(^1\)\(^2\), Russ E Carpenter\(^1\)\(^2\), Earl T Larson\(^3\), Øyvind Øverli\(^4\) and Svante Winberg\(^5\)
E-Mail: cliff@usd.edu

\(^1\)Biol; \(^2\)Basic Biomed Sci, Univ S Dakota Vermillion SD; \(^3\)Biol, Northeastern Univ Boston MA; \(^4\)Anim Aquacul Sci, Nor Univ Life Sci, Aas; \(^5\)Basic Sci Aquat Med, Nor Sch Vet Sci, Oslo, NORWAY

**Session:** MolO15

**Abstract:** Social interaction changes the temporal dynamics of glucocorticoid release and brain signalling systems. Interrelated and reciprocal regulation systems produce patterns of stress responsiveness that suggest behavior and neuroendocrine activity are both cause and consequence of that activity. Outcomes, such as differential levels of aggression, stress responsiveness, social status and even gender (in sex changing fish), depend on tightly integrated regulation and feedback systems. The ability to win fights for social dominance can be predicted from the duration of a behavioral response to environmental stress. Moreover, stress responsiveness in plasma cortisol is correlated with aggressive behavior. Fish that exhibit lower cortisol responses to a standardized confinement test are markedly more aggressive when being placed in a dominant social position later. Distinct behavioural and physiological stress coping styles influence social rank and levels of aggression. What is more, previous experience modifies those coping styles. Fish that briefly encounter larger more aggressive fish react with increased aggression towards smaller individuals. Changes in serotonin turnover caused by stress, aggression, the presence of socially subordinate fish, plasma cortisol or brain CRF are located in limbic regions like amygdala, hippocampus, hypothalamus, striatum or in raphé. These monoamine changes influence behavior, and gender in sex changing fish, such that subordinates may serve to reduce stress by means of an aggressive outlet, and provide a behavioural stress coping strategy. Supported by NIH grant P20 RR15567.
OXYGEN CHEMORECEPTION AND REFLEX DEVELOPMENT IN FISH: THE INVOLVEMENT OF IONOTROPIC GLUTAMATE RECEPTORS

Sundin, L and J. Turesson
E-Mail: lena.sundin@zool.gu.se

Department of zoophysiology, Göteborg University, Box 463, SE-405 30 Göteborg, Sweden

Session: TroO8

Abstract: Acute oxygen sensing mechanisms and accurate cardio-respiratory reflexes to maintain oxygen delivery are especially essential in water-breathing fish, since aquatic systems have low O₂ capacitance and unstable oxygen levels. It emerges that the activated cardio-respiratory reflexes (heart rate, blood pressure, ventilation frequency and amplitude) arise from input of different groups of oxygen receptors and that each reflex modality seems to have a designated area in the brainstem for integration of the oxygen receptor signals. Recent results show that glutamate may be the major neurotransmitter for the transmission, and the purpose of this study was to establish ionotropic glutamate receptors in the central integration of oxygen receptor signals in the medulla. Hypoxic stimuli before and after application of pharmacological agents either into the blood or microinjected into the medulla of fish, revealed that each respiratory reflex modality was functioning through a specific glutamate receptor type. Consequently, the ventilatory increase in frequency was dependent on functional N-Methyl-D-Aspartate (NMDA) receptors, whereas the elevated amplitude relied on kainate receptors. α-Amino-3-OH-5-Methyl-4-isoxazole-Propionic-Acid (AMPA) receptors on the other hand appear to be involved in both of the respiratory reflex components. Taken together, the picture of oxygen chemoreflex activation in fish is complex involving several oxygen receptor populations with different central projection areas and specific glutamate receptor types for each reflex modality. Supported by Swedish Research Council.

PREDATION EFFECTS OF GROWTH-ENHANCED TRANSGENIC COHO SALMON (Oncorhynchus kisutch)

L. F. Sundström, W. E. V. Tymchuk, M. Lõhmus and R. H. Devlin
E-Mail: sundstrom1@dfo-mpo.gc.ca
CAER, Fisheries and Oceans, Canada

Session: GenO11

Abstract: One of the main concerns with the production of fast-growing transgenic fish is their potential ecological impact should they escape or be released to the natural environment. In a series of experiments carried out under semi-natural conditions, we evaluated the predation effects of growth hormone (GH) transgenic and non-transgenic (wild genotype) coho salmon with different rearing backgrounds on prey populations (smaller salmonid fry). First, using hatchery-reared fish, transgenic coho salmon with growth rates that were either maximal or restricted to match non-transgenic (wild genotype) growth rates were compared to non-transgenic conspecifics. In experiment 1, fish were size matched (but of different age) and in experiment 2, fish were age matched (but of different size). In experiment 3, wild genotype salmon reared under semi-natural and fully natural conditions were compared to transgenic fish reared under semi-natural conditions. All three experiments show that predation effects caused by transgenic fish are sensitive to environmental conditions experienced by the predator during rearing. Typically, transgenic fish caused greater mortality and reduced biomass of prey compared to non-transgenic conspecifics, but these effects were reduced when transgenic fish had experienced abundant food in the hatchery or when they had been reared under semi-natural conditions prior to the experiment. Our results indicate that transgenic salmon can be stronger predators under natural conditions relative to wild genotypes, but that environmental conditions during rearing will determine the magnitude of this difference. This research was funded by the Canadian Regulatory System for Biotechnology and the Swedish Research Council FORMAS.

HYPOXIA TOLERANCE; COMPARING PERFORMANCE OF TRANSGENIC AND WILD COHO SALMON EGGS

E-Mail: line.sundt-hansen@nina.no
Norwegian Institute for Nature Research, Norway; Dept. of Fisheries and Oceans Canada, West Vancouver Laboratories; Ocean Sci. Centre, Memorial Univ. Newfoundland, Canada

Session: GenO6

Abstract: Environmental risks associated with escapes of transgenic fish are largely unknown, and an important factor influencing such risks is whether offspring from transgenic spawners are capable of surviving unpredictable conditions during critical life-stages in the wild. For salmonids, oxygen level is a critical factor for egg survival, and we have addressed this issue experimentally by exposing transgenic and wild coho salmon eggs to hypoxic conditions (2.37±0.57 (sd) mg L⁻¹) for 0, 12, 36, and 72h, and observed the survival rate and growth until the presumed emergence time. A half sibling approach was used, where eggs from each wild female were fertilised by a wild and a transgenic male. This approach enabled us to minimize maternal effects and hence reveal the effect of the transgene. There was a general
decrease in survival rate for both transgenic and wild eggs with increasing exposure to hypoxic conditions. However, transgenic eggs responded stronger to longer intervals of hypoxia than wild eggs, with a significantly lower survival rate in the 36 and 72h treatment, but not in the 0 and 12h treatment. Fry weight decreased with increasing exposure to hypoxia, but transgenic fry were significantly larger than wild fry in all time periods. Given optimal oxygen conditions transgenic eggs achieve the same survival rate as wild salmon eggs. However in strongly hypoxic environments differential egg survival is expected to select against transgenic salmon. Financed by the FUGE-program of the Norwegian Research Council and the Canadian Regulatory System for Biotechnology.

USING SUB-LETHAL PHYSIOLOGY TO GUIDE MANAGEMENT IN RECREATIONAL FISHERIES

C.D. Suski1*, J.D. Kieffer2, S.S. Killen3, K.R. Esseltine4 and B.L. Tufts5

E-Mail: cory.suski@mnr.gov.on.ca

1Harkness Lab of Fisheries Research, Ontario Ministry of Natural Resources, Canada; 2Dept. Biology, Canadian Rivers Institute, Univ. New Brunswick, Canada; 3Ocean Sciences Centre, Memorial Univ. Newfoundland, Canada; 4Ontario Ministry of Natural Resources, Kingston, ON, Canada; 5Queen’s Univ., Kingston, ON, Canada.

Session: CapO6

Abstract: Recent studies suggest that recreational fisheries in North America may be experiencing population declines as a result of angler activities. This presentation summarizes a series of research projects designed to 1) quantify the sub-lethal physiological responses of several fish species to different angling stressors, and 2) advise fisheries managers on alternative angling practices to increase the survival of released fish. Four different investigations that blended field and laboratory techniques were performed to investigate the impacts of capture depth, hypoxia, changes in ambient temperature, ammonia exposure and air exposure on various physiological metrics. Results showed that 1) fish angled from > 15 m experienced significant physiological disturbances relative to fish caught from more shallow depths, 2) small (< 5 °C) changes in water temperature and/or exposure to ambient ammonia of 100 mM Tamm can impair recovery from angling, and 3) the largest source of physiological disturbance during angling tournaments occurs during the weigh-in. Results from these studies suggest that 15 m may be a critical depth for anglers wishing to release their fish, underscore the importance of adequate water quality during fish holding at angling tournaments, and provide a novel weigh-in technique with fish being weighed in water rather than in air as a means to minimize sub-lethal disturbances for tournament-caught fish. These studies demonstrate the value of sub-lethal physiological studies for designing management strategies for recreational fisheries. Funding for this project was provided by Shimano Canada Ltd., and NSERC.

PROTEOME ANALYSIS OF ATLANTIC COD LARVAE (Gadus morhua) TREATED WITH PROBIOTIC BACTERIA

H. Sveinsdóttir1, Á. Guðmundsdóttir1 and A. Steinarsson2

E-Mail: holmfrs@hi.is

1Dept. of Food and Nutrition, Univ. of Iceland, Iceland; 2Marine Research Institute, Iceland.

Session: ProO14

Abstract: The use of probiotic bacteria for aquatic animals is increasing with the demand for environment friendly aquaculture. The aim of our project was to use proteome analysis to create a new knowledge on the effects probiotic bacteria on protein expression in Atlantic cod larvae (Gadus morhua). Newly hatched larvae were divided into 2 groups: C-group (Control), and P-group (treated group). Both groups were fed with rotifers (Brachinous plicatilis) and microalgae throughout the experiment (24 days post hatch). Treatment: Probiotic bacteria mixture was added every other day to the seawater and the larvae were fed with rotifers, which were pre-inoculated with the probiotic bacteria mixture. The survival rate was 5-fold higher in the P-group (23.9%) than in the C-group (4.4%). Total protein extracts were prepared from a pooled larvae sample. Proteins were analysed by 2 Dimensional Gel Electrophoresis and the profiles compared by computer analysis. A mean of 426 protein spots (n = 4, SD = 10.0) were resolved with p/s between 4 and 7 and molecular weights between 6 and 148 kDa for P-group and 435 protein spots (n = 3, SD = 10.0) for C-group. Statistically significant (t-test, P<0.01) changes in protein expression were determined on the basis of normalised volumes of individual spots. Six protein spots were significantly induced in the P-group compared to the controls and 24 spots were depressed. Protein of interest will be excised from stained gels and identified by peptide mass mapping. The results will demonstrate how treatment with probiotic bacteria affects expression of various proteins in cod larvae. Funded by AVS Research Fund and Univ. of Iceland Research Fund.
THE INFLUENCE OF THERMAL ACCLIMATION ON SCUP RED MUSCLE POWER PRODUCTION DURING SWIMMING
D.M. Swank\textsuperscript{1} and L.C. Rome\textsuperscript{2}
E-Mail: swankd@rpi.edu
\textsuperscript{1}Department of Biology & Center for Biotechnology, Rensselaer Polytechnic Institute, Troy, NY; \textsuperscript{2}Department of Biology, University of Pennsylvania, Philadelphia, PA

Session: MusO4

Abstract: Cold temperatures substantially decrease muscle power output, yet many fish species are able to locomote in a kinematically similar manner over a wide range of temperatures. Scup muscle power output during acute exposure to cold temperatures decreases due to slowing of maximal velocity of muscle contraction, decreased rates of activation and relaxation, and a fixed nervous system stimulation regime. We studied the thermal acclimation mechanisms employed by scup to compensate for decreased red muscle power output. We acclimated scup to 10\degree C or 20\degree C. EMGs and high speed cine films were taken of fish from both groups swimming steadily at 10\degree C and 20\degree C. EMG duration and muscle length change amplitude and frequency from four locations along the fish were calculated. These values were imposed on isolated red muscle bundles for each position to measure muscle power generation at both temperatures using the work loop technique. We found that long term exposure to 10\degree C results in nervous system acclimation that decreases muscle stimulation duration as EMG duty cycles were 18\% shorter in cold-acclimated than warm-acclimated scup. Muscle physiology was also altered as we observed a 50\% increase in activation rate. However, no change in relaxation rate was observed. Through these two mechanisms, cold-acclimated scup are able to increase total red muscle power generation at 30, 40 and 50 cm/second 3, 7, and 10–fold, respectively, at 10\degree C. Acclimation thus increases red muscle efficiency and reduces reliance on the less aerobic, more energetically costly, pink muscle.

COUNTER GRADIENT VARIATION AND LINKS BETWEEN METABOLIC RATE, TEMPERATURE AND SWIMMING PERFORMANCE IN ATLANTIC COD (\textit{Gadus morhua})
E. –L. Sylvestre\textsuperscript{1}, D. Lapointe\textsuperscript{1} J.-D. Dutil\textsuperscript{2} and H. Guderley\textsuperscript{1}
E-Mail: Helga.guderley@bio.ulaval.ca
\textsuperscript{1}Dép. de biologie, Univ. Laval, Québec, P.Q. \textsuperscript{2}Ministère des Pêches et des Océans, Institut Maurice Lamontagne, Mont Joli, Québec

Session: NorO4

Abstract: Counter-gradient variation of growth capacities suggests trade-offs between swimming and growth at a common temperature. Cold-adapted populations, such as Gulf of St. Lawrence cod (GSL), would grow faster but swim less well than their warm-adapted counterparts, such as the cod from the Bay of Fundy (BF). To evaluate this hypothesis, we first compared the metabolic, physiological and swimming performance after short-term thermal change to that at the acclimation temperature (7 °C) for one stock (GSL), before comparing the performance of the two stocks after acute thermal change. For cod from GSL, standard metabolism (SMR) increased with temperature. Active metabolism (AMR and EMR) and critical swimming speed were lower at 3 °C than 7 or 11 °C. Aerobic scope AS (AMR-SMR) and sprint performance were maximal at 7°C. Factorial AS (AMR SMR-1) and the number of burst-coast movements in Ucrit decreased as temperature rose. The two stocks did not differ in the thermal sensitivities of metabolism and swimming, except for the portion of Ucrit supported by burst-coasts. GSL cod had a higher SMR than BF cod despite similar AMR and AS. Factorial AS was significantly higher for the southern stock, GSL using more of its aerobic capacity for maintenance. Cod from GSL had a lower aerobic cost of swimming at intermediate speeds than those from BF, at low temperature. Cod from the two stocks did not differ in their Ucrit speeds, but BF cod were better sprinters. Counter-gradient variation of growth rates only compromised sprint and not prolonged swimming. Supported by NSERC, DFO and Québec-Oceans.

UNDERSTANDING THE DIVERSITY OF MECHANICAL FUNCTION IN FISH MUSCLE: WHERE TO LOOK NEXT?
D.A. Syme\textsuperscript{1}, M. Gollock\textsuperscript{2}, M.J. Freeman\textsuperscript{3} and A.K. Gamperl\textsuperscript{2}
E-Mail: syme@ucalgary.ca
\textsuperscript{1}Dept. of Biol. Sci., Univ. of Calgary, Canada; \textsuperscript{2}Ocean Sciences Centre, Memorial Univ. of Newfoundland, Canada; \textsuperscript{3}Dept. of Integr. Biol., Univ. of Guelph, Canada

Session: MusO5

Abstract: Routine, cruise swimming in fish is commonly powered by the red, axial, skeletal muscles. Accommodations for varied conditions of swim speed, temperature, and axial/radial body location must be made by these muscles, yet the nature of the accommodations is not well established. The power available from muscle is predicted by its strain trajectory, activation phase/duration, and the muscle’s inherent physiology. These were measured in swimming cod and then imposed on isolated muscle to determine its power output. Most studies, including the current one, suggest the activation phase and
duration of red muscle are rarely, if ever, optimized for maximum power at any axial location. Thus, we may need to look elsewhere for insight into the strategies employed by fish to power cruise swimming, and not restrict our focus on the function of red muscle within the implicit context of mechanical power for propulsion or a role in mechanical energy transmission. Results based on a strict mechanical focus have been highly variable, and may preclude a unifying and entirely persuasive explanation to account for the diverse activation/strain patterns and resultant power outputs observed from red muscle under various circumstances and in different species. Maximizing power output for propulsion is likely not a high priority during routine swimming; competing demands might include economy of swimming and manoeuvring. In support of this, we observed high tail beat-to-beat variability in activation parameters and an inverse relationship between muscle power and swimming economy. Funded by NSERC.

**HYPERTHERMIA-INDUCED ATRIAL NATRIURETIC PEPTIDE EXPRESSION AND DEVIANT HEART DEVELOPMENT IN SALMO SALAR EMBRYOS**

H. Takle¹, G. Baeverfjord¹, S. Helland¹, E. Kjorsvik², and O. Andersen¹
E-Mail: harald.takle@akvaforsk.no

¹AKVAFORSK, Aas, Norway. ²Dept. of Biol. NTNU, Trondheim, Norway

**Session:** CarO3

**Abstract:** Heart abnormalities are increasingly recognized as a problem in salmon aquaculture and early life-stages are particularly susceptible to elevated water temperature. Recently, heat-induced mRNA expression of the cardiac hormone atrial natriuretic peptide (ANP), which is known to be involved in modulation of cardiac growth and regulation of cardiac homeostasis, was demonstrated in Atlantic salmon (Salmo salar) embryos by RAP-PCR. To examine the relation between heat sensitive ANP expression and heart abnormalities, salmon embryos were incubated at either 10 °C (high temperature) or 8 °C (controls) from fertilization till first feeding, and subsequently reared within normal conditions to a size of ~52 g. The hyperthermic embryos showed up-regulated ANP transcription at the ~9th and ~20th somite stage and at the completion of somitogenesis as shown by RT-PCR and whole-mount in situ hybridization. The cardiosomatic index demonstrated a significant decrease in the relative heart weight of fish incubated at 10 °C during the embryogenesis compared with controls. In these fish, aplasia of septum transversum was observed in two of 25 fish, resulting in abnormally shaped hearts. Our results demonstrate that hyperthermia both induces deviant development of heart and associated structures and seems to up-regulate ANP transcription during embryogenesis. A possible role of ANP in development of heart malformations is thus suggested. Funded by the Research Council of Norway.

**DISCARD SURVIVABILITY AND ESCAPE VENT SELECTIVITY IN THE DEEP WATER RED CRAB (Chaceon quinquedens) FISHERY**

S.M.L. Tallack
E-Mail: stallack@gmri.org

Gulf of Maine Research Institute, Portland, ME, USA

**Session:** CapO10

**Abstract:** The commercial trap fishery for deep water red crab (Chaceon quinquedens) occurs along the continental shelf of New England in depths of 300-500 fathom. Landings by a small, concentrated fleet have risen steadily since 1995 to ~4000 metric tons by 2001; as such, this species has become increasingly valuable for the diversification of the New England fisheries. Industry currently uses vent-free traps and discards of undersized crab can be high. Sustainable management of this fishery may depend on: 1) the incorporation of accurate discard mortality estimates into stock assessment models, and 2) efficient fishing gear which minimizes the impact on undersized C. quinquedens and non-target deep water communities. A recently established industry-science partnership has enabled new research, scheduled for spring 2006, which will 1) estimate survivability of captured but discarded deep water red crab, and 2) improve the selectivity of the fishing gear used. Discard survivability assessments will specifically yield: 1) a preliminary estimate for the physiological survivability of C. quinquedens exposed to pressure and temperature changes associated with hauling and discarding procedures; 2) a preliminary estimate of predation effects on discards returning to the sea floor; and 3) qualitative information on the impact of handling procedures on the condition of discarded C. quinquedens. Escape vent trials will be undertaken with the aim of increasing the selectivity of traps used in the fishery. The goal will be to minimize the catch of undersized C. quinquedens and non-target species, while maximizing the catch of marketable deep water red crab. Funded by NOAA Fisheries (NE Region), Cooperative Research Partners Program.
THE NORTHEAST REGIONAL COD TAGGING PROGRAM: MIGRATION AND GROWTH OF ATLANTIC COD (Gadus morhua) IN THE GULF OF MAINE
S.M.L. Tallack
E-Mail: stallack@gmri.org
Gulf of Maine Research Institute, Portland, ME, USA

Session: TelO15
Abstract: Atlantic cod (Gadus morhua) total stock biomass estimates have shown a steady decline since the 1960s (NEFSC 2001), resulting in dramatic effects on the groundfish industry. Despite the recent stock biomass increases seen in some New England fishing grounds, a greater understanding of cod distribution, migration patterns and growth in the Gulf of Maine and neighboring waters is needed before management efforts to rebuild cod stocks will succeed; this tagging study provides insight into the movements, mixing and growth of three trans-boundary Atlantic cod stocks. The Northeast Regional Cod Tagging Program represents a partnership of fishermen and international researchers collaborating on the following objectives: (1) develop a collaborative cod tagging program between scientists and fishermen in the Gulf of Maine region, including Canada; (2) obtain and analyze data from tag recaptures to improve our understanding of cod distribution, movement and growth; (3) make the data available to the public via an online GIS mapping interface; and (4) establish a preliminary understanding of cod movements and stock structure that will enable us to develop testable hypothesis for continuing tagging studies. Between April 2003 and July 2005 >114,000 cod were T-bar tagged on >100 commercial and recreational vessels, during dedicated tagging trips in both US and Canadian waters. Tagging data are publicly accessible at www.gmamapping.org/codmapping. Recapture information from ~5% of releases has revealed migration patterns and has enabled preliminary estimates of mixing rates between stocks. Tagging estimates of growth have been generated for comparison with those currently used in stock assessments. Funded by NOAA Fisheries (NE Region), Cooperative Research Partners Program.

A BENEFICIAL SIDE-EFFECT OF AQUACULTURE: OYSTER GROW-OUT CAGES FUNCTION AS ARTIFICIAL REEFS FOR TEMPERATE FISHES
J. C. Tallman and G. E. Forrester*
E-Mail: gforrester@uri.edu
Dept. of Natural Resources Science, 1 Greenhouse Rd., Kingston, RI 02881 USA

Session: AdvP4
Abstract: Inshore nursery habitats are important for many coastal fish populations. Since aquaculture facilities are often located in or around these inshore habitats, it is important to evaluate the effects of aquaculture facilities on nearby natural habitats and describe the habitat value of the aquaculture gear itself. Oyster grow-out cages are large, high-relief structures that are colonized by fishes normally associated with rocky reefs. We compared the two habitats by performing trap surveys on 3 aquaculture sites and 5 natural reefs in 2004 and 2005. The densities and size distributions of black sea bass Centropristis striata, cunner Tautogalabrus adspersus, and tautog Tautoga onitis were similar in both habitats, whereas scup Stenotomus chrysops were more abundant on grow-out cages than on natural reefs. A mark-recapture study indicated that scup grow at higher rates on the natural habitat, but have higher apparent survival on aquaculture sites. Based on these criteria, oyster grow-out cages provide habitat for reef-associated fishes that is at least as good in quality as natural habitat.

FISH KILL MECHANISMS BY THE ICHTHOTOXIC ALGA (Chattonella marina)
J. Y. M. Tang¹, S. J. L. XU¹*, C. K. C. Wong², N. Y. S. Woo² and D. W. T. AU¹
E-Mail: 50009543@student.cityu.edu.hk
¹Dept. of Biol. & Chem., City Univ. of Hong Kong; ²Dept. of Biol., Baptist Univ. of Hong Kong; ³Dept. of Biol., The Chinese University of Hong Kong

Session: ImpO36
Abstract: Our previous studies demonstrated that exposure of goldlined seabream (Rhabdosargus sarba) to Chattonella marina (a harmful algal bloom species) induced osmotic distress akin to hyperactive elimination of ions in fish gills. To ascertain the harmful effects of C. marina on fish osmoregulatory homeostasis, we investigated the in vivo effects of C. marina exposure (CM treatment) on the expressions of two key ion-transporting proteins (i.e. Na⁺,K⁺-ATPase (NKA) and cystic fibrosis transmembrane conductance regulator (CFTR) anion channel) in branchial chloride cells (CCs) of the fish. Using a quantitative immunocytochemical approach, significant inductions of NKA (α subunit) and CFTR’s immunogold labelings were detected in the CCs of moribund fish after 6 h exposure (LT50), indicating hyperactive excretion of Na⁺ and Cl⁻ occurred in the gills. Using real-time PCR measurement, no significant changes in the gill NKA and CFTR mRNA expressions were detected in moribund fish, suggesting C. marina possibly stimulated post-transcriptional up-regulation of NKA and CFTR proteins in gill CCs. When goldlined seabream were exposed to C. marina without direct contact to cells (separated by a 10μm plankton net, the CF treatment), no significant induction of CC fractional area, serum osmolality,
Na\textsuperscript{+}, and cortisol level were detected in live fish nor moribund fish. The above osmotic distress was inducible in fish only upon direct contact with \textit{C. marina} cells. On the other hand, a significant reduction of blood pO\textsubscript{2} was found in moribund fish from both the CF and CM treatments. Our earlier and present data confirm that osmotic impairment and blood pO\textsubscript{2} reduction are two independent causes of fish kill by \textit{C. marina}. Funded by University Grants Committee of the Hong Kong Special Administrative Region, China (Project no. AoE/P-04/04 and CityU 1105/00M).

THE GH-TRANSGENIC COMMON CARP (\textit{Cyprinus carpio}):
GROWTH PERFORMANCE, VIABILITY AND PREDATOR AVOIDANCE
Zhang Tanglin, Hu Wei*, Wang Yaping and Zhu Zuoyan
E-Mail: Huwei@ihb.ac.cn
State Key Laboratory of Freshwater Ecology and Biotechnology, Institute of hydrobiology, Chinese Academy of Sciences, Wuhan 430072, China

Session: GenP1
Abstract: A stable line of “all-fish” growth hormone gene transgenic common carp was generated by crossing a F1 transgenic male against a wild type female. The 50\% of transgene’s transmission in F2 and, likewise, in F3 showed a single insertion of transgene in the host genome. Several experiments were conducted, with the F3 transgenics vs. the controls, to compare the growth performance, viability and ability to escape from predators. Mandarin fish (\textit{Siniperca chuatsi}) were chosen as predator. When the fishes were raised at the first-feeding stage communally for 2 months, the transgenics grew faster of 33.0\%-49.6\% or 69.4\%-114.5\% times than the controls in pools without predator or with predators, respectively. In the pools without predators, the survival ratio of transgenics was 36.7-39.5\% vs. the controls of 60.5-63.3\%; while in the pools with predators, the survival ratio of transgenics was 19.5-26.8\% vs. the control of 73.2-80.5\%. When the size-matched fishes (transgenics 66.3 ± 3.4 mm and controls 66.3 ± 2.3 mm in total length) were raised in pools with predators for 5 days, the survival ratio of transgenics was 11.7\% and the controls 38.3\%. Furthermore, fishes of larger size (transgenics 80.3±3.2mm and controls 81.2±2.3mm in total length) were stoked with predators for 3 days, the survival ration of transgenics was 46.7\% vs. the controls of 73.3\%. Our observation indicated that the “all-fish” GH-transgenic common carp has higher growth rate, higher mortality and lower ability to escape from predators. Funded by National Natural Science Foundation and 973 plan of China.

COMPARATIVE ANALYSIS OF REPRODUCTIVE STRATEGIES OF EUROPEAN FRESHWATER FISHES:
APPLICATIONS TO AQUACULTURE
F. Teletchea\textsuperscript{1}, A. Fostier\textsuperscript{2}, P.Y. Le bail\textsuperscript{2}, B. Jalabert\textsuperscript{2}, J.N. Gardeur\textsuperscript{1} and P. Fontaine\textsuperscript{1}
E-Mail: Fabrice.Teletchea@lsa-man.uhp-nancy.fr
\textsuperscript{1}URAFPA, INRA-INPL-UHP, France; \textsuperscript{2}Laboratoire de Physiologie des Poissons, INRA, France

Session: LinO14
Abstract: There is currently an increasing demand for the diversification of the production of fish aquaculture, yielding to either the rearing of new species or the development of new rearing systems. This particularly requires to better understand the process of domestication for various species, displaying highly divergent strategy of reproduction. Yet, today, the domestication of a new species is still essentially realized by a long, costly, and usually empirical zootechnical approach, which may be optimized. Within this context, the two main objectives of the present study were: (i) establish a numerical clustering of fish species based on their reproductive strategies and (ii) evaluate the potential implications of the results for domestication of new species, i.e. is it possible to extrapolate, for an aquacultural purpose, the knowledge acquired on one species to other ones. Bivariate comparisons, Principal Components Analysis, and Cluster analysis were performed on a dataset comprising 50 reproductive traits for 80 fresh water European fish species (both native and introduced). These data were issued from an exhaustive literature search and then gathered in a new database developed for this project, namely STOREFISH, acronym for STrategy Of REproduction in FISH. Results obtained with these three kinds of analysis will be presented both (i) for all traits together and (ii) separately for four main stages: eggs, larvae, adults, and spawning conditions. We will further discuss the main groups obtained and the potential applications of our results for domestication in aquaculture. This study was funded by the European Union. F.T. received a fellowship from the European Union.
RELEASE, DETECTION, AND DISCRIMINATION OF BILE ACIDS BY MIGRATORY RAINNOW TROUT

B. Thwaits, J.M. Fine, A. Mensinger and P.W. Sorensen
E-Mail: soren003@umn.edu
Dept. Fisheries, Wildlife Conservation Biology, University of Minnesota; Dept. Chemistry, University of Minnesota, USA.
Session: OlfP6
Abstract: The sea lamprey is an ancient and parasitic fish with an enormously developed olfactory system and an anadromous life history. Here, we report the discovery and structure elucidation of a multi-component steroidal pheromone that is released by stream-dwelling larval lamprey and which guides adults to spawning streams. Milligram quantities of this pheromone were isolated from 8000 liters of larval holding water using XAD resin and purified using HPLC-mass spectrometry while olfactory activity was ascertained EOG recording. Behavioral activity was further confirmed using a two-choice maze. The most important component was found to attract migratory lamprey at a concentration of 10⁻¹³Molar and to contain two sulfates and an unprecedented 1-(3-aminopropyl)pyrrolidin-2-one unit. Its structure is related to squalamine, an antibiotic produced by sharks. The second component is a new 28-carbon steroid with two sulfates and is only slightly less potent. The third is petromyzonol sulfate, a known lamprey-specific bile acid. The potency of the individual compounds is enhanced when they are presented as a mixture and can account for the natural activity of stream water. This mixture is the first migratory pheromone identified in a vertebrate. Funded by: Great Lakes Fishery Commission, N.I.H., Minnesota Agricultural Experiment Station

SINK OR SWIM: NOT ALL INFECTIONS IMPAIR SALMONID SWIMMING ABILITY, EVEN NEAR LETHALITY
Tierney, K. B.¹, S. K. Balfry², C. J. Kennedy¹ and A. P. Farrell²
E-Mail: ktierney@sfu.ca
¹Department of Biological Sciences, Simon Fraser University, Canada; ²Faculty of Land and Food Systems, University of British Columbia, Canada
Session: MusO7
Abstract: For salmon, pathogens have the potential to alter swimming ability and thus impair migration or predator avoidance. For sockeye salmon (Oncorhynchus nerka) returning up Barkley Sound and the Somas River, mild Saprolegnia spp. external (fungal) infection (≤1 cm² covering of any external area) was not associated with decreased critical swimming speed (Ucrit) or Ucrit re-performance 45-min later. In contrast, severe fungal infection, characterized by gill tip loss and severe fin rot, coincident with warm water temperature, was associated with reduced Ucrit and Ucrit re-performance. Ichthyophonus spp. (fungal) heart infection did not alter the initial Ucrit, but it was related to impaired Ucrit re-performance. In comparison, damaged internal organs (spleen and liver) were associated with decreased overall Ucrit. Surprisingly, intraperitoneal injections of the etiological agent of vibriosis, Listonella anguillarum, did not negatively affect Ucrit or its re-performance in adult hatchery reared rainbow trout (O. mykiss). In fact, even at a dose approaching 48-h LD50 (10⁷ CFUs; 2 of 6 trout died), swimming ability was not different from control. However, the swimming behavior of fish injected with a lower dose (10⁵ CFUs) was affected, as trout consistently burst-swam to higher Ucrit values. Our findings indicate that while some common pathogens can affect overall swimming performance, others affect re-performance only, and some, even at lethal doses, may not affect swimming performance at all. A.P.F. was funded through a Forest Renewal British Columbia Grant.

ATRAZINE, IPBC AND ROUNDUP® AFFECT JUVENILE RAINBOW TROUT OLFACTION AND OLFACTORY-MEDIATED BEHAVIORS
K. B. Tierney¹, C. R. Singh², P. S. Ross³ and C. J. Kennedy¹
E-Mail: ctkennedy@sfu.ca
¹Dept. Biol. Sci., Simon Fraser University, Canada; ²Dept. Zool., University of Manitoba, Canada; ³Institute of Ocean Sci., Fish. Oceans Canada
Session: OlfO11
Abstract: To characterize how olfactory neuron toxicity affects olfactory-mediated behaviors, we examined the effects of 30-min exposures to the carbamate antasapstain IPBC and the herbicides atrazine and Roundup® on juvenile (~30 g) rainbow trout olfaction and olfactory-mediated behaviors. Electro-olfactograms (EOGs) were used to assess neurological response while behavioral response was evaluated by odorant preference/avoidance in an avoidance trough. The amino acid L-histidine at 10⁻⁷ M was used as an odorant throughout the experiments as trout showed a preference response to it and since it was within the environmental concentration range of some amino acids. EOGs were taken before, during, and after exposing the left olfactory rosette to varying concentrations of the pesticides. L-histidine evoked-EOGs were significantly reduced within 25-min of exposure to 1 µg/l IPBC, within 10-min exposure to 10 µg/l atrazine, and within 2-min exposure to 100 µg/l (active ingredient [AI], glyphosate isopropyl amine) Roundup®. L-histidine preference behavior was eliminated following 30-min exposure to 1 µg/l IPBC and atrazine, and 100 µg/l AI Roundup®. Comparing
neurological and behavioral toxicity, the percent loss of preference behavior exceeded the percent loss in EOG for any given exposure concentration. In fact, typical L-histidine preference behavior was no longer observed when EOGs were reduced by \( \geq 60.2\% \) of control. Our results indicate that these pesticides affect olfaction and that behavioral toxicity may be a more sensitive toxicological endpoint than neurotoxicity. P. S. R. and C. J. K. were funded through a grant from the National Pesticide Research Fund of Fisheries and Oceans Canada.

ASSESSMENT OF NEW MOLECULAR STRESS INDICATORS IN FISH APPLIED TO IMMUNE STRESSORS

L. Tort\(^1\), L. Ribas\(^1\), L. Acerete\(^1\), N. Roher\(^1\), A. Krasnov\(^3\) and S. Mackenzie\(^1\)

E-Mail: Lluis.Tort@uab.es

\(^1\)Dept. Cell Biology, Physiology and Immunology, Universitat Autonoma de Barcelona; \(^2\)Centre de Referencia en Aquicultura. 08193-Cerdanyola del Valles, Spain; \(^3\)Institute of Applied Biotechnology, University of Kuopio, P.O. Box 1627, 70211 Kuopio, Finland.

Session: MolO5

Abstract: Immune stressors like infectious processes induce glucocorticoid release which generally dampen inflammatory responses. In this study, the ability of cortisol to directly modulate the transcriptional response of rainbow trout macrophages to the cellular activator lipopolysaccharide (LPS) was investigated. LPS induced a general “response” group comprising of genes within ontology classes including the response to external stimuli, stress, humoral immunity, and apoptosis which exhibited significant increases after LPS stimulation and suppression in the presence of cortisol. Categories activated with cortisol were mainly related to various aspects of metabolism (including protein biosynthesis, binding and transport of ions) and structural proteins (mainly cytoskeleton and microtubules). From these data, selected molecular indicators were chosen with the aim of testing their ability to depict changes after an immune challenge as stressor. Gene expression was analysed in different tissues at different times (6h, 24h and 72h) post i.p. LPS injection. All indicators manifested changes in expression which were both tissue and time dependent. Furthermore a meta-analysis of Enolase expression, a potential molecular indicator, was carried out across multiple microarray experiments to further assess the potential of this gene product as a general stress indicator. In conclusion the selection of biomarkers as indicators of stress represents a complex task in which functional genomics may provide some important insights. This work was funded by the Ministry of Education and Science (AGL03112) and Generalitat de Catalunya (SGR0205 and CRA).

THE ACCUMULATION OF TMAO IN ELASMOBRANCHS REVISITED:
RETENTION VS. SYNTHESIS IN THE WINTER SKATE

J.R. Treberg* and W.R. Driedzic

E-Mail: jtreberg@mun.ca

Ocean Sciences Centre, Memorial University of Newfoundland, Canada

Session: AdvO3

Abstract: Trimethylamine oxide (TMAO) is accumulated as an organic osmolyte in marine elasmobranchs to levels second only to urea (which can reach > 400 mM); however, little is known about the whole animal regulation of TMAO in elasmobranchs and existing data are contradictory. In the present study on the winter skate (Leucoraja ocellata) we determine if this species can maintain levels of TMAO in the absence of feeding and if so, is this due to endogenous synthesis or low whole animal losses. Winter skates maintain plasma TMAO levels at approximately 50 mM for up to 45 days without feeding. The liver displays methimazole oxidation, which is consistent with the presence of flavin-containing monooxygenase (E.C. 1.14.13.8) activity - the class of enzymes responsible for the physiological oxygenation of trimethylamine (TMA) to TMAO in mammals. However, no evidence for TMA oxygenation by winter skates was found using in vivo or in vitro techniques, indicating no significant capacity for endogenous TMAO synthesis. Fed skates displayed low, but measurable (~ 4-13 mmol kg-1 hr\(^{-1}\)), efflux of TMAO (plus TMA) whereas fasted skates did not. Using the loss of injected \([14C]\) TMAO, it was determined that whole animal TMAO losses are likely < 1% of whole body TMAO day\(^{-1}\). These results demonstrate that winter skates utilize low whole animal TMAO losses, rather than endogenous synthesis, to maintain TMAO levels when not feeding. Funded by NSERC.
V-H\(^{+}\)-ATPASE FUNCTION IN THE GILLS OF THE PACIFIC HAGFISH, THE SPINY PACIFIC DOGFISH AND THE FRESHWATER RAINBOW TROUT
E-Mail: martint@ualberta.ca
Dept. Biological Sciences, University of Alberta, AB, Canada; and Bamfield Marine Sciences Centre, BC, Canada
Session: IonO4
Abstract: V-H\(^{+}\)-ATPase is involved in ion and acid/base regulation in a variety of epithelia. Typically found in cytoplasmic vesicles, it can insert to either the apical or the basolateral membrane. The final localization will determine its physiological role. If inserted in the apical membrane, V-H\(^{+}\)-ATPase activity will result in net acid secretion, whereas a basolateral localization relates to net base secretion. Here we report the presence of V-H\(^{+}\)-ATPases-rich cells in the gills of an agnathan (hagfish), a marine elasmobranch (dogfish), and a freshwater teleost (trout). In dogfish, V-H\(^{+}\)-ATPase is predominantly cytoplasmic. Blood alkalosis results in V-H\(^{+}\)-ATPase translocation to the basolateral membrane in a cytoskeleton-dependent manner. This process correlates with recovery from alkalosis, suggesting that it is associated to base secretion. In trout light microscopy micrographs we found cells with two different staining patterns: one apical and the other diffuse throughout the cell. Immunogold micrographs suggest that the last staining pattern is related to the extensive basolateral tubular system of one subtype of mitochondria-rich cells. We propose that these cells are specialized for chloride uptake and base secretion. In hagfish the picture is still not clear, but preliminary results suggest that V-H\(^{+}\)-ATPase is involved in base secretion like in the dogfish. Hence, basolateral V-H\(^{+}\)-ATPase seems to play a role in base secretion in the marine organisms, but also in Cl\(^{-}\) uptake in the freshwater trout. Funded by NSERC (GGG), D. Ross Scholarship and I.W. Killam Memorial Scholarship (MT), and Alberta Ingenuity Fund (F.K.).

TEMPORAL CHARACTERIZATION OF ION CHANNELS AND TRANSPORTERS EXPRESSIONS IN GILL CHLORIDE CELLS
W.K.F. Tse, M.S. Yang and Chris KC Wong
E-Mail: ckwong@hkbu.edu.hk
Department of Biology, Hong Kong Baptist University, Hong Kong
Session: IonP7
Abstract: Ion channels and transporters (i.e. Na/K-ATPase, Na/K/Cl\(^{2}\) cotransporter (NKCC), cystic fibrosis transmembrane regulator (CFTR), inward rectifier potassium channel (eKir), aquaporin-3 (AQP-3) & Na\(^{+}/\)H\(^{+}\) exchanger (NHE) are known to be expressed in gill epithelia of teleost fish. Owing to the anatomical complexity of gill structures, their temporal expression profiles in pavement (PVCs) and chloride cells (CCs) during the course of seawater adaptation are not completely characterized. Here we isolated the gill PVCs and CCs from seawater acclimating Japanese eels to address the issue. Messenger RNA transcripts for Na/K-ATPase, NKCC, eKir, AQP-3 and NHE were all detectable in freshwater PVCs and CCs, as measured by real-time PCR. Freshwater CCs expressed the highest mRNA and/or protein levels of Na/K-ATPase, NKCC and eKir as demonstrated by real-time PCR and/or immunohistochemical staining. AQP-3 was highly expressed in freshwater PVCs. The NHE transcripts were expressed in comparative levels in both PVCs and CCs. CFTR mRNA transcript was almost undetectable in all the freshwater gill cell samples. Seawater acclimation induced the transcript and/or protein levels of Na/K-ATPase, NKCC, CFTR and eKir in CCs. The upregulation and the coexpression of these transporters in CCs suggested their cohort function in mediating Na\(^{+}\), K\(^{+}\), Cl\(^{-}\) transport. The expression of CFTR is found to be tightly regulated as its expression was restricted only in “seawater CCs”. AQP-3 transcript and protein levels in PVCs reduced significantly during the acclimation. There was no significant reduction of NHE mRNA in both PVCs and CCs, however its protein level dropped significantly in the seawater condition. Funded by Research Grants Council (2171/04M), Hong Kong.

GENETIC VARIABILITY OF HIN DIII SATELLITE DNA IN ACROSSOCEILUS PARADOXUS (CYPRINIDAE)
M.C. Tseng\(^{1}\)*, J. P. Wang\(^{2}\) and T. Y. Chiang\(^{2}\)
E-Mail: mctseng@mail.npust.edu.tw
\(^{1}\)Department of Aquaculture, National Pingtung University of Science & Technology, Taiwan; \(^{2}\)Department of Life Sciences, National Cheng-Kung University, Taiwan
Session: ProO10
Abstract: A repetitive DNA family from Acrossocheilus paradoxus, an endemic cyprinid fish of Taiwan, was isolated and identified as a tandem arrangement of satellites in genomic DNA. The satellite family was estimated densitometrically to comprise 2.35% of the \textit{A. paradoxus} genome using slot blot. The conservation of this repetitive DNA was demonstrated in related species using southern blot, which revealed similar repetitive patterns in six species of five fish genera. A monomeric repeat unit of the satellite was cloned and sequenced, and found to be 210 base pairs long and to have a base composition of 52.8% A+T. A 5S rRNA gene consists of a part of a monomer sequence with a high G+C content.
Alignment analysis by examining 45 cloned repeat DNA strands from 22 individuals from seven different streams suggests that this repetitive DNA is highly polymorphic and has direct internal subrepeats within the monomer sequence. The variability of sequences is mainly attributable to point mutations and recombination effects within all sequences. Forty-two haplotypes were identified. Genetic distances in all haplotypes ranged from 0.027-0.127, (average: 0.06). The phylogenetic relationship between populations was reconstructed. Genetic analysis revealed that all populations stay in lineage-sorting stages and are genetically highly heterogeneous. A large number of haplotypes with low levels of sequence divergences between them indicates the accumulation of mutations in a rapidly growing population of *A. paradoxus*. Funded by NCKU and NPUST.

THE USE OF FRESHWATER GILL CELL CULTURE TO ELUCIDATE MECHANISMS OF AMMONIA EXCRETION

T.K.N. Tsui and C.M. Wood
E-Mail: tsuitk@mcmaster.ca
Dept. of Biol., McMaster Univ., Canada

Session: FisO4

Abstract: Ammonia is continuously produced by fish and is eliminated mainly across the gills, though after more than 40 years of research, the exact mechanisms of ammonia permeation remain controversial. For example, the involvements of Na⁺/K⁺-ATPase, Na⁺/H⁺ exchanger, H⁺-ATPase, and K⁺ channels are still not certain. Also, the relative importance of different processes is not clear, especially during varying conditions such as different environmental pH values, buffering capacities and ionic compositions. In part, the obstacles in answering questions like these are the technical difficulties in controlling various parameters when using whole fish as experimental model. The gill cells of rainbow trout have been successfully isolated and grown on porous membranes. The cells form a confluent multi-layered epithelium which develops polarity and tolerates prolonged freshwater exposure on the apical surface. Different gill cell types (eg. pavement cells and mitochondria-rich cells) can be cultured on their own or in combination. Specific blockers for various transporters can be applied to either the apical or basolateral side of the cells, without worrying about their potential side effects on the whole fish. In addition, expensive drugs can be utilized in much smaller quantities and thus the cost of certain types of experiments is drastically reduced. This system allows us to dissect the complex mechanisms involved in ammonia excretion across freshwater fish gill. (Supported by NSERC Discovery grant to CMW).

DO COMMON CARP UNCOUPLE TO SURVIVE HYPOXIA?

T.K.N. Tsui1,2, C.Y. Hung1,2, J.C.C. Lai1, R.S.S. Wu1, C.M. Wood2, G.B. McClelland2 and D.J. Randall1
E-Mail: tsuitk@mcmaster.ca
1Dept. of Biol. and Chem., City Univ. of Hong Kong, China; 2Dept. of Biol., McMaster Univ., Canada

Session: HypO6

Abstract: Hypoxia has been reported to cause increased oxidative damage in animals. Mitochondria is one of the main sources of reactive oxidative species (ROS). Mitochondrial membrane potential is known to be positively correlated to the rate of ROS production. Nothing is known about fish mitochondrial membrane potential during hypoxia. A potential mechanism of regulating mitochondrial membrane potential is via the mitochondrial uncoupling proteins (UCPs). UCPs act as a proton translocator to increase the mitochondrial basal proton leak and, thus, decrease the membrane potential. Using microarray for common carp, mRNA levels of UCP1 and UCP2 in the liver were found to be up-regulated after 4 days of hypoxia. The effects of various inhibitors and activators of UCPs on the mitochondrial membrane potential and oxygen consumption have been investigated. It was found that free fatty acids (FFA) such as palmitate (16:0) and laurate (12:0) increased the mitochondrial oxygen consumption rate. The stimulation was reversible by addition of FFA-binding proteins. The FFA-induced oxygen consumption is thought to mediate via UCPs. The FFA-induced oxygen consumption was insensitive to GDP and ATP, which are inhibitor of mammalian UCPs. This might be an adaptation to prevent damage caused by sudden re-oxygenation. It was also found that superoxide did not cause induction of mitochondrial oxygen consumption of common carp. The negative feedback on ROS production brought about by superoxide via UCPs, thus appear to be absent in common carp. (Supported by AoE grant to CityU and NSERC Discovery grant to CMW.)
SUB-LETHAL PHYSIOLOGICAL DISTURBANCES RESULTING FROM DECOMPRESSION IN SMALLMOUTH BASS (*Micropterus dolomieu*)
B.L. Tufts¹, K.E. Esseltine² and C.D. Suski³
E-Mail: tuftsb@biology.queensu.ca
¹Queen’s Univ., Kingston, ON, Canada; ²Ontario Ministry of Natural Resources, Kingston, ON, Canada; ³Harkness Lab of Fisheries Research, Ontario Ministry of Natural Resources, Canada.

**Session:** CapO8  
**Abstract:** The nature of sub-lethal physiological disturbances resulting from fish angled from depth are relatively unknown. The current study sought to quantify the sub-lethal responses of smallmouth bass to various levels of decompression using both field and laboratory experiments. Smallmouth bass angled from deep water (> 15 m) or decompressed in the laboratory (17.5 PSI, 13.5m) exhibited significant morphological (swim bladder expansion) and physiological changes (elevated plasma concentrations of: intracellular enzymes [lactate dehydrogenase, creatine phosphokinase, and aspartate aminotransferase], hemoglobin, lactate, and cortisol) relative to fish angled or decompressed from more shallow depths. These physiological disturbances persisted for 8 hours of recovery at surface pressure, but were corrected following 24 hours of recovery at surface pressure or immediately upon re-compressing fish to acclimation pressure. Results obtained from this study provide insight into critical depths where angling causes increased physiological disturbance that could arise from catch-and-release angling and live-release tournament events. Funding for this project was provided by NSERC, Shimano Canada Ltd., and the Ontario Ministry of Natural Resources.

GROWTH AND SURVIVAL TRADEOFFS LEADING TO OUTBREEDING DEPRESSION IN RAINBOW TROUT (*Oncorhynchus mykiss*)
W. E. Tymchuk¹,², L. F. Sundström¹ and R. H. Devlin¹,²
E-Mail: tymchuk@zoology.ubc.ca
¹Center for Aquaculture & Environmental Research, Fisheries & Oceans Canada; ²Department of Zoology, University of British Columbia, BC

**Session:** FroO17  
**Abstract:** The fitness consequences of introgression through interpopulation hybridization are difficult to predict and assess. The fitness of hybrids may be altered by endogenous selection (such as physiological abnormalities that are expressed regardless of environment), exogenous selection (environment-specific fitness difference), or by a combination of both, resulting in the magnitude of heterosis or outbreeding depression being dependent on the environment. Line crosses representing pure domestic (D), pure wild (W), domestic x wild hybrids (F1), F1 x wild backcrosses (B1) and B1 x wild backcrosses (B2) were reared under: 1) culture conditions; 2) semi-natural conditions with competition among genotypes; and 3) semi-natural conditions under risk of predation. Under culture and semi-natural conditions (but not under risk of predation) there was a positive correlation between the proportion of domestic alleles in the genotype and growth. There was a positive correlation between growth and survival under competition, but under risk of predation the correlation was negative. Outbreeding depression was indicated by decreased survival of the B2 lines under risk of predation, but not under competition. Physiological mechanisms underlying these observations are being explored. This information is relevant to improving our evolutionary understanding of the interaction among genomes during hybridization events, as well to assessing the risk of introgression of domesticated fish into wild populations. Funded by NSERC and the Canadian Regulatory System for Biotechnology.

OLFACTORY FUNCTIONS RELATED WITH SALMON HOMING MIGRATION
H. Ueda, H. Hino, Y. Yamamoto and F. Morinishi
E-Mail: hueda@fsc.hokudai.ac.jp
Laboratory of Aquatic Ecosystem Conservation, Field Science Center for Northern Biosphere, Hokkaido University, Sapporo, 060-0809 Hokkaido, Japan

**Session:** OlfO17  
**Abstract:** For a better understanding on the olfactory functions related with salmon homing migration, three different analyses have recently been applied using anadromous pink salmon (*Oncorhynchus gorbuscha*) and chum salmon (*O. keta*) as well as lacustrine sockeye salmon (*O. nerka*) and masu salmon (*O. masou*) in our laboratory. The first is a behavioral analysis on upstream selective movement of chum and sockeye salmon in the two-choice test tank whether the artificial water prepared by the amino acid and related substance composition of their natal stream have attractive effects on upstream movement of matured salmon, and the results demonstrate clearly that the artificial natal stream water reconstituted by the amino acid and related substance composition of natal stream has attractive effects on both salmon upstream selective movement. The second is molecular biological studies on the identification of an olfactory imprinting-related gene in salmon by a subtractive hybridization technique of representational difference analysis (cDNA-RDA) using...
olfactory system of 1- and 3-year-old fish, and we have obtained a partial clone from a subtractive cDNA library of 1-year-old fish. The third is also molecular biological studies on the isolation of odorant receptor (OR) in salmon by nested polymerase chain reaction (PCR) and by 3' and 5' rapid amplification of cDNA ends (RACE), and we have isolated one OR gene candidate. These results will be discussed about the olfactory functions in salmon with special reference to the discriminating ability of natal stream odorants of salmon with evolutionary aspects.

INDIVIDUAL PERFORMANCE IN JUVENILE ATLANTIC SALMON: EFFECTS OF DISPERAL AND HABITAT CONDITIONS
O. Ugedal1, S. Einum1, T. Forseth1 and K. Alfredsen2
E-Mail: ola.ugedal@nina.no
1Norwegian Institute for Nature Research, Norway; 2Dept. Hydraulic and Environmental Engineering, Norwegian University of Science and Technology, Trondheim, Norway

Session: FroO2
Abstract: Growth efficiency (the ratio of growth to consumption) is an integrative measure of benefits and costs of living in a particular habitat or performing different behaviours. Here we present two studies where growth and growth efficiency were used to evaluate the energetic consequences of fish behaviour and habitat use in Atlantic salmon. In the first study we compared fish size and growth efficiency in dispersing and sedentary individuals the first months after emergence from nests. We found no significant differences in performance between behaviours. Thus, individuals having successfully dispersed away from nests had not carried extra energetic costs. In the second study we tested whether there were differences in habitat profitability between four different mesohabitat classes within a river. The mesohabitat classes (shallow riffle, shallow glide, pool, shallow slowflowing areas) differed in physical characteristics such as surface velocity, turbulence and water depth. Juveniles (1+ and 2+) were individually tagged (PIT-tags) in June and recaptured in August and September. There was large individual variation in fish performance within mesohabitats, whereas differences among mesohabitats were small. On average fish grew slightly better in pools than in the other classes, but no significant differences in growth efficiency were found among mesohabitats. Hence, juvenile salmon appears to be able to obtain good performance in habitats differing largely in physical attributes. The study suggests that competitive interactions are more important for performance of older juveniles than habitat characteristics. Funded by the Research Council of Norway.

COD ON THE RUN - MOVEMENTS OF ESCAPED AND WILD ATLANTIC COD (Gadus morhua) IN A NORWEGIAN FJORD
I. Uglem1, P.A. Bjørn2, T. Dale2, F. Økland1, R. Nilsen2, K. Aas2, I.A. Fleming3 and R.S. McKinley4
E-Mail: ingebrig.t uglem@nina.no
1Norwegian Institute for Nature Research, Norway, 2 Norwegian Institute of Fisheries and Aquaculture Research, Norway, 3 Ocean Sciences Centre, Memorial University of Newfoundland, Canada, 4 Centre for Aquaculture and the Environment, University of British Colombia, Canada

Session: TelO16
Abstract: The last decade’s experiences from fish farming in marine net-pens indicate that construction of escape proof pens might be unattainable. This will most likely also be the case in culture of Atlantic cod and knowledge on the behavior of farmed cod after escape will be important to develop methods for optimal recapture and for predicting possible ecosystems effects. The purpose of this study was to describe and compare the movements and distribution of simulated escaped and wild cod around a commercial cod farm. The cod were tagged with internal acoustic tags and their movements and distribution recorded by arrays of automatic listening stations. The results show that a majority of the simulated escaped cod departed from the area around the fish farm within few days, contrary to wild cod caught around the farm, which stayed at the farm for longer periods. A similar movement pattern immediately after departure from the farm was found for cod that that escaped during summer and winter. Moreover, the escaped farm fish appeared to have a random movement pattern in the fjord and utilized significantly larger areas than wild fish. A high proportion of the escapees visited local spawning grounds for wild fish. The results suggest that recapture of escapees around the farm will be challenging due to the fast departure from the farm and that the area of distribution for escapees overlap with wild fish. Funded by the Norwegian Research Council.
ARE THE FISH OF THE AMAZON PREPARED TO FACE ANTHROPOGENIC CHALLENGES?
Val, A. L
E-Mail: dalval@inpa.gov.br
Laboratory of Ecophysiology and Molecular Evolution, National Institute for Research in the Amazon, and State University of Amazonas, Manaus, Amazonas, Brazil

Session: TroO9

Abstract: Diversity is the keyword defining tropical aquatic ecosystems as they include hundreds of different types of water bodies, with different water composition, and different biological and physical characteristics. During millions of years the fish inhabiting these environments developed a suite of strategies to survive extreme natural conditions whether occurring seasonally or at much shorter period of time, as the daily oscillations of oxygen availability at swamps of the Amazon. Many of these habitats, however, are experiencing severe anthropogenic pressures, as eutrophication, crude oil and metal contamination, deforestation and water bodies’ siltation. In general these environmental changes impose increased oxygen demand associated with either low environmental oxygen availability or reduced oxygen transfer to tissues. Crude oil exposure, for example, elicits an increase of methemoglobin to more than 50%, simultaneously with an increase of LDH gene expression. Cadmium, another pollutant occurring at high concentration in the formation water produced during crude oil mining, affects fish behavior, causes an increase of metallothionein levels, and interacts with hemoglobin causing its polymerization. Eutrophication elicits fish and other aquatic organisms to adjust several physiological and biochemical parameters as they were facing hypoxia and they do it improving adjustments directed towards increasing oxygen transfer to tissues. However, under many of these non natural situations the adaptive responses shaped during the evolution of these fish species may play against them. So, fish of the Amazon are not prepared to face the anthropogenic challenges occurring in their environments. (FAPEAM, CNPq, CAPES, FINEP, PETROBRAS).

EFFECTS OF COPPER AND LEAD ON TAMBAQUI, (Colossoma macropomum)
Val, A.L. and Oliveira, C.P.F.
E-Mail: dalval@inpa.gov.br
Laboratory of Ecophysiology and Molecular Evolution, National Institute for Research in the Amazon, and State University of Amazonas, Manaus, Amazonas, Brazil

Session: ImpO9

Abstract: A potential extreme anthropogenic challenge that fish of the Amazon can experience is the environmental change caused by petroleum mining. Nine barrels of formation water is produced for each crude oil barrel mined at the margins of Urucu River, in the middle of the Amazon. The formation water is rich in metals, in particular lead and copper. Increased levels of lead and copper have also been detected in water bodies surrounding the major industrial areas of the Amazon, as the water bodies crossing the Industrial District of Manaus city. The present paper accessed the effects of copper and lead on a widespread endemic fish of the Amazon, the tambaqui, Colossoma macropomum. The LC50-96h was 0.735mg/L for copper and 28.71mg/L for lead. These values are relatively higher than the values reported for other tropical fish species of the Amazon and for temperate fish. Based on these values, specimens of tambaqui were exposed to levels equal to ½ of the CL50-96 hours and to both metals in a level equal to the sum of ¼ of the CL50-96 hours of each of the metals. Significant changes of hematological parameters, plasma ions, glucose, lactate and TBARS were observed. The exposure to copper and lead also resulted in serious hepatic damage in tambaqui, evidenced by increased levels of alanine and aspartate aminotransferase and alkaline phosphatase. Increased cholinesterase levels suggest also nervous disturbances. Erythrocytic nuclear abnormalities were also increased in animals exposed to these two metals. Thus, even at sub-lethal concentrations, copper and lead cause serious physiological and biochemical disturbances compromising the health of this fish species. (FAPEAM, CNPq, CAPES, FINEP, PETROBRAS).

FROM OLFACTORY RECEPTOR NEURON RESPONSES AND CHEMOTOPY TO OLFACTORY DISCRIMINATION OF AMINO ACIDS IN FISHES
Tine Valentinčič
E-Mail: tine.valentinicic@bf.uni-lj.si
Department of Biology, University of Ljubljana. Večna pot 111, Ljubljana, Slovenia

Session: OlfO7

Abstract: We propose that amino acid information in fishes is coded by the responses of olfactory receptor neurons (ORNs) that lack spontaneous activity (i.e. “silent” ORNs). In catfish, the number of ORNs responding to amino acids correlates highly with the amplitude of the EOG response to the same amino acid stimuli. These results suggest that the summed receptor potentials constitute the majority of the EOG signal. During binary mixture studies, we found that equal EOG amplitudes to different amino acids reflect equal behavioral effectiveness. Here, we report that differential olfactory bulbar activity patterns previously described in a calcium-imaging study of the zebrafish olfactory bulb (Friedrich and
Korschining, 1997) enable olfactory discrimination, whereas highly similar bulbar patterns fail to enable the discrimination. Catfish and zebrafish discriminate nearly every conditioned amino acid from every other amino acid, but as was predicted from an electrophysiological study (Friedrich and Laurent, 2001), zebrafish cannot discriminate L-Ile from L-Val and L-Phe from L-Tyr. Similarly, catfish cannot discriminate L-Ile from L-Val, which indicates a similar design of the olfactory system across unrelated fish species. In conclusion, it is possible to predict olfactory discrimination of amino acids from their chemotopic bulbar activity patterns, and it is possible to predict equal or very similar chemotopic bulbar activity patterns from olfactory discrimination studies. Funded by Slovenian Ministry of Education and Science grant P0-0509-0487. Friedrich, R. W. and Korschining, S., 1997, Neuron, 18:737-752. Friedrich, R. W. and Laurent, G. 2001, Science, 291:889-894.

INSTRUMENTAL CONDITIONING AND LEARNING BEHAVIORAL SEQUENCES IN THE FRESHWATER ANGELFISH (PTEROPHYLLUM SCALARE)
T. Valentinčič, J. Dolenšek, J. Božič, K. Pliberšek and J. Podlesnik
E-Mail: tine.valentinic@bf.uni-lj.si
Dept. of Biol., Univ. of Ljubljana, Slovenia.

Session: AdvP10
Abstract: In aquaria, cichlid fishes often exhibit a large variety of learned behaviors. An automatic feeder was constructed which delivered a food reward (enchitreid worms or insect larvae) after freshwater angelfish (Pterophyllum scalare) pulled a fiber connected to the electric switch that operated the feeder. White textile fiber whose colour resembled enchitreid worms was used initially to encourage the fish to start pulling the fiber. The angelfish learned how to operate the feeder in approximately five days. In final experiments the entire procedure was controlled by a computer using FDS Imaging Solutions software (FDS Research, Slovenia). The fish needed one week to master each of the subsequent behavior steps. Next the angelfish learned that they can operate the feeder by pulling fibers of different colors. The feeder was functional only if the conditioning lamp was on. In the following step the angelfish learned to operate the switch that turned on the conditioning lamp. After mastering that food is obtained only if the conditioning lamp is on, the angelfish learned that differentially colored fibers operate the lamp and the feeder. Finally we instructed the angelfish to first turn the conditioning lamp on and, during the short illumination period (4-6 seconds), trigger the feeder. After approximately 5-8 weeks 30-40% of the angelfish successfully mastered the sequential tasks. Acknowledgements: We would like to acknowledge the contribution of more than 80 undergraduate students that conducted parts of the angelfish conditioning experiments during their practical works in ethology since 1980.

THE EFFECT OF MALE MATING STRATEGY TO THE RISK OF INVASION OF TRANSGENIC SALMON INTO NATURAL POPULATION
K.-R. Valosaari, S. Aikio and V. Kaitala
E-Mail: kata.valosaari@helsinki.fi
Dept. of Biol. and Env. Sci., Univ. of Helsinki, Finland

Session: GenO12
Abstract: Growth enhanced transgenic (GMO) salmon may threaten natural populations if released to the wild. The invasibility of GMOs may be affected by changes in survival and fecundity, but also due to the choice of male mating strategy. The mating success of the mature male parr is usually lower than that of anadromous males in Atlantic salmon. Large anadromous GMO males would probably be preferred in sexual selection. However, the proportion of early maturing male parr strategy is presumably higher in the GMOs than in the smaller wild genotype, since large male offspring usually adopt the parr strategy. We studied the effect of mature male parr proportion in the dynamics of wild, hybrid and GMO genotypes in a modeled Atlantic salmon population, following a release of the GMOs. Genotypes were defined by two alleles in one locus and they bred in relation to their frequencies and preference in sexual selection. The genotypes of their offspring followed Mendelian inheritance. Results showed that when the proportion of male parr strategy increased in relation to anadromous strategy, the density of wild and hybrid genotype declined rapidly. The increase had only a minor effect in GMOs. The results suggest that the transgenic genotype could invade and reach high densities even if the majority of GMO males adopt the male parr mating strategy, when the fecundity of GMOs is high and it is preferred in sexual selection. Funded by the Academy of Finland.
THE 6000 KM SPAWNING MIGRATION OF THE EUROPEAN EEL
Guido van den Thillart, Vincent van Ginneken and Arjan Palstra
E-Mail: G.van.den.Thillart@biology.leidenuniv.nl
University Leiden, Institute Biology, POB 9516, 2300RA Leiden, Netherlands

Session: IntO1
Abstract: One of the mysteries of the animal kingdom is the long-distance migration of the European eel (Anguilla anguilla L.). The only evidence for the location of the spawning site of the European eel is the discovery by Johannes Schmidt of the smallest eel larvae (leptocephali) at the beginning of the previous century near the Sargasso Sea. For years it has been questioned whether the fasting eels have sufficient energy reserves to cover this enormous distance. In addition one may wonder when and how the migrating eels mature, since at the time when they leave, their gonads are in a prepubertal stage. We used swimtunnels to determine how much energy is used by the swimming eels over a large distance. In addition we tested the hypothesis that swimming is a major trigger for initiating maturation. The experiments largely confirmed both hypotheses. We found that eels can easily swim a distance of 6,000 km, even more impressive is the fact that their energy consumption remains extremely low. Thus the usage of fat for crossing the ocean is about 60 g/kg. In addition we found evidence that swimming stimulates maturation. However, as the gonads do not develop further, we assume that additional triggers are required for final maturation. This stimulus may the temperature rise at the end of the journey, which increases from about 8 °C in the open ocean to about 20 °C in the Sargasso Sea.

OLFACTORY SENSITIVITY TO FOOD-RELATED ODORANTS IN THE SENEGALESE SOLE (Solea senegalensis)
Z. Velez1,2,3, P. C. Hubbard1, E. N. Barata1,2, J. D. Hardege2, R. Bublitz2 and A. V. M. Canário1
E-Mail: zvelez@ualg.pt
1CCMAR Faro, Portugal, 2Universidade de Évora, Portugal, 3University of Hull, UK

Session: LinO10
Abstract: The Senegalese sole is a nocturnal, benthic flatfish of high commercial importance. Given that chemosensory mechanisms are important for food detection and location, the aim of this study was to identify the types of substances released by two natural food items (Nereis diversicolor and Diopatra neapolitana) that may act as olfactory cues. Macerates of these polychaetes were filtered according to molecular size down to less than 500 Da and then passed through solid-phase extraction columns (C-18). Olfactory activity of all fractions was then assessed by the electro-olfactogram (EOG). Only the C-18 filtrate containing hydrophilic molecules of less than 500 Da had significant olfactory potency. As amino acids are known to act as odorants for fish, these were then removed by passing through ionic exchange columns designed to retain amino acids. The olfactory potency of the filtrate was then tested by EOG; significant activity remained (75-89% of total). In a previous study using gas chromatography linked with mass spectrometry was shown that the method employed was effective in extracting all the ethylchloroformate-derivatised amino acids from a sample of D. neapolitana. Taken together, these results suggest that, although amino acids are important in contributing to the odour of prey species, other small molecular-weight, hydrophilic compounds are also involved. The identity of these compounds is currently under investigation. Funded by FCT, Portugal (POCTI/38831/BSE/2001; SFRH/BD/1642/2004).

OLFACTORY SENSITIVITY TO CONSPCIFIC-DERIVED STIMULI IN THE SENEGALESE SOLE (Solea senegalensis)
Z. Velez1,2, P. C. Hubbard1, E. N. Barata1,2 and A. V. M. Canário1
E-Mail: zvelez@ualg.pt
1CCMAR Faro, Portugal; 2Universidade de Évora, Portugal

Session: OlfP1
Abstract: The two olfactory epithelia of members of the family Soleidae are essentially in contact with two distinct environments; the upper (right) side samples open water whilst the lower (left) side samples interstitial water. To evaluate whether there are differences in the sensitivities, and therefore functional roles, of the two epithelia the olfactory activity of conspecific-derived odorants was assessed in both using the electro-olfactogram (EOG). The upper nostril was significantly more sensitive to conspecific bile fluid, intestinal fluid and mucus than the lower nostril. Crude fractionation of these samples (solid-phase extraction with C-18 columns) revealed that olfactory activity in each body-fluid was due to a mixture of polar and non-polar compounds. Similarly, olfactory sensitivity to a range of C24 and C27 bile acids was greater in the upper epithelium. These results suggest that intra-specific chemical communication is mediated mainly, if not entirely, by the upper olfactory epithelium. The odorants involved, and their functional roles, remain to be established. Funding by FCT, Portugal (SFRH/BD/1642/2004).
EARLY LIFE HISTORY OF CAPELIN (Mallotus villosus catervarius)
IN THE COASTAL WATERS OF SAKHALIN ISLAND
A.Ya. Velikanov and O.N. Moukhametova
E-Mail: velikanov@sakhniro.ru

Sakhalin Research Institute of Fisheries & Oceanography (SakhNIRO), 196, Komsomolskaya Str., Yuzhno-Sakhalinsk, 693023 Russia.

Session: EarO8
Abstract: Investigations on the early life stages of Far East capelin in the different regions of coastal waters of the Sakhalin Island have been periodically conducted during the periods of 1979-1989 and 2000-2002. There is presented a summarized information, concerning the following aspects of capelin eggs and larvae biology: features of distribution and size characteristics of capelin laid eggs and larvae in the tidal zone; stage development and mortality of capelin eggs in the different parts of tidal zone; impacts of some natural conditions (factors) on eggs surviving and mortality in tidal zone; features of distribution of capelin larvae in the coastal and shelf waters during a summer season.

SURFACE AREA TO VOLUME RATIO IS REDUCED IN TRIPLOID SALMONID RED BLOOD CELLS
C. Verhille and T. Benfey
E-Mail: h8c8@unb.ca

University of New Brunswick, Canada

Session: LinP5
Abstract: Artificially produced triploid salmonids have repeatedly demonstrated an inability to endure conditions of high oxygen demand and/or low oxygen availability to the same degree as diploid conspecifics. Researchers have often attributed impaired triploid performance to reduced surface area to volume ratio of the enlarged triploid red blood cells, which may reduce oxygen diffusion rates into red blood cells and thus limit oxygen transport capabilities in triploid fish. However, the possibility that triploid cells compensate by maintaining diploid-like surface area to volume ratio has never been addressed. Stereological measurements of surface area to volume ratio were performed on transmission electron micrographs of thin sectioned red blood cells from diploid and triploid Atlantic salmon (Salmo salar). Surface area to volume ratio of triploid red blood cells was 17% less than that of diploid red blood cells. When considered in conjunction with evidence of reduced oxygen carrying capacity, reduced surface area to volume ratio of red blood cells is likely a contributing factor to the decreased ability of triploid fish to cope with extreme conditions. Research funding was provided by NSERC.

STRESS AND IMMUNOLOGICAL RESPONSE OF ATLANTIC COD (Gadus morhua) AND HADDOCK (Melanogrammus aeglefinus) TO CHRONIC HIGH TEMPERATURE AND LIGHT EXPOSURE
C. Verhille, M. Burt and S. Flynn
E-Mail: h8c8@unb.ca

University of New Brunswick, Canada

Session: LinO17
Abstract: Atlantic cod (Gadus morhua) and haddock (Melanogrammus aeglefinus) are increasingly held in sea cages for culturing purposes. As present aquaculture cage site technology has been developed predominantly for salmonid grow out, sea cages hold fish relatively close to the water surface where temperature fluctuations and light exposure are greater than at the sea bottom, where cod and haddock are found in the wild. Convincing evidence exists that stress can affect the immune system of organisms, reducing their ability to resist disease. Stress-induced immuno-compromization is of great concern to the aquaculture industry, as caged fish are constantly exposed to pathogens existing in the sea water. Once a caged fish contracts a disease, the illness spreads readily through cage sites due to the close proximity of fish to each other. The effects of an 8 week exposure period to high temperature (15 C) and light on stress and immune system indices is being evaluated in cod and haddock. Plasma cortisol and hsp-70, blood glucose, haematocrit, body weight and length, interrenal cell characteristics, leukocrit and differential white blood cells were measured in stock fish before stress exposure and will be measured again after 4 then 8 weeks of stress exposure. Fish experiencing stress treatments are expected to show signs of chronic stress response and altered differential white blood cell counts, and reduced growth compared to non-stressed controls. Funding was provided by NSERC, Cooke Aquaculture and Skretting.
MALE AND FEMALE EUROPEAN EELS: HOW TO MEET AFTER A 6000KM TRIP UNDER PRESSURE?
A. Vettier, A. Amérand, C. Moisan and P. Sébert
E-Mail: aurelie.vettier@univ-brest.fr
UPCI EA3879, UHPM, UBO, Brest, France

Session: IntO5
Abstract: To reproduce, European silver eels need to swim during almost 6000 km at depth. Thus migrating eels require important aerobic capacities for swimming, especially as it is known that hydrostatic pressure could impede aerobic metabolism. It has been shown, separately, that female silver eels are able to face pressure and to swim for a long time. However an important sexual dimorphism exists which could be responsible for different pressure resistance and/or swimming speed: males must swim faster in Body Length/second (BL/s) than females to ensure the same migration speed (km/day) as females. To explore this, we have evaluated aerobic metabolism capacities of male and female silver eels which were acclimatised for 21days at 10.1 MPa. The oxygen consumption (MO₂) and the Cytochrome oxidase activities were measured in red and white muscles. Globally it appears that although more affected by HP, males have a higher functioning of aerobic metabolism than females whatever the pressure level (after pressure acclimatisation, in red muscle MO₂ = 0.37±0.03 and 0.57±0.04 µmol/min/gww in females and males respectively). Calculations suggest that swimming at 0.5 BL/s under pressure represents a higher percentage of maximal MO₂ in females than in males (females: 41.5±2.0 %; males: 25.7±1.7 %). Higher aerobic capacities of males are thus considered as a strategy to counterbalance their higher pressure sensitivity and to allow them to increase their swimming speed (in BL/s) by using the same percentage of maximal MO₂ than the females. Finally as males leave rivers sooner, the meeting of the two sexes in Sargasso Sea does not seem to be a myth. Funded by the European contract Q5RS-2001-01836.

TOXIC ACTION OF THE 2,4-D HERBICIDE ON GILLS AND LIVER EPITHELIUM OF THE FISH POECILIA VIVIPARA
A.F. Vigário*1, A.T. Yamada2 and S.M.T. Sabóia-Morais1
E-Mail: afvigario@gmail.com
1Departament of Morphology, Institute of Biological Sciences, Federal University of Goiás, Brazil. 2Departament of Histology, Institute of Biology, State University of Campinas, São Paulo, Brazil

Session: ImpP2
Abstract: The acute toxicity of the 2,4-D herbicide was investigated through the effects it has on guppies (Poecilia vivipara). Groups of fish were exposed to the herbicide in concentrations of 10, 20 and 40 μl per liter of water for 24 hours in order to detect its effects on gills and liver epithelium. The estimated LC50 was 34,64 μl of 2,4-D per liter of water. Histochemicals analysis of gills and liver epithelium to detect glycoconjugates were carried, along with Feulgen’s reaction for DNA. The histochemical techniques revealed qualitative variations of glycoconjugates present on mucous cells and granules. The four types of mucous cells had neutral granules, acids, or both on the same cell type. An increasing presence of syalomucins of the control group was observed, suggesting an increase of mucous viscosity, and, consequently, plaques formation which inhibit gas exchanges and osmoregulation. The lamellar fusion observed on the group exposed to 40 μl/l of 2,4-D suggests that it is a defense mechanism. Hepatocytes presented advanced vacuolization process on 10 and 20 μl/l groups. These alterations are responses to cellular stress. The 40 μl/l group presented Ito cells, micronucleus and nuclear swelling, indicating tumor formation and reinforcing the genotoxic potencial of the 2,4-D herbicide. The biochemical processing for detection of CYP did not reveal this protein in its active form on gills, but it was found on low concentrations on the liver. The 2,4-D herbicide has a high toxic action and there is an urge to know more about its action on environment. Funded by CAPES and FUNAPE.

“AGROCHEMICALS – ENVIRONMENT FRIENDS OR ENEMIES?” – TRANSLATING DATES OF TOXICOLOGICAL RESEARCH IN COLOQUIAL LANGUAGE TO SOCIALIZE KNOWLEDGE
A.F. Vigário* and S.M.T. Sabóia-Morais
E-Mail: afvigario@gmail.com
Departament of Morphology – Institute of Biological Sciences – Federal University of Goiás – Brazil

Session: ImpP3
Abstract: Human being interferes on environment in different ways, causing serious consequences on environmental health. Human and environmental health are dependent upon each other, thus there is an urge to change people’s mind and attitude towards it. Nowadays, environmental issues have drawn attention worldwide, but the great majority of the population is not aware of the process. Although, many studies have been done, most of them are kept as academic level, not reaching citizens knowledge. Due to this, our scientific results about toxic effects of the 2,4-D herbicide on guppies were translated to a coloquial language and organized in an illustrated pedagogic material aiming to release this project to student of public schools and workers, at the city of Goiania, through conferences or direct contact to them in a ludic and
informal way. The assessment of their understanding was done inviting the 230 subjects who attended the conferences to answer a questionnaire. The estimated calculated frequency for the participants ranged from 11 to 53 years old. Sixty three percent of them did not have any knowledge concerning agrochemicals effects on environment. A hundred percent showed interest and availability to learn more about toxic effects of substances on environment. Thus, this questionnaire proved to be an efficient tool to assess and confirm an urge to release scientific knowledge to common citizens. Funded by FUNAPE.

MOLECULAR RESPONSES TO STRESS IN FISH: THE ROLE OF CORTISOL
M.M. Vijayan, S. Wiseman and N. Aluru
E-Mail: mvijayan@uwaterloo.ca
Dept. of Biology, Univ. of Waterloo, Waterloo, Ontario, Canada

Session: MolO1
Abstract: The corticosteroid axis and its response to stressors have been characterized to a large extent in teleostean fishes. The majority of those studies have dealt with changes in plasma hormones (predominantly cortisol) and metabolite levels in response to stressors. While cortisol is thought to be a major player in the physiological adjustments to stress, the mode of action of this hormone is far from clear. Cortisol signaling is mediated via glucocorticoid receptor (GR) activation, however very little is known about either the regulation of GR or its role in the stress response process in fish. The recent development of microarray technology for gene expression studies in non-model organisms, including teleostean fishes, is facilitating the identification of molecular responses that are either stressor-specific and/or non-specific in fish. This transcriptomics approach is also allowing for the identification of novel pathways that are cortisol-responsive in fish. This talk will provide an overview of the molecular responses to stress and will highlight some of the recent findings on the stressor-specific GR modulation and its effect on target tissue cortisol signaling during stress in fish. Funded by NSERC discovery and strategic grants.

SPOT MARKS AS A TOOL FOR INVESTIGATING FEEDING MOTIVATION IN THE NILE TILAPIA
G.L. Volpato1,2*, and M.E. Yamamoto1
E-Mail: gilvolp@gmail.com
1Dept. Physiology, CB, UFRN, Natal, RN, Brazil; 2Dept. Physiology, IBB, Unesp, SP, Brazil

Session: WelP7
Abstract: We tested a visual signal as a feeding stimulus for the Nile tilapia. First, 5 fish (SL = 7.76 ± 0.87 cm) accepting daily feeding for 4 consecutive days were tested on the fifth day before feeding. Two black spots (Larger = 2.5 cm; Smaller = 1.5 mm) were concomitantly placed on the outside wall of the aquaria and bites emitted to these spots were counted for 24 min. The first bite was always emitted to the larger spot, and the fish bit this spot more frequently (L = 17.20 ± 14.79 bites; S = 3.40 ± 6.54 bites; paired t test, p < 0.05). Bites were concentrated (80.14%) in the first 2-min. In a second experiment, we found that satiated fish (n = 7, SL = 7.11 ± 0.57 cm) rarely bit the spots (3 out of 28 fish bit), and even so at a very low rate (less than 6 bites). Fed-deprived fish, however, bit the spots at a significantly higher rate after 24-h fasting, and decreased significantly after longer feed-deprivation periods (48 h and 72 h). To avoid experience interference, other fish were tested independently after 48- or 72-h fasting. Compared with the fish in the previous experiment, no significant difference occurred, but they bit more frequently than the satiated fish. Conclusions: 1) the external black spot attracted the fish, mainly the larger spot and after 24-h fasting; 2) this attraction was induced by feeding motivation, thus providing a useful tool for investigating visual food stimuli. Funded by CNPq.

EFFECTS OF DIFFERENT UNCONDITIONED STIMULI ON CONDITIONED STRESS RESPONSE IN NILE TILAPIA
G.L. Volpato1,2*, and R.E. Barreto2
E-Mail: gilvolp@gmail.com
1Dept. Physiology, CB, UFRN, Natal, RN, Brazil; 2Dept. Physiology, IBB, Unesp, SP, Brazil

Session: WelP5
Abstract: We tested the effect of two different unconditioned stimuli (US) on a conditioned stress response (CR) in the Nile tilapia, Oreochromis niloticus. First, a conditioning method was set up for grouped Nile tilapia. The fish were conditioned by pairing an innocuous stimulus (conditioned stimulus – CS), aeration off, with a stressor one (aversive unconditioned stimulus – AUS), 2 min out of water, for 10 consecutive days. This resulted in a CR, detected by elevated plasma cortisol levels when the fish is submitted to the CS only. Second, we assessed post-feeding cortisol levels in both grouped and socially-isolated Nile tilapia. Grouped Nile tilapia exhibited increased plasma cortisol levels after feeding. Nevertheless, plasma cortisol of isolated tilapia was unchanged in response to feeding. Therefore, we tested the effect of feeding as a non-aversive US (NUS) on CR. For this test, procedures were similar to those conducted for the AUS. We
found that the fish did not show a CR when trained with NUS. Thus, it suggests that, although both AUS and NUS are to some extent stressful, the difference in their intensity and severity interferes with conditioning in this species. It indicates that fish can be conditioned by pairing CR to a severe aversive stressful stimulus, but not to a non-aversive mild stressor. Funded by CNPq.

EFFECT OF HORMONAL SEX REVERSION ON BEHAVIOR OF THE NILE TILAPIA
G.L. Volpato1,2,*, L.C. Jordão2, A.A. Soares3 and N.A. Teixeira2
E-Mail: gilvolp@gmail.com
1Dept. Physiology, CB, UFRN, Natal, RN, Brazil; 2Dept. Physiology, IBB, Unesp, SP, Brazil
Session: WelP9
Abstract: We evaluated behavioral differences between normal (SL = 3.57 ± 0.19cm) and hormonally-sex-reverted males (condition R; SL = 3.48 ± 0.12cm) of Nile tilapia, Oreochromis niloticus. Experiment 1: Each fish was transferred to a novel aquarium and after 5 min video recorded for 5 min. After that, a small stone was suddenly dropped into the aquarium and the fish behavior recorded for 2 min. Spatial occupation in the aquarium was higher in reverted fish before, but not after, the alert stimulus (N = 16; mean spatial occupation ± sd; Rbefore = 4.60 ± 1.40 cm and Rafter 2.47 ± 1.86cm; t = 2.85; P = 0.008). Experiment 2: The fish were introduced in the test aquarium (with a mirror in one wall) and video recorded for 5 min. Reverted tilapia started fighting sooner (6.93 ± 2.83 s) than the normal ones (12.10 ± 4.67 s) (t = 4.55; P = 0.00008). Reverted tilapia emitted higher frequency of bites to the mirror (78.5 ± 37.82) as compared with the normal tilapia (28.00 ± 41.14) (Mann Whitney, U = 49; P = 0.0029). From the two experiments we conclude that hormonal reversion of sex in Nile tilapia increases aggression and activity, an effect supposedly caused by the higher hormonal levels of the full male group. Funded by CNPq.

ASSOCIATION OF AGGRESSION AND GONAD STAGE WITH RESPONSE TO TRANSFERENCE TO A NOVEL ENVIRONMENT IN THE RED NILE TILAPIA
G.L. Volpato1,2,*, M.S.R.F. Cacho3, S. Chellappa3, E. Gonçalves-de-Freitas4 and M.E. Yamamoto2
E-Mail: gilvolp@gmail.com
1Dept. Physiology, IBB, Unesp, SP, Brazil; 2Dept. Physiology, CB, UFRN, Natal, RN, Brazil; 3Aquatic Bioecology, CB, UFRN, Natal, RN, Brazil; 4Dept. Zoology and Botany, IBILCE, Caunesp, Unesp, Unesp, SP, Brazil
Session: WelP8
Abstract: This study correlated the response to transference to a novel environment with aggression and gonad stage in the red Nile tilapia, Oreochromis mossambicus x O. niloticus. Adult males and females were individually transferred to glass aquariums (70 x 40 x 40 cm) and time spent in locomotion and spatial distribution was registered for 15 min. After 30 min in these aquaria, a mirror was presented to each fish and aggression measured, in terms of number of bites emitted, for 10 min. Spatial distribution was measured from the position of the fish in a 10 x 10-cm grid at the frontal wall. At the end, the fish reproductive stage was determined as mature (ripe gonad) or spent. Activity was affected by sex and gonad stage (Anova, p < 0.05). In spent-gonad animals, activity profile in the novel environment was higher in males. In mature fish, activity was similar between sexes. Activity differences were abolished in the 12-14 min period after introducing the fish into the novel environment. In males with spent gonads, number of bites was positively correlated with activity in the first 5-min period in the novel environment (P = 0.030), and also in the 2nd (p = 0.048), 3rd (p = 0.017), and 4th (p = 0.030) min in this period. No association between aggression and activity was found in the other fish. Therefore, we conclude that reaction of the fish to transference to a novel environment is affected by both sex and reproductive stage of the fish. Funded by CNPq.

DETERMINING THE SPATIAL SCALE OF LOCAL ADAPTATION IN THE ATLANTIC SILVERSIDE ACROSS THE NORTH AMERICAN LATITUDINAL GRADIENT
G.N. Wagner*, T. Duffy, L. Hice and D.O. Conover
E-Mail: glenn.wagner@stonybrook.edu
Marine Sciences Research Center, Stony Brook University, Stony Brook, NY, USA
Session: FroO25
Abstract: The Atlantic silverside (Menidia menidia) is one of several fish species that exhibits dramatic variation in a variety of phenotypic traits throughout its range along the east coast of North America. These traits include physiological characteristics (growth rate), morphology (vertebral number), behavior (swimming), and the temperature-dependence of sex determination. It is known that these traits are tightly correlated with latitude, but not the minimum spatial scale or the control mechanism. We ask the following questions: 1) Is local adaptation limited by gene flow (as indexed by neutral markers), and if so at what scale? 2) Do the traits vary in synchrony or are they independent of one another? To address
these questions, common garden experiments are being collected by rearing offspring from 36 locations along the east coast from Florida to Nova Scotia in a three year study. Fish are reared at two temperatures (15 °C and 28 °C) to the juvenile stage, and then measured for growth rate, vertebral number, and temperature-dependent sex determination. Preliminary findings show a significant change occurring at Cape Hatteras for these locally adapted traits of a population that is assumed to display little genetic variation along its range. Funding for this project is being provided by and NSF grant to D.O. Conover.

RENAL FUNCTION, BLOOD PRESSURE AND METABOLIC RATES OF FRASER RIVER SOCKEYE SALMON INFECTED WITH PARVICAPSULA MINIBICORNIS

G.N. Wagner1,2*, S.G. Hinch2, M.J. Macnutt2, A. Lotto 2, S.R.M. Jones 3, D.A. Patterson4, S.J. Cooke2, J.S. Macdonald4, G. Van Der Kraak5, M.C. Healey6 and A.P. Farrell1

E-Mail: glenn.wagner@stonybrook.edu

1Department of Zoology, The University of British Columbia, Vancouver, BC, Canada; 2Department of Forest Sciences, Forest Sciences Centre, The University of British Columbia, Vancouver, BC, Canada; 3Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, BC, Canada; 4Department of Fisheries and Oceans, Science Branch, Pacific Region, Co-operative Resource Management Institute, School of Resource and Environmental Management, Simon Fraser University, Burnaby, BC, Canada; 5Department of Zoology, University of Guelph, Guelph, ON, Canada; 6 Institute for Resources and Environment, University of British Columbia, Vancouver, BC, Canada.

Session: IntO7
Abstract: The kidney parasite Parvicapsula minibicornis is endemic to the Fraser River watershed and may be a factor linked to the high mortality of Late-run sockeye salmon. Fish acquire this parasite while completing changes in ionic and osmoregulation, possibly further increasing physiological stress levels. The causal mechanism for pathogenicity of this parasite has been hypothesized to be disrupted renal function due to lesions created in the kidney glomeruli of infected fish. However, the subsequent loss of osmoregulatory ability has yet to be verified. The dorsal aorta of 10 uninfected and artificially infected fish was cannulated for repeated blood sampling and measurement of blood pressure. A catheter was secured in the urinary papilla to collect excreted urine. Routine metabolic rates were measure in a Brett-style respirometer at 0.45 bl s-1. Blood pressures and total urine flows of sockeye salmon did not decline with long-term infections of P. minibicornis. However, routine metabolic rates of infected fish were significantly higher than uninfected fish. While ionic and osmoregulatory status did not differ between control and infected fish during routine swimming, significant changes occurred in plasma osmolality with exercise. Results indicate that exercise can further compromise the stressed renal systems of infected fish, even at low parasite levels. This study was funded by a NSERC grant awarded to S.G. Hinch, A.P. Farrell, and M.C. Healey.

THE INFLUENCE OF PHOTOPERIOD ON PULSATILE UREA EXCRETION IN TOADFISH (Opsanus beta)

P. J. Walsh1,2, J. F. Barimo1,3 and Danielle McDonald1

E-Mail: pwalsh@rsmas.miami.edu

1RSMAS, University of Miami, USA, 2Dept. of Biology, University of Ottawa, Canada; 3Dept. of Biology, Portland State University, Oregon, USA

Session: AdvO1
Abstract: The gulf toadfish Opsanus beta (Batrachoididae) is one of the few teleosts to maintain a functional ornithine-urea cycle (O-UC) during adult life and possess the capability to change from ammonotely to ureotely within 24 hours in the laboratory. Captive O. beta excrete most nitrogenous waste across the gill membrane. In the lab, urea is generally excreted in daily pulses of 1.5 hrs in duration while ammonia is eliminated continually. At present, the mechanism of O-UC activation is due to an elevation of plasma cortisol (stress response) which promotes the upregulation of the key OU-C enzyme glutamine synthetase. This study examines the diel pattern of nitrogen excretion with individual toadfish in the laboratory and mesocosms. Under both experimental conditions toadfish were exposed to natural photoperiod, samples were collected hourly from toadfish in shelters fabricated with PVC pipe, and assayed for urea and ammonia with standard chemical techniques. In laboratory, conducted in 2 L containers with static seawater changed daily, urea pulses occurred at random with no apparent correlation to light or dark cycles. In mesocosm experiments, toadfish were unrestrained in 8000 L tanks with the seagrass Thalassia testudinum planted on carbonate substrate effectively simulating their natural habitat. Shelters were outfitted with an underwater IR camera connected to a time-lapse video recorder to document toadfish behavior. In preliminarily results, urea and ammonia excretion in mesocosms occurred predominately during daylight hours with peak levels near dawn or dusk. Differing results between regimes likely reflect the degree of stress.
OTOLITH TRACE ELEMENTS RECORD NATAL ORIGIN
OF SOUTHERN BLUEFIN TUNA Thunnus maccocyii IN THE INDIAN OCEAN
C.H. Wang¹, J.C. Shiao², Y.T. Lin¹, C.F. You¹, S.K. Chang³ and W.N. Tzeng *
E-Mail: wnt@ccms.ntu.edu.tw
¹Institute of Fisheries Science, National Taiwan University, Taipei, Taiwan; ²Institute of Cellular and Organismic Biology, Academia Sinica, Taipei, Taiwan; ³Department of Earth Sciences, National Cheng-Kung University, Tainan, Taiwan; 4Fishery Agency, Council of Agriculture, Taipei, Taiwan

Session: BonO2
Abstract: The trace element in otolith was used as a natural tag to track the migratory environmental history and natal origin of southern bluefin tuna (SBT) Thunnus maccocyii in the Indian Ocean. The elemental composition in otoliths of SBT collected from their feeding ground in the central Indian Ocean and spawning ground in the south of Java was analyzed using solution-based and laser-ablation inductively coupled plasma mass spectrometry. Results were analyzed with canonical discriminant analysis to understand the natal origin of the fish. The composition of 11 elements in the whole otoliths of the SBT collected in the feeding ground was significantly different between age groups of 2-3 vs. 7-8 yrs. This implies that the trace elements incorporated into the otolith changes as the fish grow in different migratory environment. The composition of five selected element/calcium ratios, including Na/Ca, Mg/Ca, Mn/Ca, Sr/Ca and Ba/Ca, was different in the otolith edge of the fish between feeding and spawning grounds, which may reflect disparities of the ambient water character in each area. However, the elemental composition in the core region of the otolith of larval and juvenile stages was similar between the feeding and spawning grounds, which may support the hypothesis of a single spawning ground of SBT in the Indian Ocean. Funded by the Council of Agriculture, Executive Yuan, Taiwan.

THE EFFECTS OF ACUTE, LOW DOSAGE EXPOSURE TO A COMMON POLLUTANT
ON SOCIAL RECOGNITION AND SHOALING IN STICKLEBACKS
Ashley Ward¹,², Jennifer Horsfall² and Suzanne Currie²
E-Mail: ashleyjwward@gmail.com
¹School of Biology, University of Leeds, Leeds, UK; ²Department of Biology, Mount Allison University, Sackville, New Brunswick, Canada

Session: ImpO37
Abstract: Behavioural assays are increasingly being used to assess the sublethal effects of pollutants on organisms. Many xenobiotic chemicals in the aquatic environment have the potential to disrupt animals’ behaviour patterns, even at low concentrations. For instance, social recognition in shoaling fishes is mediated by subtle chemical cues, which may be swamped by anthropogenic chemicals, in turn seriously impacting on their social organisation. We examined the effects of an acute exposure of one hour duration to low, environmentally-relevant dosages of the ubiquitous estrogen mimic, 4-nonylphenol, on social recognition and shoaling behaviour in three-spine sticklebacks (Gasterosteus aculeatus). A 20 μg L⁻¹ dose was sufficient to disrupt the communication of social chemical cues for a period of 15 days post exposure; a 5μg L⁻¹ dose produced the same effect for 3 days. In further trials, we found that fish lost the ability to chemically detect the presence of conspecifics following such acute, trace dosages. We discuss this in the context of its effects on social organisation and fitness. Funded by NSERC, Canadian Department of Fisheries and Oceans and the Fisheries Society of the British Isles.

DISTRIBUTION OF THE DIGESTIVE HORMONE CHOLECYSTOKININ
IN THE DIGESTIVE TRACT OF LARVAL RED DRUM (Sciaenops ocellatus)
Kenneth A., Webb Jr and G. Joan Holt
E-Mail: kenv@utmsi.utexas.edu
University of Texas Marine Science Institute, University of Texas at Austin, USA.

Session: EarO13
Abstract: Weaning of marine fish larvae to dry feeds is of great importance in commercial scale larviculture due to the high costs associated with live prey. Current feeding protocols for larval red drum (Sciaenops ocellatus) require that rotifers (Brachionus plicatilis) be co-fed with microparticulate diets for 5 days after which the fish are capable of feeding on the microparticulate diet alone. In vitro work with larvae of this species has shown that the pancreatic digestive enzymes are capable of digesting the ingredients of these commercial diets as early as first feeding and yet the larvae still require live prey for the first 5 days. Cholecystokinin has been shown to regulate the secretion of pancreatic enzymes, gut motility, and gall bladder contraction in juvenile fishes and may play an important role in the ability of larvae to digest inert diets. The current study characterizes the distribution of cells producing this hormone in the gut of larval red drum ranging from newly hatched to formation of an acidic stomach at 24dph. Funded by Perry R. Bass and the Sid W. Richardson Foundation.
NEUROBEHAVIORAL RESPONSES TO VISUAL STIMULI IN ZEBRAFISH DEVELOPMENTALLY EXPOSED TO METHYLmercury AND SELENIUM
Daniel Weber1, Michael Carvan1, Victoria Connaughton2, John Dellinger1 and Ava Udvadia1
E-Mail: dweber@uwm.edu
1University of Wisconsin-Milwaukee; 2American University, Washington, DC, USA

Session: ImpO6
Abstract: Embryonic exposure to methylmercury (MeHg) affects sensory systems development and behavioral expression in response to stimuli. While selenium reduces MeHg-induced neurotoxicity, it is unknown if interactions are long term. Zebrafish embryos (<2 hours post fertilization; hpf) were exposed to combinations of 0.0-0.30 μM MeHg and/or selenomethionine (SeMet) until 24 hpf and then placed into control media until tested at 4 months. Additionally, breeding females were fed MeHg-contaminated walleye (1-3.5 ppm MeHg; 0.2 mg food/female/d) for 2 weeks. Eggs were fertilized by unexposed males and raised in control media until 4 months. Fish were tested for visual responses to a rotating black bar at low light (~60 μW/m2). Developmental exposure to SeMet did not affect responses, except at 0.3 μM SeMet; dose responses to developmental MeHg exposure were evident at 0.01 μM MeHg (ANOVA, P<0.001). Only SeMet:MeHg exposure ratios of 1-3:1 displayed visual responses similar to controls (ANOVA, P<0.001). Dietary exposure produced significantly fewer responses than control fish only at 3.5 ppm MeHg (ANOVA, P<0.05). No gross histopathologies were observed in retina or optic tectum at any MeHg concentration. Whole-cell, voltage-gated, depolarization-elicited outward currents of intact retina of adult zebrafish were recorded in response to voltage steps from a holding potential of -60 mV (-80 to +60 mV in 10 mV increments). Adult zebrafish retinal bipolar cells from both control and MeHg-treated embryos express IK (delayed rectifying current) and IA (transiently activating current) outward K+ currents; amplitude of outward K+ currents was larger in bipolar cells within treated retinas. Funded by NIEHS.

ACUTE STRESS TOLERANCE OF ATLANTIC COD LARVAE FED DIFFERENTIALLY ENRICHED LIVE-FOOD
S.K.M. Westelmajer1, J.A. Brown1†, S.C. Johnson2 and C.C. Parrish1
E-Mail: g72skw@mun.ca
1Ocean Sciences Centre, Memorial Univ. of Newfoundland, Canada; 2Institute for Marine Biosciences, National Research Centre, Canada

Session: LinO19
Abstract: Nutritional components of larval live-food enrichment diets, particularly highly unsaturated fatty acids (HUFAs), have been shown to influence larval post-stress survival and cortisol kinetics. Studies to date have found that altering the relative ratio of three specific HUFAs, eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA) and arachidonic acid (ArA), in larval diets has a significant effect on the stress response of several teleost species. Most commercial live-food enrichment products currently available differ greatly in their nutritional compositions and HUFA ratios. The objective of this study was to determine the effect of three different dietary regimes on growth and lipid composition of larval Atlantic cod during rearing as well as larval survival and whole-body cortisol kinetics following an acute air-exposure stress. The products used for the enrichment of both rotifers and Artemia included Advantage®, AlgaMac®, algae paste (Pavlova sp.) and INVE’s Selco® products. Larval growth, measured as standard length, over the rearing period revealed no significant differences between dietary treatments. Preliminary analysis of survival data suggests that larvae fed a live-food diet enriched with a combination of AlgaMac® products and Pavlova paste have higher post-stress survival than larvae fed live-food enriched with either Advantage® or Selco® products. The analysis of larval and live-food lipid samples as well as pre- and post-stress larval whole-body corticosteroid samples are on-going. Once completed, the survival and growth trends will be evaluated in the context of the dietary lipid profiles and the larval cortisol response. Funded by AquaNet (AP-34).

OLFACTORY IMPRINTING AND CORRELATED CHANGES IN GENE EXPRESSION IN THE OLFACTORY EPITHELIA OF THE ZEBRAFISH
K.E. Whitlock1,2,3, M.R. Harden1, L.A. Newton1 and R.C. Lloyd2
E-Mail: kew13@cornell.edu
1Department Molecular Biology & Genetics, Cornell University, Ithaca, NY, USA; 2Department of Biometrics, Cornell University, Ithaca NY, USA; 3Centro de Neurociencia, Universidad de Valparaiso, Valparaiso, Chile

Session: OlfO5
Abstract: Fishes use memories of odors, formed as juveniles, to navigate in their environment. Memories formed as juveniles and retained as adults are referred to as behavioral imprinting, such as is observed in salmon. We have devised a series of experiments to determine whether zebrafish can form olfactory memories of odors experienced as juveniles and retain these memories throughout adulthood. We have demonstrated that zebrafish form and retain olfactory memories of an artificial odorant, phenylethyl alcohol (PEA), experienced as juveniles. After behavior testing of the adult zebrafish we isolated RNA from the olfactory epithelia of the “imprinted” and control siblings. We demonstrated that exposure to PEA
results in changes in gene expression within the olfactory epithelia as ascertained by microarray analysis. We confirmed these observations by in situ hybridization in developing and adult olfactory epithelia. Our analysis by in situ hybridization demonstrates that the transcription factor, otx2, which belongs to a class of transcription factors known to be important in olfactory sensory neuron differentiation, is up regulated in the olfactory epithelia in response to PEA. This increase is evident at two and three days post-fertilization and is maintained in the adult animals. Our further analysis suggested that these epigenetic changes in otx2 gene expression are manifest as an increase in the number of neuronal precursors cells olfactory epithelia of the odor-exposed fish. Thus, our results reveal a role for the environment in controlling gene expression in the developing olfactory sensory system of the zebrafish (*Danio rerio*). Funding: NIHR01 DC0421801 (KEW); GAANN Fellowship P200A000118 /Genomics Fellowship (MRH)

**A MAJOR ROLE FOR CALCIUM IN REGULATING INTESTINAL ION AND WATER ABSORPTION IN MARINE TELEOSTS**

J. M. Whittamore and R. W. Wilson  
E-Mail: j.m.whittamore@ex.ac.uk  
1School of Biosciences, University of Exeter, U.K

**Session:** IonO12  
**Abstract:** To overcome dehydration in their hyper-osmotic environment marine teleosts replace lost water by drinking the surrounding seawater. The intestine has an established role in osmoregulation where water absorption follows the active uptake of NaCl. Recent studies have focussed on the fate of Ca^{2+} and Mg^{2+} in imbibed seawater and the novel role of bicarbonate. Bicarbonate is secreted into the gut fluid, via a Cl^-/HCO_3^- exchanger, resulting in the precipitation of Ca^{2+} and Mg^{2+} as their respective carbonates, thus removing the osmotic influence of these ions and enhancing the gradient for water absorption. Using a modified in vitro gut sac technique we developed a method to explore intestinal ion and water transport using the flounder (*Platichthys flesus*). Bicarbonate secretion is specifically stimulated by calcium2, and exposure of the gut sac mucosa to an additional 15 mM Ca^{2+} resulted in a 3-fold increase in net water absorption (6.93±1.52 to 19.06±2.81 μl cm⁻² h⁻¹), with no change in net Na⁺ absorption (1.46±0.30 μmol cm⁻² h⁻¹), and only a 1.25-fold increase in net Cl⁻ absorption (1.49±0.28 to 2.06±0.27 μmol cm⁻² h⁻¹). The hypothesis that upregulated HCO_3^- secretion (via Cl^-/HCO_3^- exchange), precipitating excess Ca^{2+} and contributing to increased Cl^- absorption, cannot fully account for such dramatic increases in water transport. Currently, work is underway combining these results with observations from in vivo intestinal perfusions to further examine how HCO_3^- secretion responds to Ca^{2+}, assisting water absorption and overall homeostasis. Funded by the BBSRC. 2Wilson, R. W., Wilson, J. M. & Grosell, M. (2002). Biochimica et Biophysica Acta 1566: 182-193.

**RELATIONSHIPS BETWEEN EGG CHARACTERISTICS AND MATERNAL TRAITS IN TWO POPULATIONS OF WALLEYE (*Sander vitreus*)**

M.D. Wiegand¹, T.A. Johnston², K.E. Watchorn³, A.J. Ballewona³ and W.C. Leggett³  
E-Mail: m.wiegand@uwinnipeg.ca  
¹Dept. of Biol., Univ. of Winnipeg, Canada; ²Ontario Ministry of Natural Resources, Sudbury, Canada; ³Dept of Biol., Queen's Univ., Canada

**Session:** EarO1  
**Abstract:** Effects of various maternal characteristics on egg size and fatty acid profiles were examined for walleye from Lake Ontario (2002, 2003, 2004, total n=62) and Lake Winnipeg (2004, n=24). Egg size increased with maternal fork length in Lake Winnipeg walleye, but results were inconsistent among years in Lake Ontario. Eggs were extracted and the extracts washed by Folch procedure. Total egg lipids were saponified and the fatty acids were methylated with BF3. Fatty acid profiles were determined using capillary GC. Multiple regression models were constructed to explain variability in fatty acid profiles on the basis of several maternal characteristics. Sample year had a significant effect on Lake Ontario egg fatty acid profiles. Percentages of arachidonic acid (AA) and docosahexaenoic acid (DHA) increased with maternal size in Lake Ontario walleye while those of eicosapentaenoic acid (EPA) declined. In Lake Winnipeg walleye, there was no effect of maternal size on AA and DHA but EPA declined with maternal size. Increasing DHA levels and decreasing EPA:AA ratios with maternal size suggest that larger Lake Ontario females are producing a superior egg. Lake Winnipeg walleye, which are smaller and fatter, do not show this strategy. It remains to be determined whether the trends seen in the Lake Ontario walleye are a result of dietary differences among fish of different size or selective mobilization of fatty acid reserves during vitellogenesis. Funded by NSERC and the University of Winnipeg.
THE EFFECT OF DECREASED TEMPERATURE IN PRODUCTION OF GASTRIC DILATION AND AIR SACULITIS SYNDROME (GDAS) IN FARmed STEELHEAD TROUT (Oncorhynchus mykiss)

M.P.A. Wijekoon1, A. Mansour2, C.C. Parrish3, D. Whelan4 and D.W. McKay5

E-Mail: v19mpw@mun.ca

1Department Biology, Memorial University of Newfoundland, St. Johns, NL A1B3X9; 2Northwest Atlantic Fisheries Centre, Fisheries and Oceans Canada, St. John’s, NL A1C 5X1; 3Ocean Sciences Centre, Memorial University of Newfoundland, St. Johns, NL A1C 5S7; 4Department of Fisheries and Aquaculture, Government of Newfoundland and Labrador, St. John’s, NL A1B 4J6; 5Basic Medical Sciences, Faculty of Medicine, Memorial University of Newfoundland, St. John’s, NL A1B 3V6

Session: DisP1

Abstract: Steelhead trout are a popular species cultured in Bay d’Espoir, Newfoundland. Gastric dilation and air sacculitis (GDAS) is a syndrome that has caused serious performance problems and economic losses for steelhead farms. Morbid fish usually show gastric dilation, silver-siding, fat regurgitation and osmolality disturbances. Several suspected causes, including nutrition, change in water temperature and maturation have been thought. We examined the effect of a decrease in temperature as a suspected cause of GDAS development under laboratory conditions. A total of 270 fish was used where experimental groups have been exposed to a sudden drop in water temperature from 5.7°C to 0.5°C. Fish were monitored and blood from five fish per tank was sampled every 24hrs. Upon showing clinical signs and/or severe changes in blood osmolality, 5 fish/tank was lethally sampled every 24hrs. Blood osmolality, gill and intestinal ATPase activity, glucose, cortisol and other hormonal and ion biochemical changes are being analyzed and results will be presented. Funding for the study is provided by Department of Fisheries and Oceans, Aquaculture Collaborative Research and Development Program.

NMDA RECEPTOR FUNCTION IN THE BRAIN OF ANOXIA- AND AMMONIA-TOLERANT GOLDFISH

M.P. Wilkie1,2, M.E. Pamenter2, D.S.H. Shin2, M. Etches1, P.J. Walsh3,4, C.M. Veauvy3 and L.T. Buck2

E-Mail: mwilkie@wlu.ca


Session: HypO2

Abstract: Although goldfish (Carassius auratus) are among the most anoxia-tolerant vertebrates known, less is known about their ammonia tolerance. In most vertebrates, anoxia is associated with the excitotoxic death of neurons due to overstimulation of the NMDA receptor (NMDAr). However, using telencephalon slices and whole cell patch-clamping we report that excitotoxicity is prevented in goldfish by a lowering of NMDAr currents during oxygen starvation, as reported in the anoxia-tolerant western painted turtle (Chrysemys picta; Shin and Buck. 2002. Physiol. Biochem. Zool. 76:41). As ammonia is also thought to exert its pathological effects via the NMDAr, we also tested the hypotheses: (i) that goldfish are ammonia tolerant, and (ii) that goldfish NMDAr’s are resistant to excitotoxic injury by high ammonia levels. Acute toxicity tests on juvenile (2-5 g) goldfish revealed a 96h LC50 for NH3 of 290 μmol L-1, indicating that goldfish are among the most ammonia tolerant, exclusively aquatic freshwater fishes. In contrast to anoxia, exposure of brain slices to NH4COOH (5 & 10 mmol L-1) led to a 2.5-fold increase in NMDAr currents, in the absence of any change in membrane potential. However, this effect was reversible suggesting that goldfish neurons can withstand acute build-ups of ammonia and associated calcium entry via the NMDAr. We conclude that goldfish are ammonia tolerant and that ammonia stimulates the NMDAr. Funded by Wilfrid Laurier University (MPW) and an NSERC Discovery Grant (LTB).

STRATEGIES OF WATER AND ION CONSERVATION IN THE SLENDER AFRICAN LUNGFISH (Protopterus dolloi)

M.P. Wilkie1,2, T.P. Morgan2, F. Galvez2,3, R. Smith2, M. Kajimura2, Y.K. Ip4 and C.M. Wood2

E-Mail: mwilkie@wlu.ca


Session: IonO9

Abstract: Although metabolic depression and nitrogen metabolism have been studied extensively in lungfishes, less is known about how internal osmotic and ion balance is maintained in water and during aestivation. Accordingly, we exposed slender African lungfish to terrestrial conditions for 16 weeks at high relative humidity. As expected, a cocoon covered the dorso-lateral surface of the lungfish during terrestrialization. Plasma analysis revealed no disturbances to osmolality or ion (Na+, Cl-) balance during terrestrialization. As the ventral body surface was the only region in contact with the thin film of water lining the bottom of the terrestrialized animal’s containers, we tested the hypothesis that water and ion uptake occurred ventrally. Whole body water flux, measured after intraperitoneal injection of tritiated water, revealed that the lungfish had relatively low water turnover rates compared to teleosts while immersed in water. In acutely terrestrialized
lungfish the majority of water exchange was via the ventral surface, not the gills. Unidirectional ion fluxes, using $^{22}\text{Na}^+$ and $^{36}\text{Cl}^-$, indicated that lungfish had very low $\text{Na}^+$ and $\text{Cl}^-$ influx and efflux rates in water. Further, $\text{Na}^+$ and $\text{Cl}^-$ influx continued during terrestrialization despite the fact that the gills were likely inoperative. We conclude that the body surface of the slender lungfish, including the gills, has low water and ion permeability. We further propose that the ventral body surface of the lungfish is important for osmoregulation and ionoregulation in water and air. Funded by an NSERC Discovery Grant to CMW.

A GUT THAT DOES MORE THAN MAKE POOP: AMMONIA VOLATILIZATION IN THE INTESTINAL AIR BREATHING LOACH


¹Ecofisiologia, CIIMAR, Porto, Portugal; ²MBF-RSMAS, U.Miami, FL. USA; ³BCH-CityU HongKong, China; ⁴DBS, NUS, Singapore

Session: IonO13

Abstract: The Asian weatherloach (Misgurnus anguillicaudatus) is a facultative air-breathing teleost that makes use of its intestine as a respiratory organ. In addition to its obvious role in gas exchange, the gut has been proposed as the site of ammonia volatilization observed in these animals during emmersion and under ammonia loading conditions. We propose a model where ammonium is moved into the foregut mucosal boundary layer by facilitated transport (Na$^+$/H$^+$ exchanger (NHE) or the ammonium transporter RhCG) and the boundary layer is alkalinized by HCO$_3^-$ though a CI$^-$/HCO$_3^-$ exchange (PAT1 putative anion transporter 1; SLC26A6)). Under the alkaline boundary layer conditions, NH$_4^+$ is converted to NH$_3$ which is volatilized into the air passing through the gut. In the present study we measured base and ammonia flux rates (serosal to mucosal) using an Ussing chamber system with a pH stat system and found that ammonia flux was sensitive to the amiloride analogue EIPA (specific for the NHE). Using an RT-PCR based approach we found that PAT1 is highly expressed in foregut and kidney (but not gill). We also sequenced a fragment of Rhesus C glycoprotein RhCG (apical isof orm in mammals) and found it highly expressed in gill and kidney but not the gut. Thus our results indicate the presence of both the PAT1 and NHE in loach foregut. The RhCG likely functions as a NH$_3$ channel which is consistent with its presence in the gill. Funded by FCT grant POCTI/BSE/47585/2002.

DO COD LEK? EVIDENCE FROM A NEWFOUNDLAND SPAWNING GROUND

M.J.S. Windle¹ and G.A. Rose

¹Fisheries Conservation Chair, Fisheries and Marine Institute, Memorial Univ. of Newfoundland, Canada

Session: TelO14

Abstract: We test for the first time the hypothesis that Atlantic cod (Gadus morhua) spawning at sea employ a lekking mating system. Catch and acoustic telemetry data from 1998-2003 were used to test three predictions of lekking behaviour at a small-scale spawning ground (~25 km²) in Placentia Bay, Newfoundland: 1) that cod form male-skewed aggregations during spawning; 2) spawning arenas occur at consistent sites; and 3) on the putative arenas, there will be higher proportions of spawning fish. All predictions were verified, with some qualification. Catches significantly biased towards males occurred early in the spawning season (April) in 5 of 6 survey years, and were consistently located at depths < 50 m and mostly in one part of the ground. At these sites, significantly higher proportions of spawning females were caught relative to sets with equal sex ratios. Telemetric tracking of 25 spawning cod in 2002 and 2003 (12 males, 13 females) indicated that both males and females were highly mobile on the spawning ground (mean day to day movements = 0.5 km, mean within day movements = 0.7 km). Mobility during spawning suggests that the lekking arena may shift in space. Funded by NSERC and Memorial University.

IMPACT OF AROCLOR 1254 ON THE ORGANISMAL AND CELLULAR STRESS RESPONSE IN RAINBOW TROUT (Oncorhynchus mykiss)

S. Wiseman* and M.M Vijayan

E-Mail: stevewiseman@yahoo.com

Dept. of Biol. Univ. of Waterloo, Waterloo, Ontario, Canada

Session: MolO13

Abstract: Teleostean fishes elicit both an organismal and cellular stress response, representing an integral network of neuroendocrine, metabolic and molecular processes that are important in the recovery from stress. The objective of this study was to determine if short-term exposure to the environmentally realistic polychlorinated biphenyl (PCB) mixture Aroclor 1254 impacted the physiological stress response in rainbow trout. Fish were exposed to the PCB mixture for three
days and then subjected to a standardized handling disturbance. Plasma cortisol, glucose and lactate were measured as indicators of organismal stress response, while liver mRNA abundance of select genes, as well as metabolite and enzyme activities were measured as markers of molecular and metabolic adjustments. PCB exposure did not impact organismal stress response, while cellular responses, including molecular and metabolic responses, were disrupted. PCB exposure significantly elevated cytochrome P450-1A1 transcript level, but this was not modified by the handling stressor. Aryl hydrocarbon receptor mRNA abundance was significantly higher in the PCB group and this response was modified by the handling stressor. PCB exposure had no significant impact on heat shock protein 70, glucocorticoid receptor or phosphoenolpyruvate carboxykinase transcript levels. PCB exposure disrupted carbohydrate metabolism, as seen by significant changes in liver glycogen content and activities of hexokinase, glucokinase and lactate dehydrogenase. The results suggest that short-term exposure to PCB impairs intermediary metabolism in rainbow trout. To further examine the effect of Aroclor exposure, a cDNA microarray is being used to identify PCB-responsive genes in rainbow trout liver. Funding provided by NSERC Discovery.

DUAL SITE-SPECIFIC RECOMBINATION SYSTEMS FOR THE BIOLOGICAL CONTAINMENT OF GENETICALLY ENGINEERED FISH
A. C. Wong and A. L. Van Eeennaam
E-Mail: andwong@ucdavis.edu
Department of Animal Science, University of California, Davis, CA. 95616 USA

Session: GenP6
Abstract: Unless total physical containment is obtainable, the transgenic manipulation of fish will likely depend upon the development of biocontainment approaches to prevent the undesired spread of transgenic DNA into natural populations. We are using zebrafish as a teleost model to evaluate the tandem use of two recombination systems, Cre/loxP and FLPe/FRT, to excise transgenes and their regulatory elements from the germline of otherwise fertile transgenic fish. We designed two interacting genetic constructs and used them to produce distinct lines of transgenic fish. The first line contains the FLPe recombinase gene under the control of a germ cell-specific promoter, flanked by loxP sites (floxed). The other line contains a constitutive promoter driving a coding sequence of a gene of interest (GOI). FRT sites flank this gene such that when the two lines of fish are crossed the FLPe recombinase will excise the GOI in the germ cells, but not in the somatic tissue where expression of the GOI is desired. This recombination event is designed to position a germ cell specific-promoter upstream of Cre recombinase, both flanked by loxP sites. This will result in the subsequent expression of Cre in germ cells and cause the excision of both the cis floxed Cre and the trans floxed FLPe recombinase that initiated the excision of the GOI. We are currently testing the hypothesis that the F1 generation of fish resulting from a cross between these two lines will express the GOI in somatic tissue but will only transmit loxP DNA footprints to the next generation. Fluorescent reporter genes and molecular analysis of recombination events are being used to evaluate the efficacy and robustness of this approach for the biocontainment of genetically engineered fish. Funded by USDA BRAG.

HOW HARD IS THAT DIET? IMPLICATIONS FOR METAL ACCUMULATION AND TOXICITY
Chris M. Wood
E-Mail: woodcm@mcmaster.ca
Dept. Biology, McMaster Univ., Hamilton, ON, Canada; RSMAS, Univ. Miami, FL., U.S.A

Session: ImpO8
Abstract: The importance of the chemistry of the exposure water in reducing the uptake and toxicity of waterborne metals is well-established. However, the importance of the chemistry of the diet has been largely overlooked. I will synthesize recent evidence indicating that relatively small elevations (2-3 fold) in the calcium content of the diet (added as CaCO3) can offer a major protective impact against the uptake and toxicity of both waterborne and dietary metals to freshwater rainbow trout. To date, protective effects have been documented against cadmium, zinc, and lead, all of which can behave as calcium analogues. Analogous protective effects of elevated dietary sodium (added as NaCl) may occur for metals such as copper which are sodium analogues. The mechanistic nature of this protection will be explored, with an emphasis on the sites and mechanisms of action in the digestive tract and gills. (Supported by NSERC, MITE-RN, ICA, CDA, NiPERA, ILZRO, Teck-Cominco, Noranda-Falconbridge, & Inco).
RAPID REGULATION OF Na⁺ UPTAKE AND AMMONIA EXCRETION IN THE AMAZONIAN OSCAR, Astronotus ocellatus, DURING HYPOXIA
Chris M. Wood¹ ², Makiko Kajimura¹, Katherine A. Sloman³, Patrick J. Walsh⁴, Graham Scott⁴, V. M.F. Almeida-Val⁵ and A. L. Val⁵
E-Mail: woodcm@mcmaster.ca
Session: TroO3
Abstract: It is probable that at least part of the O₂ used by gill ionocytes comes directly from the water, but ionoregulatory responses to hypoxia have received little attention. The Amazonian oscar is extremely hypoxia-tolerant, and a suite of behavioural and metabolic adaptations have recently been described. The present study focused on ionoregulatory responses. Oscar exhibit a marked reduction in unidirectional Na⁺ uptake at the gills during hypoxia; unidirectional Na⁺ efflux is also reduced, so net balance is little affected. The inhibition of Na⁺ uptake occurs at a threshold of about 40 torr, slightly below the PO₂ at which MO₂ is reduced. During a step-hypoxia challenge (~10 torr), significant reduction in Na⁺ uptake is virtually immediate and precedes a reduction in gill Na⁺K⁺ATPase activity; the inhibition intensifies with time. Upon step-normoxia restoration, full recovery of Na⁺ uptake is delayed. These data suggest that dual mechanisms may be involved (e.g. immediate effects of O₂ availability, slower effects of Na⁺K⁺ATPase regulation). The latter is reflected in a reduction of Jmax (maximum Na⁺ uptake capacity) but little change in Km (affinity of the transport mechanism for Na⁺) during prolonged hypoxia. Ammonia excretion appears to be linked, at least in part, to Na⁺ uptake and exhibits similar patterns of progressive inhibition during hypoxia and delayed recovery upon return to normoxia. (NSERC Discovery Grant to CMW and PRONEX/CNPq/FAPEAM to ALV).

THE EFFECTS OF TEMPERATURE AND CARBON DIOXIDE ON THE BLOOD OXYGEN EQUILIBRIA OF SACRAMENTO PERCH (Archoplites interruptus)
C.M. Woodley and J.J. Cech, Jr
E-Mail: jjcech@ucdavis.edu
Department of Wildlife, Fish and Conservation Biology, Center for Aquatic Biology and Aquaculture, University of California- Davis, U.S.A
Session: HypP2
Abstract: The Sacramento perch (Archoplites interruptus) is the only California native sunfish that was abundant throughout its native habitat in the Sacramento–San Joaquin watershed. Extirpations of this species have been associated with introduced species and changing conditions, but the precise causes are not known. Little is known about the life history, physiological tolerances, and behavioral tendencies of Sacramento perch. Prior to many water alterations via damming, channeling, and irrigation, these fish had access to estuarine waters, and often inhabited areas that experienced seasonal flooding and droughts. Sacramento perch were thought be very tolerant of extreme environments (i.e. high temperatures). Adult Sacramento perch were used to assess the effects of temperature (12, 18 and 26 ºC) and carbon dioxide on hematological parameters related to evolutionary adaptations and thus environmental performance. Blood-oxygen affinity, blood-oxygen capacity, equilibria curves, Bohr factor, temperature and carbon dioxide sensitivity measurements were collected. Initial results indicate that the Sacramento perch exhibit a higher blood-oxygen affinity at 12 ºC compared with that at 18 ºC (strong temperature sensitivity). There was a decrease in blood-oxygen affinity and pH with the addition of 1% carbon dioxide (strong Bohr effect). These results suggest that Sacramento perch have the ability to tolerate hypoxic environments and display moderate aerobic activity, especially at 12 ºC. The data will be useful to the restoration of Sacramento perch by choosing sites more appropriate to their physiology. Funded by: the CA Bay-Delta Authority. ERP-02-P34.

THE IMPACT OF THE CHORION AND EXTERNAL OXYGEN LEVELS ON MOVEMENT AND GROWTH IN TROUT EMBRYOS
P.A. Wright, C.S. Ciuchandu, M.M. Ninness and E.D. Stevens
E-Mail: patwrigh@uoguelph.ca
Department of Integrative Biology, Univ. of Guelph, Canada
Session: EarO4
Abstract: Protracted embryonic development in salmonids involves encapsulation for several months within a proteinaceous shell or chorion that offers mechanical protection. Several studies were undertaken to determine if the chorion restricts movement, growth and oxygen uptake or if the chorion influences growth during hypoxia exposure. One week prior to hatching, the chorion was manually removed (dechorionated) from one group of embryos or left intact in a
control group of embryos. Video imaging of activity, body mass and oxygen uptake were measured. Dechorionated embryos moved 36 times more, had 16-35% greater mass and consumed more oxygen compared with intact embryos. Furthermore, when exposed to hypoxia (5 mg/L, 11 days) body mass was significantly lower relative to control embryos (10 mg/L), but the presence/absence of the chorion did not influence the results. In a recent set of experiments, we predicted that during hypoxia, embryos and larvae would decrease the number of movements to conserve energy. This was true for yolk sac larvae (43 and 54 dpf), but in embryos prior to hatch (33 dpf) movement was enhanced by low oxygen. We conclude that 1) the chorion has a significant impact on movement and growth in developing trout and 2) may influence behaviour in low oxygen environments.

TIME-COURSE CHANGES OF NA’/K’-ATPASE, MR CELLS MORPHONGE AND CORTISOL CONTENTS UPON COPPER EXPOSURE IN JUVENILE TILAPIA (Oreochromis mossambicus)

S. M. Wu* and H. R. Ding

Department of Aquatic Biosciences, National Chiayi University, Chiayi 600, Taiwan

Session: BioO4

Abstract: Juvenile tilapia was exposed to 200 ug/L or 2 mg/L Cu for several hours to days. After 200 ug/L Cu treatment, the Na’-K’-ATPase specific activity in gills significantly decreased during 48~72 h and restored to normal level after 96 h, but re-depressed during 120~144 h. The Na’-K’-ATPase immunoreactive cells were abounded in the filamental epithelium for the control and 96 h of Cu exposure, but it was evidently decrease during 108~144 h. A wavy-convex type MR cells appeared a dramatic change while it was significantly increased during 48~72 h but decreased after 96 h. The cortisol content showed a significantly increase only during 48~72 h of Cu exposure. In addition, the profiles of Na’ and K’ levels were similar that both them significantly decreased at 72 h but recovery during 96~144 h. The Cl− levels were significantly decreased after 48 h, but it was recovery soon until 144 h of Cu treatment. Accordingly, we suggested that MR cells modified with larger apical surface to boost Cl− uptake, the sodium pump in gills appeared a compensation response at 96 h, and cortisol may play an important role to regulate these changes. On the other hand, in 2 mg/L Cu treatment, All of these parameters were appeared counter results. Summary, tilapia juvenile could regulate physiological specialization to acclimation 200 ug/L Cu exposure, but it often surrender rather than to modify upon treatment with 2 mg/L Cu exposure. Funded by National Chiayi University, Taiwan.

MOLECULAR CLONING AND EXPRESSION ANALYSIS OF GHRH/PACAP AND SSN IN ATLANTIC COD (Gadus morhua)

M.Y. Xu1 and H. Volkoff1

1Biology Department, Memorial Univ. of Newfoundland, Canada

Session: AdvO13

Abstract: Atlantic cod is one of the most important commercial species in Newfoundland and Labrador. Obtaining optimal growth and feeding rates is one of the major concerns of cod aquaculture. In all vertebrates, growth hormone (GH), secreted by the pituitary gland, is a crucial factor regulating growth and appetite. GH secretion is tightly controlled by two hypothalamic neuropeptides, growth hormone releasing hormone (GHRH) and somatostatin (SSN). To better understand the structure and function of GHRH and SSN genes in Atlantic cod, we cloned full-length cDNAs encoding for these hormones from the hypothalamus by using polymerase chain reaction (PCR) and rapid amplification of cDNA ends (RACE).The GHRH and SSN cDNAs are 860bp and 610bp, respectively. Deduced amino acid sequences present similarities to sequences for other teleosts and mammals. Using reverse transcription PCR (RT-PCR), we examined the mRNA expression distribution of these genes in different brain regions of juvenile cod as well as their mRNA expression profile in embryos and larvae at different developmental stages. Both GHRH and SSN are highly expressed in the forebrain (telencephalon, optic-tectum and hypothalamus) of juvenile fish, suggesting that this brain region plays an important role in the regulation of growth in cod. During development, GHRH and SSN expression are first detected at the somite stage and the hatching gland stage, respectively. In post-hatching larvae, the expression of SSN appears to be affected by food availability. These results suggest that both GHRH and SSN genes are expressed soon after completion of brain development and that they are influenced by nutritional status during early larval stages. Funded by NSERC.
PHYSIOLOGICAL STUDY ON IMPRINTING AND HOMING RELATED OLFACTORY FUNCTIONS IN SALMON.
Y. Yamamoto1 and H. Ueda1,2
E-Mail: yuzo@fsc.hokudai.ac.jp

1Division of Environmental Science Development, Graduate School of Environmental Science, Hokkaido University;
2Laboratory of Aquatic Ecosystem Conservation, Field Science Center for Northern Biosphere, Hokkaido University,
Sapporo 060-0809, Hokkaido, Japan

Session: OlfP4
Abstract: Salmon are well known for their accurate homing guided by the imprinted olfactory memory of their home stream. According to recent our studies, amino acids dissolved in the home stream water might be home stream substance candidate for salmon. First, we carried out behavior experiments to test whether artificial amino acids mixtures have attractive effects for salmon to their upstream selectivity, and to examine the salmon olfactory nerve response using the electrophysiological techniques to the amino acid composition of home stream. Both homing chum salmon (Oncorhynchus keta) and lacustrine sockeye salmon (O. nerka) showed a significant selectivity for artificial amino acids mixtures of their home stream water. Chum salmon could identify difference in artificial stream waters with and/or without L-Glutamine in the cross-adaptation experiment, but did not show any selectivity in the behavior experiments. Secondly to test whether salmon can be imprinted by one amino acid that is absent in natural home stream water, we exposed one-year-old sockeye salmon to Proline (Pro) during parr-smolt transformation (PST). And electro-olfactogram (EOG) response to the experimental water was measured, and compared sensitivity to Pro of imprinted fish with non-imprinted control fish. From March to June, the responses of Pro imprinted fish to the experimental water were greater than that of non-imprinted fish. These results suggest that amino acids dissolved in stream waters are home stream substances for salmon, and salmon may be imprinted not only during PST but also either before or after PST in sockeye salmon.

EXPRESSION OF ANTIFREEZE PROTEIN GENES IN THE EMBRYOS OF WINTER FLOUNDER.
Heather M. Young1 and Garth L. Fletcher2
E-Mail: heatheryoung@nl.rogers.com

1Department of Biochemistry; 2Ocean Sciences Centre at Memorial University, St John’s NL. A1C 5S7, Canada

Session: NorP4
Abstract: Winter Flounder that inhabit the cold waters of coastal Newfoundland survive potentially lethal subzero water temperatures by producing antifreeze proteins. These proteins bind to the surface of ice crystals and inhibit growth. Winter flounder produce exclusively type I antifreeze proteins that are characterized by a high content of alanine and the formation of an alpha helical secondary structure. Three different type I antifreeze proteins have been documented, which are the liver, skin, and hyperactive antifreeze proteins. The liver type has a pre/prosequence and is secreted into the plasma. The skin type lacks a pre/prosequence implying that it functions intracellularly. The hyperactive antifreeze protein found in plasma is significantly more active in depressing the freezing point than the liver and skin type antifreeze proteins. The present study was designed to look for the expression of these three antifreeze protein genes in the pre-hatch embryos of winter flounder. Expression analysis was conducted by reverse transcribing the mRNA and examining the resulting cDNA for antifreeze protein gene transcripts using the polymerase chain reaction utilizing primers specifically designed for the gene of each protein type. The only antifreeze protein gene expressed in the pre-hatch embryos was for a skin type antifreeze protein. Research supported by NSERC.

POST-HATCH PERFORMANCE OF ATLANTIC SALMON ALEVINS FOLLOWING EGG INCUBATION IN NATURALLY VARIABLE HYPORHEIC ENVIRONMENTS
A.F. Youngson1, I.A. Malcolm1, P. J. Bacon1, I.E. Bacon1 and C. Soulsby2
E-Mail: denofkinnaird@btinternet.com

1 FRS Freshwater Laboratory, Faskally, Pitlochry, Perthshire PH16 5JL, UK; 2 Dept of Geography and Environment, School of Geosciences, University of Aberdeen, Aberdeen AB24 3UF, UK.

Session: EarO6
Abstract: Salmonid eggs incubate in streamed gravels prior to hatch, usually for prolonged periods of several months. During this time the embryos are passively dependent on interstitial water flow for the delivery of dissolved oxygen (DO). Embryo mortality and impaired performance are often attributed to low DO levels caused by fine sediment intrusion and reduced surface water delivery to redd gravels. However, in some locations the intrusion of chemically-reduced, deoxygenated groundwater (GW) also influences interstitial DO. The presence of GW in spawning gravels has not been widely researched and the impact of deoxygenated GW on embryo survival and performance is probably more widespread than is recognised. In some locations, GW intrusion is the dominant control on interstitial DO. The GW contribution to the hyporheic mixing zone shows complex temporal and spatial dynamics which vary at fine scales associated with the
hydrological controls. Exposure of salmon eggs to deoxygenated GW has been shown to cause mortality or to cause reductions in performance (body size at hatch) which vary according to local hyporheic dynamics. The present study documents the performance of alevins derived from eggs reared in a range of natural varying hyporheic conditions. The alevins were reared in surface stream water and monitored until full yolk-sac resorption.

**IS SQUALAMINE A NOVEL INNATE IMMUNE EFFECTOR IN THE SEA LAMPREY?**

Sang Seon Yun and Weiming Li
E-Mail: yuns@msu.edu
Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48824, USA

**Session:** DisP3

**Abstract:** Sea lamprey (*Petromyzon marinus*) are jawless fish that possess somewhat different immune systems from other jawed fish. Our attempt to identify antimicrobial factors from the fish resulted in the identification of an aminosterol, squalamine. This compound was originally isolated from the dogfish shark (*Squalus acanthias*) and has been being developed as a cancer drug. HPLC and MS/MS analysis of active antimicrobial fractions purified from acidic extraction of blood cells confirmed the chemical identifies of antimicrobial factor in the sea lamprey. Interestingly, it was found that squalamine is carried by white blood cells, more specifically by neutrophils, which are known as a primary innate immune system in animals. Further, immunostaing of squalamine revealed that squalamine is embedded in the plasma membrane of the white blood cells. Therefore it is plausible to postulate that squalamine may play an important role in executing innate immune functions by the white blood cells. However, it remains to be further investigated as to precisely what immune functions are mediated by squalamine in the sea lamprey.

**SYNTHESIZED MALE SEA LAMPREY PHEROMONE SUMMONS CONSPECIFIC FEMALES TO TRAPS**

Sang Seon Yun, Nick Johnson, and Weiming Li
E-Mail: yuns@msu.edu
Department of Fisheries and Wildlife, Michigan State University, East Lansing, MI 48824, USA

**Session:** OlfO18

**Abstract:** Sea lamprey (*Petromyzon marinus*) are jawless fish that possess somewhat different immune systems from other jawed fish. Our attempt to identify antimicrobial factors from the fish resulted in the identification of an aminosterol, squalamine. This compound was originally isolated from the dogfish shark (*Squalus acanthias*) and has been being developed as a cancer drug. HPLC and MS/MS analysis of active antimicrobial fractions purified from acidic extraction of blood cells confirmed the chemical identifies of antimicrobial factor in the sea lamprey. Interestingly, it was found that squalamine is carried by white blood cells, more specifically by neutrophils, which are known as a primary innate immune system in animals. Further, immunostaing of squalamine revealed that squalamine is embedded in the plasma membrane of the white blood cells. Therefore it is plausible to postulate that squalamine may play an important role in executing innate immune functions by the white blood cells. However, it remains to be further investigated as to precisely what immune functions are mediated by squalamine in the sea lamprey.

**EVIDENCE FOR REPRODUCTIVE PHEROMONE RELEASE BY THE ROUND GOBY (*Neogobius melanostomus*) AN INVASIVE SPECIES IN THE GREAT LAKES**

B. Zielinski, L.D. Corkum, S. Jasra; X. Ren, W.Li and A.P. Scott
E-Mail: Zielin1@uwindsor.ca
Dept. of Biological Sciences, University of Windsor, Canada

**Session:** OlfO13

**Abstract:** The round goby arrived in the Laurentian Great Lakes approximately 10 years ago, and has since established robust populations in these waters, where it feeds on young fish of species that are important to commercial and sports fisheries of this region. We have been working towards identifying round goby reproductive pheromones, and the physiology behind these responses. We have observed that reproductive females are attracted to water previously occupied by reproductive males, and that the olfactory epithelium of reproductive females responds strongly to this water. The olfactory epithelium of reproductive females compared to nonreproductive females, is more sensitive and more responsive to this conditioned water and to 5b-reduced steroids produced by the gonads of reproductive males. The presence of gonadotrophic releasing hormone (GnRH) containing fibers adjacent to spatially distinct olfactory bulb territories, suggest modulation of specific olfactory central processes during reproduction. Our ongoing studies are striving to understand pheromone chemoreception in this species. Funded by NSERC Discovery and Strategic Programs.
FOSSIL-FISH BIOGENIC CARBONATEFLUORAPATITE
E.L. Zodrow
E-Mail: Erwin_Zodrow@uccb.ca
503 Coxheath Road, Sydney, Nova Scotia, Canada

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Abstract: Pennsylvanian-age (ca. 300 Ma) Sydney Coalfield on Cape Breton, Nova Scotia, Canada has many rich fossil-fish occurrences. The latest occurrence reported here, from the roof of a coal seam, involves a “graveyard” of palaeoniscoids (bony fish, Actinopterygia). Abundant are small 2-3 mm, rhomboid scales, all with dentate trailing edges. Skull parts, thoracic bones, and shoulder girdles are less abundant. Only a few near-complete 60-70 mm long specimens are collected. These fossils, co-occurring with phosphatic coprolites [fluorapatite: Ca(PO4)3F], are pitch black. When exposed the fossils show turquoise-bluish color (oxidation). X-ray diffractograms of scales identify the hexagonal unit cell which is representative of the end-member of the isomorphic apatite series carbonatefluorapatite: Ca10(PO4)5(CO3)F1.5(OH)O (CFA). The morphology of the scales fits the tabular crystal habit. Semi-quantitative electron microprobe analyses of black and turquoise-bluish colored scales show no significant difference of P2O5 contents (37%). What is interesting is that this deposit is probably of marine origin, and if confirmed, a first for the Carboniferous of Eastern Canada. The CFA mineralization is regarded as primary bone representation. The significance of this find, however, rests in part on palaeogenetical testing potentials for bits of strands of DNA. This shot in the dark is suggested by successful experimental demonstration of DNA affinity with apatite in Japan, where the DNA is absorbed parallel to the apatitic c-crystallographic axis. Funded by NSERC. Acknowledged are M. Zentilli, P. Stoffyn, Dalhousie Univ., S. Turner, Queensland, and R. Carroll McGill Univ.