

A11 - Conservation Physiology

A11.1

Spatially explicit conservation physiology

Michael Kearney (University of Melbourne)

Ecophysiological understanding can powerfully inform conservation efforts in the context of environmental change. This is especially so if the physiological mechanisms can be linked directly to environmental gradients through space and time. I will discuss recent developments my colleagues and I have made in mechanistically modelling organism-environment interactions in a spatially explicit context, including the role of evolutionary change. I will illustrate how these approaches can be applied to modern conservation challenges.

Email Address for correspondence: mrke@unimelb.edu.au

09:00 Friday 2nd July 2010

A11.2

Is active range expansion of invasive species facilitated by physiological plasticity?

Frank Seebacher (University of Sydney), Craig E Franklin (University of Queensland)

Range expansions expose populations and individuals to different environmental conditions. Range expansions of invasive species often occur at rates that are much faster than evolutionary rates so that genetic adaptation may be of limited importance in matching phenotypes to novel environmental conditions. However, phenotypes may change reversibly and repeatedly during the lifetime of an organism thereby conferring an effective mechanism of compensation for environmental changes. Exercise performance is particularly important for animals that move actively to colonise novel habitats, such as the cane toad in Australia. Hence, we tested the hypothesis that oxygen transport during rest and exercise, and metabolism are plastic so that cane toads can function over a broad thermal range. We show that given sufficient time to acclimate, resting oxygen use, reflecting metabolic maintenance costs, remained constant across a broad temperature range from 20° C-30° C. Similarly, arterial blood oxygen content during exercise remained constant across temperatures, as did venous oxygen content

during rest and exercise. However, warm acclimated animals had significantly greater cardiac scope at their acclimation temperature (30° C). Hence, warmer temperatures are advantageous and there is no indication that high temperatures limit oxygen delivery, although toads have the capacity to acclimate performance to cooler temperatures. Global warming will benefit range expansion of toads, and possibly that of other anurans.

Email Address for correspondence: frank.seebacher@sydney.edu.au

09:25 Friday 2nd July 2010

A11.3

Thermal ecology of Atlantic cod in the north-east Atlantic

Julian D Metcalfe (Centre for Environment Fisheries Aquaculture Science), David A Righton (Centre for Environment Fisheries Aquaculture Science), Ken H Andersen (Danish Institute for Fisheries Research Copenhagen DENMARK), Francis Neat (Fisheries Research Services Marine Laboratory Aberdeen UK), Vilhjalmur Thorsteinsson (Marine Research Institute Reykjavik ICELAND), Petur Steingrund (Faeroe Fisheries Laboratory FAROE ISLANDS), Henrik Svedang (Swedish Board of Fisheries SWEDEN), Kathrine Michalsen (Institute of Marine Research Bergen NORWAY), Hans-Harald Hinrichsen (Leibniz Institute of Marine Sciences Kiel GERMANY), Victoria Bendall (Centre for Environment Fisheries Aquaculture Science), Stefan Neuenfeldt (Danish Institute for Fisheries Research Copenhagen DENMARK), Peter Wright (Fisheries Research Services Marine Laboratory Aberdeen UK), Patrik Jonsson (Swedish Board of Fisheries SWEDEN), Geir Huse (Institute of Marine Research Bergen NORWAY), Jeroen Van der Kooij (Centre for Environment Fisheries Aquaculture Science), Henrik Mosegaard (Danish Institute for Fisheries Research Copenhagen DENMARK), Karin Hüsey (Danish Institute for Fisheries Research Copenhagen DENMARK)

Recent studies in the marine environment have suggested that the limited phenotypic plasticity of cold-adapted marine fish like Atlantic cod will cause species distributions to compress or shift poleward in response to rising sea temperatures. Some cod stocks are predicted to collapse due to future changes

in marine climate but, since relatively little information is available on the thermal tolerance of wild cod, this conjecture remains speculative. We have analysed over 16 million temperature recordings from electronic tags attached to 384 individual adult Atlantic cod (*Gadus morhua* L.) at liberty throughout the NE Atlantic. We show that cod is an adaptable and tolerant species, capable of surviving and growing in a wide range of temperate marine climates. Total thermal niche ranged from -1.5°C in northern waters to 19°C at the southern limit of distribution; this range was narrower (1°C to 8°C) during the spawning season. Overall, growth increased with temperature and varied significantly between regions. This study is the first time that the long-term temperature experience of individual cod across its latitudinal range has been quantified and related to activity levels and individual growth rates. The results suggest that although adult cod have the behavioural and physiological plasticity to tolerate future changes in marine climate, recovery is likely to be constrained by thermally suitable habitat during the spawning season.

Email Address for correspondence: julian.metcalfe@cefas.co.uk
09:40 Friday 2nd July 2010

A11.4

Damsels in distress - stress and population regulation

Mark I McCormick (James Cook University), Monica Gagliano (University of Western Australia)

Differences in tolerance or adaptability to stress among individuals often arise from a response to the stressful conditions experienced by their parents. On high diversity coral reefs, fishes are exposed daily to stressful variations in habitat quality and density dependent interactions that will influence the quality of parental investment in future generations. Ocean warming and acidification are predicted to enhance background stress in breeding populations through reductions in habitat quality and enhanced behavioural interactions as fish compete for available resources. Our research suggests that climate induced changes will directly impact population regulation through parental stress. Our past field experiments found that density dependent stressful events on breeding female damselfish directly reduce the size of larvae produced. A laboratory experiment that simulated maternal stress through alterations in developmental cortisol found that naturally high levels of cortisol in eggs produced larvae with high levels of asymmetry. An 18mo series of field collections found a strongly negative relationship between levels of asymmetry in larvae at the end of their pelagic phase and levels of replenishment to a coral reef ($r^2 = 0.6$). Evidence suggests that anything that leads to a high level of stress in a breeding population of these fishes is likely to have

a detrimental impact on population replenishment.

Email Address for correspondence: mark.mccormick@jcu.edu.au
09:55 Friday 2nd July 2010

A11.5

Using aerobic scope to inform Pacific salmon conservation in British Columbia, Canada

Anthony P Farrell (University of British Columbia)

Over the past century, not only have great minds established a conceptual framework for explaining why the oxygen delivery capability of a fish should be tailored to its environmental niche, but they also provided the tools to make the requisite measurements. We have been using this conceptual framework and these tools to test the hypothesis that the intra-specific variability for aerobic scope among populations of sockeye salmon represents an adaptation to their environmental experiences. The importance of such a discovery is that, within large-scale ecosystems such as the Fraser River watershed where salmon populations are reproductively isolated, conservation efforts may have to considered differences at the level of populations and not just species. Data will be presented from a large team project on aerobic scope of large migratory salmon. These data will provide clear evidence for intra-specific variability not only in aerobic performance, but also in temperature tolerances. This variability can be shown to match the environmental challenges faced when they make their single spawning migration, which is critical for lifetime fitness. In this regard, temperature dependence of aerobic scope has crucial importance, especially given that the ecosystem has already shown a 1°C warming and that further warming is predicted. Examples will be presented of how these data are being used to model future warming scenarios to examine the consequences to salmon migrations and of how additional mechanistic studies might further inform conservation efforts. Supported by NSERC Canada.

Email Address for correspondence: farrellt@interchange.ubc.ca
10:30 Friday 2nd July 2010

A11.6

Conservation physiology case studies on the consequences of predator and fisheries encounters on adult migrating Pacific salmon using biologging, biotelemetry, and blood physiology indices

Michael R Donaldson (University of British Columbia), Timothy D Clark (University of British Columbia), Gra-

ham Raby (Carleton University), Scott G Hinch (University of British Columbia), Steven J Cooke (Carleton University), David A Patterson (Fisheries and Oceans Canada), Marika K Gale (University of British Columbia), Anthony P Farrell (University of British Columbia)

During their spawning migrations, adult pacific salmon We examined the response of free-swimming adult coho salmon (*O. kisutch*) to simulated predator and fisheries encounters by monitoring heart rate with implanted data loggers. We conducted experiments designed to simulate encounters with fisheries gear or predators, using a high intensity exercise stress treatment and either a short or long duration low intensity stressor. Each encounter caused a physiological response of a similar magnitude: massive tachycardia (~doubling of heart rate) and significant increases in plasma stress indices following the encounter. Recovery from the encounter was prolonged and dependent on the encounter intensity. Heart rate recovery took 7.6 h and 11.5 h for the short and long corraling treatments, respectively, and up to 16 h for the exhaustive exercise treatment. Given the duration of cardiorespiratory perturbations and the need for aerobic scope to swim, there is potential for such encounters to impair migration behaviour and lead to latent mortality. To test this, we used radio telemetry to track coho salmon that were released as by catch from a freshwater fishery. With growing conservation concerns over Pacific salmon, these case studies provide important insight into how adult salmon respond to acute, ecologically relevant stressors during the freshwater phase of their migrations.

Email Address for correspondence: mdonald@inter-change.ubc.ca
11:05 Friday 2nd July 2010

A11.7

Tailoring physiology to the environment: the story of migrating sockeye salmon populations

Erika J Eliason (University of British Columbia), Timothy D Clark (University of British Columbia), Scott Hinch (University of British Columbia), Anthony P Farrell (University of British Columbia)

It has long been established that temperature optima exist for growth and performance among different animal species. We hypothesized that cardiorespiratory performance would match the different environmental challenges experienced by Fraser River sockeye salmon (*Oncorhynchus nerka*) during their upriver spawning migration. To test this hypothesis, we measured maximum oxygen consumption, cardiac output and blood oxygen content in two eurythermal and two stenothermal populations of sockeye salmon across a range of temperatures. All populations maintained swimming and cardiorespiratory performance across the entire range of temperatures typically encountered

during their upriver migration, with Chilko sockeye emerging as the high temperature champions. We also sought to determine the physiological mechanism of cardiorespiratory collapse at elevated temperatures. At critically high temperatures, scope for heart rate approached zero, suggesting a limitation to prolonged exercise performance at the level of the heart. From this finding, we looked to the heart to assess the basis of population-specific differences in performance. In general, more athletic upriver populations traveling through treacherous Hell's Gate have significantly larger ventricles and more compact myocardium compared to coastal populations that travel shorter distances with less river elevation. Furthermore, Chilko sockeye have a significantly higher maximum cardiac output and an enhanced ability to use adrenaline, particularly at high temperature, as they have a significantly higher density of ventricular β -adrenoceptors compared to more stenothermal populations. These findings suggest that temperature optima, cardiorespiratory performance and cardiac traits are tailored to the river environment in sockeye salmon populations. Supported by NSERC Canada and BC Pacific Salmon Forum.

Email Address for correspondence: eeliason@inter-change.ubc.ca
10:50 Friday 2nd July 2010

A11.8

Physiological impacts of sea lice on juvenile pink salmon: Implications for aquaculture and salmon management in the Broughton Archipelago, British Columbia.

Colin J Brauner (Department of Zoology University of British Columbia), Michael Sackville (Department of Zoology University of British Columbia), Laura Nendick (Department of Zoology University of British Columbia), Steve Tang (Department of Fisheries and Oceans), Manuela Gardner (Department of Fisheries and Oceans), Amelia Grant (Department of Fisheries and Oceans), Anthony P Farrell (Faculty of Land and Food Systems University of British Columbia)

Sea lice, *Lepeophtheirus salmonis*, are endemic to BC's marine waters but have been implicated in reducing local pink salmon populations through impacts on juveniles as they migrate past salmon farms which are known to incubate sea lice. Little is known about the physiological impact of sea lice on these extremely small (0.2 g) salmon but we hypothesize that negative impacts on fish performance are ionoregulatory in origin due to the physically disruptive nature of louse attachment to the fish's skin in a hyperosmotic environment. By measuring drinking rate, gill Na^+ , K^+ -ATPase (NKA) activity and whole-body ion concentrations, we characterized ionoregulatory development in seawater (SW) and then quantified physiological impacts of louse infection on both

ionoregulatory homeostasis and swimming performance. Fish maintained water balance in SW, but whole-body ion levels remained elevated until gill NKA peaked two months later when fish had grown from 0.2 to 0.5-1.0 g. Additionally, louse infection at levels found in the wild significantly impaired both ionic regulation and swimming performance, but not beyond this size threshold. Impacts were also dependent on the developmental stage of the louse. These findings, support our hypothesis that infection impacts on performance are ionoregulatory in origin, but also indicate that juvenile pink salmon may be better prepared to deal with sea lice parasitism once ionoregulatory capacity is fully developed as they reach 0.5-1 g. These data are currently being used by environmental managers in the Broughton Archipelago to minimize the impact of aquaculture on wild pink salmon populations. (BC Pacific Salmon Forum/NSERC).

Email Address for correspondence: brauner@zoology.ubc.ca
11:20 Friday 2nd July 2010

A11.9

Cardiac scope in Arctic fish: using Greenland as a field laboratory to study the effects of ongoing climate change.

Michael Axelsson (Dept. Zoology Zoophysiology University of Gothenburg Gothenburg Sweden), Craig Cranklin (School of Integrative Biology The University of Queensland Brisbane Queensland 4072 Australia), Tony Farrell (Department of Zoology and Faculty of Agricultural Sciences 2357 Main Mall University of British C), Erik Sandblom (Dept. Zoology Zoophysiology University of Gothenburg Gothenburg Sweden), Kerstin Wiklander (Dept. Mathematical Sciences University of Gothenburg Gothenburg Sweden)

The ongoing change in climate coincides with a number of other antropogenically driven changes in terrestrial and aquatic ecosystems. A recent overview in Nature, pointed out declining biodiversity as one of the main problem areas and that the climate change was at least in part responsible. While reduced aerobic scope at elevated temperature is often suggested to be one of the main factors explaining reduced performance in ectothermic animals, long-term data has so far largely been lacking. Arctic fish may be particularly instrumental in long-term studies of aerobic scope as Arctic regions show a more rapid increase in surface water temperature compared to the global average. We studied cardiac scope in the shorthorn sculpin, *Myoxocephalus scorpius* caught off Qeqertarsuaq, Greenland in August 2002 when the temperature was 6°C, and in August 2009 when the temperature was 9°C. In 2002 routine cardiac output was 16 ml min⁻¹ kg⁻¹ with a maximum value of 35 ml min⁻¹ kg⁻¹ giving a factorial scope of 2.4. In 2009 routine cardiac output was 43 ml min⁻¹ kg⁻¹ with a maximum

of 69 ml min⁻¹ kg⁻¹, which meant that factorial scope was reduced to 1.6. At the same time absolute cardiac scope was higher in 2009. While the reduction in factorial scope indicates that the higher temperature was limiting performance, the increase in absolute scope suggests that the animals still had substantial metabolic reserves. Regardless, if routine cardiac output reflects the metabolic rate the cost of living was clearly much higher in 2009.

Email Address for correspondence: m.axelsson@zoology.gu.se
11:35 Friday 2nd July 2010

A11.10

Feeding in a warmer climate - effects of temperature on gastrointestinal activity in Arctic sculpins

Catharina Olsson (Department of Zoology University of Gothenburg), Albin Gräns (Department of Zoology University of Gothenburg), Henrik Seth (Department of Zoology University of Gothenburg), Erik Sandblom (Department of Zoology University of Gothenburg), Kerstin Wiklander (Department of Mathematical Sciences University of Gothenburg), Michael Axelsson (Department of Zoology University of Gothenburg)

The impact of temperature on gastrointestinal performance was examined in vitro and in vivo in three species of sculpin. Arctic sculpin (*Myoxocephalus scorpioides*) and staghorn sculpin (*Gymnocanthus tricuspis*) are both Arctic species while shorthorn sculpin (*Myoxocephalus scorpius*) is more of a generalist and can be found from southern Europe well into Arctic waters. The experiments were performed at Arctic station, Qeqertarsuaq, Greenland in August 2009 as part of a multidisciplinary expedition with the overall aim of studying physiological effects of the ongoing climate change. The sea water temperature was around 9°C, which is several degrees higher than average August temperature. Isolated smooth muscle strip preparations from the stomach of Arctic, staghorn and shorthorn sculpin were subjected to the cholinergic agonist carbachol (10⁻⁸ - 10⁻⁴ M) at three temperatures (4, 9 and 14°C). All preparations showed concentration-dependent contractions in response to carbachol, with a larger increase in mean force at 4 and 9°C than 14°C. However, the activity patterns usually varied with the temperature with higher contraction frequencies occurring at higher temperatures. Similarly, in vivo recordings of spontaneous electrical activity in stomach smooth muscle in Arctic and shorthorn sculpin showed temperature dependency with the highest activity being observed at 14°C. The fractional distribution of blood flow to the gastrointestinal tract (% of cardiac output) was also highest at 14°C in both species. The results indicate that all three species of sculpin are affected by increasing water temperature, and hence their gastrointestinal performance may be

compromised by the current global climate change.

Email Address for correspondence: c.olsson@zool.gu.se

11:50 Friday 2nd July 2010

A11.11

Changes in metabolic rate and activity explain UV-B/predation synergism in amphibians

Lesley A Alton (The University of Queensland), Craig R White (The University of Queensland), Robbie S Wilson (The University of Queensland), Craig E Franklin (The University of Queensland)

The sixth mass extinction event is arguably upon us and amphibians, being the most threatened of all vertebrate taxa, are at the forefront of this biodiversity crisis. One of the many potential drivers of amphibian declines is increased UV-B radiation with research indicating that it may lead to some species' declines through its lethal and sublethal effects on embryos and tadpoles. Little consideration has been given, however, to the effect of UV-B on metabolism and how metabolism may change in response to exposure to multiple stressors. We examined the independent and interactive effects of UV-B and predatory chemical cues (PCC) on the metabolic rate (MR), survival, and morphology of *Limnodynastes peronii* tadpoles. UV-B exposure caused tadpoles to have reduced survival and increased tissue MR, but decreased whole-animal MR, possibly because of decreased activity levels. PCC exposure had no significant effect on survival, tissue or whole-animal MR, but caused tadpoles to develop a deeper tail, which increases their survival in the presence of predators (i.e. predator-induced phenotypic plasticity). Tadpoles exposed simultaneously to both stressors had an elevated whole-animal MR, despite further reducing their activity levels, compared to those exposed to UV-B alone. This increase in whole-animal MR may explain the compounding negative effect of UV-B and PCC on survival, and also the lack of development of a deeper tail in these tadpoles. Thus UV-B and PCC, via their interactive effects on metabolism, may be driving amphibian declines by causing direct mortality of tadpoles, or by increasing tadpole susceptibility to predation.

Email address for correspondence: l.alton@uq.edu.au
12:05 Friday 2nd July 2010

A11.12

Elevated temperatures during dormancy in burrowing frogs: implications for muscle wasting?

Karen M Young (The University of Queensland), Craig

E Franklin (The University of Queensland), Craig R White (The University of Queensland), Rebecca L Cramp (The University of Queensland)

Substantial metabolic depression during dormancy is critical for the prolongation of endogenous energy stores during periods of food scarcity. Metabolic depression is also proposed as a major factor in skeletal muscle preservation during the extended muscular disuse that accompanies dormancy. Thus, any factor that diminishes the magnitude of metabolic depression achieved during dormancy may have serious fitness costs for the organism. To investigate the role of metabolic depression and rate of oxygen consumption in the inhibition of muscle disuse atrophy we manipulated metabolic rate by inducing *Cyclorana alboguttata* to aestivate at 20, 24 and 30° C. Whole-animal VO_2 (rate of O_2 consumption) was measured prior to, and during, aestivation over ten weeks. The VO_2 of dormant frogs at 30° C remained significantly higher than 20 and 24° C VO_2 throughout the aestivation period. In addition, the magnitude of metabolic depression was significantly limited at 30° C. *In vitro* tissue metabolic rates of five skeletal muscles (non-jumping and jumping) were measured at 24 and 30° C for control and aestivating frogs. The VO_2 of the gastrocnemius muscle from control (active) frogs was equivalent at 24 and 30° C. However, in aestivating frogs the VO_2 of the gastrocnemius muscle was significantly higher at 30° C than at 24° C. This was reflected in the different magnitude of metabolic depression at 24° C and 30° C, being 73% and 30% respectively. Results are discussed in conjunction with a histochemical assessment of muscle morphology to elucidate links between VO_2 , magnitude of metabolic depression and extent of muscle disuse atrophy during aestivation at elevated temperatures.

Email Address for correspondence: k.young1@uq.edu.au

12:20 Friday 2nd July 2010

A11.13

Stress Physiology as an Important Tool in Conservation

L Michael Romero (Tufts University)

There has been a recent increase in the number of studies that focus on physiology in an effort to help preserve species – the rising field of Conservation Physiology. Physiological systems that have been explored include energy and nutritional physiology, reproduction, immune function and disease, physiological responses to pollutants, and physiological processes underlying movement. There is considerable overlap between these systems and, at least in vertebrates, the physiological responses to stress are often a common feature. Two factors that are of great

concern to conservation biologists are habitat loss and human disturbance. Both of these factors are potentially stressful stimuli; often they are stressful but sometimes they aren't. Distinguishing between whether they are or are not stressful is of prime importance. Monitoring the presence, dynamics, and strength of the physiological responses to stress in potentially affected individuals can help determine whether habitat loss and/or human disturbance is adversely affecting those individuals. In other words, stress physiology can tell us how well those individuals are coping with these stimuli. How those individuals respond to stress thus becomes an index for how problematic is the habitat loss or human disturbance for that population and species. The ultimate goal is to use physiological responses to predict the health of individuals and populations that are at risk of extinction.

Email Address for correspondence: Michael.romero@tufts.edu
14:00 Friday 2nd July 2010

A11.14

Effects of temperature and substrate on the development of the stress response in larval Lake Sturgeon, *Acipenser fulvescens*

Sadaf Zubair (University of Manitoba), W. Gary Anderson (University of Manitoba), Stephan J Peake (University of New Brunswick)

Appropriate development of the stress axis in early life is critical for future success of an organism. This success becomes even more relevant for endangered or threatened species where rearing and re-introduction of juveniles is part of ongoing management efforts to sustain existing stocks. Lake sturgeon, *Acipenser fulvescens*, are considered threatened or endangered in many parts of North America. In the present study we have examined the influence of substrate and temperature on the development of the stress axis in *A. fulvescens*. Fertilised eggs were allowed to develop and hatch at 12°C over one of two substrate types, slate (hatchery) or gravel (natural) and over gravel at 9, 12 or 15°C. Resting concentrations of cortisol were highest in the slate treatment (17.59± 3.49 ng.g⁻¹) as compared to gravel (5.67±0.41 ng.g⁻¹). When stressed, the magnitude of response was equivalent for substrates (73.05±8.11 ng.g⁻¹ and 62.65±6.98 ng.g⁻¹ for slate and gravel, respectively). However, the duration was longer in the gravel treatment. Larvae reared at 9 and 15°C had elevated resting whole-body cortisol concentrations as compared to fish reared at 12°C (38.6±3.1 ng.ml⁻¹ at 9°C, 5.67±0.41ng.ml⁻¹ at 12°C, and 25.38 ±2.84ng.ml⁻¹ at 15°C). When stressed, larvae reared at 9°C were incapable of increasing cortisol concentrations. Larvae reared at 12 and 15°C did not differ in the magnitude of response when stressed (62.65±6.98 ng.g⁻¹ and 69.05±6.48 ng.g⁻¹, respectively). However, the duration was longer for

the 12°C treatment. Results will be discussed in the context of rearing programs for re-stocking purposes.

Email Address for correspondence: andersow@cc.umanitoba.ca
14:25 Friday 2nd July 2010

A11.15

Serum Corticosteroid-binding Globulin in Bears: A Potential Biomarker of Health Status for Wildlife Monitoring

Brian A Chow (Department of Biology University of Waterloo), Jason Hamilton (Department of Biology University of Waterloo), Derek Alsop (Department of Biology University of Waterloo), Marc Cattet (Canadian Cooperative Wildlife Health Centre University of Saskatchewan), Gordon Stenhouse (Foothills Research Institute), Martyn E Obbard (Wildlife Research and Development Section Ontario Ministry of Natural Resources), Mathilakath M Vijayan (Department of Biology University of Waterloo)

Developing markers to detect stress status of wildlife is an important aspect of health monitoring for wildlife conservation. Serum corticosteroid levels are routinely used as markers of stress in animals. However, a major disadvantage of using this steroid indicator for stress detection in wildlife is that the acute stress associated with capture may override the pre-capture level of this hormone. Consequently, serum corticosteroid levels are not a reliable marker of chronic stress in wildlife. Our objective was to examine whether corticosteroid-binding globulin (CBG), a 55-kDa glycoprotein that is the primary transport protein for this steroid in peripheral circulation, is a better marker of chronic stress in bears. We cloned and sequenced a full-length CBG cDNA from grizzly bear (*Ursus arctos*) testis. A peptide sequence designed from the deduced CBG amino acid sequence was used to generate a rabbit polyclonal antibody (anti-gbCBG) that immunodetected CBG in the serum of grizzly, polar (*U. maritimus*), and black bears (*U. americanus*). Capture by physical immobilization, a highly stressful method, resulted in elevated plasma cortisol levels relative to remote injection of anesthetic in grizzly bears, but serum CBG expression remained unaffected. Serum CBG expression was impacted by the metabolic status of polar bears; fasting bears had significantly higher serum CBG expression compared to feeding bears. Altogether, serum CBG expression has the potential to be used as an indicator of the chronic health status of these animals, especially because the expression of this protein is not modulated by the stress of capture and restraint in bears.

Email Address for correspondence: bachow@uwaterloo.ca
14:40 Friday 2nd July 2010

A11.16**Fitness-linked consequences of stress in teleost fish: basic and applied perspectives**

Constance M O'Connor (Carleton University), Cody J Dey (University of Ottawa), Caleb T Hasler (Carleton University), Cory D Suski (University of Illinois), David P Philipp (University of Illinois), Robert Arlinghaus (Humboldt University), Glen Van Der Kraak (University of Guelph), Kathleen M Gilmour (University of Ottawa), Steven J Cooke (Carleton University)

The consequences of stress can be direct (short- or long-term) or indirect, including carry-over effects. Carry-over effects occur when consequences of stress are spatially or temporally removed from the stressor. In order to accurately predict the impacts of stress on wild populations, the full range of consequences on individuals must first be identified. We explored the short-term, long-term, and carry-over effects of stress in a series of studies on wild largemouth (*Micropterus salmoides*) and smallmouth bass (*M. dolomieu*) at liberty. As our stress treatment, we used direct hormone manipulations to elevate circulating cortisol, the primary glucocorticoid in teleost fish. We found that stress treatment caused a short-term increase in metabolic rate and mobilization of energetic stores, with a decrease in immune function. When this stress treatment occurred during the reproductive period, fish tended to maintain behaviours necessary for parental care, but were ultimately unable to sustain the effort and exhibited increased nest abandonment. Stress treatment resulted in reduced long-term growth, with implications for future fecundity and survival. Wild fish also displayed carry-over effects; after apparent recovery following stress treatment (no differences in initial survival or activity) fish in the stress treatment group suffered earlier mortality than non-stressed fish during a subsequent natural winterkill event. This suite of effects demonstrates that stress in wild individuals can have lasting fitness-linked consequences that can ultimately affect populations. We discuss findings in the context on anthropogenic sources of stress, and the utility of our approach to the field of "conservation physiology". Email

Address for correspondence: coconno4@connect.carleton.ca
14:55 Friday 2nd July 2010

A11.17**The implications of fishing and climate change for gut carbonate production by marine teleost fish and the global inorganic carbon cycle**

Rod W Wilson (University of Exeter UK), Simon Jennings (CEFAS Lowestoft Univ. East Anglia UK), Mi-

chael Salter (Manchester Metropolitan University UK), Chris T Perry (Manchester Metropolitan University UK), Jon M Whittamore (University of Exeter UK), Chris S Cobb (University of Exeter UK)

The majority of oceanic production of CaCO_3 is conventionally attributed to marine plankton. However, marine teleosts also produce precipitated carbonate crystals within their guts and excrete these at remarkably high rates. This is a by-product of drinking calcium-rich seawater and substantial intestinal bicarbonate secretion, and plays important physiological roles in osmotic and ionic regulation, acid-base balance and respiratory gas exchange. When combined with estimates of global fish biomass, conservative measurements of individual CaCO_3 excretion rates suggest fish contribute 3-15% of total oceanic production, and potentially up to 45%⁽¹⁾. The unusually high magnesium content of fish carbonates is predicted to speed up their dissolution with depth, helping to replenish the surface ocean alkalinity and enhance absorption of atmospheric CO_2 . Total carbonate production is linked to fish size (doubling for every 10-fold drop in body mass) and abundance. Fishing selectively removes larger fish so total carbonate production falls less than expected based on population biomass. However, importantly for conservation issues, modelling suggests that fish population and their carbonate production fall rapidly at lower rates of fishing than those used as management targets for sustainable yield⁽²⁾. Control of ocean chemistry may be important to consider when assessing fishing impacts. Climate change complicates future predictions further as temperature enhances carbonate production ($Q_{10} \sim 2.5$) more than can be explained by metabolism alone ($Q_{10} \sim 1.8$), and increasing CO_2 also enhances CaCO_3 excretion (e.g. doubling at 4,500 ppm).

- 1) Wilson, RW *et al.* (2009). *Science* 323:359-362.
- 2) Jennings, S & Wilson, RW (2009). *J. Appl. Ecol.* 46:976-982.

Email Address for correspondence: r.w.wilson@ex.ac.uk
15:40 Friday 2nd July 2010

A11.18**Physiological performance in the small rodent *Myodes glareolus* from isolated and heavily polluted populations**

Edyta T Sadowska (Institute of Environmental Sciences Jagiellonian University), Magdalena Mikowska (Institute of Environmental Sciences Jagiellonian University), Renata Swiergosz-Kowalewska (Institute of Environmental Sciences Jagiellonian University), Pawel Koteja (Institute of Environmental Sciences Jagiellonian University)

Habitat fragmentation and pollution are considered

the most serious threats to the survival of animals. It is widely known that small isolated populations are especially vulnerable to extinction. One of the reasons is reduction of genetic variation, which can lead to a decreased physiological performance of individuals. Reduced physiological performance of individuals can also result from toxic effects of various pollutants. The risks of extinction are of special interest in the case of rare and endangered species, but can be effectively studied on model organisms. We tested a hypothesis that physiological performance is lower in bank voles from both the island and the heavily polluted population as compared to individuals from open populations inhabiting unpolluted areas in Poland. Nine populations were chosen: three island populations (on Dobskie Lake, Świecajty Lake and Solina Lake), three populations from open clean sites (forests near Mikołajki, Teleśnica Oszarowa and Niepołomice), and three populations from contaminated sites (two near working zinc smelters: Miasteczko Śląskie, Olkusz; one near a recently closed non-iron metals smelter: Katowice-Szopienice). As an index of individual's performance we measured the maximum aerobic metabolic rate during forced running on a treadmill. Body mass (pooled mean \pm SD; 21.6 \pm 4.3 g) and metabolic rate (4.8 \pm 0.7 mlO₂/h) did not differ between populations from contaminated and clean sites, between populations from isolated islands on lakes and populations from open areas, or between populations from the northern and southern Poland. Thus, physiological performance in the studied bank vole populations was not affected by the heavy metal pollution or fragmentation.

Email Address for correspondence: edyta.sadowska@uj.edu.pl
15:55 Friday 2nd July 2010

A11.19

Phenotypic plasticity of thermal tolerance in temperate and tropical *Drosophila*

Johannes Overgaard (Aarhus University), Torsten N Kristensen (Aarhus University), Katherine A Mitchell (University of Melbourne), Michael R Kearney (University of Melbourne), Ary A Hoffmann (University of Melbourne)

Although many species are believed to be threatened by global warming it remains difficult to predict how environmental changes will affect population distributions. This is partly due to the difficulty in identifying the climatic and physiological parameters that restrict population range, but also because populations respond to climatic changes via acclimation and adaptation. The present study seeks to identify parameters of thermal resistance that predicts species distributions and investigate how these thermal limits are affected by acclimation. Using a comparative approach,

we measured thermal tolerance in 5 tropical and 5 temperate species of *Drosophila* and found that thermal knock-down temperature was predictive for current species distributions. Thus, using climatic data along the Australian east coast we could model current species distributions to be restricted by the thermal limits for sustained activity. These thermal limits predicted distributions much better than fitness curves based on thermal limits for larval development. The limits for sustained activity were, however, only predictive if thermal tolerance was assessed in acclimated animals and acclimation should, therefore, be considered if true thermal limitations are to be identified. By comparing tropical and temperate species and including phylogenetic corrections we investigated whether the scope for thermal acclimation was constrained in tropical species compared to temperate species but, contrary to our expectations, we found no general differences. All species had a large potential for cold acclimation but only limited degree of heat acclimation, suggesting that heat acclimation is unlikely to buffer the impact of global warming in any significant way.

Email Address for correspondence: biojo@biology.au.dk
16:10 Friday 2nd July 2010

A11.20

Thermal physiological plasticity among South African ungulates

Anil K Shrestha (Resource Ecology Group Wageningen University The Netherlands), S E Van Wieren (Resource Ecology Group Wageningen University The Netherlands), S De Bie (Resource Ecology Group Wageningen University The Netherlands), H.H.T Prins (Resource Ecology Group Wageningen University The Netherlands), A Fuller (School of Physiology BFRG University of Witwatersrand South Africa), R Hetem (School of Physiology BFRG University of Witwatersrand South Africa), L Mayer (School of Physiology BFRG University of Witwatersrand South Africa)

South Africa has been experiencing irregular rainfall, frequent droughts and increased temperature over the last few decades. Understanding how ungulates species cope with changing climate is therefore crucial for their conservation and management. Adaptive phenotypic plasticity: thermal physiological tolerance (body temperature plasticity) and thermoregulatory behaviour (behavioural plasticity) are only available options for these ungulates to cope with changing climate. An explicit understanding of such thermal sensitivity and thermal limits of ungulates over space and time will be helpful to understand their adaptation to present environment and may be helping to predict effect of climate change on animal population distribution in future. Therefore, we investigate body temperature plasticity among 3 ungulates namely eland, blue wildebeest and impala

in two climatically distinct areas in South Africa. We implanted temperature data loggers to 5 individuals of each species in Mapungubwe National Park (Northern part of South Africa) and Asante Sana Game Reserve (Southern part of South Africa) to record abdominal body temperature over a year. The first author will demonstrate if these South African ungulates' body temperature vary over time and space, and will discuss implications for potential adaptation to climate change.

Email Address for correspondence: Anil.Shrestha@wur.nl

16:25 Friday 2nd July 2010

A11.21

Diving in ectotherms: Implications of a warming world

Craig E Franklin (The University of Queensland)

For aquatic, air-breathing ectotherms the effect of increasing global temperatures could impact upon their capacity to remain submerged for extended periods. Aerobic dive duration is governed by the rate at which oxygen stores are depleted. The higher the rate of oxygen consumption the shorter the dive. Given the thermal sensitivity of metabolic rate, higher temperatures are expected to increase oxygen utilisation and decrease dive duration. With long term changes in temperature thermal acclimatisation may provide a mechanism to compensate for decreases in dive duration at elevated temperatures. Studies on the effect of acute and chronic changes in temperature on diving ectotherms (snakes, turtles and crocodiles) will be presented and the implications of a warming world discussed.

Email Address for correspondence: c.franklin@uq.edu.au

16:40 Friday 2nd July 2010

A11.22

Heart function of bullfrog tadpoles exposed to an environmental relevant concentration of Roundup Transorb® (glyphosate)

Monica J Costa (Federal University of Sao Carlos), Samuel E Dal-Medico (Federal University of Sao Carlos), Fábio C Abdalla (Federal University of Sao Carlos), Raquel F Salla (Federal University of Sao Carlos), Fernando U Gamero (Federal University of Sao Carlos), Rafael Z Rissoli (Federal University of Sao Carlos)

Roundup® is one of the most common glyphosate-based herbicides employed in agricultural areas in Brazil. The aim of this study was to evaluate the effect of an acute exposure (48 h) to a concentration of Roundup® (1 ppm)

commonly observed at Brazilian inland waters over activity level (AL - %), heart frequency (fH - bpm), relative ventricular mass (RVM - %), and calcium management in the heart (isometric contractions of ventricle strips) of bullfrog tadpoles, 'Lithobates catesbeianus'. Despite the absence of alterations neither of AL nor on RVM, there was a decrease in the fH of Roundup-exposed tadpoles (R-group; 43.0 ± 3.7 bpm) in relation to the control group (C-group; 67.7 ± 3.8 bpm). The bradycardia seems to be correlated to the prolongation of the time to half relaxation, and to the increase in the resting tension of the ventricle strips from the R-group when treated with 10-6M of adrenaline. This condition (high plasmatic adrenaline) is probably similar to that observed in vivo during the exposure to this xenobiotic. It is known that any condition that impact cardiac function of amphibians on the first steps of their development can result in a high energetic cost to counteract the harmful effects of an environmental stressor. Therefore it can be concluded that low and realistic concentrations of Roundup Transorb® can have an impact on tadpoles' performance and success, jeopardizing their survival and/or population establishment. Financial support: CNPq and FAPESP (National Institute on Comparative Physiology - INCT-Fisc).

Email Address for correspondence: monica@ufscar.br
Poster Session 17:00 – 19:00 Friday 2nd July 2010

A11.24

The effect of acclimation on the aerobic scope of amphibians

Karlina Ozolina (Zoophysiology Department of Biological Sciences University of Aarhus), Tobias Wang (Aarhus University), Johannes Overgaard (Aarhus University)

Climate change has already affected distribution of animal populations and a reliable prediction of the effects of increased temperature on animal performance is therefore an immediate goal for conservation biology. Numerous recent studies emphasise insufficient oxygen transport capacity and constrained aerobic scope as the primary limitation for temperature tolerance in fish. It remains largely unknown, however, whether the popular "aerobic-scope-model" also applies to air-breathing ectothermic vertebrates. Furthermore, it is unclear to what extent thermal acclimation influences the ability of animals to secure aerobic scope at high temperatures. To address these questions, we measured the thermal dependency of resting and maximal oxygen consumption (VO_2) in cane toads (*Rhinella marina*, formerly *Bufo marinus*) acclimated at 20, 25 and 30°C. In all acclimation groups, resting VO_2 increased exponentially with a $Q_{10} \sim 2$ across the temperature range of 10-40°C. Maximal VO_2 also increased with a $Q_{10} \sim 2$ between 10 and 30°C, henceforth maximal VO_2 reached a plateau and finally

tended to decrease at the lethal thermal limit around 40°C. While aerobic scope decreased ~25 % between 30 and 40°C, our results do not support the aerobic scope model, since no obvious pejus temperature was identified before the animals approximated acute lethal limits. Acclimation improved performance at the highest temperature, hence only the toads acclimated to 30°C tolerated 41°C, whereas 20 and 25°C acclimated animals were unable to tolerate this temperature.

Email Address for correspondence: karlina.ozolina@student.manchester.ac.uk

Poster Session 17:00 – 19:00 Friday 2nd July 2010

A11.25

Heart function of bullfrog tadpoles exposed to a cadmium concentration considered environmentally safe

Monica J Costa (Federal University of Sao Carlos), Rafael Z Rissoli (Federal University of Sao Carlos), Fernando U Gamero (Federal University of Sao Carlos), Samuel E Dal-Medico (Federal University of Sao Carlos), Jamaira A Victório (Federal University of Sao Carlos), Elaine C Silva-Zacarin (Federal University of Sao Carlos), Mariana Arena (Federal University of Sao Carlos)

Bullfrog tadpoles, *Lithobates catesbeianus*, were exposed during 16 days to a cadmium concentration considered environmental safe by the Brazilian Environmental Council (CONAMA). The relative ventricular mass (from 0.06 to 0.07% of body mass) and the heart frequency (from 73 to 81 bpm) of cadmium-exposed animals (CD) were similar to the ones observed for controls (CT). However, tadpoles' activity was higher in CT-group (43%) than in CD-group (22%). Additionally, cadmium exposure resulted in a marked depression of the in vitro cardiac function, as demonstrated by a ~40% reduction in ventricle strips twitch force of CD-group (3.4 ± 0.8 mN . mm⁻²) in relation to the CT-group (5.9 ± 0.9 mN . mm⁻²) at all stimulation frequencies. Despite adrenaline could ameliorate inotropism, in vivo heart rate (in rest) was close to the upper limit of the in vitro maximal stimulation frequency. It can be concluded that cadmium-exposed tadpoles are unable to develop increases on cardiac performance to respond appropriately to increases on the energetic demand imposed by cadmium exposure. This fact can cause homeostatic disturbs and then impair growth, development and reproduction, suggesting that cadmium concentrations that are considered environmentally safe in Brazil should be revised. Financial support: CNPq and FAPESP (Brazilian Institute of Comparative Physiology - INCT-Fisc).

Email Address for correspondence: monica@ufscar.br
Poster Session 17:00 – 19:00 Friday 2nd July 2010

A11.26

The effect of temperature and drought on microbial biomass and activity in heavy metal polluted soils.

Justyna Morawska-Ploskonka (Jagiellonian University), Dominik Ploskonka (Jagiellonian University), Marcin Chodak (Jagiellonian University), Maria Niklinska (Jagiellonian University)

Soil contamination may disturb microbial communities and affect their ability to withstand additional stressing factors. The effect of pollutants may be modified by natural factors such as temperature or humidity. The objective of the study was to assess the effect of drought and elevated temperature on microbial biomass and its activity in soils contaminated with different levels of Zn and Cu. Samples of organic horizons were taken at 5 sites along Cu-pollution gradient and 5 sites along Zn-pollution gradient. The samples were placed at stressing conditions (temperature 20 - 30 °C, drought) for eight weeks and then incubated under optimal conditions for six weeks. Prior to the stress period, directly after it and then two and four weeks after the stress period measured were basal respiration (RESP), microbial biomass (Cmic) and physiological profiles (Biolog® GN plates). The heavy metal content did not affect initial Cmic and RESP values in the Cu-polluted soils, however in the Zn-pollution gradient the lowest RESP was in the most polluted soils. The stress period did not affect microbial biomass but increased RESP values, resulting in higher values of metabolic quotient. The increase of RESP was probably due to better availability of soil C. The effect of stress did not differ depending on the pollution level.

Acknowledgements: The study was supported by EEA Financial Mechanism and the Norwegian Financial Mechanism, Polish Ministry of Science and Education (Project: Factors of Population Extinction Risk, FRISC).

Email Address for correspondence: J.MORAWSKA@UJ.EDU.PL

Poster Session 17:00 – 19:00 Friday 2nd July 2010

A11.27

Salinity activates phosphatidylethanolamine N-methylation pathway in crustacean hepatopancreas. A new physiological role for phosphatidylcholine biosynthesis in osmoregulation?

Athamena Ahmed (Université Claude Bernard Lyon 1), Brichon Gérard (Université Claude Bernard Lyon 1), Trajkovic-Bodennec Selena (Université Claude Bernard Lyon 1), Zwingelstein Georges (Université Claude Ber-

nard Lyon 1), Bodennec Jacques (Université Claude Bernard Lyon 1)

Phosphatidylcholine (PC) is the main phospholipid in eukaryotic cells. It is biosynthesized through CDP-choline pathway and *N*-methylation of phosphatidylethanolamine (PE). In fish and mammals the latter pathway is mainly expressed in liver. The physiological functions of PE *N*-methylation pathway are still not clear since PE-*N* methyltransferase (PEMT) knock out mice display no obvious phenotype when fed a normal diet. We previously shown that PE methylation pathway is strongly activated in the liver of fish submitted to hyperosmotic environment. We now demonstrate by *in vivo* tracer experiments similar phenomenon in the hepatopancreas of crustaceans (*Eriocheir sinensis* and *Carcinus maenas*) during adaptation to sea-water environment. In *Eriocheir sinensis* injected with (U-¹⁴ C)-serine, adaptation to seawater (SW) resulted in an important increase in hepatopancreas PC radioactivity and in the ratio of specific PC activities between hemolymph and hepatopancreas. In *Carcinus maenas*, incorporation of (U-¹⁴ C)-serine in the PC of hepatopancreas was strongly inhibited after acclimation to diluted seawater. The results show that PC synthesis via the PEMT pathway and PC release into the circulation are both activated in seawater- compared to freshwater-adapted animals. The observations are discussed in term of putative physiological roles that this PEMT activation may play during hyperosmotic adaptation. PEMT pathway is effectively the only known pathway for choline biosynthesis in animals, and as such may have a crucial role for the biosynthesis of choline-derived osmolytes such as betaine and glycine-betaine, two known important compounds in fish and crustacean osmoregulation mechanisms.

Email Address for correspondence: ahmed.athamena@univ-lyon1.fr

Poster Session 17:00 – 19:00 Friday 2nd July 2010