ORAL PRESENTATIONS

1) Impacts of Climate Change on Aquatic Ecosystems

APPLICATION OF PLANT BIOMARKERS IN LAKE SEDIMENT CORES TO TRACK THE IMPACTS OF CLIMATE WARMING ON AQUATIC ECOSYSTEMS IN THE SPORADIC PERMAFROST ZONE

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Northern boreal ecoregions globally are experiencing a rapid loss of permafrost in response to climate warming, with many implications for aquatic ecosystems. In particular, permafrost thaw in these organic-rich landscapes is expected to increase the transport of allochthonous carbon and catchment-derived contaminants such as mercury to lakes. Lignin-derived phenolic compounds are produced exclusively by terrestrial plants, and their presence in lakes can be attributed unequivocally to allochthonous sources. They are also resistant to decomposition, and consequently preserve well in lake sediment cores, allowing their use as chemical markers to track changes in the sources of organic matter to lakes over long time scales. We used lignins and other geochemical proxies in lake sediment cores to understand how climate warming has altered allochthonous carbon inputs to lakes in the Great Slave lowlands region of the southern Northwest Territories. This includes small, closed basin lakes that have experienced substantial peat subsidence in their catchments since ~1950, and large, shallow lakes in the Mackenzie Bison Sanctuary near Fort Providence that have undergone rapid lake expansion, flooding large tracts of terrestrial vegetation. We observed changes in source of terrestrial organic matter entering lakes, and document relationships between allochthonous carbon inputs and changes in lake ecology and mercury accumulation in the sediments. The novel application of plant biomarkers we developed for this study will contribute to our understanding of how transformative changes occurring in the terrestrial environment as a result of recent climate warming influence lakes in permafrost-supported northern boreal forests.

ASSESSING THE ROLES OF CLIMATE CHANGE AND NUTRIENTS ON DEEPWATER OXYGEN DEPLETIONS IN ONTARIO LAKE TROUT LAKES: A PALEOLIMNOLOGICAL PERSPECTIVE

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The ecological, economic and cultural value of Ontario's Lake Trout (*Salvelinus namaycush*) populations necessitate effective management. The low recruitment, slow maturation, and

specific physiological criteria of this taxon make them particularly sensitive to over exploitation and habitat degradation. Lake Trout require cold, oxygen-rich conditions; therefore, recent declines in late-summer, hypolimnetic dissolved oxygen (DO) concentrations in many Lake Trout lakes presents a new challenge for populations already under duress.
Declines in hypolimnetic DO have typically been associated with nutrient loading. However, recent observations of DO depletion in lakes with steady or declining total phosphorus (TP) concentrations indicate that additional stressors complicate the relationship between DO and TP. For instance, regional climate warming has lengthened the period of thermal stratification, and in turn has increased the likelihood of late-summer hypolimnetic anoxia. Due to the lack of direct long-term monitoring data, we use paleolimnological techniques to examine past trends in TP and DO in Lake Trout lakes using diatom and chironomid remains preserved in lake sediments. Temporal changes in diatom-inferred TP and chironomid-inferred DO from Lake Trout lakes in eastern, central and north-western Ontario will be compared with long-term monitoring records (~30 years). TP-DO dynamics are of particular interest because management strategies currently focus on controlling TP inputs. Thus, it is necessary to assess how the role of TP may have changed under the influence of additional stressors. These data will improve the understanding of Lake Trout habitat to better inform Ontario resource managers on future changes that may accompany ongoing climatic warming.

CLIMATE IMPACTS ON NUTRIENT DYNAMICS AT THE ARCHEOLOGICAL SITE KOOKOOLIK, ST. LAWRENCE ISLAND, ALASKA: A PALEOLIMNOLOGICAL INVESTIGATION

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Recent climate changes have resulted in decreased sea-ice stability, altering the distribution of marine mammal species in the Bering Sea. The Yupik people who inhabit the area are predominantly subsistence hunters of marine mammals, primarily of walrus, seals, and whales, and are culturally and economically tied to these resources. In the late 1870s on St. Lawrence Island, Alaska, a change in weather patterns had a devastating impact on the historical village of Kookoolik, impairing the seasonal hunting success, causing famine and, ultimately, the abandonment of the site. Here, we use fossil diatom and chironomid assemblages from two ponds adjacent to the old village of Kookoolik, and two non-impacted ponds, to track the impacts of the historical occupation and changing climatic conditions on water quality. The archeologically impacted ponds recorded marked changes in the diatoms, suggesting that nutrients began increasing in the ponds shortly after the village was abandoned in 1870, an increase which corresponds with chironomid-inferred warming. In contrast, the non-impacted ponds showed subtle diatom changes, but with chironomid assemblages also reflective of warming occurring in the late 1800s. The increase in nutrients in the impacted ponds may be reflective of the melting permafrost releasing stored nutrients and oil from meat caches at the Kookoolik site. Our study has implications for sites across the Arctic, where nutrients, from archaeological or recent sources, currently entombed in permafrost, may be released with

warming, suggesting that these sites might be among the most susceptible to shifts in the algal communities with climate change.

USING PALEOLIMNOLOGY TO TRACK THE RESPONSE OF DIATOMS AND CLADOCERA TO CLIMATE WARMING ACROSS LAKES OF THE FAR NORTH OF ONTARIO

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The vast peatlands and lakes of the Far North of Ontario warrant study given their hydrological complexity and status as a significant global carbon sink. Interest in the region is growing with recent mineral discoveries termed the “Ring of Fire” (RoF). Mineral exploration and infrastructure planning are ongoing; however, environmental monitoring is only beginning. Baseline ecological information are required to determine the impacts of future resource extraction within the context of multiple environmental stressors (including recent climate warming). Sedimentary chlorophyll-*a*, diatom and cladoceran assemblages were used to examine biotic responses to warming over the past ~150 years. Study lakes cover a variation in lake type and setting across the RoF including two deep lakes (~10 m) on the Boreal Shield and two shallow lakes (~2 m) in the Hudson Bay Lowlands (HBL). Over the past ~100 years, the most notable change in the four study lakes was a shift from littoral/benthic dominated assemblages to greater abundances of pelagic Cladocera (by ~34%) and planktonic diatom taxa (by ~3-22%). An increase in planktonic taxa is consistent with warming-induced changes in lake properties including longer ice-free periods and changes in aquatic habitat availability. The response of biota in shallow HBL lakes to warming was concurrent with substantial increases in aquatic primary production and preceded biological changes in deep Boreal Shield lakes by ~45-60 years. These paleolimnological data can help distinguish the potential ecological impacts of resource development and extraction from both natural variation and ongoing responses to regional warming.

CLIMATE WARMING RESULTS IN MORE SPECIALIZED CLADOCERAN TAXA IN CANADIAN ARCTIC LAKES

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ORAL PRESENTATIONS

Shifts in the distribution of freshwater algal communities due to climate-related limnological changes are well documented; however, the impacts of warming on higher trophic levels have received less attention. Little is known about how Cladocera (Crustacea, Branchiopoda), often dominant invertebrates and key ecological indicators, have responded to recent warming on broad spatial and temporal scales. We used paleolimnological methods to track the impact of climate warming on cladoceran assemblages in five lakes from the Mackenzie Delta region of Canada's western Arctic, one of the most rapidly warming areas globally. In all five of the lakes studied, warming has resulted in an increase in functional group specialization in cladoceran assemblages in the Mackenzie Delta region. Generalist taxa capable of occupying multiple habitats and employing diverse feeding strategies have been systematically replaced by more specialist taxa. The timing and nature of cladoceran assemblage changes were related to study site location and limnological conditions such as lake depth. In the deepest lakes, pelagic taxa such as Bosmina and Daphnia, increased coincident with warming. In the shallower lakes, taxa with specialized habitat and feeding strategies including macrophyte-associated scrapers increased relative to generalist littoral taxa. The cladoceran response was analogous to what has been inferred for algal communities across the northern hemisphere; however, this is among the first evidence for consistent patterns of change in the invertebrate Cladocera. This research highlights the importance of assessing functional group and habitat preferences in addition to species assemblage composition in lake sediment-based studies of climate-induced ecological changes.

TEMPORAL AND SPATIAL ASSESSMENTS OF DIDYMO BLOOMS IN EASTERN CANADA

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Didymosphenia geminata (didymo) is a benthic diatom that produces massive amounts of extracellular stalk biomass in pristine oligotrophic rivers worldwide. Nuisance blooms were first reported in 2006 from eastern Canadian rivers that support wild Atlantic salmon. Since then, government agencies and recreational users are concerned about the potential impacts of these blooms on wild Atlantic salmon. We first used paleolimnological approaches and assessed sedimentary diatom assemblages from Lac Humqui (control lake) and Lac au Saumon (lake with an inflowing river currently supporting blooms). The presence of didymo valves through-out the Lac au Saumon sediment core suggests that didymo is not an introduced species and has been present since at least ~1970, and likely longer (Lavery et al. 2014, *CJFAS*). A shift in life strategy from benthic fragilarioid to small, planktonic cyclotelloid diatoms ~ 1970s in the Lac Humqui core coincides with increases in regional air temperature and earlier ice-out dates on the Humqui River. To assess whether didymo blooms affect present-day benthic diatom assemblage composition, we undertook a spatial survey of rock scraping samples across the Patapédia and Upsalquitch rivers along a gradient of didymo bloom-densities. Similar to a recently published study (Gillis and Lavoie 2014, *Diatom Research*), minimal differences were found between sites with and without blooms in both rivers although significant (albeit minor) differences were observed in the Patapédia River. In addition, didymo bloom-density had no significant effect on diatom species diversity and richness. Collectively, our studies suggest that regional climate

warming likely played a role in triggering recent didymo blooms in eastern Canadian rivers and that blooms have a surprisingly minimal effect on diatom assemblage composition.

MULTI-CENTURY ICE DYNAMICS OF LAKE SUWA AND TORNIO RIVER: CLIMATE CHANGE, LARGE-SCALE CLIMATE DRIVERS, AND WEATHER

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Lake ice is a sensitive indicator of climate change and variability. Climate change, large-scale climate drivers, and weather are all important drivers of ice freeze and breakup dates for Lake Suwa, Japan from 1443-2004 and Tornio River, Finland from 1693-2013. Using long-term records, we identify a regime shift in ice freeze and breakup coinciding with the start of the Industrial Revolution, the end of the Little Ice Age, and increases in atmospheric CO2 concentrations and air temperatures. In the past century relative to earlier centuries, we observed earlier ice breakup, later ice freeze, a doubling to tripling in the rates of change in the timing of ice freeze and breakup, decreased importance of very short-term or long-term oscillatory dynamics for Tornio River, and increased probability of no-freeze years in Lake Suwa. Using these long-term ice records we highlight the fallacy of using short-term records to infer progressive climate change or the absence of it when so much variation in ice dynamics is caused by inter-annual and decadal climate drivers and local weather.

RECENT REGIME SHIFTS IN A NORTHERN MANITOBA BOREAL FOREST LAKE

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Northern high latitudes and tundra ecosystems have experienced some of the greatest warming worldwide, ranking them amongst the most globally susceptible regions to climate change. However, the boreal and treeline regions of northern Manitoba have, until quite recently, remained quite stable compared to the amplified warming observed throughout much of the Arctic tundra only a few hundred km to the north, likely due the thermal buffering capacity of ice dynamics on nearby Hudson Bay. The purpose of this study was to examine recent changes (past 150 years) in temperature, productivity and Chironomidae assemblages from Buckland Lake, located in Manitoba's northern boreal forest. Results show two periods of change within the stratigraphy; the first change occurs in the 1970's with the increase in several warm-water chironomid indicators including *Dicrotendipes* sp., *Heterotrissocladius* sp., *Polypedilum* sp. and *Tantytarsus lugens*. A second and more drastic shift occurs in the 1990's with further introductions of warm-water indicators as well as declines in cold-water species.
These results support other studies that suggest that southern Hudson Bay had until recently been a refugia from observed regional climate change, but has since undergone dramatic change. Our results show that this drastic shift has extended beyond the Hudson Bay Lowlands and into the nearby boreal forest. These chironomid-inferred changes in temperature have been accompanied

by changes to autochthonous production, as inferred by stable isotope analysis, and this may serve as a secondary gradient exacerbating the ecosystem effects of regional climate warming.

LIMNOLOGICAL CHANGES TO AN ARCTIC POND DOWNSTREAM OF PERMAFROST SLUMPING

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The incidence of retrogressive thaw slumps in the Canadian Arctic has increased in recent decades. Previous research has indicated that the limnological effects of retrogressive thaw slumps include nutrient enrichment and increases in major ion concentrations due to inputs from slump materials. Paleolimnological approaches have focussed on the effects of shoreline permafrost slumps on Arctic lakes; in this study we examine the effects of an upstream-catchment slump on a small, shallow thermokarst pond in the Mackenzie Delta region of the Canadian Arctic. A sediment core was collected from a small pond (informally named "FM1") near Fort McPherson, Northwest Territories, with a large, currently-active retrogressive thaw slump within its catchment. Analysis of recent aerial photographs indicate the thaw slump originated between 1970 and 1990, and stratigraphic analysis of sediment core characteristics (% organic, % siliciclastic, grain size) identified the initiation of slump materials entering the FM1 basin. While a time series of aerial photographs indicated that FM1 shifted from a clearwater system to a turbid system after slump initiation, stratigraphic analysis of subfossil midge (Chironomidae) assemblages inferred that, due to inputs from the within-catchment slump, FM1 underwent dramatic limnological shifts in its light and thermal regime such that the shallow pond became thermally stratified. More recent stratigraphic intervals inferred a reversion back to unstratified conditions, possibly due to the basin becoming shallower as a result of rapid sediment infilling from slump materials.

THE NATURE OF PHYTOPLANKTON IN THE EPILIMNION AND SUMMER DEEP CHLOROPHYLL MAXIMUM IN THE GREAT LAKES

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The formation of deep chlorophyll maxima (DCM) during summer stratification in the Great Lakes has been well-documented. Floristic and ecological differences between the epilimnetic and DCM algal communities, however, have not been extensively investigated. Consequently, we do not adequately understand the form and function of the DCM. Here, we examine changes in Great Lakes epilimnetic algal communities from 2001 through 2012, and relate these to differences between Great Lakes summer epilimnetic and DCM algal communities from 2007 through 2012. Pooled results from all five Great Lakes show a decadal increase in the relative contribution of the cyanophyta to the overall biovolume of the summer epilimnetic algal community concurrent with decreases in relative and absolute biovolume contributions from centric and pennate diatoms. Additionally, mean taxon-specific cell biovolumes are lower among

siliceous algal taxa (diatoms and chrysophytes) from integrated epilimnetic samples than from those in DCM samples. The opposite trend is exhibited for cyanophytes. These findings, along with consistently dense spring diatom blooms and steadily-increasing integrated epilimnetic water temperatures in all lakes, suggest that diatom sinking loss rates are becoming accelerated due to steepened epilimnetic water density gradients. The rapid loss of diatoms from the summer epilimnion may be viewed as an ecological release that allows for increased production of more buoyant cyanobacteria, especially in increasingly stratified waters. The consistency of this phenomenon across multiple lakes implies the broad-scale influence of nutrient-independent mechanisms related to climate change and is consistent with multi-decadal paleolimnological findings from all of the Great Lakes.

CAPACITY OF FISHES TO RESPOND TO CLIMATE CHANGE

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Increasing global temperatures represent a major stress for fishes and may limit the ability of many species to persist in their current habitats. We use two complementary systems to examine the capacity of fishes to respond to climate change and the likelihood of population collapses within the next century. Using guppies, a small tropical fish that lives close to its thermal maximum, we show that acclimation to warmer temperatures alone is insufficient to maintain performance at fitness and life history traits. Improvements to some traits were observed after four generations of experimental evolution at high temperatures, but strong selection for thermal performance led to a significant reduction in genetic variation relative to control populations. Using Chinook salmon, an ecologically and economically important fish in Canada, we show that both acclimation and genetic variation contribute to physiological performance at high temperatures. However, neither acclimation nor genetic variation affect the arrhythmic temperature of the heart, constraining the upper thermal limit in these salmon. Linking this constraint on thermal tolerance with present-day river temperatures and projected warming scenarios, we predict a 17% chance of catastrophic loss in the population by 2100 based on the average warming projection, with this chance increasing to 98% in the maximum warming scenario. Climate change mitigation is thus critical to ensure the future viability of global fish populations.

THE EFFECTS OF MULTI-DAY HEAT STRESS ON WILD JUVENILE ATLANTIC SALMON (*SALMO SALAR*)

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ORAL PRESENTATIONS

Juvenile Atlantic salmon (*Salmo salar*) demonstrate a physiological stress response when water temperatures exceed 23ºC. Once temperatures approach the incipient lethal limit (~28ºC), wild juveniles must manage their metabolism via behavioural thermoregulation. Observed thermal patterns from a heat event within the Little Southwest Miramichi River were replicated in a laboratory setting using a fluctuating acclimation regime of 16-21ºC (12hour heating & 12hour cooling) and a simplified 3-day heat event (daily maximum of 27ºC with daily minimum varying with treatment). Fish were sampled for heat shock protein 70 (HSP70), ubiquitin, liver glycogen, muscle lactate, and blood metabolites. Subsequent critical thermal maxima tests (CTMax) were conducted to test thermal tolerance after several days of heat exposure. Preliminary data suggests maximum exposure temperature may positively influence short-term thermal tolerance, yet repeated exposure may increase mortality. Juveniles exposed to 27ºC saw a significant increase in thermal tolerance of 0.9ºC (33.27±0.3ºC) from those exposed to the acclimation regime (32.32±0.4ºC). HSP70 levels increased with heat exposure ($p<0.01$) in both blood and liver tissues and remained significantly elevated throughout. With future climate change scenarios predicting further increases in water temperature, it is likely that physiologically important temperature thresholds for juvenile salmon will be surpassed on a more frequent basis. It is critical that we consider how predicted climate change scenarios might affect fish species. With more knowledge about the biological response to warming water temperatures, effective management strategies can be developed to help protect cold- and coolwater species during periods of high thermal stress.

CAN SMALL, ISOLATED FISH POPULATIONS RESPOND PLASTICALLY TO ELEVATED TEMPERATURE?

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Assessing whether small, isolated fish populations can respond plastically to elevated temperature is understudied but important for forecasting species persistence under projected climate warming scenarios. We investigated plasticity to increasing temperature in a common garden experiment using eight fragmented populations of brook trout (*Salvelinus fontinalis*) varying nearly 50-fold and 10-fold in demographic and genetic population sizes, respectively. We specifically contrasted three alternative hypotheses about the relationship between the size of an isolated population and plasticity: (i) small populations should exhibit consistently lower plasticity than large populations because small population habitats are generally poor in quality and genetic diversity underlying plasticity should be lost as population size is reduced; (ii) small populations should exhibit consistently higher plasticity as a response to the increased environmental variation that can accompany habitat fragment size reduction; and (iii) small populations should exhibit greater variability in plasticity, as habitat fragmentation can increase variability in habitat types. Across six, early life history traits and three temperatures, we found virtually no evidence for differences in either the magnitude or variability of plasticity in relation to population size, despite that two temperatures represented climate warming scenarios, including an extreme one. The documentation of similar plastic responses of small and large populations suggests that phenotypic plasticity is not reduced as population size decreases, and

that even very small populations of some fish species might have the ability to respond to climate change.

ASSESSING BIOENERGETICS IMPACTS OF CLIMATE CHANGE TO FRESHWATER FISHERIES PRODUCTIVITY IN NORTHERN ECOREGIONS: A CASE STUDY WITH ARCTIC GRAYLING

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Physiology, growth, metabolism, and behavior of organisms are directly related to temperature and have been recognized to be affected by global warming. However, due to complex nature of topography and heterogeneous land cover, the warming is highly spatially heterogeneous. Consequently, warming effects vary for a given species across space. In temperate regions, growth and metabolic rates of ectothermic vertebrate species, including most fishes, are likely to be affected by the warming as growth rates are predicted to initially increase with the rising water temperatures, but then to decline as individuals struggle to maintain cardiac function and respiration in the face of increased metabolic demands. In this study, we show seasonal and spatial variations of Arctic grayling (*Thymallus arcticus*) productivity (weight) and characterize how climate change affects growth and consumption rates in its geographical distribution. The results indicate that the amount of food consumed to gain a particular weight differs among seasons (summer/winter/spring) but it depends on whether they are found in cold or warm ecoregions. Our data demonstrate that increasing water temperature have pushed Arctic grayling above the point where warming is beneficial to growth, and suggest mechanism for range contraction as a result of warming. If Global warming continues, the direct metabolic effects on this species due to increasing water temperatures may lead to a decline in productivity and to a range contraction.

PREDICTING THE EFFECTS OF CLIMATE CHANGE ON WALLEYE AND SMALLMOUTH BASS DISTRIBUTIONS IN ONTARIO INLAND LAKES: ARE WALLEYE IN A PICKLE-REL?

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Climate change is expected to alter freshwater fish distributions by causing range shifts, contractions or expansions, which may lead to novel biotic interactions, changes in food web dynamics, and potential extirpations. The objective of our study is to elucidate the effects of climate change on walleye (*Sander vitreus*) and smallmouth bass (*Micropterus dolomieu*) populations in Ontario inland lakes. Lake and fish data were obtained from the OMNR's aquatic habitat inventory survey and broad-scale monitoring program for 9736 lakes. Logistic regression models suggest that walleye prefer large lakes with low water-clarity, lower air temperatures, and high precipitation. We predicted that walleye populations will decline by an average of 19% by 2050, and 24% by 2070. We also found that these declines occur in Ontario's southern lakes,

and that walleye are expected to expand into more northern regions of Ontario. Smallmouth bass prefer larger, warmer lakes, with high water clarity and low precipitation and are expected to expand their range by 258% in 2050 and 305% in 2070. We will next consider how walleye and smallmouth bass may interact under future climate scenarios.

PREDICTING THE IMPACTS CHANGING SPECIES DISTRIBUTIONS ON FISH SPECIES IN ONTARIO LAKES

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Several warm and coolwater predatory fishes in Ontario have significantly shifted their distributions northward over nearly 30 years of climate warming. Using contemporary and historical survey data from more than 1500 lakes across the province we examined which species were most vulnerable to introductions of centrarchid predators outside of their historical range. We introduce a simple but powerful method for predicting the impacts of these species introductions based on historical species associations. We find that introductions of predators which are expanding their ranges appear to negatively impact both native top predators and their prey.

PANIC AT THE CISCO: PREDICTING THE EFFECTS OF CLIMATE CHANGE ON CISCO DISTRIBUTIONS IN ONTARIO

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Increasing lake water temperatures in response to climate change is expected to alter the distribution, thermal habitat, and growth of many aquatic organisms, including an ecologically and economically important coldwater fish species, cisco (*Coregonus artedii*). Our project examines the effects of climate change on the distribution of cisco populations in Ontario. Using a historical dataset of 9885 Ontario inland lakes surveyed between 1957-1986 and a contemporary dataset of 722 lakes sampled between 2008-2012, we will identify important environmental characteristics, such as lake morphology, lake chemistry and presence of predators and prey on cisco occurrence in Ontario. Subsequently, we will predict future cisco occurrence across Ontario for the years 2050 and 2070 by incorporating future climate change scenarios from 19 general circulation models and four greenhouse gas scenarios into our best predictive model of cisco occurrence. Using a logistic regression model, we determined that cisco prefer larger, deeper lakes, in cooler regions of Ontario. Warming air temperatures corresponded to a decline of cisco occurrence ranging from 8-37% ($\bar{x}$ = 20%) by 2050 and 7-47% ($\bar{x}$ = 26%) by 2070. Under 126 future climate scenarios, cisco populations were predicted to experience a southern range contraction by 388 km in Ontario. The loss of these forage prey species has consequent impacts on the growth of top predators such as lake trout. Through understanding the main drivers that control cisco populations and how future climate changes may impact them, we may further improve fisheries management decisions before cisco become extirpated in Ontario lakes.

ORAL PRESENTATIONS

PREDICTING THE IMPACTS OF CLIMATE CHANGE ON THE SPREAD OF AQUATIC INVASIVE SPECIES: A CASE STUDY IN THE PROVINCE OF ONTARIO

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Changing climatic conditions are likely to impact the dispersal and establishment of aquatic invasive species (AIS). Warming waters may become increasingly hospitable to new exotic species, while some native species' ranges may expand into more northern waters. Using a suite of IPCC climate models bounded by the A2 and B2 scenarios; we conducted a risk assessment of potential species introductions across the province of Ontario by assessing the temperature suitability for survival, reproduction and growth of fish. The likelihood of species spread is assessed for key fish species that are already established in the Great Lakes basin (i.e. gobies, smallmouth bass), as well as broad categories with temperature requirements characteristic of warm, cool and cold water classes to incorporate all potential invaders. Additionally, predicting AIS introductions requires a thorough understanding of the pathways of spread, which includes socioeconomic factors that facilitate species movement. By overlaying the temperature requirements with an empirical model of the accessibility of waters to people (the primary method of species spread across Ontario), we evaluated the overall likelihood of introduction and establishment of new species. The analysis was conducted on a provincial scale, and at three timelines: short (by 2040), medium (by 2070) and long (by 2100). These predicted futures allow adaptive management practices to be developed under multiple possible climate change scenarios.

POTENTIAL INLAND SPREAD OF INVASIVE GREAT LAKES FISHES GIVEN CLIMATE CHANGE, STREAM-LAKE CONNECTIVITY AND PROPOSED DAMS

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The Great Lakes currently harbour a number of non-native fishes that are thermally limited to the comparatively warm waters of Lake Erie and Lake Ontario. Climate change could facilitate the inland spread of many non-native species as the Great Lakes and their tributaries warm putting thousands of inland lakes and streams at risk. We investigated how climate change, watershed network configurations, and proposed hydro-power development could influence invasion risk in tertiary watersheds of the Great Lakes Basin. The amount of suitable thermal habitat was estimated using future air temperature projections. Electric circuit theory was used to model hydrologic accessibility of aquatic ecological networks (i.e., lake, river, and impoundment chains) within tertiary watersheds. Proposed hydro-power dam sites and their upstream catchments were used to evaluate invasion given passable, semi-passable, and impassable dams. Total risk of invasion was measured as the product of suitable habitat, probability of non-native species spread (hydrologic accessibility), and dam passability. We show that projected climate change will lead to more coolwater stream and warmwater lake habitat. Overall invasion risk of

cool and warmwater species was highest in southern Ontario and surprisingly in northern watersheds draining into Lake Superior. This risk could be partially mediated by proposed dams if dams reduce connectivity and access to potentially suitable habitat.

2) Genomic, proteomic and transcriptomic advancements in aquatic monitoring, assessment and response.

MECHANISMS OF REPRODUCTIVE TOXICITY FOLLOWING EXPOSURE TO BISPHENOL A IN ZEBRAFISH (*DANIO RERIO*).

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Bisphenol A (BPA) is a high production chemical present in epoxy resins and polycarbonate plastics, and is ubiquitous in the environment. Previous evidence demonstrated that BPA induces oestrogenic signalling pathways associated with adverse effects on reproduction in vertebrates, and the potential for epigenetic effects has also been suggested. We aimed to investigate the reproductive effects of BPA in fish, and document the potential (epi)genetic mechanisms mediating these effects. We conducted a 15 day exposure of breeding zebrafish to 0.01, 0.1 and 1mg/L BPA. BPA (1mg/L) significantly increased egg production, but reduced the rate of fertilisation. Hepatic transcript profiling for genes involved in reproductive processes revealed that BPA induced the expression of vitellogenin (*vtg*) in males (1mg/L), and disrupted the expression of oestrogen receptor 2b (*esr2b*). Transcript profiling for genes involved in epigenetic modifications revealed that BPA strongly down-regulated the expression of the global maintenance DNA methyltransferase enzyme (*dnmt1*) in female fish exposed to 0.1 and 1mg/L BPA. This transcript, as well as histone deacetylase 3 (*hdac3*), were also down-regulated in males. In addition, BPA disrupted the expression of the transcript encoding the methyl-CpG binding domain protein 2 (*mbd2*) and methyl CpG binding protein 2 (*mecp2*) in liver tissue of males. Our findings to date suggest that BPA disrupts reproduction in zebrafish, likely via oestrogenic mechanisms. In addition BPA may disrupt DNA methylation patterns via regulation of key enzymes involved in DNA methylation maintenance.

PROTEOME REMODELLING IN RESPONSE TO NUTRIENT STRESS IN AN AQUATIC CONSUMER

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ORAL PRESENTATIONS

Aquatic consumers such as Daphnia are known to frequently face nutritional limitation in their diets caused by an imbalance between their nutrient requirements and the nutrient composition of their food source. This nutritional imbalance causes changes in physiology such as decreases in growth rate which ultimately leads to changes in population dynamics. Given the strong effects of food quality on growth rate and elemental composition, we examined how the proteome remodels itself to deal with nutritional limitation from both a dietary and environmental limitation. We grew Daphnia pulex for 6 days on a high food quality and quantity, low food quantity (high quality), low phosphorus, and low nitrogen green algae. We also grew Daphnia on low calcium media fed with high food quality and quantity algae. After 6 days of growth, we saved animals for their elemental composition and freeze dried animals for proteome analysis. Proteins were extracted in acetone: trichloroacetic acid, digested with formic acid and analyzed used an RP-LC-Q-TOF with the resulting peptides identified using the Cladocera database. Nutritional stress reduced growth and changed the elemental composition of daphnids as expected for low food, low nitrogen and low phosphorus diets. We found the relative number of proteins decreased especially with nutritional stress and evidence that protein composition varies strongly between nutrient treatments. The results of this study will provide a more mechanistic understanding of how metabolism is remodelled to deal with nutritional limitation.

LINKING TOXICITY AND ADAPTIVE RESPONSES ACROSS THE TRANSCRIPTOME IN THE BROWN BULLHEADS (*AMEIRUS NEBULOSUS*): RNA-SEQ DE NOVO ASSEMBLY USING TRINITY PLATFORM

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Urbanisation and industrialisation have caused an increase in point-source pollution, especially in the aquatic environment. Advancements in aquatic monitoring is essential to detect biological effects from contaminants before the ecological effects are too severe to reverse or mediate. Transcriptome (gene expression) screening provides just such a sensitive monitoring tool. In this study we characterize the transcriptome of brown bullheads from two sites (highly polluted (Trenton Channel) and less polluted (Peche Isle)) within the Detroit River, before and after challenging them with polluted sediment. The RNA-seq data consists of over 8.7 million reads that we assembled into gene contigs using Trinity software. Our assembled transcriptome resulted in the identification of >6000 genes of known of putative function across the bullhead genome. We found substantial variation in the level of transcription (sequence copy number) between challenged and control fish from the two sites. Differentially expressed genes (DEGs) were investigated using Reads Per Kilobase of transcript per Million mapped reads (RPKM) method. To further characterise the function of the DEGs, gene ontology annotation and metabolic pathway enrichment analysis was performed. Our data provide new insights into the bullhead transcriptome response to toxicants in natural environments as some responding genes were expected while others are novel for aquatic ecotoxicology. Based on our results, we

selected genes showing strong response to the xenobiont stimulus for potential development into rapid and sensitive biomarkers for aquatic environment experiencing point and non-point pollution.

GENETIC VARIABILITY IN POPULATION RESPONSES OF ATLANTIC COD TO ENVIRONMENTAL CHANGE AND THE TRANSCRIPTOMIC RESPONSE TO TEMPERATURE

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Key questions surrounding the issue of variable population responses to environmental change include the spatial scale at which differences in plasticity exist and the molecular basis (i.e. specific genes or genetic variants) of these adaptations. We are interested in how Atlantic cod inhabiting different thermal regimes respond differently to changes in temperature. Traditional approaches to studying local adaptation evaluate either genotypic (e.g. mapping spatial variation in genetic markers thought to be under selection) or phenotypic (e.g. common-garden experiments) variation within species, often failing to establish either the phenotypic consequences or the molecular basis of adaptive variation, respectively. By integrating common-garden experiments across a range of temperatures with transcriptomics (i.e. genomic expression profiles) using RNA sequencing, we aim to bridge the gap between genotypic and phenotypic variation among Norwegian cod populations to determine: 1) the transcriptomic response of larval cod to temperature, 2) the spatial scale of adaptation for plasticity, and 3) the molecular basis of thermal adaptation in cod. This presentation will focus on how larval cod gene expression varies in response to temperature for a Skagerrak coastal cod population, how gene expression changes through early development, and how these patterns of expression relate to the increased growth and decreased survival that was observed in response to warmer temperatures in the lab. Understanding the genetic basis of thermal plasticity will help us to predict the response of wild cod populations to rising ocean temperatures and manage populations effectively to prevent population collapse and biodiversity loss.

CONNECTIVITY IN A LONGNOSE SUCKER (*CATOSTOMUS CATOSTOMUS*) HIERARCHICAL METAPOPULATION IN NORTHERN LABRADOR

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ORAL PRESENTATIONS

Given that limits to gene flow can result in population isolation and a greater risk of extinction, an understanding of the factors responsible for reducing gene flow will significantly contribute to the development of effective conservation management strategies for river ecosystems. The Kogaluk River system in northern Labrador is an ideal system for studying gene flow because it is both pristine and closed to immigration. Microsatellite markers were used to characterize the population structure of longnose suckers (*Catostomus catostomus*) within this system and to identify those factors that are most limiting of gene flow within this metapopulation. Of particular interest is the effect of several waterfalls within the system which are thought to be complete barriers to gene flow. Alternatively, environmental factors such as distance and elevation differences between lakes could also limit gene flow. Over 1200 fin clip samples were collected from eight lakes within the Kogaluk River system from 2006 to 2014. These samples will be genotyped at 20 microsatellite loci. By correlating neutral genetic divergence (Fst) between each pair of lakes with several environmental factors (waterfall presence, distance, elevation) the relative influence of each factor on gene flow can be determined. The results of this study will therefore provide a baseline characterization of gene flow of a fish species in a pristine river system. Preliminary analysis suggests that gene flow of longnose suckers within the Kogaluk River system is relatively unimpeded between lakes.

ANALYSIS OF SEMINAL PLASMA PROTEINS FROM ALTERNATIVE REPRODUCTIVE TACTICS OF CHINOOK SALMON (*ONCORHYHNCHUS TSHAWYTSCHA*)

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Although alternative reproductive tactics (ART's) are common across a range of taxa, little is known about whether the different tactics have adapted to sperm competition risk. Chinook salmon has two ARTs: large males that participate in dominance-based hierarchies for access to spawning females, known as hooknoses and small males that attempt to sneak fertilizations during spawning events from peripheral positions, known as jacks. Jacks continually face sperm competition risk because they always spawn in the presence of another male, whereas hooknoses face relatively low sperm competition risk because other males are not always present during spawning events. Due to this asymmetry in sperm competition risk, theory predicts that jacks ought to invest significantly more into sperm related traits important for sperm competition success relative to hooknoses. In the present study we examine differences in proteomic profiles of seminal fluid in the two ARTs. Through the use of high throughput tandem mass spectrometry (LC-MS/MS) and data independent acquisition (MSe) as our platform, proteomic libraries of seminal plasma were generated and compared between jack and hooknose males. It is anticipated that this study will yield a candidate list of intrinsic factors involved in the attenuation/enhancements of sperm motility. In addition a catalogue of mutually exclusive proteins within seminal plasma and sperm will be generated. We interpret these proteomics results in light of sperm competition theory that is based on differences in sperm competition risk and alternative investment possibilities among ARTs.

ORAL PRESENTATIONS

GENETIC DIFFERENTIATION AND POPULATION CONNECTIVITY IN NORTHWEST ATLANTIC POPULATIONS OF THE SEA SCALLOP, *PLACOPECTEN MAGELLANICUS*, USING WHOLE-GENOME SCANNING.

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Understanding the patterns of connectivity and genetic differentiation among marine populations can inform fisheries management, allowing managers and policy makers to conserve identified populations and diversity. Advances in high-throughput sequencing (HTS) technologies now provide a more complete genomic picture allowing both neutral and gene associated regions of the genome to be surveyed in non-model species. The application of HTS provides access to genome-wide single nucleotide polymorphisms (SNPs) which can resolve genes associated with adaptive divergence and illuminate cryptic diversity masked using other markers. Using restriction-site associated DNA sequencing on 245 individuals across 12 locations from Newfoundland to the Mid-Atlantic Bight, we identified and genotyped 7163 informative SNPs in the sea scallop *Placopecten magellanicus,* a commercially important North American marine invertebrate species. Population structure analysis revealed a major discontinuity between northern and southern populations associated with a suite of genes of potential adaptive importance. Bayesian outlier analysis identified selection in 112 loci (1.5%), and multivariate analysis revealed associations between these outliers and ocean climate (r^2=0.58). This work supports the hypothesis that climate associated adaptation is a significant force structuring scallop populations along eastern North America. Recognizing functional separation and adaptive diversity in sea scallop populations will help identify which populations can be grouped for management and which should be managed individually. Future analyses will explore ongoing adaptation and connectivity in sea scallop populations at multiple scales, providing critical information that can influence environmental policy and economic decisions as demands on marine resources and the need for effective management increase.

HYBRID BREAKDOWN IN TRANSCRIPTION OF CHINOOK SALMON: IMPLICATIONS FOR REINTRODUCTION AND SUPPLEMENTATION EFFORTS

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Individual translocation and hatchery supplementation are attractive management options for conserving declining salmonid populations. Unfortunately these efforts are rarely as successful as expected and may inadvertently compromise the genetic viability of wild populations. The fitness consequences (outbreeding depression) of these actions may not be apparent for many generations. It is important to develop methods that can detect the potential for outbreeding depression without requiring many generations of controlled breeding. One such approach is to quantify the disruption of gene expression in hybrids relative to pure-type individuals. We assayed gene transcription of pure-type and reciprocal hybrid families created from replicated

full-factorial breeding design between four Chinook salmon populations. Transcription for many genes followed an additive genetic inheritance pattern. However, a surprising number of genes exhibited transcriptional patterns that were consistent with non-additive genetic and maternal effects. We document extensive amounts of reciprocal hybrid disagreement in gene transcription, indicative of breakdown of gene expression regulation complexes that are likely co-adapted. We further compare patterns of hybrid breakdown in gene transcription to empirical data for these families to assess the effect this breakdown has on growth and survival. The anomalous hybrid gene transcription we report suggests conservation strategies that employ or create the potential for intraspecific hybridization should be approached cautiously and we have demonstrated a method that could be used to test the suitability of populations for supplementation.

STOCK AND INTERSPECIFIC COMPETITION EFFECTS ON INTESTINAL MICROBIOTA OF ATLANTIC SALMON

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The microbial community found in the gut is known to affect many biological processes in their host, including both negative effects (pathogens) and positive effects (symbiotes). The symbiotic gut microbes aid in nutrient digestion and absorption, resistance to infection by pathogens and development of the intestine. Gut bacterial composition depends not only on their physical environment, but also influenced by biotic factors, such as ecological interactions and their evolutionary history with their host. In this study, we characterized the microbial community in the intestines of Atlantic salmon from two populations (Sebago and LaHave) experiencing different forms of interspecific competition. For each population we created six treatments: Atlantic salmon reared alone, Atlantic salmon reared in equal numbers with each of the four competing species (Chinook salmon, coho salmon, rainbow trout and brown trout), and Atlantic salmon reared with all the four species. We PCR amplified the 16S rRNA gene using intestinal bacterial DNA as template and conducted massively parallel sequencing to characterize the gut microbiome for 178 individual fish. In total, we obtained more than seven million reads. We estimate bacterial community diversity (alpha and beta) and identified shared and unique bacteria between the two Atlantic salmon populations and among the treatments. Overall, we found that source population had larger effects on composition and diversity of gut microbiota than interspecific competition.

USING ENVIRONMENTAL DNA TO DETECT ENDANGERED REDSIDE DACE, *CLINOSTOMUS ELONGATUS*

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ORAL PRESENTATIONS

Effective management of endangered species requires sensitive detection of their occurrences, which is often difficult for low-abundance species. In aquatic environments, detection of rare species can be further confounded by site accessibility, sampling gear, and capture efficiency, with direct observation being difficult at best. Redside Dace, an endangered species native to southern Ontario, has been experiencing population declines as a result of habitat fragmentation. Traditional methods to detect their presence include seining and electrofishing; however, species often go undetected even if present at the site. A novel application of DNA barcoding has been to develop species-specific detection in aquatic habitats from environmental DNA (eDNA). The utility of this methodology was tested at 29 sites where Redside Dace were historically known to be present. The study design assessed several factors for their effects on eDNA detections, including seasonality, temporal versus spatial replicate sampling, and appropriate thresholds for classifying detections versus nondetections (resolving true versus false positive and negative detections). The combined results indicate that eDNA is a reliable method for species detection in freshwater systems, and can be used as an effective sampling technique for documenting occurrences of aquatic endangered species.

VALIDATION OF UNTARGETED SPECIES DETECTION IN ENVIRONMENTAL (eDNA) SAMPLES USING NEXT-GENERATION SEQUENCING

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The use of environmental DNA (eDNA) for targeted species detection of both invasive and endangered species has become a widely used surveillance tool in recent years. Although powerful, targeted single-species methodologies are limited in that they do not allow for the detection of a broad view of species composition (communities or species assemblages) within samples collected from aquatic habitats. It is possible that newly invasive or low abundance endangered species are present but overlooked in water samples and this information is being lost through targeted detection of only a handful of species of interest. Untargeted detection would be beneficial in establishing previously unidentified habitat occurrences / occupancy for endangered species, as well as enabling detection of undocumented invasive species. We targeted a small region of the cytochrome oxidase subunit I (COI) of the mitochondrial genome, using conserved ("universal") primers to determine if the entire species composition of water samples could be detected using next-generation sequencing. Results indicated that universal primers are too inclusive and the highest proportions of sequences obtained were for uncatalogued species. Further testing using fish-specific primers yielded much more useful and manageable results. Our findings indicate that next generation sequencing may be useful if the tests target specific higher-order taxonomic groups within water samples rather than full (multi-kingdom) biotic community composition using universal primers.

MONITORING AQUATIC SPECIES' INVASIONS USING ENVIRONMENTAL DNA

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ORAL PRESENTATIONS

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Invasive species can negatively affect communities and become uncontrollable once established in new environments. Environmental DNA (eDNA) detection based on DNA barcoding is an efficient method for detecting target species at low densities where traditional census methods fail. We used eDNA detection to monitor the round goby (*Neogobius melanostomus)* along its invasive pathway in the Trent-Severn Waterway (Central Ontario), from the area of original introduction to the upstream expansion front. Environmental DNA sampling was intensified approaching the expansion front to assess the efficiency of this method for detecting the presence of the species in low density areas. The protocol used to monitor the dynamics of the round goby eDNA in the Trent Severn system was tested in the recently invaded Moselle River (France) in order to locate the expansion front. Experiments were conducted to assess how environmental factors, including round goby biomass, flow velocity and depth, were affecting the spread of eDNA molecules in the system, and improve our interpretation of eDNA signals in a field context. An appropriate sampling strategy should allow one to determine stages of invasion, as well as localise the actual expansion front where individuals are scarce, and where management intervention may be effective in reducing the spread of invasive species.

AQUATIC MICROBIAL COMMUNITY STRUCTURE AND FUNCTION ACROSS A GRADIENT OF LOGGING, FIRE, AND INDUSTRIAL WATERSHED DISTURBANCES

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The role of microbial communities in the recovery of aquatic ecosystems from watershed disturbance has received little attention despite their important role in energy and nutrient cycling. This study investigates the structure and function of microbial communities on a standardized substrate (alder leaves) in small streams across a wide gradient of watershed disturbances. Microbial communities appeared to effectively track changes in their environment with lower hydrolase enzyme activities at all disturbed streams compared to undisturbed streams, and the lowest rates of microbial decomposition, fungal biomass, and differences in microbial community composition at the most severely disturbed streams. Forest and wetland cover were identified as important watershed features that provide DOC to fuel microbial activity in aquatic ecosystems. Increasing road density within the watershed was identified as having a negative impact or association on microbial activity that appeared to be linked to inputs of inorganic solutes that were measured through increased levels of specific conductance in stream water samples. This study is one of the first of its kind and it provides some important evidence that leaf litter associated microbial communities respond to disturbances with quite predictable patterns and as such can be used as good indicators of watershed disturbance and potentially the state of recovery of aquatic ecosystems.

ORAL PRESENTATIONS

3) Stable Isotope and Diet Analyses in Aquatic Food Webs

ISOTOPE MEASUREMENT BY AMS IN THE LABRADOR AND BEAUFORT SEA

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Due to global warming and climate change the Arctic has increasingly become an important topic of debate throughout the scientific community recently. It is seen as important now more than ever that we understand the Arctic and accompanying oceanographic systems.
I^{129} has always been the isotope of choice for measuring ocean current and transit times due to its abundance in the oceans. It was easy to measure with the less robust technology of the time and gave relatively reliable results. However due to its ability to be created in the atmosphere via spallation, and Iodine's importance in biological processes it is victim to several influences which may result in less reliable data.
U^{236} is an anthropogenic isotope that is created over time in standard nuclear reactors and is a product of nuclear explosions. It is not considered important for biological processes and therefore avoids many of the potential shortcomings of I^{129} the issue was that until recently there was no technology sensitive enough to reliably measure its concentration in the ocean.
Samples of U^{236} and I^{129} were collected from the Labrador and Beaufort Seas in 2014 and analyzed using Accelerator Mass Spectrometry which is sensitive enough to measure the low levels of U^{236} present in the oceans. It is hoped that U^{236} can become the new robust isotope of choice for transit time and current measurements in the ocean.

DEVELOPMENT AND APPLICATION OF $\delta^{34}S$ AS A TRACER OF RADIONUCLIDE UPTAKE IN AQUATIC FOOD WEBS THROUGH SEDIMENTARY PATHWAYS

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Sediment is an important environmental sink for many contaminants. Radionuclides and contaminants released into aquatic systems are rapidly bound to suspended particulate material and deposited in the sediments where they may be biologically available to benthic invertebrates and biota. Therefore, the identification of food chains supported by detritus in littoral zones is important for understanding the flow of nutrients and contaminants in aquatic food webs. Stable sulfur isotopes are commonly applied as a means of distinguishing between members of food chains that are based in the water column and those based on sedimentary detritus. The Atomic Energy of Canada Limited (AECL), Chalk River Laboratories (CRL) have documented various accidental releases of radionuclides to the Ottawa River over the last sixty years. Contaminated sediments adjacent to the process output in the Ottawa River and within CRL may have detrimental chemical and radiological impact on resident biota. I propose to trace the flow of organic matter in benthic and littoral zones of freshwater systems affected by historical radionuclides release, using sulfur isotopes to identify the role of sedimentary pathways in radionuclide uptake. Initial $\delta^{34}S$ values measured in Ottawa River and Perch Lake biota at CRL demonstrate that benthic feeding organisms obtain more sulfur from the sediment than from the

water column. I hypothesize that benthic feeding biota will also exhibit the greatest radionuclides uptake supporting the development and application of $\delta^{34}S$ as a tool to predict radionuclide uptake and transfer in aquatic food webs via sedimentary pathways.

A DYNAMIC APPROACH TO MODELING STABLE CARBON AND NITROGEN ISOTOPES IN AQUATIC FOOD WEBS

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Stable carbon and nitrogen isotopes are commonly used to quantify trophic linkages and relationships in aquatic food webs. However, seasonal variation observed in lower trophic levels and in many systems limits the broad applicability of stable isotope techniques. Dynamic approaches that can handle the complexity of seasonal variation in stable isotope signatures would increase the generality of the technique and would lessen the need to force these dynamic data into steady state solutions. In this paper, we present stable isotope data from the Ottawa River and a dynamic solution to seasonal variation in stable carbon and nitrogen isotope signatures. The Ottawa River receives hypolimnetic water from upstream reservoirs, and zooplankton exhibit extreme variation in both stable carbon and nitrogen isotopes. Through a mass balance approach that incorporates field derived estimates of carbon and nitrogen turnover, we describe the seasonal pattern in the pelagic, zooplankton-smelt-walleye food web of the Ottawa River. This mass balance approach is readily applicable to any system and provides a dynamic solution to stable carbon and nitrogen isotope variability at lower trophic levels and its transfer to higher trophic levels.

A NEW PROBABILISTIC METHOD FOR QUANTIFYING N-DIMENSIONAL NICHES AND NICHE OVERLAP

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Much effort has recently been directed toward development of statistical tools that quantify trophic relationships using stable isotope ratios. Fisheries ecologists are often interested in quantifying isotopic niche size and overlap among species, particularly when considering effects of invasive species and anthropogenic stressors. We build upon recent progress in this discipline and present a newly-published probabilistic method for determining niche region and niche overlap. The method quantifies probability of pairwise niche overlap, can be extended to n dimensions, and accounts for uneven distribution of organisms in niche space. Unlike geometric methods, such as standard area ellipses, the method produces consistent and unique bivariate projections of multivariate data. Uncertainty in probability of overlap is accounted for in a Bayesian framework. Application is illustrated with three-dimensional isotope data, but any continuous indicator of ecological niche in any number of dimensions may be used. We suggest

that this represents an advance in our ability to quantify ecological niches as "n-dimensional hypervolumes".

DOES ECOLOGICAL NICHE BROADEN WITH TIME SINCE ESTABLISHMENT FOR INVASIVE SPECIES?

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It is often suggested that for widespread establishment of invasive species, a broad ecological niche is required. The invasive Round Goby (*Neogobius melanostomus*) has a vast geographical establishment within the Great Lakes Basin with varying establishment histories. We hypothesized that populations of Round Goby in longer established locations have broader ecological niches. We used Bayesian ellipses of $\delta^{13}C$ and $\delta^{15}N$ from muscle and liver tissue to depict the isotopic niche of each population in reference to Dreissenid whole tissue. For the 869 Round Goby sampled from 11 locations (total length 65.3 ± 0.7, mean ± S.E) muscle tissue $\delta^{13}C$ ranged from -17.7 ± 0. 2 to -26.0 ± 0.1 and $\delta^{15}N$ ranged from 8.0 ± 0.1 to 14.7 ± 0.1. Despite this range, the isotopic niche of Round goby varied less than 20% annually (2011 to 2013) with the exception of Hamilton Harbour (32%). This variation was matched in the isotopic niche of Dreissenid mussels across sampling sites for 2011 but not 2012 or 2013, which suggests spatial variation in isotopic niche of Round Goby was partly ecosystem driven but also influenced by plasticity in feeding ecology at different sites. All years combined, isotopic niche breadth broadened significantly with time since establishment, ranging 1.85 ± 0.16 to 0.73 ± 0.13 (R2 = 0.34, Standard Ellipse Area ± S.E. Established in 1991 and 2004). Our findings suggest that ecological niche broadens with time since establishment as species adapt to a wider range of resources, as long as additional resources are available.

NICHE WIDTH AND TROPHIC POSITION OF THE BOWFIN (*AMIA CALVA*) IN THE LOWER HURON-ERIE CORRIDOR: AN UNDERAPPRECIATED TOP PREDATOR

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The Great Lakes have a variety of top predators that are integral to the structure and function of food webs and provide a model system for studying niche width and trophic position in freshwater systems. Known as the "living fossil", Bowfin (*Amia calva*) are often overlooked in regards to their status as predators and relationship with other high trophic level fish. Stable isotopes of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) in muscle and liver tissue were used to determine the seasonal and spatial influence on niche width and trophic position of Bowfin. Spring 2013 trophic position estimates based on $\delta^{15}N$ of Bowfin in Mitchell's Bay were 4.8±0.7 (mean ± SE) compared to other top predators in the system; Northern Pike (4.5±0.2), Walleye (4.7±0.1), Longnose Gar (5.1±0.1), and Largemouth Bass (4.6±0.2). Isotopic niche width of Bowfin was larger than, and exhibited a high degree of niche overlap with Largemouth Bass and Northern Pike, but a low degree of overlap with Longnose Gar and Walleye. Trophic positions and niche widths of Bowfin from other seasons and sites will be discussed. Our findings of a broad isotopic niche and comparable trophic positions indicate Bowfin have a broad diet which overlaps with

other top predators in the Huron-Erie Corridor, suggesting Bowfin may be better equipped to respond to fluctuations in prey availability than other top predators in the Huron-Erie Corridor. These results suggest the Bowfin plays an important role in the structure and function of food webs in the Great Lakes.

NICHE SPACE, OVERLAP, AND DIET RECONSTRUCTION OF LAKE ONTARIO SALMONID SPECIES USING STABLE ISOTOPES AND STOMACH CONTENTS

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Lake Ontario has a number of native (Lake Trout and Atlantic Salmon) and non-native (Chinook Salmon, Coho Salmon, Rainbow Trout and Brown Trout) salmonids maintained largely by stocking. Management goals to maintain both highly-valued recreational fisheries by stocking non-native salmonids and to also restore native salmonids raise concerns about the potential for prey resource limitation among salmonids. The objectives of this study are to quantify Lake Ontario salmonid trophic positions (niche overlap and width) and diet using stomach content and stable isotopes (C and N) in muscle tissue. Fish ($n \approx 680$ individuals) were collected across Lake Ontario in 2013 and across size classes (> 300 mm) to determine spatial and ontogenetic trends. Lake Trout has the largest isotopic niche width but has little overlap with the other salmonid species, due to higher $\delta^{15}N$ values that suggest they occupy the highest trophic position. The remaining salmonid species have significant similar isotopic ($\delta^{13}C$ and $\delta^{15}N$) positioning (ANOVA, $p < 0.001$) and trends show similar standard ellipse areas (SEA_c) amid these fish. This is likely due to similar life histories as these salmonids are believed to spend most of their time foraging in epilimnetic, pelagic water targeting Alewife. Diet reconstruction using stable isotope mixing models indicate that Alewife is the most important prey (60 to 80%) for all the salmonid species, which is consistent with stomach content analysis. Brown Trout also show a high dependence on Round Goby (36%) which is not observed in the other salmonids (14 to 20%). Additionally, a diverse diet is observed in Lake Trout which consume the largest amount of Rainbow Smelt, Deepwater Sculpin, and Slimy Sculpin. Stable isotopes suggest that non-native salmonids do not compete with Lake Trout but are in direct competition with Atlantic Salmon for resources.

THE ADDITION OF SULPHUR STABLE ISOTOPES TO STUDIES OF LAKE TROUT FORAGING IN LAKE ONTARIO

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ORAL PRESENTATIONS

Stable isotope analysis is commonly used in foraging studies of aquatic communities over stomach content analysis alone. Carbon isotopes (δ^{13}C) show little fractionation across trophic levels and distinguish between littoral and pelagic resource pathways. In comparison, nitrogen (δ^{15}N) predictably increases with trophic level. More recently, sulphur (δ^{34}S) has been identified for its ability to distinguish between water column or benthic sediment resource pathways in freshwater and to show little to no enrichment across trophic levels. In our study, we added analysis of sulphur (δ^{34}S) to an isotopic study of Lake Ontario lake trout (*Salvelinus namaycush*) foraging. We examined the foraging patterns of lake trout collected from multiple sites around Lake Ontario during 2008 and 2010, along with samples of common prey fishes, invertebrate groups, and pellet food samples from Lake Ontario hatcheries. We observed that small fish (< 250 mm fork length) had higher δ^{13}C and δ^{34}S values consistent with the isotopic compositions of hatchery foods, indicating that isotopes can be used to infer hatchery or wild origin of lake trout during early life stages, but this distinction was not possible later in life, likely due to tissue turnover. Our results support a previous analysis based on δ^{13}C alone that lake trout diet is more closely linked to the nearshore littoral community as compared to the offshore pelagic community. The addition of δ^{34}S to stable isotope studies may increase our ability to refine inferences of foraging patterns and should be considered in isotopic studies of freshwater communities.

HAS THE FEEDING BEHAVIOUR OF LAKE TROUT (*SALVELINUS NAMAYCUSH*) IN LAKE ONTARIO CHANGED IN RESPONSE TO SHIFTS IN PREY FISH COMMUNITY COMPOSITION?

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Lake trout inhabiting the Great Lakes have faced many challenges over the past century. In Lake Ontario, lake trout that were once abundant were considered extirpated by the early-1950s, became the focus of re-introduction efforts in the late-1960s, and presently exist at low abundance levels. Prey fish communities (both native and non-native fish species) in Lake Ontario have also faced many challenges. Changes experienced in the forage fish community can directly impact lake trout by affecting the availability of their food resources. Understanding lake trout diet can help us better understand lake trout ecology, productive capacity, and ultimately success. To characterize lake trout feeding ecology we examined the contents of more than 11,000 lake trout stomachs from 1992 to 2014. Diet results will be related to prey fish abundance, distribution, and how this may affect lake trout behaviour, energetics, and fitness.

ORAL PRESENTATIONS

COMPARATIVE DIET ANALYSES OF FOUR CO-OCCURRING GADOID SPECIES OFF THE SOUTH COAST OF NEWFOUNDLAND

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Southern Newfoundland waters contain a thermal transition zone with complex spring temperature gradients spanning cold (<1°C) shallow shelf habitats to warmer (4-7°C) shelf slopes. This region contains the northern range limits of some gadoid species and recent, observed increases in the abundances of these gadoids may have implications for resident species, including Atlantic cod (*Gadus morhua*). Aboard the *RV Celtic Explorer* in April and May 2012-2014, acoustic-directed bottom trawls yielded samples of haddock (*Melanogrammus aeglefinus*), pollock (*Pollachius virens*), and silver hake (*Merluccius bilinearis*) along the shelf edges and slopes. Sampling was concentrated in these regions as this is where these four species co-occur in the spring. Analyses of stomach contents and spatial distributions facilitated quantification of dietary overlap among four gadoid species. These samples revealed a low degree of diet similarity between Atlantic cod and three other gadoids. Atlantic cod is a more generalist predator relative to the other species in this region and there is no evidence of predation on cod by other gadoids in the spring. The dominant prey species found in Atlantic cod were *Chionoecetes* and *Hyas* crab species and sandlance. Capelin accounted for less than 6% of prey consumed by cod in all years, although it was a dominant species in silver hake and pollock diets. Haddock diet was most similar to cod diet, and was dominated by benthic invertebrates. The extent of diet and spatial overlap at other times of year cannot yet be evaluated given spring sampling.

ARE YOU WHAT YOU EAT? AN ASSESSMENT OF INORGANIC CONTAMINANTS IN FARMED SHELLFISH IN THE HUMAN DIET

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The consumption of shell fish is an important portion of the diet of many segments of the North American population. We surveyed the sources of seafood and shell fish sold in large chain grocery stores in Ottawa, ON Canada. We found that farmed seafood is the dominant or often only type of tilapia, salmon, trout, shrimp, mussels and clams sold to consumers. Broader surveys support this observation that farmed seafood is a rapidly increasing fraction of the seafood consumed throughout North America and in many other areas.

Farmed seafood is reared in different conditions and often has a diet different from their wild cousins. We hypothesized that the different and controlled diet of farmed seafood would lead to lower concentrations of radionuclides and trace metals in their flesh. We tested this hypothesis by measuring the concentrations of several of the most important inorganic contaminants found in the edible portions of seafood.

Clams and mussels have the highest concentrations of these contaminants in any of the seafood tested. The concentrations in farmed clams and mussels fall within the range of values reported

for their wild cousins while the concentrations of Po-210 concentrations in shrimp are lower than their wild cousins

ASSIMILATION OF AQUACULTURE WASTE BY LAKE WHITEFISH IN LAKE DIEFENBAKER, SASKATCHEWAN

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Lake Diefenbaker, a large reservoir located on the South Saskatchewan River in central Saskatchewan, is home to one of the largest inland aquaculture facilities in Canada with a production capacity of 1750 metric tonnes of rainbow trout per year. Lake whitefish (*Coregonus clupeaformis*), zooplankton, aquatic invertebrates and particulate organic matter (POM) were sampled throughout the reservoir in 2012 and 2013. Whitefish were weighed, measured and gonad weight recorded. In gravid females, a subsample of eggs was taken to assess fecundity. Aquaculture waste products (pelleted fish feed, fish fecal matter and domestic rainbow trout tissue) were collected directly from the aquaculture facility. Carbon and nitrogen stable isotope analysis was used to assess the importance of the aquaculture waste to the diet of lake whitefish throughout the reservoir. Lake whitefish collected directly adjacent to the aquaculture cages showed $\delta^{13}C$ and $\delta^{15}N$ values indicative of a diet consisting largely of aquaculture waste. Whitefish collected throughout the rest of the reservoir showed no influence of aquaculture waste products to their diets. Relative weight (W_r) was used as a measure of overall condition. Whitefish feeding on aquaculture waste had higher relative weights than those that were not. Impacts of the aquaculture facility on the diets of lake whitefish found in Lake Diefenbaker appear to be restricted to the area immediately surrounding the cage culture facility.

BEFORE OVERWINTERING – FEEDING OF THE NEWFOUNDLAND CAPELIN STOCK

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Pelagic forage fishes are an important component of aquatic food webs, transferring energy between mesozooplankton and large vertebrate predators such as piscivorous fishes, birds and mammals. Within the Newfoundland and Labrador shelf, the capelin (*Mallotus villosus*) population has collapsed during the early 1990s and has not yet recovered. Previous research suggests that bottom-up control explains the lack of recovery. To further explore potential trophic effects driving capelin dynamics, the main objective of this study is to describe the feeding ecology of this key forage species during before there overwintering period (September – December). The research includes the following specific objectives: (1) identifying the key prey taxa and quantifying their contributions to gut content of capelin sampled by Fisheries and Oceans Canada in the autumn surveys of 2008-2012; (2) determining the spatial variation in diet

and distribution of Newfoundland capelin stock; and (3) identifying possible environmental factors influencing temporal and spatial variation in diet and driving population dynamics. By yielding key information on capelin feeding ecology and the nature of trophic interactions with lower trophic levels, this research will inform management of the Newfoundland capelin stock and of predatory fish stocks that depend on abundance of this forage resource.

UNDERSTANDING THE ISOTOPIC STRUCTURE OF LAKE WHITEFISH SPAWNING AGGREGATIONS OF LAKE HURON

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Lake Whitefish (*Coregonus clupeaformis*) is an ecologically important and commercially valuable species in the Great Lakes. In Lake Huron their current population structure is of interest because of dramatic prey-base changes in recent years and changes in body condition and diet, in addition to anthropogenic stressors. Previous studies on population structure have primarily used tag-and-recapture, catch, and genetic data, but a more contemporary and ecological approach is needed. Here we investigate the isotopic structure of an extensive lake-wide collection of 31 spawning aggregations collected in 2012 from Lake Huron's main basin, North Channel, and Georgian Bay. $\delta^{13}C$ values of muscle tissue show 10‰ total variation across groups, and 2.7‰ - 7.2‰ ranges within groups. We identified an isotopically unique group of fish in northern Georgian Bay. Our results provide strong evidence for both high resource use variability and isotopic structure in Lake Huron. Isotopic analysis of muscle tissue and stomach contents from 12 additional summer feeding locations in 2014 will determine the amount of isotopic variation that can be explained by spatial baseline differences, feeding preferences, and potential fish mixing during spawning. This study will provide a unique and previously unexplored view of Lake Whitefish ecological structure.

BRAINIACS: A FOOD WEB APPROACH TO STUDY THE RELATIONSHIP BETWEEN ECOLOGY AND BRAIN SIZE IN FRESHWATER TELEOST FISHES.

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Predators at the top of trophic pyramids have stabilizing roles in food webs through top down control. However, the characteristics that confer predators their ability to occupy high trophic levels are largely unknown. Larger brains may be the answer, as the brain is responsible for cognitive and sensori-motor processing involved in many aspects of trophic and environmental

interactions. In fish, the brain is a plastic organ susceptible to changes in morphology due to selective pressures. Trophic position, habitat use flexibility (habitat coupling), and features of the environment could all be driving forces for changes in brain size during ontogeny (phenotypic plasticity) or by natural selection across generations. This study investigated the influence of ecological variables in a food web on brain size in fish. Eleven teleost fish species from the Parry Sound area of Georgian Bay, Lake Huron were investigated using stable isotope analysis for 13C and 15N isotopes to generate data on trophic level and habitat use. The relationship between the ecological variables and body size-corrected brain size residuals were analysed using generalized estimating equations. Preliminary results based on specimens collected in summer 2013 show that brain size residuals increase significantly with trophic position (X^2_W= 5.241, p=0.022) and habitat use flexibility (X^2_W=5.940, p=0.015). This correlative evidence indicates that trophic level and habitat use may be important drivers of brain size in fish and help us understand the contribution of food web interactions on the shaping of a plastic anatomical trait relevant to behaviour.

RIPARIAN, MARINE AND FLOODPLAIN SUBSIDIES FUEL WATERHOLE FOOD WEBS IN DYNAMIC TROPICAL RIVERS

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Few rivers worldwide remain unregulated with an intact flow regime that enables seasonal expansion and contraction of aquatic habitat and subsequent feeding opportunities for mobile consumers. An exception is the free-flowing rivers of Australia's wet-dry tropics that harbor diverse and productive assemblages of fish and other aquatic organisms. Here we use stable isotopes of C, N and S to understand how these food webs are maintained by external subsidies. We evaluate the role of three "internal" (plankton, periphyton, macrophytes) and four "external" (leaf litter, floodplain, marine, savanna) sources of production in fuelling body mass of a range of vertebrate consumers from tiny blue-eye (*Pseudomugil* spp., maximum size < 4 cm) to saltwater crocodiles (*Crocodylus porosus*, maximum size > 4 m), all of which pack into constricted waterholes for approximately half the year. We find that larger organisms derive most of their diet from outside the waterholes, exemplified by barramundi (*Lates calcarifer*) that feed in coastal areas before retreating back to the waterholes, and saltwater crocodiles that obtain more than 75% of their diet from external sources, including mammalian prey. While many small organisms can be supported solely by internal sources, these results clearly demonstrate how the production of many iconic and commercially important species is made possible because of the intact lateral and longitudinal connectivity in these river basins, a feature that has been lost or is under threat in many parts of the world.

ORAL PRESENTATIONS

INSIGHTS ON FOOD WEB ORGANIZATION IN LATERAL DEPTH GRADIENTS ALONG A FRESHWATER-ESTUARINE CONTINUUM.

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Studies on lateral gradients in rivers and estuaries are rare, despite physical differences in light and temperature along these gradients that likely alter ecological structure and function. Using a stable isotope approach, we provide insights into trophic organization and basal food sources sustaining fish fauna between shallow and deep habitats situated along a freshwater-estuarine gradient in Patos Lagoon, Brazil, one of the largest coastal lagoons in the world. Food web components were sampled in shallow (<1.5m) and deep (~5m) habitats in three major regions: I)Freshwater, II)Upper Estuary and III)Lower Estuary. Linkages between basal food sources and consumers were established using a Bayesian stable isotope mixing model. Kruskal-Wallis tests revealed significant differences ($p<0.05$) in $\delta^{13}C$ values of basal food sources and fish between shallow and deep habitats for nearly all regions. Mixing model outputs revealed that dominant flows of energy were associated with the benthic system. Fish in deep habitats were mainly dependent on particulate organic matter in the sediment (SOM). In contrast, emergent macrophytes, commonly found along the lagoon's margins, were as important as SOM to consumers in the shallow littoral zone. This strong trophic benthic subsidy apparently explains not only the higher fish diversity found in shallow areas but also high fish densities, especially for zoobenthivores in deeper areas. Although fishes play important roles as habitat couplers, our results suggest that trophic organization in shallow and deep areas are partially segregated and should be considered as different subsystems, both in freshwater and estuarine reaches of this important coastal lagoon.

4) Aquaculture and Its Impacts on Aquatic Environments

MANAGING SEA LICE ON FISH FARMS TO PROTECT WILD SALMON

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A decade ago, a native parasitic copepod emerged as a major conservation issue for some wild salmon stocks in British Columbia. Epizootics of sea lice of wild juvenile salmon were associated with fish farms in the Broughton Archipelago. Some populations declined in response to the epizootics, and policy was implemented to control parasites on fish farms. Sea lice population dynamics are sensitive to abiotic conditions of temperature and salinity. Control of parasites on fish farms is conducted by in-feed parasiticide treatment with emamectin benzoate, Slice. Models suggest treatment in late winter is optimal for minimizing exposure of wild juvenile salmon during the spring out-migration season. Winter treatment on farms has become increasingly synchronized among farms, though perhaps not due to coordinated management but rather as a dynamical consequence of coupled oscillator theory. This new treatment regime has resulted in a major decline in sea lice abundances on wild juvenile salmon, and occurs due to changes in treatment timing without an increase in the frequency of treatment. Wild salmon have

shown an increase in marine survival in response to improved parasite control under the current management regime.

A CULTURED PHENOTYPE IN FISHES AS REVEALED THROUGH META-ANALYSIS AND GEOMETRIC MORPHOMETRICS OF ATLANTIC COD (*GADUS MORHUA*)

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Many authors make reference to the existence of a 'cultured phenotype', common to fishes that have been exposed to culture. This phenotype is most often presented in a manner that implies that its existence across species and types of culture is definite. However, we were unable to find either a review or formal analysis that has shown this to be true.
We sought to determine through a formal review and meta-analysis of the literature if indeed a 'cultured phenotype' exists and if so, are the differences in morphology between cultured and wild Atlantic cod consistent with it.
Our preliminary review and analysis of the literature, using vote counting, revealed consistent morphological differences between cultured fish and their wild conspecifics. Cultured cod were found to develop different morphology than their wild counterparts, and the morphology of the cultured cod appeared to match the stereotypical morphological response to culture seen in the majority of fishes.
The results of a more formal meta-analysis will also be presented as well as a discussion of best practices for reporting differences in morphology so that between-study comparisons are made easier.

POTENTIAL IMPACTS OF FARM SALMON ESCAPES ON WILD POPULATIONS THROUGH REPRODUCTIVE INTERACTIONS

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Escapes from aquaculture sites can pose both ecological and genetic risks to native species. Wild Chinook salmon (*Oncorhynchus tshawytscha*) populations could be adversely affected through reproductive interactions with escaping farm salmon. To determine the reproductive ability of farm Chinook salmon relative to wild salmon, we compared sperm traits, as well as competitive fertilization and reproductive success in spawning channels. Farm Chinook salmon males had greater sperm performance relative to wild males, and farm males were equally successful at competing for mates and fertilizing eggs in spawning channels. Farm salmon males may thus pose an ecological risk to wild populations by removing reproductive opportunities from wild males. However, farm-sired offspring experienced significantly lower survival to the fry stage, which could mediate any impact on the wild population. Nevertheless, given that hybridization can lead to negative genetic effects via outbreeding, we also tested for outbreeding depression over two generations in Chinook salmon by measuring fitness related traits in outbred individuals in captivity. We found no evidence of outbreeding depression in Chinook salmon,

which further suggests that the introgression of farm genes into wild populations would not result in negative consequences for wild salmon populations. Overall, our study demonstrates that farm salmon escapes may pose potential ecological risk to wild populations however the genetic risks associated with these escapes may be limited.

GENETIC AND ENVIRONMENTAL DETERMINANTS OF ALTERNATIVE REPRODUCTIVE TACTICS IN CHINOOK SALMON, *ONCORHYNCUS TSHAWYTSCHA.*

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When males within a species compete in different ways over the availability of females, alternative reproductive tactics (ARTs) in the form of alternative phenotypes may occur. ARTs are found in multiple vertebrate taxa, including Chinook salmon, *Oncorhyncus tshawytscha*, where males exist in two phenotypes: large "hooknose" males and smaller "jacks" that reach sexual maturity after only 1 year in seawater and before any females or hooknose males of the same cohort. The mechanisms behind ARTs involve both genetics and the environment, with the latter affecting differential growth rates through competition for resources, aggression, or a combination of the two. The objectives of the current study are to: (1) determine the genetic architecture of jacking (i.e., the significance of maternal, additive, and non-additive components); and (2) provide evidence that growth rate is a predictor of jacking in Chinook salmon. To examine the genetic architecture of ARTs, Chinook salmon offspring resulting from a full-factorial breeding design were raised until sexual maturation. Growth rates of jack, hooknose, and female Chinook salmon during the one-year period prior to sexual maturation of jacks was recorded in order to assess differential growth rates amongst the three life histories. Salmon are an important source of income in the aquaculture industry; however, because jacks are smaller in size and have poor flesh quality, fish farming hatcheries experience a loss of economy associated with resources invested in raising these individuals. Information regarding the mechanisms behind ARTs may allow aquaculture practices to reduce the incidence of jacks and increase profit.

INFLUENCE OF HYBRIDIZATION WITH DOMESTICATED CONSPECIFICS ON ALTERNATIVE REPRODUCTIVE PHENOTYPES IN MALE ATLANTIC SALMON IN MULTIPLE TEMPERATURE REGIMES

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Alternative reproductive phenotypes are a means by which organisms can respond to environmental conditions. Understanding the effect of hybridization on reproductive phenotypes is of particular importance in the context of interbreeding between domesticated and wild

animals. Domesticated individuals are subject to artificial selection to obtain a phenotype associated with commercially desirable traits within stable, controlled environments. This could result in a reduced capacity to express some reproductive phenotypes or plastically respond to environmental variation, resulting in fitness consequences for domesticated-wild hybrids. Male Atlantic salmon (*Salmo salar*) possess two conditional reproductive phenotypes that are ideal for studying the effect of domesticated-wild hybridization on reproductive phenotypes and their plasticity: a large, migratory form (anadromous males) and a smaller, younger, and generally non-migratory form (mature male parr). We generated crosses of one wild population and domesticated-wild hybrids (F1, wild backcrosses), and reared them under three different temperatures to determine the effects of hybridization and thermal regime on levels of parr maturation. Parr maturation exhibited a significant quadratic relationship with body mass. Cold thermal regimes inhibited maturation, but moderate and warm thermal regimes had no effect on overall levels of parr maturation. However, the sizes at which male parr exhibited maturation increased between moderate and warm thermal regimes. Although size-related maturation thresholds did not differ between crosses, F1 hybrids and backcrosses exhibited drastically reduced levels of male-parr maturation relative to wild fish (4.8%, 9.3%, and 30.1%, respectively). This reduction could have significant negative genetic and fitness consequences for wild populations exposed to domesticated escapees.

5) Conservation and Rehabilitation of Natural Habitats and Biodiversity

INFLUENCE OF METABOLIC RATE ON MIGRATORY BEHAVIOUR IN LAKE SUPERIOR BROOK TROUT (*SAVELINUS FONTINALIS*)

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The relationship between metabolic rate and behaviours believed to be tied to migration were tested in a population of polymorphic Brook Trout from Nipigon Bay, Lake Superior. Two distinct ecomorphs of Brook Trout (*Salvelinus fontinalis*) reside in Lake Superior and its surrounding tributaries. Residents are smaller in size and remain within the tributaries whereas migrants are larger in size and move between tributaries and the lake. The migrant form has greatly declined in abundance and is of conservation concern. In 2011, migrant and resident adults were caught and crossed generating 26 families that were either migrant or non-migrant. In 2014, 3 individuals (year 2+) from 20 families were put through a series of respirometry and behavioural experiments (n=60). The resting and maximum metabolic rate of each individual was measured using intermittent flow respirometry. Behavioural experiments measured time to exit refuge (risk-taking behaviour), proportion of time spent moving (general swimming activity), and net displacement (propensity to disperse). It is predicted that individuals that exhibit higher resting and maximum metabolic rates will take less time to exit the refuge, spend a greater proportion of time spent moving, and have a greater net displacement. A possible link between behaviour and metabolism may provide valuable insight as to why some individuals adopt the migrant over resident lifestyle which will ultimately aid in the conservation and rehabilitation of the migrant ecomorph.

ORAL PRESENTATIONS

DOES VARIATION IN BEHAVIOUR OF TWO ECOTYPES OF LAKE SUPERIOUR BROOK TROUT (*SALVELINUS FONTINALIS*) INFLUENCE PROPENSITY TO DISPERSE?

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We tested if offspring from different ecotypes of Brook Trout (*Salvelinus fontinalis*) caught from tributaries along the north shore of Lake Superior showed consistent individual differences in behaviours hypothesized to be associated with an individual's propensity to disperse. Lake Superior Brook Trout have at least two ecotypes: a smaller resident form that permanently resides in stream tributaries and a larger bodied form that migrates between the tributaries and the lake. The abundance and distribution of the migrant ecotype has been severely reduced resulting in a bi-national interest in the restoration of historic populations. Adult resident and migrant fish were captured and crossed to create 22 families. Two year old individuals from these families were used to test for individual differences in behaviour including time to exit refuge (risk-taking), proportion of time spent moving (general activity), and proportion of time spent close to reflection (social behaviour). These behaviours were linked to an individual's propensity to disperse in a controlled laboratory experiment. Multi-state Markov models will be used to correlate movement data and individual predictors to estimate transition rates for individuals. This research will aid managers in conservation efforts focused on the restoration of Lake Superior Brook Trout and ultimately contribute to our understanding of partial migration.

THE EVOLUTION OF MOVEMENT RATE IN HIGHLY MOBILE PELAGIC SPECIES AFTER THE ESTABLISHMENT OF LARGE MARINE RESERVES

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Fisheries biologists have claimed that marine protected areas will have a negligible effect on preserving stocks of tuna or sharks in the Pacific Ocean. This is because tuna and sharks move a lot, and most marine reserves are small. Even the biggest marine reserves will be 400 nautical miles across, and many tuna travel more than 1000 nautical miles over their lifetime. But, it is also the case that many individuals are ‘lazy’ and move less than 50 nautical miles over their lifetime. It is reasonable to expect that the offspring of highly mobile tuna and sharks will inherit their parents’ high mobility, and the offspring of ‘lazy’ (less mobile) individuals will inherit their parents’ laziness. It is also likely that lazy individuals are more likely to stay in a reserve and survive, while highly mobile individuals are more likely to leave the reserve and die. Over several generations, the number of lazy fish should go up, and the number of highly mobile fish should go down. This evolution should result in an increased density of fish in the marine reserves, and a shift in the average fish’s behavior. We are combining a population dynamic model (wherein populations go up or down depending on fishing) with an evolutionary dynamic model (wherein the number of lazy or highly mobile individuals goes up or down depending on which is most likely to be fished) to predict the effect of marine reserves on tuna and shark stocks. The fact that some individuals are lazy and some individuals move a lot is a basic ingredient for the evolution of movement distance. What we am trying to show is that, perhaps,

ignoring the possibility that fish will evolve gives fisheries managers an unreasonably negative impression of how effective marine reserve can be.

PHENOTYPICALLY PLASTIC NEOPHOBIA: WHAT CAN TROPICAL FISH TEACH US?

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Prey rely on public information about local conditions to balance the conflicting demands of predator avoidance and other activities such as foraging and reproduction. However, environments undergo both short and long term changes resulting from a combination of natural and anthropogenic pressures, leading to increased uncertainty among prey animals. We have recently proposed that 'phenotypically plastic neophobia' may function as an adaptive mechanism to allow prey to reduce the costs associated with uncertain predation threats. In a series of laboratory and field trials, we have shown that: 1) elevated predation risk, even over a period of a few days, can induce an antipredator response to novel predator cues, 2) prey retain induced neophobic responses for ecologically relevant periods, 3) neophobia shapes the strength and retention of predator recognition learning and 4) exposure to increased predation risk is linked to neophobic foraging and space use patterns. An intriguing possibility is that this phenotypically plastic neophobia can be used in life skills training protocols. We will discuss our current results as a potential tool to enhance post-stocking survival of hatchery-reared fishes such as Atlantic salmon.

EGG MORTALITY AND DEVELOPMENT OF WILD ATLANTIC SALMON (*SALMO SALAR*) IN THE MIRAMICHI RIVER SYSTEM

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An understanding of the early life stages of the Atlantic salmon (*Salmo salar*) is essential for quantifying juvenile recruitment and establishing baselines for more accurately assessing the impacts of environmental disturbances**.** The objective of this research is to assess Atlantic salmon egg survival and development in a range of natural spawning sites in the Miramichi River system from October - May for two years (2013-2014 and 2014-2015). Three riffles in five river reaches were selected based on observed spawning activity. Within each riffle, six artificial redds were seeded with 400 eggs collected from wild broodstock, for a total of 36 000 eggs. Three redds were sampled at the eyed stage of development (at ~200 degree-days, in March), and three were sampled after the spring freshet (late May). Relative egg survival was calculated using hatchery-incubated controls. Dead eggs were collected at each sampling period and "cleared" using Stockard's solution to determine stage of development and approximate time of death. A variety of abiotic variables were measured over the winter incubation period. Correlations between the abiotic environmental variables measured (water temperature, DO concentration, groundwater contribution, water level, ice formation/cover and sedimentation) and egg survival and development from the first year (2013-2014) will be presented, with

preliminary data from the second year (2014-2015) included. Strong relationships are already being observed in preliminary analyses. Implications for future salmon management will also be discussed.

LINKING BEHAVIOUR AND CONSERVATION: LESSONS FOR SALMON STOCKING AND HABITAT IMPROVEMENT

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Several years' worth of field experiments and observational studies involving the antipredator behaviours of young-of-year Atlantic salmon (*Salmo salar*) and the differences in relative predation pressure they experience in nursery streams in the Miramichi system yielded surprising suggestions towards improving the success rate of stocking programs and enhancing habitat improvement strategies. Many studies have explored different aspects of life skills training for hatchery-reared fish, including conditioning exposures to predator cues and rearing in high-complexity settings mimicking natural conditions, yet even trained fish still appear to experience substantial mortality rates immediately following their release. At the end of a tethering experiment, surviving hatchery-reared salmon demonstrated strong preferences for the sites they had been occupying and almost all fish immediately took shelter under the substrate following their release. Observations on microhabitat selection by free-swimming fish revealed that in streams where predation pressure was estimated to be greater based on the tethering experiment, salmon were preferentially occupying sites with coarser-grained substrates, potentially sacrificing longer fields of view for greater abundances of physical refugia. Careful *a priori* selection and preparation of release sites based on proximity to cold-water plumes and high substrate complexity, in combination with enforced residency within the release area via predator-excluding barriers for some initial acclimatization period (hours – days), may serve to reduce or eliminate the high observed levels of post-stocking mortality.

THE EFFECT OF HABITAT COMPLEXITY ON ATLANTIC SALMON BEHAVIOUR

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Increasing the complexity of stream environments by adding boulders is a common method of increasing or restoring habitat quality for stream salmonid fishes. However, the costs of territorial defence for visually-oriented animals increases in low visibility environments because it is harder for defenders to detect potential intruders and prey items. Previous work indicates that the density of young-of-the-year Atlantic salmon increases with habitat complexity, yet the fitness costs to individuals have not been investigated. This project tested the predictions that increasing the habitat structure would cause a decrease in: (1) the rates of foraging and (2) aggression, (3) territory size and (4) growth rate in wild young-of-the-year Atlantic salmon. Trials were performed in mesh net enclosures at Catamaran Brook, New Brunswick. Individually

tagged fish were weighed, measured and stocked at densities of 1 fish/m^2. Fish were exposed to one of two habitat treatments: fine gravel substrate (low complexity) or fine gravel substrate with boulders added (high complexity). Our results suggest that fish from low complexity environments had higher foraging rates, aggression rates, and territories than fish in high complexity environments, however growth rate did not differ significantly.

PERFORMANCE OF THREE CANDIDATE POPULATIONS OF ATLANTIC SALMON FOR REINTRODUCTION INTO LAKE ONTARIO: COMPETITIVE ABILITY AND THIAMINASE TOLERANCE

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Atlantic salmon were once abundant in Lake Ontario, but were extirpated by 1898. A large-scale restoration effort has been initiated, but faces significant challenges. Two potential hurdles for establishing self-sustaining populations are (1) competition with introduced (non-native) salmonids and (2) ecological effects from thiamine deficiency due to consuming high thiaminase-containing prey fishes. It is unknown whether the source populations being used for the restoration effort (LaHave, Sebago, and Lac Saint-Jean) possess pre-existing coping abilities or adaptations for these challenges. In separate experiments, we examined the effects of competition with four non-native salmonids and a high thiaminase diet on juvenile Atlantic salmon from the three candidate populations. Juvenile salmon were placed into artificial streams with four non-native salmonids: after 10 months, the presence of brown trout followed by rainbow trout had the greatest negative impact on the survival and growth of the Atlantic salmon, whereas there was little impact from the presence of Chinook and coho salmon. In a separate experiment, sub-adults (age 2+) from each Atlantic salmon population were given a high thiaminase diet, produced by mixing bacterial thiaminase *into prepared feed.* After 8 months, swimming performance was reduced and there were trends for changes in body appearance. Sebago and Saint-Jean tended to have better performance than LaHave, especially on the high thiaminase diet. We discuss candidate population selection theory for restoring extirpated populations.

STRATEGIC RESTORATION OF ATLANTIC SALMON (*SALMO SALAR*) HABITAT – A CASE STUDY OF A PARTNERED APPROACH TO RESTORING A SUBWATERSHED IN THE GREATER TORONTO AREA

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Conservation and rehabilitation of natural habitats and biodiversity is essential to the health and survival of many sensitive coldwater fish species; without high quality habitat for spawning, migration and juvenile growth, Atlantic Salmon (*Salmo salar)* and trout would not survive. The Lake Ontario Atlantic Salmon Restoration Program is a large multi-level private-public

partnership to restore a self-sustaining population of Atlantic Salmon to Lake Ontario, where the species has been extirpated since the 1890s. The extirpation was primarily from historic farming and development practices on the landscape and watercourses along Lake Ontario, which affected natural ecological processes including the movement of water and sediment, storage of flood waters, recharge of groundwater, and habitat diversity. This Greater Toronto Area coldwater habitat restoration case study is a 700ha priority catchment area of the Mitchell Creek subwatershed (Duffins Creek, Pickering). The catchment was prioritized by Toronto and Region Conservation (TRCA) through the use of an Integrated Restoration Prioritization (IRP) process incorporating hydrology-based desktop and field techniques. Guided by this planning process, and through partnerships with TRCA, Transport Canada, Ministry of Natural Resources and Forestry and Ontario Federation of Anglers and Hunters, 7km of re-connected watercourse were restored. Project-specific partnerships have allowed for the synergy of resources to decommission four online ponds, plant 6.5ha of riparian zone and enhance 4ha of wetland habitat. The metrics used to identify Mitchell Creek as a priority will be re-assessed once work is completed and are important for measuring the ecological benefits of these habitat restoration projects.

RIDEAU VALLEY WATERSHED FISH HABITAT ENHANCEMENT PROJECTS

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The Rideau Valley Conservation Authority in partnership with a wide variety of partners including Fisheries and Oceans, Environment Canada, Shell Fuelling Change Program, Muskies Canada - Ottawa Chapter, National Defence Fish and Game Club, Community Foundation of Ottawa, Otty Lake Association and the Ottawa Flyfishers Society have partnered to create, restore and enhance fish habitat in the Rideau Valley Watershed in 2014. There are three projects to highlight 1) Brewer Park Pond Restoration involves reconnecting 16000 m² of fish habitat back to the Rideau River 2) Jock River wetland embayment created 1000 m² of new spawning, nursery, rearing, and feeding habitat for the 40 species of fish that reside in the Jock River and 3) Otty Lake smallmouth bass habitat enhancement project.

EFFECTIVENESS MONITORING OF FISHES IN MECHANICALLY RESTORED FISH HABITATS IMPACTED BY INVASIONS OF *PHRAGMITES AUSTRALIS* (COMMON REED).

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Phragmites australis (Common Reed) has expanded rapidly within Long Point Bay, Lake Erie, Ontario. In response, efforts are underway by municipal, provincial and non-government organizations to mechanically remove invasions. The primary goal of these efforts is to restore

open water habitat lost through the invasion. In 2012, DFO and MNR began a three year effectiveness monitoring program in Long Point Bay. This was initiated to: 1) determine the use of newly created open-water habitats by native wetland fishes; and 2) assess the quality of the newly restored habitats. Wetland sites were assessed by sampling newly (2012) and recently created (6-7 years old) wetland habitats, and nearby reference sites. Fishes were sampled by five repeated hauls of a 9 metre bag seine within a 75 m^2 area, enclosed by a block-net. Fish community has been sampled twice per year for the first two years of this study.

MULTISPECIES SPACE USE AND MOVEMENT IN RESTORED HABITAT IN THE TORONTO HARBOUR

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Widespread development has led to impairment of freshwater coastal embayments, which provide critical and unique habitat for most fish species. In the Toronto Harbour Area of Concern (AOC), restoration efforts have been directed towards improving the amount and quality of fish habitat in the harbour. In order to evaluate the effectiveness of this restoration work, it is important to determine whether both target species (e.g., Northern Pike) and the fish community as a whole are using restored areas. From 2012 to 2014, eighty-five individuals from six species (Common Carp, Largemouth Bass, Northern Pike, Walleye, White Sucker, and Yellow Perch) were tagged and tracked using a large acoustic telemetry array in Toronto Harbour. We present results from this ongoing embayment-wide study evaluating: 1) the use of restored areas by these six species based on occupancy models and 2) species-specific movement patterns among coastal embayments and between the inner and outer harbour sections. Results from this study will help determine the success of past restoration efforts in the Toronto Harbour and inform the development of future restoration projects.

INDIVIDUAL PHYSIOLOGICAL HEALTH METRICS AS A PROXY FOR EVALUATING RESTORATION SUCCESS – LESSONS FROM THE COASTAL WETLANDS OF THE ST LAWRENCE RIVER

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ORAL PRESENTATIONS

The concept of contingency in restoration ecology contends that land use legacies, management actions and landscape setting all impinge on the successional trajectory of restored ecosystems; however the relative influence of each factor remains unclear. In this study we use the individual physiological health status of a ubiquitous model fish species (*Lepomis gibbosus*) to evaluate the success of a habitat enhancement initiative in the coastal wetlands of the St. Lawrence River. The use of individual health metrics (blood glucose, hematocrit, organosomatic indices and energy density) as an indicator of habitat condition represents a novel approach to characterizing restoration success. Our findings suggest that landscape setting may be a prominent driver of individual response to restored habitats, and we provide relevant lessons for evaluating individual fitness in a landscape context.

EVALUATING EXCLUSION FENCING AND ECO-PASSAGES AS A MITIGATION STRATEGY

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The expansive road network in Southern Ontario has resulted in habitat fragmentation and road mortality, affecting many species in this biodiverse region. Construction of the Long Point Causeway in 1927 separated Big Creek Marsh from Long Point Bay, and made this the 5th deadliest road in North America for freshwater turtles, including the Blanding's turtle (BLTU) and the spotted turtle (BLTU). In 2008, exclusion fencing was installed along the causeway to prevent turtles from accessing the road. To allow turtles to safely cross the road, three eco-passages were installed in fall 2012. Our first objective was to determine the effectiveness of exclusion fencing in reducing road mortality by evaluating survey data collected 5 years before and 5 years after fencing installation. Our second objective was to determine if BLTU use eco-passages. For this component, we installed stationary antennas at the outflow of each eco-passage to monitor the movements of 30 PIT-tagged turtles. We found that only fully fenced road sections were associated with a significant decrease in mortality of both BLTU and SPTU; the partially fenced road sections showed no significant difference compared to unfenced sections. We confirmed that two male BLTU utilized the large aquatic eco-passage to move safely between habitats. In summary, the combination of exclusion fencing and eco-passages has significantly reduced road mortality and successfully provided safe passage and habitat reconnection for some of the province's most at-risk turtles. We recommend that fencing and eco-passages be used as a conservation strategy within southern Ontario.

REKINDLING THE ASSOCIATION WITH THE DECLINING AMERICAN EEL THROUGH STEWARDSHIP THAT ENGAGES THE YOUNG

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ORAL PRESENTATIONS

American eels (*Anguilla rostrata*) have long been revered and relied upon as a dependable food resource by Aboriginal peoples of the St. Lawrence and Ottawa river watersheds. This valued association is rapidly being lost for everyone because of the dramatic decline of the species caused by the accumulation of many factors and the unique migratory life cycle of eels. Eels are universal integrators and important indicators of the well-being of both freshwater and marine environments. Restoring this long-standing association between eels and people is important in not only recovering the species but informing humans of their impact on aquatic systems. We report stewardship initiatives that are critical in rekindling this association with the American eel. To encourage good stewardship, we emphasize the use of intriguing eel biology (e.g., ongoing studies of winter habitat and the unique communal wintering "balling" in soft bottom silt) to fascinate and inform people of the mysteries of eels. Through outreach programs in schools, we focus on stewardship in young students (producing murals and mobiles) and, through these engagements, their families. Fun and hands-on knowledge of eels has been initiated through the Society of Conservation Biology in schools in the Kingston area by a series of games and activities developed specifically for the project (e.g., Eels and Ladders, Eel Jeopardy). Instilling knowledge, respect, and passion for eels will inspire families to become stewards of the species and to support their recovery and rehabilitation, as well as protection of the aquatic environment.

CONTAMINATION AND MULTI-DECADAL DECAY OF RESERVOIR-LIBERATED MERCURY IN A DOWNSTREAM FISHERY: EFFECTS OF FISH TROPHIC LEVEL, SIZE, AND AGE

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Hg contamination can pose risks to both human health and commercial fisheries. When reservoirs are constructed in rivers the resulting flow reduction and flooding of vegetation can promote Hg methylating bacteria that can transform this relatively benign contaminant into the far more toxic methyl-Hg (MeHg) form. As a consequence, multiple jurisdictions have set commercial fish maximum Hg concentrations at 0.5 mg/kg. Hg concentrations in both artificial reservoirs and affected downstream sites can exceed this limit and take decades to decay to background concentrations after impoundment. To date, data are lacking on mercury decay rates and the biological factors that mediate these rates in linked contaminated systems. The present study examines the characteristics of fish affecting mercury decay between a hydroelectric reservoir created in 1963 and an affected site downstream in the Saskatchewan River Delta. Rates of decay in Tobin Lake (reservoir) and Cumberland Lake (delta) were analyzed using exponential regression. Northern pike (*Esox lucius*), sauger (*Sander canadensis*), goldeye (*Hiodon alosoides*), and walleye (*Sander vitreus*) all showed significant decay rates between the 1970s and present (Tobin: $p < 0.05$ for all regressions; Cumberland: $p < 0.01$ for all regressions). In *S. vitreus*, contemporary Hg concentrations were strongly correlated with length and age. Stable N isotopes were used to assess correlations between Hg and trophic levels, but explained little additional variation beyond that accounted by length and age. Our results suggest that concentrations have decayed to levels that are acceptable under consumption guidelines.

ORAL PRESENTATIONS

COMPARING ECOSYSTEM FUNCTION OF RESTORED AND NATURAL PRAIRIE PONDS

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Although the role of inland waters in the global carbon cycle is increasingly understood, there is a dearth of information concerning prairie ponds, despite their ecological and hydrological importance in North America. Over half of these ponds have been drained for agricultural development, though some have been restored in the hope of recovering lost ecosystem services. In this investigation, we compare the metabolism (ecosystem function) of prairie ponds along a gradient of restoration age, and address to what extent their metabolisms differ. Metabolic status of ponds was assessed using the diel oxygen method coupled to measurements of CO_2 fluxes. We find that restored ponds were consistently net heterotrophic between the two years of measurement, whereas a natural, never-drained pond was heterotrophic in one and autotrophic in the other. CO_2 fluxes told a similar story, but proved to be a relatively insensitive tool for understanding metabolism at finer time scales in a high-pH system. When scaled up to the considerable area covered by prairie ponds, these results have significant implications for carbon cycling in a future, warmer, world.

THRESHOLD RESPONSE OF BENTHIC AND FISH COMMUNITIES TO ECOLOGICAL STRESSORS IN THE CREDIT RIVER, ONTARIO, CANADA.

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Dramatic changes in invertebrate and fish communities have been observed over the 14-year (1999-2012) Integrated Watershed Monitoring Program (IWMP) record in the Credit River upstream of the Highway 10 South monitoring station. The two most concerning changes have been the near total loss of brook trout (*Salvelinus fontinalis*), which occurred sometime between 2005 and 2007, and the increase of pollution tolerant worms (Oligochaeta), which occurred between 2002 to 2006 reaching a relative abundance of nearly 80% of the invertebrate community. An analysis of all IWMP monitoring data at or near the station was undertaken to determine what environmental factors best explained these observed changes. Results suggest that mean annual total phosphorus and nitrogen (nitrate+nitrite) loading were significantly related ($r2 = 0.85$; $p=0.02$) to this change to a more pollution tolerant benthic community at this site. Importantly, however, the benthic community showed a threshold response to the excessive nutrient loading only responding to high phosphorus concentrations after a nitrogen (nitrate+nitrite) threshold was crossed. Although the benthic community has since recovered at this monitoring station the brook trout biomass remains low. These results highlight the importance of understanding ecological thresholds and multiple stressors in the conservation of aquatic resources.

ORAL PRESENTATIONS

THE EFFECTS OF STOCKING TECHNIQUES ON THE DENSITY, DISPERSAL, GROWTH AND SURVIVAL OF (0+) ATLANTIC SALMON (*SALMO SALAR*).

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Human activities, habitat loss and invasive species have resulted in the extirpation of many wild populations of Atlantic salmon. This loss of biodiversity has generated great concern, which has lead to the implementation of restoration projects. Restoration by stocking hatchery raised juvenile Atlantic salmon into former habitats is an expensive undertaking and maximizing juvenile survival is essential in rehabilitation. In this study 180,000 Atlantic salmon (age:0+) were stocked into fourteen separate stocking sites in the Boquet River, New York, using three different stocking techniques; spread, point, and multi-point. Each stocking site was electro-fished at ten different locations, up to 1600 meters downstream, to determine densities and dispersal of stocked fish. Weights and fork-length were taken for all fish caught. In this study we examine how stocking technique affects the density, dispersal, growth and survival of juvenile Atlantic salmon in an effort to provide information that can be used by fishery managers to improve stocking efforts.

6) Understanding and Managing Non-native Species

RING THE ALARM: BEHAVIOURAL MANIPULATION OF SEA LAMPREY POPULATIONS WITH DAMAGE-RELEASED ALARM CUES AND PREDATOR CUES

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Sea lamprey (*Petromyzon marinus*) invaded the upper Great Lakes in the early 20th century and caused extensive economic damage to a variety of native fish populations. We demonstrated that sea lamprey show a significant nocturnal avoidance response to migratory sea lamprey extract, white sucker (*Catostomus commersonii*) extract, 2-phenylethylamine (PEA), human saliva (predator cues) and a migratory sea lamprey extract and human saliva combination (injured conspecific and predator cue). Sea lamprey nocturnal avoidance response was consistently induced after being exposed to the majority of the above stimuli 4x and 8x, respectively, the previous day. During the day, mobile sea lamprey showed an avoidance response only to PEA and human saliva once water temperatures had risen to mean (± SD) = 13.7 (± 1.4) °C. Resting or hiding sea lampreys did not show an avoidance response to any of the stimuli. Sea lamprey ammocoetes increased the rate of escape attempts and direction changes after exposure to larval lamprey extract, suggesting that larval sea lamprey are responsive to potential chemosensory risk assessment cues. However, our recent research suggests that ammocoetes do not leave their burrows in seminatural "risky" habitats. Further, common white suckers, but not rainbow trout (*Onchorhychus mykiss*), avoid artificial stream areas labelled with sea lamprey extract and PEA. Our findings support the continued investigation of natural damage-released alarm cue and

predator-based repellents for the behavioural manipulation of sea lamprey populations in the Laurentian Great Lakes.

ADDITIVE OR SYNERGISTIC: COMBINING A PREDATOR CUE WITH DAMAGE-RELEASED ALARM CUE TO DETER SEA LAMPREYS (*PETROMYZON MARINUS*)

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Sea lampreys, an invasive pest in the upper Great Lakes, avoid odours that represent danger in their habitat. These odours include damage-released alarm cues of conspecifics and predator cues. A promising predator cue, 2-phenyethylamine (PEA), is found in the urine of mammalian predators and is avoided by sea lamprey. The objectives of this study were: (1) determine if the avoidance response of sea lamprey to PEA is graded or hypersensitive, (2) determine if the avoidance response to the combination of a predator cue (PEA) and damage-released alarm cue is synergistic or additive. To meet the first objective, groups of ten lampreys were placed in an artificial stream-channel and presented with stepwise concentrations of PEA ranging from 4×10^{-8} to 4×10^{-10} M. Sea lampreys avoided PEA at concentrations as low as 4×10^{-9} M and the response was graded. To meet the second objective, lampreys were exposed to PEA, conspecific damage-released alarm cue, or a combination of the two. Sea lamprey responded to the combination of predator cue and damage-released alarm cue in an additive manner, as the response to the combination of cues did not trigger a significantly greater response than the sum of their separate effects.

TAGGING EFFECTS AS A SOURCE OF VARIATION IN TRAPPING EFFICIENCY ESTIMATES OF SEA LAMPREY (*PETROMYZON MARINUS*)

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Studies for the purpose of research or management of invasive Sea Lamprey *Petromyzon marinus* employ a range of methods to mark, track, and recapture migrating spawning-phase adults. I tested whether tagging methods may account for the noticeable range of trapping efficiently estimates found across recent studies (10-40%). Individuals were marked in one of three ways: (i) fin clip, (ii) passive integrative transponder (PIT) tag, or (iii) both PIT and acoustic telemetry (AT) tags. Treatment groups were released concurrently at three locations 300m downstream from traps at the Clergue Generating Station, St. Marys River, Sault St. Marie, Ontario during Sea Lamprey migration June 10 to June 20 2011. Using visual observation (for treatment one) and coded wire tag (CWT) detectors (for treatments two and three) trap operators from the Great Lakes Fisheries Commission recorded any re-trapped Sea Lamprey during daily trap empties. Cumulative catch curves reflecting the total number of individuals caught over time were created. To test for imperfect tag detection of Sea Lamprey in treatment two, we ran laboratory trails with the CWT detector to determine detection probability. For the same purpose, 3-D acoustic tracks were compared with corresponding data. Cumulative catch curves were then corrected using simulation models and all three treatments were compared,

testing whether differences provided a reasonable explanation for the variation in trapping efficiency estimates. This study will contribute to fisheries science by delineating limitations associated with tagging studies and will help managers account for observed discrepancies in trapping efficiency estimates.

MANIPULATION OF DISCHARGE FAILS TO IMPROVE TRAPPING SUCCESS FOR INVASIVE SEA LAMPREY: A BEHAVIOURAL EXPLANATION

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Invasive species are a global management concern. Understanding their behavioural response to actions intended to improve trapping can be fundamental in improving the success of control programs. We tested whether sea lamprey altered their behaviour and increased their vulnerability to traps in response to large-scale manipulations of discharge from a hydroelectric generating station in the St. Marys River, Canada. We used passive integrated transponder telemetry to track and a multi-state Markov modelling to quantify sea lamprey encountering, and entering or departing, traps. Sea lamprey altered their behaviour with changes in discharge, but with minimal improvement to trap success. Rates of encounter with traps increased when discharge was high versus when it was low, but rates of departure simultaneously increased. Rates of entrance did not change with discharge. Our findings suggest that over longer distances, increased discharge attracted sea lamprey to traps, while at shorter distances, increased discharge encouraged departure from rather than entrance into traps. Invasive species can have counteracting responses to manipulations intended to increase trap success. Managers need to understand the full behavioural response of the invasive organism to improve trapping success in control programs.

INDIVIDUAL BEHAVIOUR LIKELY EFFECTS TRAPPABILITY OF AN INVASIVE SPECIES, THE SEA LAMPREY

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We tested if variation in individual behaviours may explain why few Sea Lamprey (*Petromyzon marinus*) enter traps upon encounter. Trapping is used to control invasive species, but in many cases we see lower than desired trapping success. This is true for Sea Lamprey, an invasive species in the Upper Great Lakes and the target of binational control. We hypothesized that this is due to consistent individual differences in the behaviour of lamprey, where some of those

behaviours are more susceptible to trapping. To test this, we compared the behaviours of lamprey captured in traps with those captured by electrofishing. We developed behavioural tests to assess if lamprey show individual differences in activity, latency to exit a refuge, and response to a predator cue. Individual lamprey differed consistently in all three of the behaviours measured. Trapped lamprey were on average more active and decreased their activity in the presence of a predator cue compared to those captured by electrofishing. These results suggest that the design of effective trapping of invasive species requires an understanding of the functional effects of individual behaviours.

BOLDNESS, DISPERSAL AND METABOLISM IN ROUND GOBY (*NEOGOBIUS MELANOSTOMUS*) AT THE EDGE OF AN INVASION FRONT

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Individuals at the leading edge of an invasion front have the option of either staying where they are, or exploring new regions and expanding the species range. Since range expansion is often linked to a few individuals that explore and establish new populations, the behaviour and dispersal ability of these individuals may play a role in the successful expansion of invasive populations. We used invasive Round Goby (*Neogobius melanostomus)* from the Trent-Severn Waterway, Ontario, Canada to test for behavioural and physiological traits associated with active range expansion. In the summer and fall of 2013, behavioural tests measuring boldness and dispersal potential were used to assess personality traits of individuals collected from the expanding edge of the Round Goby range, and an area that has had an established population for ~10 years. Resting metabolic rate of fish collected in the fall was also compared between the two sampling areas. Round Goby from the edge of their expanding range emerged from a shelter sooner, moved farther and faster in a laboratory flume, and had higher resting metabolic rates than individuals from the established area. The high proportion of bold individuals with increased dispersal potential located at the invasion front may facilitate further dispersal, and could help explain the rapid expansion of Round Goby in North America and Western Europe. However, the dispersal benefits of bold phenotypes may be offset by the increased energetic costs while at rest.

ROUND GOBY (*NEOGOBIUS MELANOSTOMUS*) ACOUSTIC ECOLOGY AND REPRODUCTIVE QUALITY ASSESSMENT AS POSSIBLE TOOLS FOR POPULATION ESTABLISHMENT MANAGEMENT STRATEGIES

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The round goby (*Neogobius melanostomus*) is an invasive benthic fish from the Ponto-Caspian region that has altered the ecosystem of the Great Lakes since its accidental introduction in the early 1990s. This species is a nest brooder and the male produces calls to attract females to his

nest. The current study focuses on characterizing male calls and determining female call preference to enable the use of passive acoustic recordings as a tool for tracking population establishment. Males were recorded using a hydrophone in the absence and presence of a reproductive female and calls were analysed for duration, number of pulses, dominant frequency and interpulse interval. Call characteristics were compared against total length, head width, body weight, gonad weight and gonadosomatic index (GSI) to assess correlations between calls and possible fitness characters . Female choice for male calls was assessed behaviourally by tracking female movements to call playback. Male total length significantly correlated with dominant frequency and interpulse interval and head width significantly correlated with duration and interpulse interval. Females tended to choose males with greater interpulse intervals, potentially choosing larger males, showing the potential for honest signalling in this species. Characterization of male calling patterns and female responses is currently being exploited in our lab to assess reproductive status of established goby populations and has potential as an additional management tool to assess establishment patterns of this invasive fish.

CARBON DIOXIDE AS A NON-PHYSICAL BARRIER FOR ASIAN CARP MOVEMENT

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Non-native Asian carp are established in the Mississippi River basin in the United States and are at risk of entering the interconnected Great Lakes basin. While the two basins have been separated by electric barriers, there is value in considering additional mechanisms for redundancy. We have conducted a series of laboratory and field studies to determine the effectiveness of carbon dioxide (CO_2) as a non-physical barrier to Asian carp. (i) Laboratory experiments on larval and juvenile fishes revealed that elevated CO_2 triggered a stress response and behavioural avoidance under small scale, controlled conditions. (ii) Pond experiments demonstrated that free-swimming fishes will avoid areas of elevated CO_2 and that it is possible to treat large volumes of water with CO_2 to concentrations that can affect the movement and behavior of Asian carp. (iii) We have tested the capacity for physiological acclimation following extended exposure to CO_2 and observed that extended exposure will induce physiological and performance changes, but will not alter thresholds of avoidance. Together, these studies demonstrate that CO_2 has potential as a barrier to prevent the movement of Asian carp.

ORAL PRESENTATIONS

EFFECT OF CALCIUM CONCENTRATION ON PREDATORY RESPONSE OF ROUND GOBIES

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Physico-chemical gradients can generate variation in the distribution, abundance and performance of invasive species, thereby mediating their impact on native communities. Invasive fish and invertebrates originating from the Ponto-Caspian region evolved in ion-rich waters, whereas native species in the St. Lawrence River are freshwater adapted. The St. Lawrence River has a gradient of conductivity and dissolved calcium ([Ca]) where it mixes with the Ottawa River, and the impacts of Ponto-Caspian invaders may be constrained in parts of the river that are not physiologically optimal. We tested the functional response (FR) – relationship between predation rate and prey supply – of the Ponto-Caspian invasive Round Goby *Neogobius melanostomus* at high (35mg/L) and low (12mg/L) [Ca] after two months of acclimation in either condition. During the acclimation, Round Gobies in high [Ca] conditions ate more food pellets and tended to gain more body mass. Functional responses revealed that Round Gobies in high [Ca] acclimation and high [Ca] FR conditions had the highest predation rates, whereas fish in all other treatment combinations had similarly low predation rates. Our results indicate that impacts of the Round Goby on native communities may be mediated by calcium concentrations. Identifying other key physico-chemical factors that influence impacts of invaders may aid management efforts.

CONNECTIVITY CONTROVERSY: BALANCING RESTORATION OF MIGRATORY NATIVE FISHES AND CONTROL OF INVASIVE FISHES

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Dam removals in the Laurentian Great Lakes are revealing tensions between the use of dams to control the impacts of aquatic invasive species and the removal of dams to enhance connectivity and the production of native fishes. Controversy surrounding dams used to control the Sea Lamprey (*Petromyzon marinus*), an invasive species in the Great Lakes, exemplify the ecological and economic importance of these tensions. I hypothesize the tensions arise from three phenomena. First, the long-term success of the Sea Lamprey control program can cause local managers and stakeholders to underestimate the need for sea lamprey control. Second, ignoring uncertainty in the success of dam removals can cause local managers and stakeholders to overestimate the benefits of restoring connectivity. Third, the mosaic management structure in the Great Lakes, combined with how benefits and costs of dam removals are distributed among management agencies, can facilitate adoption of a free rider tactic, where local managers and stakeholders pursue the fishing benefits expected from restoring connectivity, while placing the added cost of invasive species control on neighbouring jurisdictions and partner agencies. Decision tools are needed to improve the understanding and communication of these phenomena and ensure that connectivity decisions are balanced and scientifically defensible.

ORAL PRESENTATIONS

SOME LIKE IT HOT: THERMAL PHYSIOLOGY OF NON-NATIVE PUMPKINSEED LIVING IN A MILD CLIMATE

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The adaptive response of thermal physiology has the potential to mitigate the effects of changing thermal environments on fish, however, given the relatively rapid changes expected as a result of climate change, it is unclear if wild populations have the capacity to respond quickly enough for such adaptations to be effective. Here, we use non-native pumpkinseed (*Lepomis gibbosus*) introduced into the mild climate of southern Europe ~ 100 years ago, to determine if the thermal physiology of wild warm water fish populations can respond to rapid changes in climate. We compare physiological traits of two native Canadian, and two non-native Spanish populations, raised under a common environment in central Ontario, across a wide range of acclimation temperatures (5 - 35^{o}C). We demonstrate that Canadian and Spanish populations show similar rates of resting metabolism and somatic growth at seasonally low temperatures, however Canadian populations have consistently higher rates when measured at high temperatures. Similarly, short term upper thermal tolerance was comparable among populations except at the highest temperatures measured, where Spanish populations showed superior performance. Stomach evacuation rate and digestive efficiency are also assessed. These results indicate that the thermal physiology of pumpkinseed can respond to rapid changes in climate within as little as ~50-80 generations in the wild, and that physiological performance at high temperatures will be the first to respond to exposure to warmer climates.

DETECTION OF NON-NATIVE FRESHWATER FISHES FROM THEIR ENVIRONMENTAL DNA IN WATER SAMPLES

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Early detection of newly-introduced species is an essential aspect of non-native species management, allowing a rapid response (eradication or containment) so to avoid the risk of wider adverse environmental impacts. This study reports on the design and testing of DNA primers for detecting the environmental DNA of four non-native freshwater fishes introduced to the UK from: Asia (topmouth gudgeon *Pseudorasbora parva*; TMG); continental Europe (sunbleak

Leucaspius delineatus); and North America (pumpkinseed *Lepomis gibbosus*; fathead minnow *Pimephales promelas*). The two former species are currently invasive in the UK, the latter two have been predicted to become invasive under the projected future, warmer climatic conditions. In laboratory trials, the DNA of all four species was detected within 24 h, regardless of their density in aquaria (1, 5 and 10 fish per 44 L aquarium; five replicates of each density). In outdoor experimental ponds (25 m^2), pumpkinseed were detected within 6–12 h. In five former fishfarm ponds, DNA of TMG was detected in the three ponds known to contain TMG and not in the two ponds where TMG has never been captured or observed. The TMG primers were used to test the effectiveness of a TMG eradication (intensive trapping, followed by native fish predator introduction) in a small (1.4 ha) angling pond – the absence of DNA of TMG in the water samples (four replicates at each of 24 locations, 12 littoral zone, 12 pelagic zone) was confirmed by spiking water samples with TMG DNA to test for false negatives.

ZEBRA MUSSEL POPULATION PERSISTENCE IN RESERVOIRS

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The zebra mussel (*Dreissena polymorpha*) is a widespread invasive species with large impacts on aquatic ecosystems. Their introduction into a new ecosystem is often associated with significant changes to the food web, economic impacts, and losses to biodiversity. Due to a pelagic life stage, zebra mussels have been very successful when invading lentic ecosystems, but have demonstrated limited success in lotic ecosystems. However, many lotic ecosystems have been modified by the creation of reservoirs. These reservoirs can act as stepping stones for invasive species allowing range expansion and invasion into new landscapes, and can serve as source populations for propagules into downstream lotic ecosystems. Here we present a simulation model to determine the physical characteristics of a reservoir necessary for the persistence of a zebra mussel population. Our simulation model consists of four sub-models: a zebra mussel life history model, a temperature model, a reservoir model, and a hydrodynamic model. This model predicts that zebra mussel population persistence in reservoirs is primarily driven by reservoir size, depth, and flow regime. Within a set of reservoir conditions, zebra mussel population persistence is most sensitive to larval mortality and thermal thresholds. Results from this model can be used to predict reservoirs which, if invaded by zebra mussels, could serve as a threat to persisting native mussel populations in lotic ecosystems.

A MESOCOSM STUDY: EVALUATION OF NON-PERMANENT BARRIER TECHNOLOGIES TO PREVENT FISH MOVEMENTS

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ORAL PRESENTATIONS

Increasingly, the number and type of aquatic invasive species are on the rise worldwide. When dealing with invasive species, preventing transport and introduction is considered one of most effective management options. While permanent barriers may be best in deterring fish movements, in many instances, they may not be feasible due to various logistical constraints and/or costs. Alternatively, various non-permanent barriers using electricity, light, sound, pressure, and bubbles are being developed and deployed in efforts to limit the spread of aquatic invasive species or to achieve fish guidance and conservation. However, effectiveness of these barriers is quite variable, and testing is often lacking or limited to small-scale lab settings. To evaluate the effectiveness of non-permanent barriers in preventing fish movement, we conducted a mesocosm study in a boat slip near Hamilton Harbour, Ontario. In 2014, we deployed 8 acoustic receivers and tracked over 100 tagged fishes in the boat slip that is divided in half by non-permanent barriers such as acoustic water gun and seismic boomer plates. The results of 2014 field season will be discussed. Our results will be critical to the evaluation of management options to prevent the spread of invasive species.

EXPERIMENTAL INTRODUCTIONS OF *HEMIMYSIS ANOMALA* SUPPORT PREDICTED IMPACTS ON NORTH AMERICAN ZOOPLANKTON COMMUNITIES

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Hemimysis anomala (the 'bloody red shrimp'), a non-native mysid from the Ponto-Caspian region that preys upon a wide variety of zooplankton, was first detected in Lake Michigan and Lake Ontario in 2006, and have since been introduced into the St. Lawrence River. General predictions of their North American impacts on zooplankton communities have been based on surveys and experimental work in Europe, along with single species feeding experiments, but inconsistent results between systems (e.g. reservoirs vs. rivers), and a lack of community-based experimentation, have made accurate predictions difficult. To better estimate their North American impacts we conducted two mesocosm experiments that introduced adult *H. anomala* to naïve zooplankton communities. The first experiment contrasted uninvaded with invaded zooplankton communities, and the second applied an increasing invasion gradient (0.01-0.1 individuals L^{-1}) to investigate potential density thresholds. We found that uninvaded communities were dominated by cladocerans, while invaded communities were primarily comprised of copepods. Declines in *Dapnhia pulex/pulicaria*, small cladocerans, and juvenile *Daphnia* generally occurred above 0.08 individuals L^{-1}, and we also detected that *H. anomala* were primarily consuming smaller-sized *Daphnia*. These results indicate the reductions in cladoceran abundances that are likely to occur following *H. anomala* invasion, as well as their preference for *Daphnia* over other food sources. North American invasions of the bloody-red shrimp will therefore likely result in large cladoceran declines and compositional shifts towards lower-quality zooplankton prey, potentially influencing trophic transfer (e.g. upwards into zooplanktivorous fish) and nutrient cycling.

ORAL PRESENTATIONS

DEVELOPMENT OF A MANITOBA-SPECIFIC WALLEYE HABITAT MODEL

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Walleye (*Sander vitreus*) constitute an important resource in Manitoban lakes as its largest and most valuable commercial fishery, contributing to 70% of its average annual landed value. With the recent invasion of zebra mussels (*Dreissena polymorpha*) into Lake Winnipeg, concern is rising in regards to the potential effects of these filter feeding mussels on walleye production in Manitoban lakes. Fish habitat changes induced by dreissenid mussels are important to consider with regards to potential impacts on walleye production and yield, but to date have not been thoroughly explored. We used readily available limnological data to create a model which predicts water clarity changes with dreissenid invasion. We then evaluated a previously published model which relates water clarity to walleye production and adapted it for Manitoban lakes to make predictions of changes in walleye yield over the invasion period. The results here are a starting point for evaluating the effects of dreissenids on vulnerable ecosystems and provide examples for managers of extending those predicted effects to other ecosystem aspects beyond water clarity alone.

PERSISTENCE OF THE LAKE ERIE GILLNET FISHERY FOODWEB: THE ECOLOGICAL ROLE OF NON-NATIVE WHITE PERCH

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Despite significant ecological change in Lake Erie food web, the Ontario gillnet fishery persists, and in that sense is ecologically stable. Harvested species comprise native Walleye (*Sander vitreus*), Yellow Perch (*Perca flavescens*), White Bass (*Morone chrsops*) and non-native White Perch (*Morone americana*). Food-web theory suggests that the observed stability might be accounted for if harvested species indirectly weakly interacted (competed), and harvesters switch between species, with different direct interaction (predation) strengths dictated by price. These predictions were tested with long-term data on harvest, price and interaction strengths estimated from state-space surplus-production models and Bayesian model averaging. Counter to conventional perceptions of effects of non-native species, there was little evidence that White Perch competed with commercially valued species. Further, harvesters switched, with different interaction strengths based on price, between White Perch and more highly valued species, consistent with the idea that White Perch harvests may be stabilizing both ecologically and economically.

ORAL PRESENTATIONS

7) Multiple Stressors and Aquatic Ecosystems

MULTIPLE STRESSORS INVOLVED IN LOSS OF CRITICAL MUSKELLUNGE HABITAT IN SOUTHEASTERN GEORGIAN BAY: WATER LEVELS, SITE GEOMORPHOLOGY, SHORELINE MODIFICATIONS AND INVASIVE SPECIES

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Georgian Bay, Lake Huron supports a world class muskellunge fishery. Despite the apparent sustainability of the Georgian Bay population as a whole, some sub-populations are displaying signs of recruitment failure. In southeastern Georgian Bay, young-of-the-year (YOY) are no longer found in historic nursery sites. This absence coincides with an array of unprecedented habitat changes in Georgian Bay, including 15 years of sustained low water levels, increased shoreline modifications and anthropogenic impacts, and the establishment of invasive species. All of these factors have been implicated as potential stressors involved in the absence of YOY. Comparisons of the nursery sites between 1981 (last known YOY presence) and 2012 (YOY absent during resampling), reveal changes to the fish and vegetation community that suggest these sites are no longer suitable habitat. We are currently assessing changes to the abiotic characteristics of these muskellunge nursery sites with particular focus on the role of sustained low water levels and its interaction with site geomorphology. The resulting changes to the bathymetric structure of the sites will be evaluated as possible direct stressors (e.g. loss of sufficient habitat space, change in site slope), or as a mechanism behind the observed changes to the biotic community (i.e. altered vegetation community due to loss of water level variability). Given that several stressors are likely responsible for the current absence of YOY muskellunge, our results should identify the relevant stressor and/or relationship between stressors that would lead to actionable management strategies.

CONSEQUENCES OF EXPERIMENTAL CORTISOL MANIPULATIONS ON THE THERMAL BIOLOGY OF THE CHECKERED PUFFER

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Climate change is altering temperature regimes for coastal marine fishes. However, given that temperature changes will not occur in isolation of other stressors, it is necessary to explore the potential consequences of stress on the thermal tolerances and preferences of fish in order to understand the thresholds for survival, and predict the associated ecological consequences. Exogenous cortisol injections were used to investigate the effects of a thermal challenge on checkered puffers (*Sphoeroides testudineus*) as a secondary stressor. There were no significant differences between control and cortisol-treated fish 48 hours following cortisol treatment for swimming ability, blood glucose concentrations or standard metabolic rate. In the lab, control and cortisol-treated puffers were exposed to ambient (29.1 ± 1.5ºC), ambient +5ºC (heat shock) and ambient -5ºC (cold shock) for 4 hours to evaluate the consequences of abrupt temperature

change on puff performance and blood physiology. Following cold shock, control fish exhibited increases in cortisol levels and weak 'puff' performance. Conversely, fish dosed with cortisol exhibited consistently high cortisol levels independent of thermal treatment, although there was a trend for an attenuated cortisol response in the cortisol-treated fish to the cold shock treatment. A complementary field study conducted in the puffer's natural habitat revealed that cortisol-implanted fish selected significantly cooler temperatures when compared to controls. These results, and particularly the discrepancies between consequences documented in the laboratory and the ecological trends observed in the field, highlight the need to establish the link between laboratory and field data to successfully develop management policies and conservation initiatives with regards to climate change.

TEMPORAL SYNCHRONIZATION OF INVASIVE TROUT AND WARMING MAXIMIZES THEIR SYNERGISTIC EFFECT ON PLANKTONIC COMMUNITIES

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Interactions between climate warming and invasive species are expected to drive their net effects on native aquatic communities. Increasing higher temperatures may enhance the effects of stocked sportfish on montane lake food webs and facilitate future fish invasions. However, the net effect of these two stressors is unknown and may be influenced by their timing and order of exposure. We hypothesized that 1) warming amplifies the effects of invasive trout on naturally fishless lake communities, and 2) their net impact depends on their sequence of exposure. We conducted an outdoor mesocosm experiment in which plankton from five lakes were exposed to six treatment combinations of invasive trout and warming: control, fish-stressed, heat-stressed, fish-then-heat stressed, heat-then-fish stressed, and dual-stressed. Warming amplified the positive effect of invasive trout on zooplankton biomass by stimulating reproduction of smaller herbivorous species that were dominant in fish-stocked communities. Invasive trout also increased primary production, which likely provided the enhanced food supply required to support higher abundances of small herbivorous species under warmed conditions. The synergistic net effect of invasive trout and warming was largest when the stressors were applied simultaneously, suggesting that temporal synchronization maximized their combined impact. Order of stressor exposure did not influence the net effect of invasive trout and warming, possibly because their individual effects were highly asymmetric. These findings highlight the potential for concurrent environmental drivers of change to amplify the effects of aquatic invasive species.

NITROGEN TRANSFORMATIONS IN A LARGE DYNAMIC RESERVOIR (LAKE DIEFENBAKER, SASKATCHEWAN)

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ORAL PRESENTATIONS

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Lake Diefenbaker, a large mesotrophic reservoir in the Canadian prairies, retains 95% of the phosphorus from the inflowing South Saskatchewan River; yet is a net generator of nitrogen (N), specifically nitrate (NO_3^-). Nutrient inputs along the length of the reservoir are negligible, and the down-reservoir transitional zone is characterized by a decline in turbidity, an increase in light availability, and a doubling of gross primary production. We sought to determine the source and fate of in-lake production of NO_3^- over a 3-year period. There was a distinct shift in the $\delta^{15}N$ isotopic composition of epilimnetic particulate organic matter (POM) between up-reservoir (6.9 $\pm$ 2.7 ‰) and down-reservoir (10.1 $\pm$ 1.6 ‰) sites, associated with a doubling of epilimnetic NO_3^- and decline in ammonium (NH_4^+) concentrations. We hypothesize that this shift is associated with increased rates of nitrification down-reservoir. Instances of N deficiency are rare, indicating that NO_3^- derived from nitrification is not being assimilated and is accumulating within the reservoir. The spatial enrichment of $\delta^{15}N_{POM}$ suggests that phytoplankton are drawing on an increasingly enriched pool of NH_4^+. An additional in-lake source of N (N_2-fixation by diazotrophs) was considered, but is a minor contribution due to light limitation of diazotrophs (which only represent < 2% of the phytoplankton community), combined with low heterocyst biovolumes (1.5 $mm^3\ m^{-3}$) and high $\delta^{15}N_{POM}$ values (9.3 $\pm$ 2.3 ‰). We conclude that Lake Diefenbaker nitrifies most of its N inputs, and is a source of NO_3^- to the downstream, N deficient chain of lakes.

CUMULATIVE IMPACT OF PHOSPHORUS LOADING REDUCTIONS, CLIMATE CHANGE AND INVASIVE SPECIES ON MINIMUM VOLUME-WEIGHTED HYPOLIMNETIC DISSOLVED OXYGEN IN LAKE SIMCOE, 1980-2012

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Lake Simcoe has been affected since 1980 by multiple drivers especially by reductions in phosphorus (P) loading, climate change and invasive species such as zebra mussels which became firmly established after 1996. We examined the cumulative impact of these drivers on the ice-free minimum volume-weighted hypolimnetic dissolved oxygen concentration ($VWHDO_{min}$) below 18 m at station K42 in Kempenfelt Bay. DO depletion began in early spring when thermal stratification was observable but weak and continued throughout the ice-free season until cooling sufficiently lowered stability. There was good agreement between predicted and observed minimum VWHDO using the formula: Predicted $VWHDO_{min}$ = $VWHDO_{initial}$ − depletion rate * L (where $VWHDO_{initial}$ is the VWHDO at the beginning of the DO depletion period, depletion rate is the slope of VWHDO vs time and L is the length of the depletion period). Mean $VWHDO_{initial}$, $VWHDO_{min}$ were higher and VWHDO depletion rate decreased after 1996 but climate change was reflected in the longer duration of the depletion period. We

calculate that the mean $VWHDO_{min}$ during 1996-2012 would have been 1.8 mg/L instead of the 4.2 mg/L observed if the $VWHDO_{initial}$ and depletion rate remained at mean 1980-1990 levels. Hence, climate change may have offset improvements in $VWHDO_{min}$ generated by P controls and invasive species.

FISH COMMUNITY EFFECTS OF WINTER DRAWDOWN

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Hydrological modifications, such as winter drawdown for flood control and hydropower generation, are widespread and are considered one of the major stressors on aquatic biodiversity. Previous research has demonstrated important effects of winter water level drawdown on lake littoral zones, which may impact fish communities by altering refuge habitat, prey resources, and other factors. However, synthetic multi-lake studies of drawdown effects on fish communities are rare. We used data from >30 lakes in Québec and the northeastern United States to examine the relationship between fish community structure and the magnitude of winter water level drawdown. Specifically, we hypothesized that the abundances of invertivores, spring littoral spawners, and littoral specialist species would be negatively related to magnitude of drawdown. We test these hypotheses using multivariate analyses and multiple regressions, and discuss the results in the context of current understanding of the effects of hydrologic modification on lake fishes.

IS ICE ROAD TRUCKING A SIGNIFICANT SOURCE OF PAHS TO REMOTE LAKES?

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The 600 km Tibbitt to Contwoyto winter road is constructed each year to service mining and exploration activities in the Northwest Territories, with 87% of the length crossing frozen lakes. Over the past 12 years, an average of 3868 tonnes of material has been hauled each day along the ice road during the 2 month open season. Due to the extreme temperatures, transport trucks are kept idling when not in use, contributing a continuous input of diesel exhaust to this otherwise remote area. This study aimed to quantify the potential load and composition of polycyclic aromatic hydrocarbons (PAHs) released by this winter traffic, which subsequently enters the lakes during spring freshet. At the end of the hauling season (March 2014), integrated snow samples, surface water and surface sediments were collected from nine lakes along the ice road, including one area where trucks are allowed to idle for extended periods of time, as well as eight lakes in the Yellowknife area to place results from this remote region in the context of a sub-Arctic urban centre. Samples were analyzed for the 16 US EPA priority PAHs, dibenzothiophenes and their alkylated counterparts. Lakes along the ice road span treeline, and as such are already subjected to environmental stressors related to climate warming. As activities

associated with resource extraction continue to intensify in remote Arctic and sub-Arctic regions, it is critical to assess the potential impacts of development on contaminant burdens in these sensitive aquatic ecosystems.

COMPARATIVE DEPOSITION HISTORIES OF POLYCYCLIC AROMATIC HYDROCARBONS AND ORGANIC CARBON TO LAKES NEAR PETROCHEMICAL ACTIVITY IN NORTHWESTERN CANADA

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Radiometrically-dated lake sediment cores were analyzed for both unsubstituted (parent) and substituted (alkyl) polycyclic aromatic hydrocarbons (PAHs) in proximity to the following petrochemical activities: (1) in-situ oil sand extraction; (2) open pit oil sand extraction; (3) abandoned conventional natural gas exploration and (4) pump-jack extraction of conventional resources, to characterize PAH concentrations and sources in these environments. The PAH profiles were examined against the timing of gas and oil developments to determine if temporal patterns in sediments agree with historical emission patterns. We also looked at trends in the potential sources of PAHs (especially pyrogenic versus petrogenic), which were differentiated over a period that extends to pre-development times, using ratios of specific PAHs that can be traced to their potential source. Additionally, we used multivariate indirect ordinations as an exploratory method for identifying potential PAH markers in the different regions. The sediment cores taken near open-pit oil sands mining show a shift from pyrogenic sources (primarily wood and coal burning) in pre-development sediments to petrogenic sources in more modern sediments, as well as large increases in concentrations of PAHs that are consistent with the onset of open-pit mining in the area. Cores near in-situ oil sand extraction operations show some evidence of increasing concentrations and shifting sources, while all conventional sites show no clear changes in either sources or concentrations that are coincident with the onset of their respective petrochemical developments. PAHs can be harmful to living organisms, including humans, thus the novel comparative approach we use provides a critical context for assessing potential environmental risks of petrochemical development.

WHAT IS THE RISK OF MARINE OIL AND HNS SPILLS IN THE GREAT LAKES?

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This study reports on the first risk assessment aiming to characterize the risk of marine spills of oil and hazardous noxious substances (HNS) in Canadian waters.

Risk was defined as the product of the probability of a spill occurring and the potential impacts should a spill occur. These two elements were estimated for 4 regions of Canada, including the Great Lakes- St Lawrence River ecosystem. Oil spill frequency was estimated based on mean annual Canadian traffic and oil cargo volumes as crude oil and refined products. Oil spill frequencies were described according to four spill volume categories ranging from 10 m^3 to ≥ 10,000 m^3. HNS frequencies were expressed as mean annual volumes of 4 classes of chemicals. Impacts were estimated using an Environmental Sensitivity Index (ESI) based on geographic layers describing the physical, biological and human environments.
Within the Great Lakes- St Lawrence River system, the highest risk values for small to medium size spills of oil were observed in the St Lawrence River and in Lake Ontario. For HNS, the highest risk values were observed for organic and inorganic chemicals, close to large urban areas. Within each lake, nearshore areas had a higher risk compared to off shore areas. Results will be discussed based on data availability in the Great Lakes and in the light of the Canadian context.

ANALYTICAL TECHNIQUES IN ECOTOXICOLOGY - PAST, PRESENT, AND FUTURE TRENDS

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Instrument based chromatography and spectrometry were dedicated professions limited to modern drug discovery around 30 years ago. With recent advancements in analytical techniques the scope and the applicability of chemical analysis have considerably widened. In the past decade, significant improvements in hardware, hyphenation (combining separation and detection) and software have enabled environmental scientists and related disciplines to apply these techniques for the detection of target molecules in complex matrices including biota, sediment and water. In the area of separation science, high resolving power and shorter run times have played a key role in improving the peak capacity, throughput and retention time reproducibility. In the in the area of detection, mass spectrometry and nuclear magnetic resonance spectrometry have been successfully applied to the detection of contaminants of emerging concern (e.g. active pharmaceutical ingredients) and non-point source pollutants (e.g. pesticides). These advancements have certainly played a key role in addressing the pressing environmental questions. Specific examples will be presented regarding the detection of anatoxin-a (a cyanobacterial toxin) in freshwater, fluoxetine (an antidepressant drug) in fish and atrazine (a pesticide) in fresh water.

ORAL PRESENTATIONS

FACTORS INFLUENCING RECREATIONAL RE-CAPTURE OF UPSTREAM MIGRATING ATLANTIC SALMON (*SALMO SALAR*) THAT HAVE BEEN PREVIOUSLY CAPTURED AND RELEASED

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Atlantic salmon are captured by recreational anglers during their upriver migration to spawning territories, however, many salmon are released by anglers with the intention that they will continue migration. To determine how angling affects salmon behaviour and catchability, recapture of salmon released by anglers (N = 27) was compared to that of control salmon (i.e., that was captured in bag nets and tagged prior to river entry; N = 33) via radio tracking in River Gaula, Norway. Angled and released salmon were captured by anglers at a rate similar to that with which control salmon were captured by anglers, indicating that angled salmon did not avoid recapture by anglers ($p = 0.52$). However, observations of recapture events indicated that the tagged salmon were not typically recaptured by the same gear as they were initially captured by. To test whether gear preference influences salmon recapture, catch data from four Norwegian salmon rivers were evaluated to determine how frequently salmon are recaptured by different gear from which they were initially captured (i.e., gear switch). Among 339 salmon angled, tagged (radio and anchor tags), and released in Norwegian Rivers Gaula, Orkla, Otra, and Lakselva in 2012 and 2013, 64 (14%) were recaptured, 70% of which exhibited gear switch. If recapture gear is independent of initial capture gear, a 70% rate of gear switch is highly unlikely based on the relative gear usage in these rivers ($p < 0.01$).

EFFECTS OF HYDROLOGIC ALTERATION ON FISH COMMUNITY STRUCTURE IN REGULATED RIVERS

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Alterations to seasonal patterns, temporal variability and magnitudes of river discharges resulting from damming and specific flow regulation practices can have severe ecological consequences for freshwater systems. However, little has been done to develop a holistic approach to assess the effects of hydrological alterations on fish community indices across a wide range of rivers and between different types of regulation strategies. To address this, we used daily and hourly hydrologic data from gauges in 24 rivers, comprising 10 regulated and 14 unregulated systems, from 1997 to 2009. While some regulated rivers did not appear to exhibit flow characteristics differing from regional unregulated reference systems, others demonstrated significantly greater attenuation of high flows (decreased flow magnitude maxima) as well as increased periods of low flows (annual baseflows) and greater flashiness. Extensive community surveys to estimate fish abundance, biomass, diversity indices and habitat guild representation were conducted on

these same rivers. In regulated systems, deviations from mean fish community measures relative to unregulated rivers were regressed against tabulated alterations from flow reference conditions. Our results demonstrate that biological impairment consisting of significant alterations to fish community indices from the unregulated means is directly related to the degree of flow alteration, with run-of-river systems experiencing the smallest degree of fish and flow alteration and hydro-peaking type schemes, experiencing the greatest alterations. The findings of this novel approach emphasize the potential range of ecological consequences of anthropogenic alterations to natural flow regimes on freshwater fish communities.

RELATIONSHIPS BETWEEN HABITAT, SHORELINE ALTERATIONS AND NEARSHORE SMALL FISH COMMUNITY STRUCTURE IN LAKE SIMCOE, ONTARIO

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Nearshore small fishes represent a large proportion of the fish biodiversity of Lake Simcoe, a lake subject to multiple stressors including eutrophication, invasive species and shoreline alterations. Over the past several decades, the species richness of this community has declined while there has been a dramatic increase in the abundance of mimic shiner *Notropis volucellus;* drivers of community change remain unclear. The goal of this study is to understand how nearshore habitat and shoreline alterations shape the small fish community in Lake Simcoe. Nearshore small fishes were sampled using gillnets, fyke nets and seine nets in 2011-2014 along the southeastern shoreline of Lake Simcoe in both June and August. Habitat (substrate and cover) was assessed using side-scan sonar and visual observations. Shoreline alterations, such as docks and breakwalls, were recorded at fish sampling sites. Analyses explored relationships between fish communities, habitat and shoreline alterations, with a particular emphasis on explaining variation in mimic shiner abundance. Trends in mimic shiner abundance were compared to those in Lake Huron to better understand the generality of these patterns and point to potential drivers of abundance. Understanding the roles of habitat and shoreline alterations in structuring the small fish community can help elucidate drivers of recent observed changes in the fish community and inform strategies for fish community management.

FISH SCALES - A NON-INVASIVE ASSESSMENT TOOL FOR EVALUATING THE EFFECT OF POLLUTION ON *CIRRHINUS MRIGHALA* FROM THE RIVER

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The present study evaluated the effects of pollution on *Cirrhinus mrigala* in the Ravi River by comparing DNA extracted non-invasively from their scales to DNA extracted from the scales of fish collected from controlled fish farm. A single, random sampling was conducted. Fish were

broadly categorised into three weight categories: W_1 (500 to 1000 g), W_2 (1001 to 1500 g) and W_3 (1501 to 2000 g). DNA was extracted non-invasively from control and experimental samples. The quantity and quality of DNA from the control and experimental samples were compared. The experimental samples in the W_1, W_2 and W_3 categories had an average DNA concentration (µg/µl) that was lower than the control samples. All control samples had a single DNA band; whereas the experimental samples in W_1 fish had 1 to 2 bands, the experimental samples in W_2 fish had two bands and the experimental samples in W_3 fish had fragmentation in the form of three bands. These bands show the effects of pollution on fish in the Ravi River. We concluded that this non-invasive assessment tool could be successfully used in scale-bearing fish species for assessment of contaminants and damage in the DNA as a rapid, non-lethal and biologically reliable indicator of water quality for the presence of various toxicants in surface water and their effect on the fish health.

DO BOTTOM-DRAW RESERVOIRS AFFECT THE SPATIAL PATTERNS OF FISHES DOWNSTREAM?

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Hydropower now accounts for over half of Canada's electricity generating capacity. As a result, hydroelectric dams and their storage reservoirs are prevalent throughout the country. The release of water from these reservoirs can alter the thermal regime of rivers downstream; for instance, releases from bottom-draw reservoirs usually elevate water temperatures in the winter and lower them in the summer. Given that fishes are generally unable to regulate their own body temperature, such alterations may affect condition and ultimately survival. Despite this possibility, there remains a paucity of information regarding how fishes downstream of reservoirs are affected. In this study, we examine the spatial patterns of fish condition (namely, Fulton's condition factor) and density along the longitudinal gradient of two regulated and two unregulated rivers in the Tobique River Basin, New Brunswick. Our primary species of interest is the slimy sculpin (*Cottus cognatus*), a small-bodied benthic stream fish. Slimy sculpin are particularly well suited to this type of study because they exhibit strong site fidelity. Our preliminary results indicate that both slimy sculpin condition and density decrease with distance downstream in regulated rivers, whereas the opposite is true in unregulated rivers. Changes in condition and density closely followed changes in macroinvertebrate density and water temperature; indeed, macroinvertebrate density and water temperature were the best supported predictors of slimy sculpin condition and density.

NET EFFECTS OF MULTIPLE ANTHROPOGENIC STRESSORS PLAUGING GLOBAL FRESHWATER BIODIVERSITY AND ECOSYSTEM FUNCTION: A META-ANALYSIS

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ORAL PRESENTATIONS

The accelerating rate of global change has centered attention on the cumulative impacts of novel and rapid environmental changes (i.e., stressors), especially in marine ecosystems. As integrators of the effects of local catchment and regional atmospheric stressors, freshwater ecosystems are also ranked highly sensitive to the net effects of multiple stressors, yet there has not been a large-scale quantitative synthesis. We analyzed data from 318 published freshwater experiments involving paired combinations of stressors, and discovered that their overall net impact was less than expected based on independent stressor effects (i.e., an antagonistic interaction). The mean net effects of paired stressors on diversity and functional performance endpoints were additive and antagonistic, respectively. In individual studies, combined effects of stressor pairs were additive (45%), antagonistic (26%), synergistic (14%) and reversals (15%). A reversal occurred where the net impact of two stressors was opposite to that predicted based on their individual effects. Crucially, the mean net effects across different stressor pairs and response metrics were always either antagonistic or additive. This is in contrast to marine syntheses, which found that synergistic interactions were common. We suggest that differences in the physiology of biota and environmental context, such as variance in thermal regimes, contribute to the disparity between responses to dual stressors observed in marine and freshwater ecosystems.

THE DIFFERENTIAL EFFECTS OF CHANGES TO HABITAT CHARACTERISTICS AND HABITAT STRUCTURE ON STREAM FISH COMMUNITIES

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Community composition is largely determined by abiotic, biotic, and the spatial characteristics of the habitat network. In areas which are undergoing rapid environmental change, such as urbanization, changes to both abiotic conditions (e.g. temperature) and the structure (e.g. fragmentation) of ecological networks occur. Community composition in these areas is impacted because as the changing environment conditions become more suitable for some species and less suitable for others. These concomitant changes are due to the interactions between environmental characteristics and species traits. While some trait-environment interactions are well understood, environmental characteristics and habitat structure rarely change in isolation and they interact with one another. These cumulative effects make it difficult to determine the relative importance of various changes to habitat characteristics and connectivity on community composition. Data collected on stream fish communities in 14 watersheds in the Greater Toronto Area demonstrate these complex effects and the interactions between environmental characteristics and habitat structure on community composition. Further, they demonstrate that the relative importance of changes to environmental characteristics and habitat structure differs among species-trait groups. These differential effects are due to differences between environmental variables and both morphological traits and life history traits.

ORAL PRESENTATIONS

CAN SUPPLEMENTAL FEEDING OF NEST GUARDING SMALLMOUTH BASS MITIGATE THE EFFECTS OF EXPERIMENTAL CORTISOL ELEVATION?

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During the reproductive period, male smallmouth bass provide parental care for developing offspring until their brood reaches independence. During this energetically demanding life stage, males cease active foraging as they vigorously defend their offspring. This period is an inherently challenging period in their life-history, and thus provides an interesting opportunity to experimentally manipulate cortisol levels in parental males to understand the fitness consequences of additional challenges. Using control and cortisol-manipulated nesting smallmouth bass, we examined whether supplemental feeding reduced nest abandonment and maintained fish condition relative to non-fed individuals.

DO BODY SIZE AND BROOD SIZE INFLUENCE PARENTAL CARE BEHAVIOURS AND NEST SUCCESS IN CHRONICALLY STRESSED MALE SMALLMOUTH BASS?

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Parental care is an advantageous reproductive behaviour in fish; fitness of the caregiver is increased through improving the chances of its offspring's survival. Parental care, however, is energetically costly for care giving parent(s). The size of the parental fish and the size of its brood can affect nest abandonment decisions in care giving fish; larger (older) fish with larger broods are proposed to invest more energy into reproductive events compared to smaller (younger) fish with small broods because larger fish would have less future reproductive capacity. Cortisol, the primary circulating stress hormone in fish, is beneficial at basal and maintenance levels, though when chronically elevated can produce secondary stress responses which can negatively affect bodily functions, consequently having implications on parental care behaviours and nest abandonment decisions. Our objectives were to explore the effect that chronically elevated stress levels had on parental-care providing smallmouth bass relative to brood size and male body size. Stress levels of parental fish were chronically elevated using intraperitoneal cortisol injections and their brood size manipulated to test the hypothesis that responses to a physiological challenge vary with brood size and body size.

TRACKING THE POPULATION RISE AND ECOLOGICAL EFFECTS OF DOUBLE-CRESTED CORMORANTS ON NESTING ISLANDS IN LAKE ONTARIO USING PALEOLIMNOLOGICAL APPROACHES

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ORAL PRESENTATIONS

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The double-crested cormorant (*Phalacrocorax auritus*) in the Laurentian Great Lakes has gone from being nearly extirpated to being a highly controversial species because of a rapid population increase during the 1970s-1990s that now raises issues over competition with sport fisheries and the destruction of terrestrial vegetation by toxic amounts of guano. Here we use water chemistry and dated sediment cores from a highly impacted pond and a minimally impacted pond on near-shore nesting islands in eastern Lake Ontario to track the cormorant population increase and determine impacts on freshwater systems. We demonstrate that sedimentary $\delta^{15}N$ and chlorophyll-a concentrations track the increase in cormorants in Lake Ontario. Water samples from the high-impact pond demonstrate the influence of cormorant wastes with higher nutrient and major ion concentrations compared to the low-impact pond. Diatom assemblages in the post-1970s sediments of the high-impact pond were comprised of >80% *Fistulifera saprofila*, a species tolerant of hyper-eutrophic and polluted systems, whereas the low-impact assemblage did not indicate nutrient enrichment. We show the potential for using paleolimnology to track cormorant population changes across the Laurentian Great Lakes, which has important implications for putting double-crested cormorant population changes in historical context

PRELIMINARY ANALYSIS OF STEROLS AND STANOLS IN ORNITHOGENIC POND SEDIMENTS NEAR A SEABIRD COLONY AT CAPE VERA, DEVON ISLAND, NU

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Sterols are a group of steroid alcohols with a structure of three cyclohexanes and one cyclopentane. They are natural unsaturated compounds found in various biomaterials. Sterols in ornithogenic sediments may be a useful tool to track changes in animal-derived inputs to sediments from seabirds. Here we present a preliminary analysis of the sterol and stanol record at Cape Vera in the Canadian High Arctic. Our study site is located near cliffs where 10,000 breeding pairs of northern fulmars (*Fulmarus glacialis*) are nested each summer. Twenty-three surface sediment samples were collected in 2004 and 2006 in these ponds. Eleven sterols were analyzed in these samples, and eight were detected in most samples. Cholest-5-en-3b-ol and sitosterol were two dominatant sterols, consisting of approximately 50% of al the sterols found. We observed an inverse correlation between several sterol concentrations in sediment and distance from the seabird colony. Our results indicate that specific chemical markers such as sterols and stanols in lake sediments may be used to track ornithogenic inputs in sediments, suggesting that the paleo-history of ornithogenic inputs to sediments may be revealed by these chemical markers.

ORAL PRESENTATIONS

Hg BIOGEOCHEMISTRY IN TUNDRA LAKES DISTURBED BY SHORELINE RETROGRESSIVE THAW SLUMPING IN THE MACKENZIE DELTA REGION

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Shoreline retrogressive thaw slump (SRTS) events often lead to lower DOC and higher sulfate concentrations in adjacent lakes. The potential for enhanced Hg mobility and methylation in aquatic systems under such dynamics is of concern. We surveyed 25-30 lakes from 2009-11 along a north-south transect east of the Mackenzie River Delta, using the percent of catchment area disturbed by thaw slumping (%CD) as our main predictor variable. Undisturbed catchment soils were 2.7 and 6.3 -fold greater in total Hg (Hg_T) and organic C content, respectively, when compared with slump soils, suggesting lower potential for catchment Hg-transport to lakes with greater slump disturbance. Additionally, undisturbed lakes closer to the Arctic marine coast had greater Hg_T, suggesting a marine or temperature related influence up to 100 km inland from the coast. However, we observed significantly lower Hg_T in lakes as a function of %CD, indicating the dominant influence of SRTS events on Hg in aquatic systems. Both aquatic Hg_T and MeHg were positively correlated to DOC, while only Hg_T was negatively related to sulfate. Periphyton Hg measurements were not related to %CD or DOC, however periphyton Hg bioaccumulation factors (BAF) were positively related to %CD. Additionally, periphyton Hg BAFs demonstrated a threshold relationship with DOC, peaking at 5.8 mg DOC/L. Given the affinity for both Hg_T and MeHg to DOC and how SRTS events reduce Hg_T in lakes, these results suggest that any remaining Hg in slump-affected lakes is more available for biological uptake when DOC concentrations are below 5.8 mg/L.

DISSOLVED ORGANIC MATTER KINETICALLY CONTROLS MERCURY BIOAVAILABILITY TO BACTERIA

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Mercury is a global pollutant which toxicity is mostly attributed to the consumption of fish and shellfish containing hazardous levels of organic methylmercury. Concentration of Dissolved Organic Matter (DOM) is among the numerous environmental variables affecting the levels of methylmercury (MeHg) in fish. Its effect is generally attributed to the formation of poorly bioavailable mercury complexes to fish; yet, the role of DOM on the availability of inorganic mercury (Hg^{II}) substrate for methylation by bacteria remains to be examined. In this study, we use a whole-cell gram-negative bioreporter to evaluate the direction and magnitude of changes in net accumulation of Hg^{II} by bacteria in response to changing DOM concentrations, in both equilibrium and non-equilibrium conditions. We show that under non-equilibrium conditions Hg^{II} uptake by bacteria is enhanced in the presence of low to moderate levels of DOC, typically found in boreal lakes; this pattern disappears once equilibrium is reached after 24h. We propose that a highly labile carbon source within the complex DOM pool acts as a shuttle for Hg^{II} uptake by bacterial cells. These findings contribute to explain the bioavailability of Hg newly deposited to aquatic ecosystem.

ORAL PRESENTATIONS

MANY WAYS OF KNOWING: RECOGNIZING THE ROLE THAT TRADITIONAL KNOWLEDGE AND GIS DATABASES CAN PLAY IN BIOASSESSMENT PROGRAMS

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Traditional Ecological Knowledge (TEK) has been part of environmental assessments in Canada for decades, but a constructive and thoughtful integration of "western science" and TEK in bioassessments remains elusive. Similarly, although the Canadian Aquatic Biomonitoring Network (CABIN) and other national and regional bioassessment programs have used landscape-scale observations and Geographic Information System (GIS) tools for more than a decade, the full potential of a landscape-scale perspective in bioassessment is as yet unrealized. "GIS variables" have crept into predictive models, but landscape-scale descriptors are often looked at with suspicion. How can we say anything about climate in the area of the site based on records from a weather station 100km away? There is also a wealth of GIS geodatabase, analytical and cartographic tools available that could significantly improve the data management, analysis, and reporting of bioassessments, but these have just not found their way into most bioassessment programs. I will briefly review the general data model of RCA bioassessment, and contrast the pros and cons of site- (e.g. current velocity), landscape-scale (e.g. % granitic bedrock geology in catchment area), and TEK-based observations, including the collection, aggregation, management, analysis, and quality assurance of these different types of knowledge.

PREDICTIVE MODELS OF BENTHIC COMMUNITIES FOR ASSESSMENT OF ANTHROPOGENIC IMPACTS

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Quantifying the magnitude and sources of spatial and temporal variability in biological data is a critical step in the development of ecological assessment systems. Long term biological datasets collected in several, spatially diverse, pristine areas of Ontario using the Canadian Aquatic Biomonitoring Network (CABIN) protocol were matched with relevant environmental variables, including water quality, hydrological and land use data. Several biological community descriptors were employed to quantify biological variation through time, including measures of community stability and persistence. High values of annual turnover were observed in the community, and a significant temporal trend was observed for community persistence. Biological metrics currently used for ecological assessment such as Taxa richness, Berger–Parker dominance index, the Canadian Ecological Flow Index, the Hilsenhoff Family Biotic Index and % of EPT families showed more limited ranges of inter-annual variation. Clear spatial

aggregation of the data was observed with 3 distinct spatial clusters identified in the dataset. The implications of the results will be discussed in light of current ecological assessment in use in Canada and approaches to integrate such results will be suggested.

IS THERE A COMBINED EFFECT OF *BYTHOTREPHES LONGIMANUS* AND CALCIUM DECLINE ON ZOOPLANKTON COMMUNITIES?

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Bythotrephes longimanus and a regional decline in calcium concentrations are two stressors affecting lakes on the Precambrian Shield. Field studies and experiments conducted to understand the independent impacts of *Bythotrephes longimanus* and calcium decline have revealed significant negative impacts on zooplankton communities. However, there is no existing data on how zooplankton communities will respond in the presence of *Bythotrephes longimanus* and calcium decline. Whereas lab studies on *Daphnia* suggest that reproduction and growth is impaired at low levels of calcium (e.g. 1.5 mg Ca/L), we have limited knowledge on the impacts of calcium decline on zooplankton community structure in the field. Gaining an understanding on how these two stressors may interact is important given their widespread occurrence across lakes on the Precambrian shield. To investigate the combined effect of *Bythotrephes longimanus* and calcium decline on zooplankton communities, a mesocosm experiment was established in Havelock Lake, Haliburton Forest and Wild Life Reserve, Haliburton, Ontario. The experiment consisted of two treatments: *Bythotrephes longimanus* (presence/absence) fully crossed with a calcium gradient, from 1.2 to 2.6 mg/L. The experiment ran for eight weeks. *Bythotrephes longimanus* reduced small cladoceran abundance by 14% and calcium rich species, by 42%, across weeks in comparison to uninvaded treatments. Daphniid abundance and richness was reduced by 67% and 28% respectively in the presence of *Bythotrephes longimanus* in comparison to uninvaded treatments; however, there was no discernable effect on community metrics such as total abundance and total species richness. There were no discernable effects of calcium on coarse community metrics, functional groups or on species response.

RECOVERY CHALLENGES FOR AURORA TROUT IN A DECLINING CA ENVIRONMENT

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Aurora trout are a rare colour morph of brook trout (2 native lakes in the world) that were an iconic indicator species in the battle for acid rain reductions in the 80's. The combination of government supported captive breeding programs, a lake liming intervention and most importantly a massive pollution reduction program (95% SO_2 reduction) were needed to restore reproducing populations to the two native aurora trout lakes in remote Lady-Evelyn Smoothwater Park. In recent decades the increase in pH (now approx. 5.5) and DOC "brownification" has stabilized but Ca levels have continued to decline to potential stressful

levels (1mg/L). An in situ blood physiology study and an overall population assessment were conducted to determine the effects of the declining Ca using the international ICP Waters biomarker protocols. Recent findings will be presented.

ELEVATED METAL CONCENTRATIONS INHIBIT BIOLOGICAL RECOVERY AND ALTER ZOOPLANKTON SIZE STRUCTURE IN PREVIOUSLY ACIDIFIED BOREAL SHIELD LAKES

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Beginning in the late-19th century, lakes near Sudbury, Canada, were exposed to intense acidification and metal contamination due to emissions of the regional mining and smelting industries. Emission controls substantially improved the pH of many of the surrounding lakes, however biological recovery continues to lag. We assessed the current state of biological recovery using multiproxy paleolimnological records from two nearby lake districts (Sudbury and Killarney) that were affected by acidification, but differed in metal contamination due to distances from the smelters. Furthermore, we assessed the impact of acidification on zooplankton size structure using measures of sedimentary *Bosmina* spp. remains. Cladoceran shifts were most pronounced in the metal-contaminated Sudbury lakes, with assemblages tracking industrial activity. In contrast, the Killarney lakes experienced minimal changes in their sedimentary cladoceran assemblages. Each of the previously-acidified lakes experienced shifts in size structure of *Bosmina* spp. during acidification, with limited or no recovery following pH improvements. Our results suggest that biological recovery continues to be inhibited by ongoing metal contamination. Furthermore, recent increases in chlorophyll-*a* and coincident shifts in cladoceran assemblages suggest that climate is an increasingly important driver of ecological change, and a return to the biotic structure of the pre-smelter era is unlikely.

AGRICULTURE AND PEAT EXTRACTION HAVE OPPOSITE EFFECTS ON ALGAL BIOMASS IN COASTAL RIVERS WITH MINIMALLY DISTURBED CATCHMENTS (<15%) IN NORTHEASTERN NEW BRUNSWICK

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Eutrophication is a major threat to coastal zones around the world when agricultural activities cover more than 30% of a catchment's surface area. However, it is unknown if signs of eutrophication become apparent at lower levels of disturbance (<15% agriculture or other resource extraction activities). Here, we consider four coastal watersheds in Northeastern New Brunswick characterized by relatively low levels of perturbations (deforestation, agriculture, peat extraction, all < 15% of watershed area) and nutrient-poor waters. A three year sampling program suggests that natural land features (drainage ratio) as well as anthropogenic land features (percent peatland area) are associated with increased dissolved organic carbon

concentrations and lessened algal biomass. In contrast, nutrient concentrations were unrelated to algal biomass. Similarly, a paleolimnological study suggests that, as peat extraction activities increased during the second half of the 20th century, algal biomass decreased, suggesting that organic matter derived from peatlands may induce light-limitation of algal abundance. In contrast, peak agricultural activities during the 1930s were associated with peak algal abundance. Overall, even at low levels (less than 15% of the catchment's surface area) landscape disturbance has observable effects on algal abundance with agriculture and peat extraction appearing to have opposite effects.

FACTORS REGULATING SPATIAL AND TEMPORAL VARIABILITY IN LAKE ERIE CARBON FLUX: A MULTIPLE STRESSOR CONTEXT

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Over the last several decades, Lake Erie has received considerable attention for its high phosphorus loads and degraded water quality. Here, we characterized spatio-temporal heterogeneity in Lake Erie's ecological state within the context of carbon cycling by using a multi-decadal database to identify patterns of spatial and temporal variability of net atmospheric surface flux of CO_2. In particular, we quantified how CO_2 fluxes compare across the East-West productivity gradient (oligotrophic to hypereutrophic) encompassing three basins that differ in their base geology, morphometry, and material loading and processing. The long-term average of daily fluxes of CO_2 (range: 0-15 mmol $Cm^{-2}d^{-1}$) decreased with increasing basin productivity, and only the shallow western basin was net autotrophic, and usually only during the occurrence of algal blooms. In addition, the presence of coherent, interannual variation in net fluxes (range: -10-50 $Cm^{-2}d^{-1}$) suggests the additional potential importance of climate drivers of carbon cycling, and the need to consider the roles of multiple, interacting environmental stressors in the regulation of Great Lakes carbon cycles.

TERRETRIAL-AQUATIC LINKEAGES TO AQUATIC ECOSYSTEM RECOVERY IN SMELTER-IMPACTED WATERSHEDS

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ORAL PRESENTATIONS

Aquatic ecosystems are intimately linked to their watersheds, with forests and wetlands providing a steady flow of terrestrial organic matter (tOM) and acting as "modulators" of lake water quality. Littoral communities are strongly affected by terrestrial ecosystems, and this linkage is particularly important in disturbed watersheds. In smelter-impacted watersheds, tOM has been shown to correlate to increased diversity of littoral benthic invertebrates, with an apparent subsidizing effect on these communities. Despite this positive relationship, these nearshore communities are still stunted and lack key taxa such as leaf shredders and sensitive indicators like *Hyallela*. We propose a model whereby the increased abundances of *Hyallela* are related to a reduction in bioavailable metals (as measured with diffusive gradients in thin-films, DGTs) which is related to wetland area in the watershed. While the bioavailable forms of some metals have been reduced by tOM, others are not as strongly regulated by tOM. Wetlands have acted as sinks for several metals for decades, but these overburdened wetlands have now become sources of these metals, and this is exacerbated by drought conditions. The results of this study suggest that ongoing land reclamation projects could be targeted to subsequently aid in the recovery of aquatic communities in disturbed watersheds.

DEVELOPMENT, VALIDATION AND APPLICATION OF MICROBIAL BIOSENSORS OF OXIDATIVE STRESS

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Monitoring the fate and effects of toxic chemicals in the environment is important in order to follow regulation and to inform risk assessment for ecotoxicological purposes. Current monitoring strategies exhibit practical and cost issues. Microbial bioreporters inform on the bioavailability of contaminant and on the synergistic effects of chemical mixtures. Microbial bioreporters are sensitive, easy to use, cost-effective, can be tailored to be site-specific and they do not require permits for ethical use. The objectives of this project are to develop, validate and apply an oxidative stress sensitive bioreporter assay to assess the water quality of environmental samples. We have developed a bioreporter sensitive to pro-oxidants based on the promoter region specific to the catalase enzyme. We show that our bioreporter can be used as an early warning signal in the context of assaying polluted environmental samples.

COUPLING REDOX HOMEOSTASIS TO MERCURY CYCLING IN A PURPLE NON-SULFUR PHOTOTROPH

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Two major drivers for Hg(II) reduction to Hg(0) are light (photochemistry) and the activity of microbes. Abiotic photoreduction dominates in surface waters while microbial activity drives Hg reduction at depths where light alone cannot account for the levels of Hg(0) observed. Much of the focus regarding microbially-mediated Hg redox cycling has been on chemotrophic bacteria while phototroph-mediated pathways remain poorly understood. The objective of this work was to provide mechanistic details for Hg resistance strategies and Hg redox cycling pathways in the

metabolically diverse purple non-sulfur bacterium (PNSB) *Rhodobacter capsulatus*. We hypothesized that PNSB reduce and detoxify Hg(II) through strategies for maintaining redox homeostasis during photoheterotrophic growth such as shuttling excess electrons onto exogenous electron acceptors and releasing reduced compounds into the environment. To test this hypothesis, growth conditions were controlled to compare 1) the response to sublethal concentrations of Hg(II) and 2) Hg(0) production associated with live, heat-killed and filtered cells for phototrophic and chemotrophic metabolisms. Phototrophic cells detoxified Hg whereas chemotrophic cells did not. Resistance was higher for cultures grown on the more reduced substrates, acetate and glucose, compared to those grown on the more oxidized pyruvate. Hg(0) production was higher for filtered and heat-killed cells compared to cells growing on acetate and the no inoculum control. These results suggest the presence of a redox-mediated Hg detoxification strategy in *R. capsulatus* and that metabolic exudates can increase Hg photoreduction although ongoing comparisons of Hg(0) production associated with more reduced substrates will be presented to provide additional mechanistic details.

SUDBURY INFLUENCE RE-VISITED: EFFECT OF DECLINING CALCIUM ON ZOOPLANKTON SPECIES SUGGESTS SIMILAR OUTCOME AS IMPACTS FROM HISTORIC ACIDIFICATION

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Historically, acidification in the Sudbury area caused significant damage to zooplankton communities. Although lake acidity is recovering due to emission control policies, many acid-sensitive species, such as large cladocerans with heavily calcified carapaces (e.g. *Daphnia pulex*) have not re-colonized. Coincidently, calcium, a critical component of cladoceran exoskeletons, has been declining in soft-water lakes over the last few decades. Current concentrations in many Killarney lakes are now below laboratory-defined reproductive thresholds (e.g. <1.5mg L^{-1} $[Ca^{2+}]$ for *D. pulex*). We investigated the individual and interactive effects of these co-occurring stressors on zooplankton recovery in acid-damaged lakes. Mesocosms were stocked with zooplankton from the regional species pool and two treatments were applied in a factorial design: pH (5.9 and 6.3) and calcium (0.9mg L^{-1} and 2.3mg L^{-1}). Low calcium and pH each resulted in reductions in *D. pulex* abundance, a large and heavily calcified cladoceran. In high calcium treatments we observed an increase in small cladoceran abundance, including smaller, acid-tolerant and calcium-poor daphniids (*D. catawba, D. ambigua*). When both stressors were combined, the resulting decline in *D. pulex* abundance was of similar magnitude to that observed in the individual stressor treatments. This suggests that recovery of pH may be offset by declining calcium levels.

CAN INVERTEBRATE COMMUNITIES IN COAL MINING END-PIT LAKES SUPPORT STOCKED FISH POPULATIONS?

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ORAL PRESENTATIONS

Due to a high demand for fishable waters in Alberta, coal mining end-pit lakes are being explored as alternate fishing opportunities through fish stocking. Aquatic invertebrates form the base of the consumer food-web in lakes, however, in end-pit lakes, invertebrates are exposed to a challenging physical and chemical environment. We hypothesize, that these physical and chemical features of coalmine end-pit lakes and the resulting limnology reduce crucial littoral habitat and hence reduce invertebrate diversity and biomass, thereby limiting the potential for these lakes to be naturalized. To this end, we compared the invertebrate community, along with habitat and water quality variables, of five end-pit lakes and five natural lakes. We found lower invertebrate diversity and abundance in the end-pit lakes, which we attribute to small to non-existent littoral zones resulting from steep shorelines and high depth-to-surface ratios in end-pit lakes. Furthermore, habitat diversity in end-pit lakes is limited and cover provided by macrophytes is scarce. Lingering water quality issues, especially elevated water hardness and selenium, as well as low allochthonous organic matter input have the potential to further reduce invertebrate diversity. If fish stocking in end-pit lakes commences, our findings suggest, that invertebrates may become a bottleneck for fish survival due to low abundance of prey.

8) Collaborative Fisheries Research in Canada

INTRODUCTION TO THE SESSION AND OVERVIEW OF THE NSERC CANADIAN FISHERIES RESEARCH NETWORK

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This session will highlight examples of collaborative research and presentations that discuss the benefits and issues surrounding collaborative fisheries research.

The NSERC Canadian Fisheries Research network (www.cfrn-rcrp.ca) is a unique collaboration among Canada's academic researchers, fishing industry and government. The network is re-shaping fisheries research in Canada, bringing together industry, the academic community and governmental research on priority research questions of relevance to industry and management. The research of the network is aimed at increasing knowledge that will enhance ecological sustainability, viability, and improved management of Canadian fisheries. It includes research to overcome information gaps in relation to important fisheries, improve the use of industry information in assessment and management, enhance ecological sustainability while achieving operational efficiency, and improve the basis for the ecosystem-based approach to fisheries management. The network has an emphasis on training, including the development of a unique cohort of graduate students and post-doctoral fellows who have direct experience of collaborative research approaches and of academic, industry and governmental perspectives.

ORAL PRESENTATIONS

HYDRONET'S TOOLS TO ASSESS THE EFFECTS OF ENVIRONMENTAL CONDITIONS ON METRICS OF FISHERIES PRODUCTIVITY IN RIVERS

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HydroNet is a national research network whose general objective is to provide scientists and managers with new knowledge and tools to better assess, and minimize, the effects of human activities on aquatic ecosystems, and in particular, on metrics of fisheries productivity. This partnership between academic (13 professors from 10 universities), government (12 scientists from Fisheries and Oceans Canada, Manitoba Water Stewardship, and Québec's Ministry of Natural Resources), and industry participants (BC Hydro, Manitoba Hydro) surveyed a total of 28 river segments (including 13 river segments located downstream of hydropower facilities) distributed from New Brunswick to Alberta. In each river, metrics of fisheries productivity (community species richness, density, and biomass), nutrients, geomorphic features, flow regime, and thermal regime were assessed. These data were used to test the existence of generally applicable relationships between metrics of fisheries productivity and a suite of environmental conditions. Analyses permitted to identify that it is possible to explain between 57% and 70% of metrics of fisheries productivity using 2-3 key environmental conditions. The models suggest that, within the range of rivers surveyed, nationally applicable tools may permit to forecast the impacts of human activities on metrics of fisheries productivity. These models may also be used to identify mitigation measures and their potential effects, and to assess the extent to which offsetting measures may be needed. As such, the tools developed by HydroNet may contribute to inform the decision-making process in the context of the Fisheries Act (2012) and the Fisheries Protection Policy (2013).

AN ACADEMIC-INDUSTRY-GOVERNMENT PARTNERSHIP TO IMPROVE ASSESSMENT OF ATLANTIC HALIBUT IN THE GULF OF ST. LAWRENCE

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Atlantic halibut is a species of high economic importance in Atlantic Canada. A distinct population located in the Gulf of St. Lawrence accounts for a third of total landings. The Gulf stock is considered healthy with increasing catch per unit effort in recent years, and harvesters are advocating that the stock is likely underexploited. However, Fisheries and Oceans Canada scientists can only recommend modest quota increases given the general lack of reliable abundance and biological data for the stock. An academic-industry-government working group was created to address this issue and its main recommendation was to implement a conventional

tagging program to provide exploitation rate for the stock, and simultaneously deploy pop-up satellite archival tags (PSATs) to provide baseline biological information on seasonal migrations and habitat use. As part of a pilot program, 20 fish were tagged with PSATs in 2013, and 223 and 24 fish were respectively tagged with conventional tags and PSATs in 2014. Preliminary results emerging from PSATs deployed in 2013 suggest that adult Atlantic halibut migrated from inshore (150 m deep areas) toward the center of the Gulf (300 m deep areas) from October to April. Spawning occurred in February in the central Gulf, and fish migrated back inshore in May. Pop-up locations indicated that half of the fish did not return to the area where they were tagged. By providing baseline biological data for this population, this study is an important first step in the development of a precautionary approach framework for this valuable resource.

RECRUITMENT PROCESSES IN FISH: AN INVESTIGATION ACROSS SPATIAL SCALES

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Information on recruitment is necessary to determine sustainable yields, but the relationship between fish stock and recruits is highly variable. Recruitment is the complex result of a series of density-dependent processes, which can be greatly influenced by environmental variability. Early life stages, where the two main causes of mortality are competition for food and predator avoidance, are particularly important in determining recruitment. The importance of early life stages in recruitment dynamics supports the idea that the availability and quality of spawning and juvenile-rearing habitat could be an important factor affecting recruitment. The objectives of this study were to (1) Develop a conceptual framework explaining how the availability of spawning habitat can influence biological processes that lead to recruitment variability; (2) Build an age-structured population model that includes the effects of the availability of multiple habitats; and (3) Parameterize and test the predictions of the model using data from the British Columbia rainbow trout (*Oncorhynchus mykiss*) fishery. The knowledge gained on recruitment dynamics at the local scale (lake) can be used to improve estimates of fish production that, once integrated with angler behaviour information, are used to assess the vulnerability of a fishery at the landscape scale and explore appropriate management approaches.

USING BURBOT LIVER APPEARANCE TO ASSESS FISH HEALTH: A COMMUNITY MONITORING APPROACH

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Burbot (Lota lota), like other members of the cod family have large lipid-rich livers. Aboriginal people living along the lower Mackenzie River in the Northwest Territories have long valued the livers of burbot (locally known as loche) as a traditional food source. Community concern has been raised over the poor condition of some Burbot livers and the possible link to contaminants. In this study, livers of burbot were collected by traditional harvesters from four sites in the lower Mackenzie River. These harvesters then ranked the livers in terms of their perceived palatability based on appearance. The relative liver condition was then compared to a variety of metrics used to assess the overall health of each fish including; condition factor, gonadosomatic index, contaminant load, and parasite burden. We found that livers ranked by harvesters to be of poorest quality were found in fish with the highest parasite burden indicating that stressed fish have lower liver quality. Not surprisingly, livers ranked the most palatable looking were those with high lipid content which is often correlated with increased concentrations lipophilic contaminants. The results of this study demonstrate that traditional methods of assessing the quality of livers can be used as a rough index of overall fish health for some metrics, and could be easily incorporated into a community-based monitoring framework. This study underscores the importance of incorporating traditional and local knowledge into the development of scientific studies, from scoping to implementation, to make research relevant to the resource users.

PRISTINE, BOREAL 'LAKESCAPE' POPULATION GENETIC STRUCTURE INFLUENCED BY DEPTH, BASIN AND PLASTICITY IN LAKE TROUT

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Maintaining population diversity is important for species survival and fisheries productivity. Research on several large lakes has documented the presence of multiple genetically- and morphologically-distinct populations within harvested fish species but less is known of population structuring in pristine lakes. We characterized population structuring of lake trout throughout Mistassini Lake, Quebec (2335km^2), using data from nineteen microsatellite DNA loci, spatial habitat use, morphology and local Cree traditional knowledge. We found that the lake is home to a minimum of five populations. These exhibit low to modest levels of genetic differentiation, partial spatial segregation by depth and basin, indiscriminate body and head morphologies, but remarkable within-population variation in morphology. The relationship between genetic and ecological differentiation was inconsistent across ecological metrics assessed, and traditional knowledge recognized attributes of some, but not all of the demarcated populations. We contend that the higher apparent level of within-population phenotypic variation in lake trout relative to other previously studied predatorial fish species in Mistassini Lake may explain their lower level of population differentiation, despite their use of numerous distinct habitat niches. We discuss how identifying and recognizing multiple forms in such a pristine boreal lake system, both with western and traditional knowledge has implications for a better understanding of population diversity and conservation in lake trout and related species elsewhere.

ORAL PRESENTATIONS

THE POTENTIAL EFFECT OF RIPRAP ON THE UTILISATION OF SPACE BY FISH COMMUNITIES

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Riprap is a form of riverbank stabilization that is commonly used to protect road and bridge infrastructures from fluvial erosion. However, little is known about how riprap can affect the repartition of the fish communities. In fact, we know the physical environment is a crucial determinant of the habitat selection by river fish. The objective of this study is to assess potential impacts of riprap on fish communities through a pairwise comparison of stabilized and non-stabilized stream in the Lowland regions in Southern Québec (Québec, Canada). The present study aims at acquiring knowledge on how the fish use that riprap zone and also on how we can design the riprap to have minimum impact. Another main interesting part of the study is to develop a method to sample fish in disturbed rivers like the ones that are located in the Lowland and when some kinds of method, like the seine and the electrofishing, are difficult to use because of the riprap zone.

FISHERY DEPENDENT FLATFISH LANDINGS DATA: SPATIAL DISTRIBUTIONS, ENVIRONMENTAL INFLUENCES AND BYCATCH AVOIDANCE

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On Newfoundland's Grand Banks, gadoid fisheries moratoria largely limit current groundfish catches to flatfish, including yellowtail flounder (*Limanda ferruginea*), while by-catch restrictions on American plaice (*Hippoglossoides platessoides*), constrain the spatial distribution of the fleet targeting yellowtail flounder. Therefore, increased understanding of the drivers of spatial distributions and overlap of these target and non-target flatfish species is essential to minimize by-catch and understand how key characteristics (size, age, community composition) are affected by local environmental conditions, including temperature and depth. In order to examine these patterns, we draw upon a detailed industry-derived catch database that includes geo-referenced catch rates, by-catch, and environmental conditions spanning times of year that are otherwise not covered by fishery-independent surveys. Based on univariate and multivariate analyses of habitat-distribution relationships, our results depict a system in which the overlap and catch/by-catch rates of these two key species and their life stages are influenced strongly by subtle changes in bottom water temperature differentially influencing the spatial distributions of these south-temperate (yellowtail flounder) and north-temperate (American plaice) flatfishes. An increased appreciation of seasonal thermal habitat use by target and non-target species through collaborative data collection and analyses can inform both fishers and fisheries managers of observed and expected changes in flatfish distributions and catch rates under changing ocean conditions on the Grand Banks.

ORAL PRESENTATIONS

TEMPORAL AND INDIVIDUAL VARIABILITY IN REPRODUCTIVE SUCCESS FOR TWO SKAGERRAK NORWEGIAN COASTAL COD POPULATIONS

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Reproductive success is a fundamental parameter that largely determines a population's growth rate, resilience to fishing pressures and ability to recover following severe depletion. All things considered, there is a surprisingly shallow depth of knowledge with regards to how it varies both temporally and individually. The purpose of this study was to investigate the individual and temporal variability of reproductive success in two Skagerrak Norwegian cod populations. Wild adult cod were collected from two genetically distinct populations on the Skagerrak coast: (1) inner and (2) outer Risør fjord; and subsequently placed in a semi-natural environment where they were allowed to spawn uninterrupted. During the entire spawning season, egg samples were collected daily and incubated until 50% hatch, at which point 50 larvae were genotyped for the final parentage analysis. For both cod population's results indicate considerable variability and skew in reproductive success, both temporally and individually, thus highlighting the need for a more comprehensive understanding of this variation in one is to develop more effective fisheries management practices.

9) Aquatic Nutrients: Dynamics and Algal Blooms

MORE THAN 20 YEARS OF INTERNAL PHOSPHORUS LOAD AND ITS EFFECTS ON POLYMICTIC EUTROPHIC LAKE WINNIPEG, MANITOBA

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Recent cyanobacterial blooms and other signs of eutrophication in Canada's 6th largest lake, Lake Winnipeg, Manitoba, have caused concern. While the lake's enormous watershed (40x lake area) is responsible for a large nutrient input there are indications of an internal phosphorus source as P release from bottom sediments even though the lake rarely stratifies. Such P is highly biologically available and could support cyanobacteria blooms.
There is a strong P gradient from the south (110 µg/L) via the Narrows (84 µg/L) to the North Basin (50 µg/L) with its outflow. The southern basin with the largest P load (Red River) is shallow and extensively mixed so that sediment is resuspended creating high turbidity; the deeper northern basin and the Narrows are less turbid and cyanobacteria here are more likely to respond to redox-dependent P release from sediment, as supported by chlorophyll concentrations.
Using long-term data (1992-2012) collected by provincial and federal agencies and experimental results from previous studies, internal load was quantified by several approaches (summer-fall TP increases; annual mass balances by 1 and 2 box models; P release and hypoxia model) in Lake Winnipeg's three basins (North, South and the Narrows). Results specify a substantial internal load in all three lake sections that is as large as or larger than annual external load.

Significant correlations indicate that internal load affects algal and cyanobacterial biomass in late summer and fall. In addition, winter internal load under ice possibly triggers algal blooms in the South Basin.

IRON, SULFUR, AND PHOSPHORUS CYCLING IN SEDIMENT PORE WATERS FROM ALBERTA LAKES: IMPLICATIONS FOR EUTROPHICATION

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Sediment pore waters from shallow lakes in central Alberta were analyzed geochmically in order to better parameterize the nature of sediment phosphorus (P) retention and release. These processes are potentially key to understanding widespread eutrophication of lakes in the prairie-boreal transition and recent increases in toxic cyanobacterial abundance. Although the majority of pore waters exceed saturation with respect to hydroxlyapatite, P exchange between sediment and water is primarily regulated by iron (Fe) rather than calcium (Ca). Dissolved sulfur (S) and Fe concentrations are inversely correlated in all pore waters, and P is no longer retained in sediments above a threshold S concentration of ~100 μmol/L. Simultaneous release of base cations and phosphate characterize these S-rich pore waters. These ions all cycle independently in pore waters when Fe exceeds 25 μmol/L. We surmise that, when sulfides are able to preferentially scavenge Fe, the capacity of sediments to retain P diminishes stoichiometrically. Therefore, the productivity of Central Alberta lakes is closely associated to S loading such as those from diffuse industrial sources, given that sulfate concentrations are rate-limiting to the production of sulfides in anoxic pore waters. These results couple the elemental cycles of P, Fe, and S operating in sediments from representative central Alberta lakes, providing a novel suite of diagnostics for internally-driven eutrophication processes.

LINKING LAND USE TO DISSOLVED ORGANIC CARBON AND DISSOLVED ORGANIC PHOSPHORUS IN LAKE ERIE

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The importance of dissolved organic phosphorus (DOP) as a nutrient in freshwater ecosystems is not well understood despite evidence that it can be an important source of bioavailable phosphorus to aquatic food webs. To better understand this potential nutrient source, we measured DOP speciation and dissolved organic carbon (DOC) quantity and quality in a series of Lake Erie tributaries and explored their relationship to land use (eg., agricultural, forested, wetland). The three basins of Lake Erie, all major and some minor tributaries in Canada and the USA were sampled in spring, summer and autumn for dissolved and particulate phosphorus and carbon. Quantities of phosphomonoesters, phosphodiesters and refractory DOP were measured using enzymatic hydrolysis followed by a colourimetric assay. DOC was quantified by persulfate digestion and characterized using spectrofluorometry. In the spring, DOC concentration in the

tributaries varied between 2.17 and 9.37 mg/L, whereas DOP varied substantially more between 2.84 and 156.86 μg/L. Preliminary results show that DOP speciation may vary with land use, whereas more human-dominated landscapes (e.g., intensive agriculture) exhibited greater concentrations of the bioavailable phosphodiesters. These results point to a potentially important and relatively neglected form of phosphorus not typically studied in Lake Erie.

CLIMATE EFFECTS ON WETLAND SOILS CREATE THE "PERFECT STORM" FOR TOXIC CYANOBACTERIA BLOOMS: FRESH PERSPECTIVES ON AN OLD PROBLEM

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A grand challenge for the 21st century will be better management of lands to ensure the provision of safe and reliable water supplies. Watersheds and their wetlands are filters for nutrient loading to surface waters. Recent reports show that the frequency and intensity algal blooms in surface waters are increasing, particularly cyanobacteria, which can produce potent toxins. What has historically been a problem for nutrient-rich (eutrophic) waters is starting to occur in nutrient-poor (oligotrophic) waters without the obvious triggers of major phosphorus sources. Competing paradigms have led to contentious debates. Our focus has turned to the role of wetlands as bioreactors and controllers on the loading of macro and micronutrients that limit the growth of cyanobacteria. Our research explores how climate affects the variable redox areas of wetlands by changing the timing, magnitude, and organization of reducing conditions, which in turn changes the fates of macronutrients (N removal, P release) and releases essential micronutrients that can be accessed by cyanobacteria through an iron-scavenging system. All of these factors create a perfect storm for the promotion of cyanobacterial blooms.

PREVENTING CYANOBACTERIA BLOOMS: THE CRITICAL ROLE OF ANOXIA AND FERROUS IRON

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A novel conceptual model linking anoxia, phosphorus (P), nitrogen (N), iron (Fe) and sulfate to the formation of noxious cyanobacteria blooms is presented that explains the timing, size and distribution of cyanobacteria blooms along a trophic gradient (Molot et al. 2014, *Freshwater Biology*). The model has several critical concepts: (1) In most systems, P regulates biomass and productivity in freshwaters until excessive loading renders a system N-limited or light-limited but (2) it is the availability of ferrous iron (Fe^{2+}), which is normally vanishingly low in the mixing zone, that regulates the ability of cyanobacteria to compete with its eukaryotic competitors because cyanobacteria have high Fe requirements and cannot transport ferric iron (Fe^{3+}); (3) Fe^{2+} diffusing from anoxic sediments (internal loading) is a major Fe source for cyanobacteria, which acquire it by migrating downwards into Fe^{2+}-rich anoxic waters from

above. Once light and temperature are physiologically suitable for cyanobacteria growth, bloom onset is regulated by the onset of internal Fe^{2+} loading which in turn is controlled by anoxia, reducible Fe content of surface sediments and sulfate reduction rate. Evidence indicates that this model holds across trophic, salinity and acidity gradients. Management implication of this model: (a) blooms can be prevented by maintaining oxidized sediments and (b) N_2 fixation will render N controls of bloom formation ineffective as along as sediment redox is low enough to allow ferric reduction

BLOOMS REPORTS IN ONTARIO FROM 1994 TO 2014

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The Ontario government has a protocol in place for response to algal blooms. The protocol provides clarity on the roles and responsibilities of the government agencies involved, ensuring that bloom incidents are managed effectively. Our role is to provide algal identification services, and we've been recording the number of blooms reported in the province since 1994. We've seen a significant increase in reports ($P < 0.001$), with the greatest rate of increase in blooms of cyanobacteria ($P < 0.001$). Although several of the lakes from which these blooms were reported were characterized by higher median total P concentrations compared to a large dataset of Ontario lakes, 26 % of the lakes were classified as oligotrophic, indicating that an array of factors contributed to bloom occurrence. The most common taxa identified were *Anabaena*, *Aphanizomenon*,*Microcystis* and *Gloeotrichia*. We attributed the trend to increases in nutrient inputs in some areas which promote the growth of algae, factors associated with climate warming which may exacerbate bloom conditions, and an increase in public awareness of algal blooms and associated issues. An increase in public awareness is evident in an increase in media reports on algal blooms in Ontario over the last decade. In this presentation we will also compare the spatial distribution of the cyanobacterial bloom reports since 2009 and evaluate which blooms tested positive for the presence of the algal toxin microcystin. We will further assess whether there were consistent taxa noted in the blooms where toxins were present.

USING MOLECULAR TOOLS TO TRACK HISTORICAL CHANGES IN TOXIC CYANOBACTERIAL ABUNDANCE AND DIVERSITY

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Paleolimnological analyses have estimated historical occurrences of cyanobacterial blooms using pigment and fossil remains. However, these proxies have limitations in determining whether toxic cyanobacteria in particular are increasing in temperate lakes. By comparing gene copy numbers of the microcystin-synthesizing gene (mcyD) to concentrations of sediment microcystin concentrations, we were able to evaluate the past incidence of toxic blooms in a naturally eutrophic lake (Baptise, Alberta) and a trans-boundary lake experiencing more recent

eutrophication (Lake of the Woods, Manitoba/Ontario/Minnesota). In Lake of the Woods, these proxies of toxic cyanobacteria were only detected beginning in the early 1980s (mcyD) and 2000s (microcystin) and were significantly correlated with one another. In Baptiste Lake, both mcyD and microcystins could be detected throughout the entire core as far back as 1830. Microcystins in this system were not highly correlated with the mcyD gene but did correlate to 16S rRNA gene copies representative of the genus Microcystis, a known toxin-producer. Additionally, pyrosequencing of genes specific to cyanobacteria in the Baptiste core suggested that the cyanobacterial diversity (based on Operational Taxonomic Units) has decreased in more recent times, although total abundance has increased based on both the cyanobacterial pigment echinenone and 16S rRNA gene copies representative of cyanobacteria. Our results imply a recent shift towards more monospecific blooms (Baptiste Lake) and an increased occurrence of toxic blooms (Lake of the Woods). Increased monitoring and mitigation efforts are advisable for these lakes to ensure the temporal trends in toxic cyanobacteria observed from the sediment record are kept in check.

CHARACTERISTICS OF ALGAL COMMUNITIES IN THE NEARSHORE ZONE OF LAKE ST. FRANCIS (ST LAWRENCE RIVER) AND ASSOCIATED TRIBUTARIES AND THEIR RELATIONSHIP TO LAND-USE' AND WATER QUALITY

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In recent years, occurrences of nuisance algae have been reported in the watershed and nearshore area of Lake St. Francis, a fluvial portion of the St. Lawrence River near Cornwall, Ontario. These nuisance algae blooms have been known to include potentially hazardous cyanobacteria (blue green algae). There is a concern that algal blooms are occurring more frequently and that adverse impacts to wildlife, human activities and public health could occur. However, there is a general lack of information on the location, frequency and types of algal occurrences in this part of Eastern Ontario. This research seeks to address this lack of information through intensive sampling and citizen science in order to create the information that is necessary to document the occurrence of harmful algal blooms and the associated environmental conditions in and around Lake St. Francis. Analysis of this data will allow possible causative factors (e.g. land use, river/lake characteristics and water quality measurements) associated with algal blooms to be identified. This research will help local agencies and organizations manage harmful algal bloom occurrences responsibly and support the ongoing effort to reduce eutrophication (plant and algal growth) conditions in the Cornwall area as well as meet provincial guidelines.

ASSESSING THE POTENTIAL FOR RESTORATION OF BENEFICIAL USE OF IMPAIRMENTS IN HAMILTON HARBOUR USING LINEAR INVERSE MODELLING

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ORAL PRESENTATIONS

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Ecopath with Ecosim (EwE) is a modelling platform that depicts the trophic relationships among biotic components of an aquatic ecosystem. The present analysis focuses on the potential of Linear Inverse Modelling (LIM) to serve as a parsimonious complementary tool to EwE. To address this research question, we developed a new EwE model to assist with the examination of alternate management plans for the Hamilton Harbour Area of Concern. This model reproduces the trophodynamics of 12 functional groups critical to the Harbour's food web. An equivalent LIM model was developed using the biological rates (primary productivity, production and consumption rates) derived from the balanced EwE model. Variation (+/- 20%) in the biological rates of all biotic groups was used to examine the nature of the trophic relationships in the system. We also evaluated the impact of the anticipated water quality improvements, stemming from the planned nutrient loading reductions, on the top fish predators. Specifically, a scenario reflecting 30% decrease in the primary productivity levels of Hamilton Harbour was examined. Our analysis suggests that the reduction in primary productivity is likely to have significant implications for the goal of achieving a self-sustaining piscivorous community in the Harbour. Our next steps involve the examination of scenarios with varying biological rates that would put these projections into perspective and shed light on the ecological mechanisms that could modulate the outcomes of planned restoration actions.

THE HABER BOSCH – HARMFUL ALGAL BLOOM (HB-HAB) LINK

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Intensification of fertilizer use is occurring worldwide, but the rate of increase in use of nitrogen (N) fertilizers has outpaced that of phosphorus (P) fertilizers. Much of the increase in N fertilizers is also now in the form of urea, a reduced form of N. Excess nutrient loads to receiving waters are leading to aquatic eutrophication, but of particular concern is the increased occurrence of harmful algal blooms (HABs). Many phytoplankton causing HABs have physiological adaptive strategies that make them favored under conditions in which waters are increasingly enriched with nutrients that are elevated in N:P and in forms of N that are chemically reduced. We thus propose that the HB-HAB link is a function of 1) the inefficiency of incorporation of N fertilizers in the food supply chain, the leakiness of the N cycle from crop to table, and the fate of

the lost N relative to P to the environment; and 2) adaptive physiology of many HABs to thrive in environments in which there is excess N relative to classic nutrient stoichiometric proportions and where chemically reduced forms of N are increasing. Although HAB events are occurring now worldwide, the rate of their expansion is particularly pronounced in China where the frequency, duration and extent of blooms in both inland waters and marginal seas are related to increased urea use. Without more aggressive N control the future outlook in terms of HABs is likely to include more frequent events of potentially greater toxicity.

CHANGES IN ANTHROPOGENIC NITROGEN AND PHOSPHORUS INPUTS TO THE ST. LAWRENCE BASIN OVER THE LAST 100 YEARS: IMPACTS ON RIVERINE EXPORT

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Human activities have increased the flow of Nitrogen (N) and Phosphorus (P) on earth, leading to the degradation of air, soil and water quality. Here we aim to identify the hotspots of N and P inputs and the variability of major sources in the St. Lawrence basin (SLB) for 76 watersheds throughout the 20thcentury. We also aim to quantify the fraction of those inputs that is exported to rivers. Using historical data, all known anthropogenic N and P inputs (fertilizer, biological fixation, atmospheric deposition, detergent and net imports in food and feed) were quantified using NANI/NAPI (net anthropogenic nitrogen/phosphorus input), a mass balance modeling approach. Our results show that N inputs vary greatly among regions (110 to over 10000 kgN km^2yr^{-1}) and are strongly related to riverine fluxes, where NANI explains 85% of the variance. As expected, riverine P exports show more variable patterns relative to NAPI revealing a clear legacy effect. NANI and NAPI have increased 2- and 5-fold respectively in the SLB since 1900 with a peak in 1990 mainly due to atmospheric N deposition and P fertilizer application. Since that time, atmospheric deposition has reduced substantially, however N fertilizer inputs have increased resulting in a minimal net change. This work highlights the relevance of NANI as an excellent management tool and the potential use of historical NAPI to quantify P legacies in rivers.

MICROCYSTIN CONCENTRATIONS ACROSS A SERIES OF IRON-AMENDED LAKE MESOCOSMS IN RELATION TO ENVIRONMENTAL AND BIOLOGICAL VARIABLES

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Microcystins—potent toxins produced by certain cyanobacteria—have been implicated in poisonings of aquatic invertebrates and fish, wild and domestic animals, and humans. These

toxins have been detected in lakes and reservoirs across all Canadian provinces. In this study, we examined microcystin concentrations in fifteen mesocosms (2 m in diameter x 5 m deep) installed in hypereutrophic Nakamun Lake, Alberta. Mesocosms were amended with different doses of iron (2 to 225 g m^{-2}, as $FeCl_3$) to test the hypothesis that iron will suppress cyanobacterial blooms, and thus microcystin production, by inhibiting phosphorus release from sediments. As hypothesized, iron diminished internal phosphorus loading and significantly lowered total algal biomass in a dose-dependent manner. Surprising, microcystin concentrations were reduced by iron addition above and beyond the iron-induced suppression of cyanobacterial biomass. To understand this unexpected result, we conducted a series of multivariate analyses to better understand the relationship between microcystin concentrations and environmental and biological variables. We show how variation in water chemical parameters and species-level cyanobacterial counts were associated with elevated concentrations of microcystins, to give insight into the role of iron in microcystin dynamics.

IRON REMEDIATION OF AERATED VERSUS NON-AERATED EUTROPHIC RESERVOIRS: A REPLICATED WHOLE-ECOSYSTEM EXPERIMENT

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Removal of point and non-point phosphorus (P) sources from eutrophic reservoirs may not lead to rapid improvement in their water quality, highlighting the need for in situ remediation strategies that suppress internal loading of P. Biogeochemical theory suggests that iron (Fe) plays a key role in removal of P from the water column and its burial in sediments, especially under oxic conditions. We tested whether aeration amplifies the ability of Fe to suppress total phosphorus (TP) and phytoplankton growth in agricultural reservoirs (i.e. dugouts) by performing a Multiple Before-After-Control-Impact experiment across 20 sites located in central Alberta, Canada. A single addition of $FeCl_3$ (54 – 101 g Fe m^{-2}) during May 2011 significantly suppressed TP by 86% and 47% in non-aerated and aerated reservoirs, respectively. Amendments also significantly decreased total dissolved nitrogen and organic carbon concentrations only in the non-aerated reservoirs. In comparison, Fe addition and aeration did not suppress phytoplankton biomass until the following summer with the suppression of cyanobacteria and green algae. Our findings highlight how iron remediation of eutrophic reservoir ecosystems does not necessarily depend upon artificial aeration.

INTEGRATING PHYSIOLOGY AND ECOLOGY TO UNDERSTAND CYANOBACTERIAL BLOOMS IN EUTROPHIC ECOSYSTEMS

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Cyanobacterial blooms are linked to eutrophication and temperature increases worldwide, dramatically affecting water use. Far from being a homogenous group, bloom forming

cyanobacteria are found in Chroococcales, Oscillatoriales and Nostocales, which differ in their functional traits and environmental preferences. Analyses integrating physiology and ecology are needed to better predict cyanobacterial bloom occurrences. We analyzed the distribution of cyanobacteria in the freshwaters (3000 data points, 63 ecosystems) of a subtropical region (Uruguay, 30 °S to 35°S) and then used an ecophysiological approach to study the responses of cyanobacterial blooms to abiotic factors. Blooms of the three orders were common and widespread in lentic and lotic ecosystems with Nostocales being the most frequent group and Chroococcales the one that reached the highest biomass. Total cyanobacterial biovolume was not correlated with temperature changes, and different species displayed divergent responses to temperature. Cyanobacterial dominance of the phytoplankton was positively associated with eutrophication. We used an experimental approach to study cyanobacterial bloom responses to phosphate dynamics with natural communities and a model species (*Cylindrospermopsis raciborskii*). Our results reveal that cyanobacteria have flexible physiological responses to environmental phosphate fluctuations, which helps to explain the resilience of blooms. The studies performed with C. *raciborskii* demonstrated its physiological flexibility under different nutrient, light and temperature conditions, which explains the increasing success of this cyanobacterium in freshwaters. Our results show the importance of integrating multiple approaches to improve our understanding of cyanobacteria.

BACTERIAL COMMUNITY COMPOSITION ASSOCIATED WITH FRESHWATER CYANOBACTERIAL BLOOMS OF *CHANNA ARGUS* INTENSIVE CULTURE PONDS

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The diversity of freshwater bacterial communities has not been deeply studied despite their important role in foodwebs and the cycling of carbon and associated elements. In order to explore and characterize the composition of the bacterial communities associated with cyanobacteria in the freshwater ponds of *Channa argus* in intensive culture, we examined the bacterial community of non-cyanobacterial blooms freshwater ponds (NCBP) and cyanobacterial blooms freshwater ponds (CBP) using PCR-denaturing gradient gel electrophoresis (PCR-DGGE) and 16S rDNA clone library. The results indicated that Actinobacteria (15 OTUs, 31.9%), Bacteroidetes (13 OTUs, 28.7%), Fibrobacteres (7 OTUs, 14.9%) and Proteobacteria (5 OTUs, 10.0%) were the dominant groups in C; the four dominant groups in CBP were Bacteroidetes (17 OTUs, 34.7%), Actinobacteria (9 OTUs, 18.4%), Fibrobacteres (6 OTUs, 12.2%) and Proteobacteria (8 OTUs, 16.2%). The distribution of sequences belonging to Fibrobacter in CBP (22.2% of the 99 clones) was twice as that of NCBP (11.1% of the 99 clones). These results suggested that the dominant bacterial groups in the freshwater ponds of *Channa argus* in intensive culture were not different in NCBP and CBP, but the ratio of each

bacterial group has changed. Firmicutes group (KC494209 in DGGE and 3 OTUs in NCBP library) only existed in the non-cyanobacterial blooms ponds (NCBP). The rate of the Firmicutes and Bacteroidetes would be a candidate predictor of cyanobacterial blooms in intensive culture freshwater ponds.

MODELING ALGAL TOXIN CONCENTRATIONS IN A CHANGING WORLD: THE IMPORTANCE OF CROSS-SCALE INTERACTIONS

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Several factors are believed to determine the concentration of cyanobacteria in lakes. In particular, eutrophication and climate warming are suggested to be driving a global expansion of cyanobacteria in freshwater ecosystems. This is cause for concern not only because of the substantial economic loss it entails, but also because cyanobacteria are known to produce harmful neuro- and hepatotoxins. Importantly, although strong local-scale cyanotoxin models have been described, modeling the abundance of microcystin (a group of cyanotoxins), across broader spatial scales has been difficult and production remains highly dynamic through space and time. For instance, at the local scale (southern Québec lakes), 46% of the microcystin variance was explained by explanatory variables, whereas a meta-analysis developed across Canadian lakes explained far less variance (10% explained). Such scale dependencies may be due, in part, to interactions between processes across different spatial scales (defined as cross-scale interactions), where overarching regional drivers cause local-scale relationships to differ. The goal of this project was thus to develop robust microcystin response models that account for these cross-scale interactions. To address this objective, we analyzed a dataset of >1000 randomly selected lakes, ponds, and reservoirs sampled by the U.S. Environmental Protection Agency (USEPA) and applied generalized zero-inflated mixed-effect models, which effectively modeled the large number of sites with microcystin concentrations below the detection limit, allowed for local relationships to vary by region, and tested the cross-scale interactions among environmental drivers.

EFFECTS OF BIODIVERSITY ON AQUATIC MACROPHYTE DECOMPOSITION RATE: IS THERE A MEDIATING ROLE OF TISSUE NUTRIENT CONTENT?

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The decomposition of aquatic macrophytes plays an important role in lake nutrient cycles and, given the high biomass of macrophytes, can mediate significant carbon storage in lake sediments. While many past studies measured rates of aquatic plant decomposition on species held separately, diverse plant communities are typically found in lake littoral zones and decomposition typically occurs as mixes of multiple species. Here we examined how biodiversity affects the decomposition rates of aquatic macrophytes. Specifically, we used senesced biomass of four species of variable elemental composition (*Myriophyllum*

heterophyllum, *Ceratophyllum demersum*, *Typha* x *glauca*, *Potamogeton robinsii)* to create single, double, triple, and quadruple species mixtures that were incubated in Pigeon Lake (Ontario) for 70 days. We measured dry mass loss after different time periods and the change in biomass elemental composition at the end of the experiment. Preliminary results show differences in decomposition rates between individual plant species and different mixtures, some of which appeared to be non-additive effects. These results suggest that changing plant diversity could idiosyncratically affect rates of aquatic plant decomposition and affect littoral nutrient cycles. By coupling decomposition results with changes in biomass elemental composition, we will further determine how this will affect nutrient storage and/or release from littoral sediments.

10) Experimental Lakes Area

LONG TERM CHANGES IN NUTRIENT DYNAMICS AND PLANKTON IN AN EXPERIMENTAL RESERVOIR

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Reservoirs have been created on many rivers in Canada and around the world for power generation, flood control, irrigation, and other purposes. We use long-term data collected from a whole-ecosystem flooding experiment at the Experimental Lakes Area to address 2 questions: 1) how does reservoir creation affect nutrient concentrations and plankton community structure?; and 2) how long do impacts persist after initial flooding? As part of the ELA Reservoir Project in Lake 979, we followed changes in nutrient concentrations, nutrient budgets and plankton biomass and composition for 1-2 years prior to (1991-92) and for 17 years after (1993-2010) the construction of a dam at the outflow that raised water levels 1.3m and increased lake volume by 6X. Following closure of the dam, average total phosphorus (P) concentrations increased from approximately 7 ug/L to above 20 ug/L. For 6 years following initial impoundment, Lake 979 changed from being a net sink to a net source for P and elevated P concentrations were observed for >10 years. Phytoplankton and zooplankton biomass increased more than 10X and these elevated levels persisted for >10 years. Results from Lake 979 may represent a worst-case scenario for reservoirs on the Canadian Shield because the experiment flooded a peatland with large stores of decomposable carbon.

IS THERE PHOTOFERROTROPHY IN THE ANOXIC HYPOLIMNION OF L227 AT THE ELA?

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Photoferrotrophy, where Fe2+ is used as an electron donor for carbon fixation in the presence of light, is of interest for understanding Fe cycling in lakes and in the Archean ocean.

ORAL PRESENTATIONS

Photoferrrotrophy in ancient ferruginous oceans may pre-date the evolution of cyanobacteria and oxygenic photosynthesis, playing a role in supplying Fe3+ for the globally distributed banded iron formations. Lake 227 at the Experimental Lakes Area has been the site of a long term and controversial nutrient addition experiment spanning more than 45 years. Following the start of nutrient additions in 1969, the hypolimnion became completely anoxic with O2 penetration only at lake turnover. Fe2+ concentrations are very high and both SO42- and S2- are low. Light levels in the hypolimnion are minimal but sufficient for these autotrophs. Stable carbon and nitrogen isotope analyses reveal that particulate organic matter (POM) in the hypolimnion curiously does not match surface POM or lake sediments. Differences between stable isotopes of NH4+ and DIC compared to POM are consistent with fractionation due to biological uptake of both N and C. Stable isotopic analyses of Fe show fractionation similar to laboratory cultures of ferrotrophs. Measures of DOC quality indicate unusually high levels of biopolymers that are likely associated with active biological production. Sequence analysis of 16S rRNA genes is underway to identify the organisms. Results from L227 are compared with those from other lakes with anoxic hypolimna but no nutrient additions. Is L227 a model of the Archean Ocean? Does photoferrotrophy affect P cycling in lakes?

ROLE OF IRON AND PH ON THE PHOTODEGRADATION OF DISSOLVED ORGANIC CARBON IN AQUATIC ENVIRONMENTS

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Dissolved organic carbon (DOC) is the largest input of carbon to northern shield lakes. Photodegradation of DOC is an important abiotic process for DOC loss. Products of DOC photodegradation; particulate organic carbon (POC), dissolved inorganic carbon (DIC), and photolytically altered DOC affect the size of carbon pools in lakes. Concomitantly, lake parameters such as pH, DOC and Fe concentrations can influence the rates of formation and the distribution of these products within the carbon pools in lakes, yet these influences are poorly understood. As global atmospheric CO_2 concentrations increase, contributing to the planet's greenhouse effect, it is important to understand what influences the quantity of CO_2 emitted from sources, such as lakes. In recent experiments, pH and Fe concentration of two ELA streams and one Dorset stream were manipulated to observe the impact on DOC photodegradation, and DIC and POC formation during photolysis. pH, DIC, Fe, DOC and the $\delta^{13}C$ of the DIC produced were sampled throughout the experiment and a carbon mass and isotopic mass balance was performed. A size exclusion method, LC-OCD, was used to analyze differences in stream DOC quality before and after photolysis.

FATE AND EFFECTS OF SILVER NANOPARTICLES FOLLOWING WHOLE-LAKE ADDITION AT THE EXPERIMENTAL LAKES AREA

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ORAL PRESENTATIONS

The potential release of nanoparticles into aquatic environments is raising global concerns about their impact on foodwebs. As antimicrobials, silver nanoparticles (AgNPs) are among the most prominent nanoparticles in use. Despite this, their fate, long-term toxicity, and ecological relevance have yet to be investigated under natural settings. To better understand the environmental significance of AgNPs, we released these particles into a lake at the Experimental Lakes Area beginning in May 2014. Assuming no loss, our dosage rate would increase the total cumulative concentration to 15 ppb by late October 2014. Mean total silver increased to 6.78 µg/L in the lake epilimnion and to 3.34 µg/L in the hypolimnion by August 2014. Silver was accumulating in the particulate fraction with up to 5.48 µg/L observed in >0.8 um sestonic fraction. Overall, AgNP remained suspended in the water column and was detected spatially throughout the lake by the end of the summer. Despite this, we found no difference in chlorophyll concentrations between the exposed and reference lakes, as well as no discernible consequences to foodweb components. The presence of dissolved and particulate organic matter may have reduced toxicity. Our experiment provides the first whole-lake perspective toward silver fate and toxicity, suggesting small scale experiments may overestimate environmental responses.

RESPONSES OF NATURAL LITTORAL MICROCRUSTACEAN COMMUNITIES TO AN ADDITION OF SILVER NANOPARTICLES

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Silver nanoparticles (AgNPs) are recognized as the most commonly used nanomaterial, due to their potent antibacterial properties. With the increased use and subsequent release of AgNPs into the environment, it has become critical to assess the environmental impacts these nanomaterials could have on aquatic ecosystems. Nanosilver has been shown to have detrimental effects on lower aquatic trophic levels; however, these findings were obtained in controlled laboratory settings and over short periods of time. In this study, we released environmentally relevant (if no loss is assumed up to 15 ug/L) concentrations of AgNPs into a lake at the Experimental Lakes Area throughout the summer and autumn of 2014, with aims to identify changes in natural littoral planktonic and epibenthic microcrustacean communities. Epizoobenthic communities could be especially susceptible to the toxicity of AgNPs, due to the potential of these particles to aggregate and accumulate in the sediments of the lake. Artificial substrates were placed at five locations along the littoral zone of the experimental (Lake 222) and reference (Lake 221) lakes, and allowed to colonize for three months in both the year prior to, and during the silver addition. Ag was detected within the experimental lake at the time of collection. Microcrustacean abundance varied between 0.12 and 0.96 individuals/cm^2, although richness was not different between exposed and reference lakes. The results of this study will help assess sensitivity of natural microcrustacean communities to AgNPs, as changes in these communities may in turn affect the structure and function of the entire lake ecosystem.

ORAL PRESENTATIONS

MALE REPRODUCTIVE BEHAVIOUR DURING THE COLLAPSE AND RECOVERY OF A FATHEAD MINNOW POPULATION

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Male fish exposed to estrogenic compounds found in municipal wastewater effluent exhibit altered reproductive behaviour and have diminished reproductive success, although this has yet to be confirmed for wild populations. Male fathead minnow (*Pimephales promelas)* show elaborate courtship behaviour and extended parental care, and have become a model species for understanding the impacts of estrogenic compounds. We quantified individual reproductive behaviour of male fathead minnow from in-lake video recordings taken before, during (2001-2003) and after a synthetic estrogen used in birth control pills (ethynylestradiol, EE2) was added to Lake 260 at the Experimental Lakes Area. The fathead population collapsed after the first year of EE2 addition and remained supressed for 5 years. Male fathead minnow exposed to EE2 showed marked changes in courting behaviour that were not observed pre-exposure or in the reference lakes. Contrary to lab studies, exposed males showed an increase in aggressive encounters, which was in response to greater numbers of fish surrounding the nest that we presume were feminized male conspecifics. As a result of frequent aggressive encounters, exposed males reduced time spent tending to eggs. Thus, the few fathead males that were able to breed during the exposure period faced increasing nest threats from conspecifics that reduced their ability to defend egg clutches and resulted in significantly fewer eggs per nest compared to pre-exposure. Our study highlights the complex ecological and behavioural interactions that occur in natural systems and further demonstrates the need for studies conducted at the scale of a whole-ecosystem.

DOES THE DIFFERENTIAL WARMING HYPOTHESIS EXPLAIN LONG-TERM VARIATIONS IN THE DIET OF A COLD-WATER FISH?

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Boreal lakes are sensitive to climate warming due to changes in air temperature. Rising air temperatures accelerate initiation of thermal stratification, thereby increasing its duration and intensity. Intense stratification generates the potential for large temperature differences between hypolimnetic-pelagic and nearshore-littoral sub-habitats within a lake. Water temperatures remain fairly constant in pelagic zones, whereas littoral zones are highly influenced by air temperature. This differential warming between lake habitats establishes physical habitat barriers to coldwater fish species that cannot tolerate warm water. Despite these physical barriers, lake stratification also coincides with the period when lake production is greatest and when fish obtain energy for reproduction, somatic growth, and energy storage for winter. For coldwater species, the differential warming hypothesis predicts that years with earlier spring ice

break-up, warmer air temperatures, and longer, more intense stratification periods should reduce energy derived from littoral habitats. This pattern is predicted to be exacerbated in lakes without pelagic prey fish species. We test this hypothesis using stable isotopes and stomach contents from archived samples of lake trout (*Salvelinus namaycush*) collected 1978–2012 from two long-term references lakes at the ELA. We relate variations in the relative use of littoral vs. pelagic food sources by lake trout to air and water temperature, duration of stratification period, and accessibility of littoral zones. Preliminary results support our predictions; lake trout had higher trophic positions and utilized more littoral carbon in years with cooler spring–fall air temperatures. Understanding how climate-driven differential warming affects lake trout diets will help predict how this species will respond to future climate warming.

APPARENT EXTIRPATION OF PREY FISH COMMUNITIES FOLLOWING NORTHERN PIKE (*ESOX LUCIUS*) INTRODUCTION

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Introductions of top-predators in lakes can have devastating consequences to native fish communities. Northern pike (*Esox lucius*) were stocked into Lakes 221, 227 and 110 at the Experimental Lakes Area in northwestern Ontario, Canada during 1987-1994, none of which supported native predator fishes. In lake 227, prey fish were undetectable after 1995 (three years after pike addition) and pike were removed from the lake during 1996. Since then, multiple independent visual and trapping surveys suggest this lake remains fishless. In 2012, we surveyed fish communities in Lakes 221 and 110 using baited minnow traps, fyke nets, trap netting, gill netting, angling, and visual observation. Despite extensive efforts, no forage fish of any species were observed or caught in either lake. In all three lakes where pike were added, prey fish populations had been extirpated or were too small to detect. We estimated the current Lake 221 pike population at 49±37 individuals, a 59% decrease since 2000 when prey fish were still present. Mean total length and body condition in Lake 221 had not changed since the prey community collapsed. Our findings suggest that introducing northern pike to naturally piscivore-less lakes permanently alters fish community structure, to the detriment of both pike and prey fish populations. We hypothesize that the apparent extirpation is a likely a combination of species-level intolerance of northern pike, as well as a lack of evolved predator-avoidance strategies.

WHOLE LAKE DYNAMIC MODELS FOR DEVELOPING INTEGRATED UNDERSTANDING OF AQUATIC PROCESSES AND FOR ORGANIZING DATA AND KNOWLEDGE.

Raymond H Hesslein

Technical innovations have allowed environmental data to be collected faster and at finer time and space resolutions. Many more parameters can now be measured. Fortunately electronic data storage capacity has increased rapidly, so basic storage is not a problem. However, the challenges of integrating the data into the existing body of knowledge and expanding that body

in a way to take advantage of the resolution of the new data require dynamic models. Organization of the data and knowledge can also be accomplished through the use of process based dynamic models. This is particularly important in the face of the large number of studies now available in many sub-disciplines. The presentation will present a dynamic model for lakes and discuss how it is useful in the understanding of lake processes and the organization of data and knowledge.

11) General Contributed Papers

A CANADIAN ARCTIC ENIGMA: WHERE ARE THE JUVENILE GREENLAND SHARKS (*SOMNIOSUS MICROCEPHALUS*)?

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Life-stage based management of marine fishes requires information on juvenile habitat preferences to ensure sustainable population demographics. This is especially important in the Arctic region given very little is known about the life histories of many native species, yet exploitation by developing commercial and artisanal fisheries is increasing as the ice extent decreases. Through scientific surveys and bycatch data from gillnet fisheries, we document captures of rarely reported juvenile Greenland sharks (*Somniosus microcephalus;* ≤200 cm total length [TL]) during the ice-free period in the Canadian Arctic. A total of 22 juvenile animals (42% of total catch; n = 54), including the smallest reliably measured individual of 117 cm TL, were caught on scientific longlines and bottom trawls in Scott Inlet and Sam Ford Trough over three consecutive years. Molecular genetic nuclear markers confirmed species identity for 44 of these sharks sampled; however, two sharks including a juvenile of 150cm TL were identified as carrying a Pacific sleeper shark (*Somniosus pacificus*) mitochondrial cytochrome *b* (cyt *b*) haplotype. This represents the first record of a Pacific sleeper shark genetic signature in Greenland sharks in Eastern Arctic waters. Juvenile sharks caught as bycatch in gillnet fisheries were only observed offshore in Baffin Bay surrounding a fishery closure area, while larger sub adult and mature Greenland sharks (>200 cm TL) were caught in all fishing locations, including areas where juveniles were observed. The repeatable occurrence of juvenile Greenland sharks in a fjord and their presence at two offshore sites indicates these smaller animals either reside in nurseries or have defined home ranges in both coastal and offshore regions and/or undertake large-scale inshore-offshore movements.

ORAL PRESENTATIONS

HABITAT USE OF SILVER SHINER (*NOTROPIS PHOTOGENIS),* A THREATENED SPECIES, IN ITS KNOWN RANGE IN THE GREAT LAKES BASIN.

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The Silver Shiner (*Notropis photogenis*) is a small riverine fish currently listed as Special Concern by the Canadian Species at Risk Act (SARA) under Schedule 3. In 2011, COSEWIC recommended that the status of this species be increased to Threatened due to its limited population and susceptibility to habitat loss and degradation. Little is known regarding the habitat preferences of this species and therefore risk of extirpation and critical habitat estimations are based on general habitat use assumptions. In 2011, revisiting the work of M. Baldwin, extensive sampling was conducted by Fisheries and Oceans Canada in four watersheds in the Great Lakes basin from which Silver Shiner are known: Bronte Creek, Sixteen Mile Creek, Thames River, and Grand River. Fishes were collected using a repeat sampling method with a seine net and fine-scale habitat assessments were conducted at each site. Habitat parameters were measured including water velocity, water depth, dominant substrate type, water temperature, conductivity, pH, turbidity, and dominant aquatic vegetation type. An electivity index was used to determine habitat preference.

EFFECT OF CHANGING FEEDING ENVIRONMENT ON THE SURVIVAL OF LARVAL ATLANTIC HERRING OFF NEWFOUNDLAND

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Atlantic herring play an important role in the North Atlantic ecosystem by transferring energy from secondary producers to higher trophic levels. Newfoundland herring populations are composed of spring and fall spawners, targeted as a mixed fishery. In the past, spring spawners accounted for ~90% of the total catch. Within the last decade, spring spawners substantially decreased, while fall spawners slightly increased, now dominating the catch. Peak production of copepods species such as *Pseudocalanus sp.* and *Calanus finmarchicus* has simultaneously shifted from spring to fall. These copepods are known to play an important role in the diet of several species of larval fishes. We test the hypothesis that the shift in herring abundance is related to larval feeding success and survival. Larval samples were collected using bongo tows in Trinity Bay, Newfoundland, between 2002 and 2013. In 2013, simultaneous mesozooplankton collection allowed us to estimate prey selectivity. We also relate the time series of diet composition to a zooplankton time series (1999-2013) to examine if changes in the timing of preferred prey production correspond to those in the dynamics of the herring stock. This study

will provide information on how prey availability contributes to the early survival and recruitment of herring.

RESPONSE OF RESIDENT RAINBOW TROUT TO WATER DIVERSION AT RUN-OF-RIVER PROJECTS

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A surge in new hydropower development in British Columbia in the 2000s, coupled with an absence of clear guidance on scientific requirements for long-term monitoring, led British Columbian and Canadian government agencies to develop monitoring protocols for these projects. The protocols require a minimum of two years of pre-project (baseline) data and five years of post-project (operational) data. The recommended experimental design was based on a target power of 0.8 to detect a 50% decline in target fish species abundance or biomass. Here we present results of fish community monitoring after five years of operation for a group of four run-of-river projects operated by Innergex Renewable Energy. The four projects are located on streams in south-western British Columbia and have fish communities in the diversion reaches composed of only Rainbow Trout. The experimental design for fish community monitoring used a BACI design, with sampling conducted in the project diversion reaches (n=5 per stream) and control sites (n=5 per stream). The primary sampling method was closed-site electrofishing. Data on water flow, temperature, chemistry, habitat, geomorphology, and invertebrate abundance were also collected. After five years of operational monitoring, increases in Rainbow Trout density and biomass were observed in the diversion reaches of all four streams, relative to control and baseline conditions, despite earlier environmental assessment predictions of habitat losses related to flow diversion. Integrated analysis of physical and biological metrics is on-going and will facilitate better understanding of causal mechanisms.

USE OF HYDRODYNAMIC MODELING AND HABITAT SUITABILITY INDICES TO PREDICT LAKE STURGEON SPAWNING HABITAT IN THE SPANISH RIVER, ONTARIO

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Lake Sturgeon aggregate at the base of Espanola Falls of the Spanish River during spawning periods. Hydro generation at Espanola Falls, and additional upstream power stations have been thought to pose significant risks to Lake Sturgeon. A TELEMAC hydrodynamic model was calibrated for the river system under two flow regimes, then used to estimate water depth and flow velocities for the receiving environment downstream of Espanola Falls for the sturgeon spawning periods in each year from 2001 to 2011. Hydrodynamics were modeled for four operational scenarios (flow regimes) that included: (1) existing conditions (i.e., modest peaking); (2) smoothed peaking; (3) run-of-river; and (4) naturalized flow regime. The hydrodynamic model results were then used as input to a spawning habitat suitability model that considered flow velocities, water depth and substrate texture, and predicted conditions for pixels of ~6 m^2 in

size. The model also considers water temperature, the timing of spawning, and the likelihood that eggs will go dry because of variations in water elevations. Habitat use by radio-tagged sturgeon supported the hydrodynamic modeling results.

RESIDENCY AND DISTRIBUTION OF ARCTIC COD (*BOREOGADUS SAIDA*) IN RESOLUTE BAY, LANCASTER SOUND

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With climate change resulting in unpredictable sea ice conditions from year to year, it is crucial to gain a more comprehensive understanding of the subsequent effects to the Arctic marine ecosystems. Resolute Bay, Cornwallis Island (74° 44' N, 095° 04' W), is an important hunting ground for the local Inuit population and a historically known site for Arctic Cod (*Boreogadus saida*) aggregations. Arctic Cod are believed to be a key species in the Arctic marine ecosystem, serving as a food source for members of higher trophic levels. To investigate the residency and distribution of Arctic Cod, an acoustic receiver array of 60 Vemco VR2W 180 KHz was established and 85 Arctic Cod implanted with Vemco V6 acoustic tags. Following an 86 day period of residence in the bay area, all but three individuals exhibited a collective departure. During this absence 51 Arctic Cod were detected ~2 km outside of the mouth of the bay. Following the 14 day absence, 49 Arctic Cod collectively returned to the bay array and the rest were not detected inside the bay again. After a 65 day long second residence inside the bay, again all but the same three individuals displayed a collective departure and eight cod were then detected on the outside gate monitors. Ingress and egress from the bay appear to be primarily driven by environmental changes associated with the transition from the open water to ice cover period, as indicated by the results of a general linear mixed-effects model (GLMM).

SEASONAL MOVEMENTS OF THE DEEPWATER FLATFISH, GREENLAND HALIBUT (*REINHARDTIUS HIPPOGLOSSOIDES*), IN THE COASTAL FJORDS OF BAFFIN ISLAND

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Greenland halibut are one of the most important commercial fish species in the Canadian Arctic, with interest expressed in many northern communities of developing local fisheries to provide much needed economic development. Greenland halibut are known to be highly mobile, yet very little is understood about the timing of their movements or the implications this may have on management decisions. Seasonal movements of Greenland halibut were therefore examined in Scott Inlet and Sam Ford Fjord, Baffin Island, Nunavut, using passive acoustic tracking technology. Smaller fish (<55 cm fork length) were found to be more transient, with all fish tagged in September exiting into Baffin Bay by the end of November, and three fish returning the following summer, around July. Large fish (>55 cm fork length) were more sedentary, with some individuals staying in the system year-round and moving deeper into the fjords during the

winter/ice-covered period. This information can aid the development of sustainable fishing practices by the nearby community of Clyde River if a winter (through-ice) fishery commences, as this would most likely target a subset of the large fish present in the system and avoid the smaller transient ones. A better understanding of the inshore-offshore connectivity of this stock will assist in establishing meaningful management boundaries and quotas between the local artisan fisheries and offshore commercial vessels to achieve sustainable management of Greenland halibut.

ALTERNATIVE MIGRATORY STRATEGIES OF ARCTIC CHAR (*SALVELINUS ALPINUS*) IN A HIGHLY VARIABLE ENVIRONMENT

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In the summers from 2012-2014, parties from the Kugluktuk Hunters and Trappers Organization and Golder Associates and I conducted research on the arctic char run in Nulahugyuk Creek, Nu., in response to local concern over the size of the migration. Over the course of the migration the creek discharge declined quickly, forcing char to migrate through shallow water with large daily temperature fluctuations (>10°C) and high temperature extremes (e.g. 21°C). The downstream migration of adults (>55 cm) began in mid June and continued into early July, while the downstream migration of juveniles (<30 cm) began in mid-to-late June and continued until late July. The upstream adult migration began in late June and continued until mid-July, which is much earlier than typical migrations. There was no appreciable upstream migration of juveniles and char of 30 to 55 cm were absent from the migratory population. The average age at first migration was four years old and the youngest returning adult char was eight years old. The missing size and age classes, and the observation that all sampled upstream-moving adult char were reproductively mature indicate that unlike most char populations, char in our study system may not return to their natal system until they are ready to reproduce. Together the data suggest that Nulahugyuk Creek arctic char possess a novel life history that limits unnecessary exposure to restrictive migratory conditions.

MIGRATING ATLANTIC COD OTOLITHS REFLECT MOVEMENT THROUGH WATER MASSES: LINKING DATA STORAGE TAG DATA WITH HIGH RESOLUTION TRACE ELEMENT AND ISOTOPE GEOCHEMICAL SIGNATURES

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Geochemical signatures are frequently used in otolith research to reconstruct the ambient conditions experienced by a fish. Oscillations in δ18O and Sr/Ca corresponding to alternating opaque and translucent aragonite growth bands have been reported in several marine fishes. Both δ18O and Sr/Ca in otolith aragonite have been reported to be inversely correlated with

temperature, however, other factors (kinetic, physiological or ontogenetic effects) may influence this correlation. In this study we compared the geochemical patterns of fish moving (migrating) through water masses, with those experienced by sedentary (penned) fish. The objective of this was to investigate typical seasonal oscillations in trace element and isotopic signatures for non-migrating fish to elucidate patterns that indicate true fish movements. To do this, we linked ambient temperature from a migrating Atlantic cod from a recaptured data storage tag, (DST) with otolith δ18O and trace element (Sr/Ca, Mg/Ca, Ba/Ca, Na/Ca) analyses. The same analyses were run on a number of penned cod with known ambient conditions. DST records coupled with the high spatial resolution analyses permitted temperature calibrations for both Sr/Ca and δ18O. An increase in the amplitude of annual Sr/Ca maxima and minima occurred at approximately age 3 in the wild cod, consistent with the onset of inshore-offshore migratory behaviour. A change in the amplitude of Sr/Ca was not observed in the penned cod. These findings give unique insight into geochemical fluctuations observed in migrating fish as distinct from the oscillations experienced by resident or penned fish.

THE PELAGIC FISH COMMUNITY IN THE CANADIAN BEAUFORT SEA – VERTICAL DISTRIBUTION, DIVERSITY AND FOOD WEB LINKAGES

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In summer 2012, the pelagic fish community was studied in the Canadian Beaufort Sea as part of the Beaufort Regional Environmental Assessment (BREA) Marine Fishes Project. A large pelagic trawl (Cosmos-Swam mid-water trawl) and an Enzenhofer and Hume mid-water trawl were deployed at 21 stations representing various depths and geographical locations. The sampling events were divided into sub-surface, mesopelagic and supra-benthic depth groups. Overall there were 1994 fishes collected, including 1939 Arctic Cod (*Boreogadus saida*), 24 Kelp Snailfishes (*Liparis tunicatus*), 13 Glacier Lanternfishes (*Benhtosema glaciale*), 8 Gelatinous Snailfishes (*Liparis fabricii*), 8 Arctic Staghorn Sculpins (*Gymnocanthus tricuspis*) and 2 Ribbed Sculpins (*Triglops pingelii*). Age analysis of Arctic Cod revealed that fishes in the sub-surface catches were primarily of 0+ age (young of the year), while deeper in the water column 1+ and 2+ year classes were dominant. Analysis of stomach content from fishes collected in the mesopelagic catches showed that the youngest fishes fed on the smaller- and medium-sized copepods while diets of larger fishes contained larger copepods and amphipods. The pelagic fish community of the Canadian Beaufort Sea exhibits low diversity dominated by Arctic Cod, relative to that found in benthic habitats.

MECHANISMS FOR REDUCTIONS IN FISH PRODUCTIVITY IN DARK WATERS: HABITAT SQUEEZE, GROWTH AND REPRODUCTION.

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ORAL PRESENTATIONS

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Spatial and temporal variations in water colour resulting from terrestrial dissolved organic carbon (DOC) inputs may have important implications for the productivity of affected ecosystems and their consumers. A reduction of fish production has been observed in lakes with high DOC concentrations but we know little about the mechanisms for this and how they are manifested in individual fish. It is possible that a reduction in basal resources and thermocline/oxycline depth lead to a habitat squeezing effect in darker lakes which may lead to reduced growth rates and reproductive output in fishes. Here, we show evidence of habitat squeeze in largemouth bass using telemetry and a whole-lake experiment. We also show evidence that growth and reproductive output of sunfish decreases with increases in water colour. The shifts in life history (e.g. maturing at later ages) for these fish could have implications in maintaining viable recreational fisheries in the light of increasing DOC concentrations.

DO DIFFERENCES IN BEHAVIOURAL TYPE AND ANGLING TECHNIQUE INFLUENCE VULNERABILITY TO CAPTURE?

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Size-selective harvest associated with commercial and recreational fishing practices has been shown to alter life history traits through a phenomenon known as fishing-induced evolution. This phenomenon may be a result of selection pathways targeting life-history traits directly or indirectly through correlations with behavioural traits that make certain individuals or species more susceptible to capture. Here, we report on the relationship between individual differences in behaviour and angling technique (crankbait versus worm) in 200 wild-caught largemouth bass (*Micropterus salmoides*) and rock bass (*Ambloplites rupestris*) from Lake Opinicon in Ontario, Canada. Each angling technique was meant to target individuals based on their behavioural type (bold / shy). For example, bold individuals, which are more likely to take risks, were targeted using a diverse range of crankbaits that were brightly coloured, noisy and retrieved quickly. In the same habitat, more timid individuals were targeted using naturally coloured, plastic worms and a slow retrieve. All captured individuals were then held for 24 hours and tested for boldness using a large in-situ experimental arena. Individual differences in behavioural type strongly correlated with method of capture in the wild. Our study highlights the relationship between angling technique and behavioural type in natural populations of popular sport fish and underscores the potential risk of sampling biases associated with method of animal capture for behavioural, population, and conservation biologists.

ORAL PRESENTATIONS

IMPACTS OF CHANGES IN DENSITY-DEPENDENT GROWTH AND RECRUITMENT RELATIONSHIPS ON SUSTAINABLE FISHERIES HARVEST

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Density-dependent growth and recruitment are important ecological feedbacks that influence population dynamics. Large scale ecosystem changes can also alter these relationships, and in turn impact harvest. In this study, we examined how changes in density-dependent growth and recruitment relationships affect population dynamics and harvest of Lake Whitefish in Lake Huron, a lake that has undergone substantial ecological change in recent years. Using an individual-based model, we simulated combinations of reduced growth potential, reduced early survival, and increased strength of density-dependence in somatic growth and recruitment in response to large-scale ecological change, at three levels of fishing mortality (F=0.3, 0.6, and 0.9). Moderately reducing growth potential or early survival, or moderately increasing the strength of density-dependence in the model, often considerably reduced population biomass and harvest. Effects of altering the density-dependent growth relationship occurred mainly through reduced size-at-age, whereas those associated with altering the stock-recruitment relationship resulted from overall declines in population abundance. Low growth potential alone was sufficient to lead to population collapse over all levels of fishing mortality examined, whereas low early survival only resulted in population collapse at high fishing mortality ($F_{0.9}$). Just moderate reductions in growth potential and early survival were needed to result in population collapse when density-dependent growth and recruitment relationships were altered concurrently and fishing mortality was high. Given the reductions in growth and recruitment observed in Lake Huron lake whitefish populations, recent ecosystem changes have likely played some role in harvest declines, and may have also affected the sustainability of the fishery.

STABILITY IN PROBABILISTIC MATURATION REACTION NORMS FOR AGE AND SIZE AT MATURATION IN LAKE ERIE YELLOW PERCH

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Age and size at maturation are important life history traits of harvested fish populations, because changes in these traits can affect population dynamics and potential yields to harvesters. Lake Erie Yellow Perch have been harvested for decades and the population biomass has fluctuated widely since 1975. Over the last 20 years, age and size at maturation have also fluctuated and such rapid changes in life history traits are not consistent with fisheries induced evolution (FIE) but rather plastic life history responses by individuals to changes in their environment. Probabilistic Maturation Reaction Norms (PMRN) for age and size at maturation incorporate the effects of growth and survival on life history decisions in an attempt to disentangle individual plastic response from population genetic changes in maturation. However, it is not clear if PMRNs account for other changes in life history unrelated to growth or survival. Our research indicates that PMRNs are stable in Lake Erie Yellow Perch over two decades despite large and bidirectional changes in maturation traits over the same time and that PMRNs may be showing an upward shift in age and size at maturation contrary to most other heavily fished stocks. Our

result with Lake Erie Yellow Perch support recent theory about how the relationship between fishing intensity and selectivity influence changes in age and size at maturation in fish stocks.

SHIFTING IMPORTANCE OF REPRODUCTION AND PREDATION TO VARIATION IN RECRUITMENT BY LAKE ERIE YELLOW PERCH (*Perca flavescens*)

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Prediction of fish recruitment is difficult, if not impossible, in part due to the non-stationary nature of variation in recruitment caused by predictors that shift with time. Failure to recognize temporal shifts in relationships between various predictors and recruitment may lead to unreliable recruitment forecasts over both short- and long-terms. We examined the sensitivity of variation in recruitment to variation in reproduction (indexed by spawning stock size) and predation by Walleye (*Sander vitreous*) for Yellow Perch (*Perca flavescens*) in Lake Erie between 1978 and 2013. At that temporal scale, recruitment was influenced more by predation by age-1 Walleye on age-0 Yellow Perch than by spawning stock size. At decadal scales, the influence of Walleye predation relative to stock size was greater, ambiguous, and less, respectively, before 1990, between 1990 and 2000, and after 2000. Our evidence is consistent with the idea that non-stationary responses of recruitment to various factors imperils reliable recruitment predictions, and underscores the risk inherent in the use of constant correlations derived from past years for forecasting recruitment into the future.

ASSUMPTIONS IN FISHING EFFORT: TESTS AND CONSEQUENCES

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The two fundamental variables generated from commercial fisheries are landed catch and fishing effort. The derived Catch per Unit Effort (CPUE) provides both a simple index of abundance and a data series that is regularly incorporated into current population assessment methods such as virtual population analyses, statistical catch-at-age, and integrated analyses like stock synthesis. However, the implied proportionality of catch to effort is seldom examined. Factors that could invalidate this assumption include: vessel movement among neighbouring fishing grounds, selective fishing for "target species", and interference between or facilitation among fishing vessels. Furthermore, effort is usually considered in terms of one aspect (number of traps, hours trawled) with other components (vessel size, search time, etc.) treated as covariates to be statistically controlled. Current quantitative methods (GLM, GLMM, GAM, etc.) provide the necessary tools to consider all aspects of effort equally in our analyses. This approach can develop "catch per typical trip" as a metric for fishery comparisons that reflects the multifaceted nature of effort and is easier to communicate among fishery stakeholders. Insights gained in this treatment of effort promise to both improve the quantification of effort dynamics and reduce biases that may otherwise enter into our application of catch and effort statistics.

ORAL PRESENTATIONS

QUANTIFYING TARGETING BEHAVIOUR AND CATCH TRENDS IN THE LAKE WINNIPEG COMMERCIAL FISHERY

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Targeting behavior is widely recognized in multispecies fisheries but is seldom examined objectively in population assessments. Successful fishers can sustain high catch rates of target species through moderate changes in underlying fish numbers, making catch rates a questionable indicator of changing abundance. In this study we identified targeting behaviour by the skew of the distribution of logged catch rates on a seasonal basis for three species fished under a quota, walleye (*Sander vitreus*), sauger (*Sander canadensis*) and lake whitefish (*Coregonus clupeaformis*), as well as two species expected to be by-catch. When the fishery is targeting a specific species the successful location of high abundance aggregations should result in a negatively skewed distribution. To examine trends in landed catch, we created a catch model for each of the three species that was broken into a binary portion to assess the probability of a successful fishing event and a non-zero portion to evaluate the amount caught during a successful fishing event. A generalized additive mixed model (GAMM) was used for the non-zero portion to account for individual variation and autocorrelation in the catch records.
We were successful in identifying walleye as the main target species using statistical properties of the catch records as well as standardizing catch in relation to timing, temperature and effort for all three quota species. Objective identification of behavioral bias in catch records is key in creating and interpreting the catch models used in population assessments.

META-ANALYSIS ON STANDARIZATION OF CATCH AND EFFORT DATA.

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Despite years of research, there is still debate over the validity and reliability of the use of commercial catch and effort data to estimate fish abundance. Our study analyzes 91 previously published scientific reports, drawn from broader literature search of 3246, to find out whether catch is proportional to nominal effort. The formal meta-analysis for this project examines proportionality through the slope of the log-log regression of catch on effort. To account for "errors-in-variables" bias, both ordinary least squares (OLS) and reduced major axis (RMA) regressions are used. We investigated the role of fishery type, effort type, time unit, gear, and gear type as a moderator variables in a mixed meta-analysis. Our study demonstrates the importance of considering "error-in-variables" when using catch-effort relationships and the potential for the relationship to vary from proportionality in specific fisheries. Even though the slope can differ from one in some fisheries, it is not consistently different for the moderator variables examined.

ORAL PRESENTATIONS

THEORETICAL CONSEQUENCES OF UNRECOGNIZED POPULATION STRUCTURE IN A FORAGE FISHERY

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Forage fish are vital to marine ecosystems and fisheries. Many predators including seabirds, marine mammals and commercially exploited fish rely on forage fish as a primary food source. In British Columbia, Pacific herring (*Clupea pallasii*) support important commercial, recreational and food fisheries, and provide nutrient subsidies to iconic terrestrial predators including bears and wolves. Conservation of forage fish is a growing concern, and management practices for the seven Pacific herring 'stock management areas' in British Columbia are designed to be precautionary. However, stakeholder perspectives differ on Pacific herring population structure within management areas, raising fears that serial local depletion could occur under existing management practices. Therefore, we developed a mathematical model to reconcile the potential mismatch between herring population structure and the spatial scale of management. The model incorporates (a) a common larval pool, (b) juveniles recruitment to distinct populations, and (c) fishing effort that is not equal across populations. The common larval pool is consistent with the observed absence of genetic markers for local population structure. Recruitment to distinct populations is explained by the entrainment hypothesis, whereby knowledge, such as migratory behaviour and habitat utilization, can be acquired by fish through social learning. Concentrated fishing effort is a consequence of regional-scale management of fish that aggregate at a local scale. We analysed the model under realistic management rules and fishery behaviour to identify potential consequences of regional-scale management for individual Pacific herring populations.

LAKE TROUT SPAWNING IN A NORTHERN BOREAL LAKE: DOES IT MATTER WHICH WAY THE WIND BLOWS?

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Unlike most salmonids, breeding by lake trout (*Salvelinus namaycush*) occurs without parental care or the construction of a redd. Lake trout typically spawn in the fall on cobble rock shoals located along wave-swept shores. It is generally assumed that wave-induced currents provide the best conditions for egg incubation through aeration and removal of fine sediments, however this remains largely untested. While an essential behavioural trait of lake trout is assumed to be the ability to select high quality sites in order to maximize reproductive success, the question remains what factors do lake trout use to select suitable spawning sites? Here, we quantified the variation in lake trout spawning habitat in a sub-Arctic lake (Alexie Lake, NWT). Spawning habitat quality was determined from egg incubation experiments and a fetch-based-wind-wave model, a surrogate for wave exposure; both of which demonstrated high spatial variability among spawning sites in Alexie Lake. Suitable spawning substrate was widespread in Alexie Lake and wind direction was also found to be unpredictable within and among spawning seasons. As a

result, lake trout spawning site use was widely distributed and not limited to shoals facing predominate wind direction. No relationship was found between wind exposure and embryonic success; however, acoustic telemetry data indicated that lake trout select potential spawning sites with greater wind exposure. This suggests an indirect relationship of wind exposure on habitat quality and challenges conventional wisdom relating to wind driven lake trout spawning site location.

BYCATCH MORTALITY CAN CAUSE EXTIRPATION IN FOUR FRESHWATER TURTLE SPECIES

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Bycatch of non-target species in commercial fishing nets can have adverse impacts on their populations. Freshwater turtle populations are particularly susceptible to increases in adult mortality, and freshwater turtles are among the most threatened vertebrates. As a case study, the population-level impacts of bycatch mortality on freshwater turtles was evaluated in Lake Opinicon, Ontario, a lake that supports a small-scale commercial fishery. Using population viability analyses, the impacts of bycatch on common snapping turtles (*Chelydra serpentina*), eastern musk turtles (*Sternotherus odoratus*), northern map turtles (*Graptemys geographica*), and painted turtles (*Chrysemys picta*) were evaluated. In all four species, even low levels of additional annual female mortality as a result of bycatch were sufficient either to reduce population size or cause extirpation of the local population within 500 years. Bycatch reduction programs, such as seasonal closures and implementation of bycatch reduction devices, can help alleviate the risk of extirpation. Although these findings are specific to the study area, the same principles apply to other areas where similar simple bycatch reduction strategies can be employed to prevent the extirpation of other freshwater turtle species. Considering the consequences of bycatch and of bycatch reduction programs on populations provides managers with important information to support development of risk-averse conservation strategies.

INFLUENCE OF HYDROLOGICAL CONNECTIVITY ON WINTER LIMNOLOGY IN FLOODPLAIN LAKES OF THE SASKATCHEWAN RIVER DELTA, SK.

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Globally, hydrological connectivity between rivers and their floodplains has been reduced by river flow management and land transformation. The Saskatchewan River Delta is North America’s largest inland delta and a hub for fish and fur production. To determine the influence of connectivity on limnology within this northern floodplain, water chemistry and stable isotopes

($\delta^{18}O$ and $\delta^{2}H$) were analyzed during February and March 2014 in 26 shallow lakes along a hydrological gradient. A total of 5 lake connectivity categories were determined by optical remote-sensing images of surface water coverage area (SWCA) from years of varying flood intensities. Accuracy of categories were verified by degree of ^{18}O and ^{2}H enrichment within lakes as an indicator of evaporation prior to ice-in. Both isotopes showed marked successional enrichment between connectivity categories with more isolated lakes exhibiting greater enrichment. Water chemistry in lakes with greater connectivity to the main channel were characterized by higher pH, dissolved oxygen, nitrates and sulfates, and lower total nitrogen, total phosphorus, and ammonia, compared to more isolated lakes. These findings illustrate how connectivity influences water chemistry in northern floodplain lakes and how it might determine the suitability of these lakes as winter refuge for fishes. Additionally, our study provides supporting evidence for the effective use of optical remote sensing imagery, an inexpensive and accessible source of data for researchers, for determining connectivity characteristics of large northern floodplain systems. Understanding year-round influence of river-floodplain connection is imperative for assessing potential impacts of climate change and future water regulation on such ecosystems.

COLLECTION OF REFERENCE STREAM SITE DATA IN THE FAR NORTH OF ONTARIO: PREPARING FOR DEVELOPMENT IN THE RING OF FIRE.

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The Ring of Fire in the Far North of Ontario is considered be one of the most promising mineral development opportunities in Ontario in almost a century. Covering an area of about 5,000 km², recent estimates suggest that the Ring of Fire holds significant potential production of nickel, copper and platinum as well as potential for world-class multi-generational production of chromite. In advance of significant development in this region, we collected baseline benthic invertebrate and environmental data at more than a hundred stream sites in the Attawapiskat River basin in 2013 and 2014 to initiate a set of reference sites using consistent field and laboratory protocols. Many of these sites have or will also be sampled for a comprehensive suite of water chemistry indicators under the Ontario Provincial Water Quality Monitoring Network. These data are intended to be used in the future for the detection and assessment of the effects of development activities, including cumulative effects. In this presentation, we provide an overview of Far North stream sampling efforts in 2013 and 2014, including preliminary results. We also compare these data with those collected in the Fraser River basin in British Columbia and the Yukon River basin to examine concordance of benthic community structures and environmental influences across the three regions. This work provides insight to the spatial application of reference sites that may provide for more efficient sampling in remote northern regions.

ORAL PRESENTATIONS

WHOLE-LAKE BROWNING EXPERIMENT REVEALS DOC EFFECTS ON CONSUMER PRODUCTION AND CARBON CYCLING

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Terrestrially-derived dissolved organic matter (tDOM), concentrations of which are increasing in many surface waters, strongly structures lake ecosystems. Theory and observations suggest that increases in tDOM loads drive reductions in primary, secondary, and fish production in lakes. We tested these predictions with a four-year whole-lake experiment. The DOC concentration in the treatment basin increased from 7 to 12 mg L^{-1}, leading to increased pelagic primary production and respiration, decreased net ecosystem production, and decreased benthic primary production. The epilimnion in the treatment basin was 25% less deep than in the reference basin, due to water color effects on the heat budget. This constrained the available habitat for some organisms; for instance, temperature-tagged fish remained in the epilimnion nearly constantly in both basins. Contrary to expectations derived from observational studies, we observed increases in zooplankton and zoobenthos production in the treatment basin relative to the reference. Our results emphasize the complexity of ecosystem-level responses to changing tDOM inputs, and suggest that very high DOC concentrations may be required to impose strong negative effects on consumer production.

PHYSIOLOGICAL BASIS OF GROWTH-PERFORMANCE TRADE-OFFS AMONG DIFFERENT STRAINS OF RAINBOW TROUT

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Growth rate is an intrinsic life history trait that varies among individuals and populations. Selection for fast growth is thought to compromise survival when adaptations to grow fast trade off against other performance metrics like swimming ability (to avoid predators) or starvation resistance. To better understand the potential tradeoffs associated with fast growth, we measured standard and maximum metabolic rate, digestive capacity, and tissue energy content among 3 strains of rainbow trout that differ in growth and ecology. To test for growth-related trade-offs along a resource gradient, fish were reared at (i) satiation, (ii) 1% of body mass (maintenance), and (iii) complete food deprivation.
Higher growth of the domestic hatchery strain was associated with a larger digestive tract at all rations, greater maximum consumption, and a higher standard metabolic rate than the slower growing strains. Contrary to expectation, the high growth strain achieved a higher growth efficiency than slower growing strains and did not lose weight faster under starvation. However, the fast growing hatchery strain had reduced maximum metabolic rate, indicating that high

growth is traded off against a reduced capacity to do metabolic work (implying reduced swimming performance). This study suggests that high growth is achieved through tradeoffs among organ-systems that support growth (digestive tract) vs. activity (musculo-skeletal/circulatory), corresponding to an ecological tradeoff between resource acquisition and predator avoidance; and that selection on growth is associated with correlated changes in a suite of physiological traits that are traded off against other correlates of performance.

DEVELOPING HARVEST REGULATIONS FOR A PREVIOUSLY UNEXPLOITED LAKE TROUT (*SALVELINUS NAMAYCUSH*) POPULATION

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Slow population growth, overfishing, and species-specific habitat restrictions have drastically reduced lake trout (*Salvelinus namaycush*) abundance in New York State's Adirondack Park. We combined field and literature data, hydroacoustic surveys, and mark-recapture abundance estimates to parameterize an age-structured model for an unexploited population of Adirondack-heritage strain lake trout. We used the model to evaluate the impact of alternative management scenarios on lake trout abundance and biomass over a wide range of angler effort. Model results suggest that the population is extremely susceptible to exploitation. We therefore recommend that special regulations – such as a catch-and-release or minimum size restrictions – be implemented to maintain an unstocked, high-quality recreational fishery.

LIFE-HISTORY VARIATION AMONG FOUR SHALLOW-WATER MORPHOTYPES OF LAKE TROUT FROM GREAT BEAR LAKE, NT

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Phenotypic variation within populations is common in many species of salmonids, especially when inhabiting northern postglacial systems. We compared the life-history attributes among four Lake Trout morphs co-existing in the shallow-waters of Great Bear Lake, NWT, Canada. Adult growth rate, age- and size-at-maturity, and survival differed among morphs, consistent with their degree of foraging specialization and predictions from foraging theory, e.g., reduced somatic growth and higher investment in reproduction in the generalist morph, high growth throughout life in the piscivorous morph, and intermediate life-histories in the more benthic- and pelagic-oriented morphs. However unexpected findings also arose, reflecting the complexity of

this system, such as comparable immature growth rates among morphs. Other traits, such as the high proportion of resting individuals among all morphs, suggest life-history adaptations to northern latitudes. Longer resting periods may allow greater investment in post-maturation growth. Fecundity and egg size also varied among morphs. Overall, Lake Trout from Great Bear Lake demonstrated remarkable longevity and exceptional asymptotic sizes, even for a northern freshwater ecosystem. Our study of polymorphic Lake Trout provides insights into life-history evolution among morphs that use different food sources and habitats, and contributes to our understanding this lake ecosystem that exhibits one of the highest recorded levels of intraspecific diversity among freshwater fish.

DOES GENETIC VARIATION CORRELATE WITH ADAPTIVE POTENTIAL? AN EMPIRICAL TEST USING TRANSLOCATIONS OF NATURAL TROUT POPULATIONS

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Determining characteristics that predict the capacity of natural fish populations to persist in the face of novel environmental change represents an understudied, yet crucial, area of research for conservationists and fisheries management. In the absence of data measuring adaptation within a population's changing natural environment, controlled replicated transplants to novel environments represent the best means to assess how different population level characteristics affect the capacity of natural populations to respond to environmental change. We conducted replicated transplants of brook trout (*Salvelinus fontinalis)* to novel pond environments to determine what population-level parameters predicted performance in changing environmental regimes. Multiple population level traits were integrated in our analysis, including estimates of effective population size, standing levels of genetic variation measured by microsatellites and coding single nucleotide polymorphisms (SNPs), and the degree of environmental change as measured by the difference between a population's native habitat and novel transplant environment. SNP heterozygosity and effective population size were both significantly positively associated with performance in novel environments; however, the parameter that most significantly predicted performance was the pH of a novel pond environment relative to a population's native habitat. By identifying parameters that best predict vulnerability to environmental change, our research will allow managers to efficiently allocate scarce resources to populations most in need of protection. While the genetic management of populations of conservation concern should remain a priority, our results show that slowing the rate of environmental change experienced by threatened populations may be most critical to their conservation.

SPAWNING OF ADFLUVIAL LAKE TROUT (*SALVELINUS NAMAYCUSH*) AND LAKE WHITEFISH (*COREGONUS CLUPEAFORMIS*) IN THE YELLOWKNIFE RIVER BELOW BLUEFISH DAM, NWT, CANADA

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ORAL PRESENTATIONS

From September to November of 2014, we investigated a section of the Yellowknife River between the Bluefish Hydroelectric Dam and Prosperous Lake, to confirm spawning use by adfluvial Lake Trout (*Salvelinus namaycush*) and Lake Whitefish (*Coregonus clupeaformis*).The objectives of this study were to document water quality parameters (dissolved oxygen, conductivity, temperature), area (m^2), depth (cm) and velocity (m/sec) at egg deposition sites and to define seasonal duration of spawning. Lake Trout spawned in early fall at 12-13° C in swift, shallow water over a range of substrate sizes. Lake Whitefish spawning was more protracted, peaking at 6-7° C but continuing until water temperature dropped to 1° C. Lake Whitefish spawning habitat overlapped Lake Trout spawning areas but was more widespread and occurred at greater depths in some locations. In addition, we will demonstrate how underwater photography and videography were used to document spawning activity and physical characteristics in the spawning/egg deposition areas at micro and meso habitat levels. An aerial drone was also used to photograph the overall area and images served as a basis for categorizing spawning habitat and creating a visual atlas of the Yellowknife River at the proximity of Bluefish Dam.

THE POTENTIAL GENETIC BENEFITS OF POLYANDRY IN CHINOOK SALMON

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Polyandry is very common across all species, but it is not always clear why females multiply mate, as mating is very costly. Female Chinook salmon (*Oncorhynchus tshawytscha*) spawn multiple times over the course of the spawning period and with multiple males typically involved in each bout, as a result multiple males fertilize their eggs through sperm competition. Due to the presence of alternative reproductive tactics within male Chinook salmon, a female's eggs not only get fertilized by males adopting the same tactic, but from males that adopt different tactics. Males either adopt a guard tactic (hooknoses) or a sneaking tactic (jacks) and although females have been shown to prefer hooknoses, both male tactics end up fertilizing female's eggs. There are a number of hypotheses that try to explain why females would mate with multiple males in a non-resource based mating system (where no material benefits are possible) and all of them suggest that it may be because females can increase the genetic quality of their offspring and as such increase their fitness indirectly. This talk will explore some of these hypotheses to determine if female Chinook salmon obtain genetic benefits through increased offspring fitness by multiple mating with jacks and hooknoses.

NEW APPROACHES TO MEASURE ^{210}PB IN SEDIMENTS AND BIOTA

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ORAL PRESENTATIONS

^{210}Pb is a useful radionuclide in many aquatic studies. It is a member of the ^{238}U decay series that is widely distributed in nature because it is a longer lived radioactive product of ^{222}Rn decay and radon is a volatile noble gas. ^{210}Pb is an important geoscience tool for dating sediment, soil and peat accumulation, calculating metal transport through catchments, determining erosion rates, measuring exposure to radon progeny and understanding atmospheric transport and deposition of trace elements.
To date, the two primary analytical methods for ^{210}Pb measurement are (1) gamma spectrometry and (2) the measurement of the ^{210}Po granddaughter isotope by alpha spectrometry despite the fact that alpha spectrometry often requires the sample to be stored to ensure the two isotopes are in secular equilibrium. However a new generation of mass spectrometers provide alternative approaches. ^{210}Pb can be measured by ion counting the number of atoms using Inductively Coupled Plasma Mass Spectrometry or Accelerator Mass Spectrometry. This paper compares the alternative approaches to measure ^{210}Pb on samples of different sizes, and concentrations. High resolution gamma spectrometry using a well detector equipped with Compton suppression is still the most sensitive technique. However, mass spectrometry and a new generation of gamma spectrometers equipped with better low energy resolution are now competitive for some types of measurements.

THE BENEFITS OF NON-LETHAL TISSUE SAMPLING: LONG-TERM MERCURY MONITORING IN LAKE TROUT FROM TWO NORTHERN LAKES
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In 2007, a Slimy Sculpin (*Cottus cognatus*) survey in Lac de Gras, Northwest Territories, revealed that body burdens of mercury were significantly greater in a population exposed to diamond mining effluent, compared to two reference populations within the same lake. To determine whether similar mercury increases were occurring in the larger, edible fish of Lac de Gras, a Lake Trout (*Salvelinus namaycush*) mercury monitoring program was implemented in 2008, and repeated in 2011 and 2014. Mercury concentrations were measured in Lake Trout captured in two connected lakes, Lac de Gras and Lac du Sauvage, using non-lethal sampling methods. Non-lethal sampling methods provide an accurate alternative to the traditional destructive fillet sampling technique, which can impact the older, slower-growing Lake Trout populations found in the North. Mercury concentrations were found to be increasing from 2008 to 2011. However, in 2014 mercury concentrations decreased in both lakes, and were found to be at concentrations similar to those observed prior to effluent release in Lac de Gras. The use of a non-lethal sampling protocol has allowed for mercury analysis to be repeated for multiple years in these two northern lakes, without putting the local Lake Trout population at risk.

SIZE SPECTRUM AND ENVIRONMENTAL INFLUENCES ON FISH MERCURY CONCENTRATIONS IN ONTARIO LAKES
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ORAL PRESENTATIONS

Many studies attempted to explore how mercury concentrations in fish are affected by environmental, physico-chemical, or biological factors. Results are often limited because of the complex relationships between biotic and abiotic factors or among species. Mercury bioaccumulation in fish is strongly related to species metabolism, consumption rate, and the flux of energy and matter in aquatic ecosystems. These relationships could be considered by using size spectrum approach based on the size distributions of individual organisms within each ecosystem. The size spectrum slope can indicate how quickly species density declines as size increases, energy transfer efficiency, and the size ratio between prey and predators. In this study, *we* examine the relationships between fish mercury concentrations in Ontario lakes and size spectrum when accounting for environmental variables. We use lake environmental data, mercury concentrations in fish such as walleye, northern pike, lake trout, and smallmouth bass, and size spectrum information from Ontario lakes. Multivariate statistical approaches such as principal component analysis and generalized linear model are used to examine how mercury concentrations in fish are affected by the physical, chemical, and biological characteristics of aquatic ecosystems. Results indicate that mercury concentrations in fish are strongly influenced by water pH, and have a positive relationship with the size spectrum slope. Fish with higher mercury concentrations are more likely to occur in aquatic ecosystems with lower pH and steeper size spectra, which may have greater energy losses and require larger amount of biomass at the basis of food webs to support top consumers.

INFLUENCE OF FLOODPLAIN CONNECTIVITY ON LITTORAL MACROINVERTEBRATES IN A LARGE SUBARCTIC DELTA

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The Mackenzie Delta is the largest source of freshwater to the Arctic Ocean from North America and a hotspot of biodiversity and ecosystem productivity for northern Canada. It is also changing rapidly as warmer temperatures and earlier spring melt alter permafrost and floodplain dynamics, with unpredictable consequences to the ecology of the numerous lakes in and around the Delta. We present preliminary results from the 1st year of a PhD study examining the ecology of benthic macroinvertebrates in the Mackenzie Delta, which have received scant attention until very recently despite their use as indicators of environmental change. In the summer of 2013 we sampled water chemistry and littoral benthic macroinvertebrates in 11 lakes within the Delta and 8 lakes in the nearby tundra uplands. Within the Delta, elevation, sill morphology, and water isotopes indicated variation in connectivity to the main channel. In a preliminary multivariate analysis, elevation was the most important determinant of benthic community composition, which is a proxy of hydrological connectivity to flood-influenced ecosystem dynamics. Preliminary species richness estimates were correlated with elevation for most of the Delta lakes (which are connected to the river during annual peak water level or longer), but were lowest in the highest elevation lakes, which are rarely inundated, and the uplands lakes. Our results highlight the importance of hydrological connectivity to benthic communities in this Arctic system, and provide a baseline for detecting changes in a multi-year study.

ORAL PRESENTATIONS

MODELLING THE SPATIOTEMPORAL DISTRIBUTION OF BENTHIC MACROINVERTEBRATES: A HIERARCHICAL BAYESIAN MODEL FOR ZERO-INFLATED BIOMASS DATA.

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Fisheries and Oceans Canada conducts an annual bottom-trawl survey in the southern Gulf of Saint Lawrence (sGSL) each September since 1971. The main objective is to quantify the abundance and the distribution of fish species in the top level of the marine food web. Nevertheless, the survey has been extended to examine various marine species since 1988. In this study, we focus on the abundance and the distribution of epibenthic invertebrates such as urchins. Epibenthic invertebrates play an important role in the structure and the biodiversity of the sGSL ecosystem. Scientific surveys conducted by ecologists lead to a sampled biomass commonly used as an indicator of stock abundance. The catch biomass often presents a high proportion of zeros. This excess of zeros induces a modeling challenge to reach the main purpose of this survey: how to learn about the state of a population in this ecosystem?
We propose a Bayesian hierarchical model to represent the spatiotemporal biomass distribution of urchin sampled in the sGSL. Due to the excess of zero values, the observation layer is a zero-inflated distribution based on a compound Poisson with gamma marks. The latent layer accounts for the spatial and temporal components with a process-convolution approach. In order to take into account ecological factors, environmental variables such as temperature or sediment type have been included into the model. The spatiotemporal model developed is flexible and efficient and opens a whole range of perspectives. A dynamical model accounting for ecological knowledge on epibenthic invertebrates is under investigation.

BYTHOTREPHES LONGIMANUS PRESENCE ALTERS THE VERTICAL DEPTH DISTRIBUTION OF DAPHNIA SPECIES ACROSS CANADIAN SHIELD LAKES

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Disturbance is an important force influencing the structure and dynamics of ecological communities. As a biotic disturbance, the establishment of invasive species can negatively impact species diversity, nutrient cycling and energy flow in ecological communities. In the Muskoka Region, the invasive zooplankter, Bythotrephes longimanus, has been shown to negatively impact the abundance and diversity of phytoplankton, zooplankton, macro-invertebrate predators and fish species. However, lakes in this region exhibit heterogeneity across a number of important physical and water chemistry variables, potentially influencing the response of zooplankton communities to B. longimanus invasion.
I conducted a field survey of 63 lakes in the Muskoka region across a gradient of physical (surface area and depth) and chemical variables (dissolved organic carbon, total phosphorus, pH, calcium), as well as macro-invertebrate predator communities consisting of combinations of B.

longimanus and three native species. Daphnia collected from each lake were subjected to behavioural experiments to determine their vertical depth distribution. Stratified samples were also collected from each lake. Behavioural experiments showed no difference in vertical depth distribution across populations from invaded and uninvaded lakes. Preliminary analyses of stratified samples suggest that vertical depth distribution of Daphnia populations was not different between invaded and uninvaded lakes. However Daphnia populations in lakes with higher abundance of Bythotrephes had lower vertical depth distribution. Vertical depth distribution of Daphnia across the landscape was also significantly impacted by dissolved organic carbon, secchi depth and total phosphorous concentrations.

IMPORTANCE OF CHARA TO INVERTEBRATE POPULATIONS IN INTERIOR BC LAKES

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Small productive lakes in the interior of British Columbia support a world-class rainbow trout fishery. However, anglers and fisheries managers have recently noticed a decline in the abundance of some macroinvertebrates, which are a major food source for trout in these lakes, as well as a decline in the Chara (calcareous algae) beds that we suspect are critical habitat for those macroinvertebrates. Our objectives were to determine 1) if Chara provides superior invertebrate habitat compared to marl substrates in these lakes, and 2) does the presence of trout affect benthic communities and their substrate selection? To test these hypotheses we sampled 10 small lakes in May and June of 2014; 6 lakes that are stocked with rainbow trout (*Oncorhynchus mykiss*), and 4 fishless lakes. We took 6 randomly-located petite Ponar grab samples within Chara beds, and 6 in adjacent marl substrates.
We found that the invertebrate community in Chara beds was different from that in marl. There were significantly more chironomid and damselfly larvae in Chara beds in both trout and fishless lakes, and dragonfly nymphs were found exclusively in Chara beds. Amphipod densities were greatest in Chara beds in the fishless lakes. We conclude that Chara beds do form critical habitat for macroinvertebrates eaten by rainbow trout. This study will be expanded in 2015 to include mapping the extent of Chara bed decline over the past several decades, and to examining the factors responsible for the decline.

AN OVERVIEW OF THE LAKE DIEFENBAKER STUDY

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ORAL PRESENTATIONS

Lake Diefenbaker (LD) was created on the transjuristictional South Saskatchewan River (SSR) in 1967. The reservoir represents the largest supply of good quality water in southern Saskatchewan. The system is 225 km long with a water storage capacity of 9.4 km^3 (for comparison, Lake Simcoe has 11 km^3). LD has multiple uses: hydro-power, municipal water supply, irrigation, drought and flood control, aquaculture and recreation) and is pivotal for the economic future of the region. LD also functions as a major sink for nutrients along the SSR system. The capability of this reservoir to continue to provide water of reasonable quality under increased economic development and a changing climate is unknown. A comprehensive evaluation of its sensitivity to current and future activities (that affect nutrient input and dynamics) is essential to manage and protect this resource. We report on multidisciplinary research to gain an understanding of the reservoir's nutrient dynamics, which includes ongoing and interrelated observational studies on nutrient status and sensitivity, algal assessment, nutrient loads and patterns, water quality assessment via satellite imagery and microbial pathogens in association with hydrodynamic water quality modelling. The past four years have been characterized by extreme high flows into the reservoir from the SSR in June or July. These events have had a dominant influence on the limnology of LD, rendering it a very dynamic system on seasonal and annual time scales. We report on research during the past four years (2011-2014) which has significantly increased our understanding of this important prairie reservoir.

LIGHT AND NUTRIENT EFFECTS ON PHYTOPLANKTON POPULATIONS IN LAKE DIEFENBAKER, A LARGE PRAIRIE RESERVOIR

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Management of aquatic systems requires an understanding of the factors that control algal biomass. Primary production in freshwater systems may be limited by nutrients such as phosphorus (P) and nitrogen (N), or by environmental conditions such as availability of light. Lake Diefenbaker is a multi-purpose reservoir located on the South Saskatchewan River. To date, not a lot is known about what controls algal populations in the reservoir, changes in which can affect water quality. To investigate this, we measured various biological and environmental conditions and conducted a series of nutrient status assays. Sampling sites were located in both the main channel and embayments along the length of the reservoir. Temporal patterns were assessed from monthly samples collected from June to October in 2011 and 2012. Light limitation was more prevalent in 2011 than 2012, with higher indications of deficiency in the main channel than the embayments in both years. Differences in nutrient and light limitation between the two years were likely due to considerably higher flows in 2011, resulting in higher P inputs and increased turbidity. The hydrological regime has important implications for the trophic status of the reservoir and appears to influence both light and nutrient limitation.

ORAL PRESENTATIONS

TROPHIC STATE AND ENVIRONMENTAL FACTORS ASSOCIATED WITH PHYTOPLANKTON DYNAMICS IN LAKE DIEFENBAKER

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Lake Diefenbaker is a large reservoir that receives about 98 % of its water from the South Saskatchewan River (SSR) in the Canadian Prairies. The composition and ecology of the phytoplankton community is poorly understood in the reservoir. This is a potential problem for a reservoir that serves as a source of water for drinking, agriculture and recreational activities. To understand the current state of Lake Diefenbaker, we collected whole water samples at a 2 m depth along the length of the reservoir in the open water season (June to October) in 2011 and 2012. Carlson's trophic status index (TSI) for chlorophyll *a* varied throughout the reservoir, but the mean TSI (43.75 in 2011 and 41.54 in 2012) placed it as a mesotrophic system. We observed 72 phytoplankton genera with the chlorophytes having the highest number of genera (33). The diatoms and the cryptomonads were the two dominant groups, constituting ~ 89 % of the total phytoplankton biomass. The diatoms dominated from September to October in conditions of reduced inflow, high water transparency and low water temperatures; whereas the cryptomonads dominated from June to July in conditions of high inflow, low water transparency and high availability of nutrients in the reservoir. Inflow, dissolved oxygen (DO) and the molar ratio of particulate carbon to nitrogen (C:N) explained 52 % of the variation in the biomass of the diatoms. Inflow and ammonium (NH_4^+) concentrations explained 35 % of the variation in the biomass of the cryptomonads.

LAKE DIEFENBAKER FROM ABOVE, LONG TERM PATTERNS IN WATER QUALITY AS DETERMINED BY SATELLITE IMAGERY

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A nearly three-decade historical survey of the Secchi disk depth (SDD) and chlorophyll-*a* concentration (Chl-*a*) was completed at Lake Diefenbaker using Landsat imagery. This large, multi-purpose reservoir was studied from 1984-2014 during May-October each year. Novel predictive models were developed by comparing 2011 and 2012 field data to reflectance data from Landsat imagery. These models were applied to the archived satellite data (1984-2012) to predict SDD and Chl-*a*. Predicted and actual measurements for SDD and Chl-*a* were significantly related (R^2=0.84 and 0.57; RMSE 0.59 m and 1.43 µg/L^{-1}, respectively). Data used to test models was not used in model development. Furthermore, the models can be used to identify future trends because they do not require additional field data. Water clarity and Chl-*a* concentration were positively correlated during the survey, suggesting light limitation occurs in this reservoir. Predicted mean SDDs and mean Chl-*a* concentrations have decreased in the reservoir from 1984-2012. Secchi disk depth and Chl-*a* followed a decreasing sigmoid pattern over the length of the study period. This pattern was significantly related to seasonal flow from the South Saskatchewan River, causing significant reductions in SDD and Chl-a concentrations (R^2=0.28 and 0.25, p=0.048 and 0.021, respectively). Algal blooms were observed in the

reservoir during the study period, and were most frequently found in the Qu'Appelle arm of the reservoir. However, despite concerns from some local residents, algal blooms did not appear to be increasing in frequency over the 29 year period.

ACTION CAMERAS: BRINGING AQUATIC AND FISHERIES RESEARCH INTO VIEW

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Digital action cameras are increasingly being used for important research topics in fisheries and aquatic research. This presentation will review action camera technology, address the applications of action cameras in fisheries and aquatic research, and examine the limitations associated with using action cameras in aquatic systems for fisheries research. We found that action cameras are cost effective, provide versatile mounting options, yield detailed imagery, and are durable enough to withstand use in dynamic and rugged field research. The literature revealed that action cameras are increasingly being used for (a) research videography (both in the field and the laboratory), (b) animal-borne studies as well as for (c) outreach and education purposes. Nonetheless, action cameras have a number of limitations primarily related to environmental constraints (e.g., depth, turbidity), and deployment considerations (e.g., lens choices, settings, battery life). Action cameras are continually evolving due to heavy interest from the public with respect to outdoor pursuit and sports markets that push camera technology development and indirectly provide the researcher with innovative, cost-effective options. As action camera technology continuously evolves - becoming smaller, lighter, and with more imaging options - their use in fisheries and aquatic research will likely be found only in the creativity of those using them.

DEVELOPMENT AND PERFORMANCE OF AN ACOUSTIC TELEMETRY TRANSMITTER DESIGNED TO DETECT PREDATION EVENTS

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Acoustic telemetry provides a useful tool to estimate the behaviour, movements and survival of free-ranging aquatic animals. Accurate survival estimates rely on the assumption that telemetered data represent the movement of live target animals and not tags within the gut of predators. Tracking small or juvenile species frequently violates this assumption. Identifying predation events can be difficult and has, to date, involved post-hoc analyses of tag movement data that; is reliant on *a priori* assumptions of 'normal' prey movement and expected predator movement, is prone to underestimating predation rates, and may not be suitable for many studies.
Here, we report some preliminary results from the testing of an acoustic tag that has been specifically designed to detect predation events. Our objective was to test the performance of predation tags in two prey species (Yellow Perch, *Perca flavescens* and Rainbow Trout,

Oncorhynchus mykiss) being consumed by a predator (Largemouth Bass, *Micropterus salmoides*) at three water temperatures. Further, we also wanted to assess the rate of false positive signals when the tagged fish were not consumed.
The partial results to-date suggest that prototype tags were 100% successful (n=23) at identifying consumption of the tags. The time lag between consumption of live tagged prey and the first transmission of the 'predated' signal was 9.2 hours (mean, range = 3.4 to 17.9) for Rainbow Trout at 22ºC and 12.2 hours (mean, range = 9.0 to 16.5) for Yellow Perch at 22ºC. Mean gastric evacuation rates for the tags were 2.8 and 2.5 days, respectively.
We discuss updated and recent results, future directions for continued development of these transmitters, and the implications, advantages and potential applications of this new technology.

LAMPRICIDE IMPAIRS OLFACTION AND OLFACTORY-RELATED BEHAVIOURS IN YOUNG-OF-THE-YEAR LAKE STURGEON (*ACIPENSER FULVESCENS*)

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Fish that feed or travel in low light conditions particularly rely on their chemical senses, such as olfaction, for survival. Exposure to toxicants at concentrations lower than those causing mortality can have detrimental effects on olfactory senses. Here we found the lampricide 3-trifluoromethyl-4-nitrophenol (TFM) caused a reduced olfactory response to L-alanine, taurocholic acid and a food cue, reduced attraction to the scent of food and reduced consumption of food in young-of-the-year (YOY) lake sturgeon. Fish were able to detect the scent of TFM, but did not significantly avoid it, which may expose fish to the full toxic effects. These results have negative implications for YOY lake sturgeon that survive TFM treatments.

MOVEMENTS OF LISTED GRASS PICKEREL IN AN AGRICULTURAL DRAIN AND THE IMPLICATIONS FOR DRAIN MAINTENANCE

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Scientists and managers are being pressed to find ways to conserve biodiversity in systems that have been heavily modified by human activities. We combined passive integrated transponder (PIT) tags and multi-state models to quantify movements of Grass Pickerel *Esox americanus vermiculatus* in Beaver Creek, an agricultural drain near Fort Erie, ON. Grass Pickerel is listed as a species of Special Concern under Canada's Species at Risk Act. Parts of Beaver Creek require maintenance (dredging) to restore drainage function. Our study focused on movement because of its importance to the ecology and life history of stream fishes. Three questions were of interest. First, to what degree do Grass Pickerel display movements at a spatial scale greater than a typical maintained section of drain (0.5 – 1 km)? Second, do these movements represent

migration or dispersal? Third, is the propensity to make long-distance movements related to spatial, seasonal, and individual phenotypic factors known to influence movement in other species of stream fishes? Over 1,500 Grass Pickerel were PIT tagged and their movements monitored at three antenna stations, two on the main branch and one on the south tributary of Beaver Creek. We found that only a small proportion of tagged Grass Pickerel covered distances greater than a typical maintained section of drain. Grass Pickerel movements were dispersive in nature and were influenced by seasonal and individual phenotypic factors. Our findings will contribute to the development of management practices that balance the needs of the agricultural community and fish habitat managers.

DISTRIBUTION AND LIFE HISTORY OBSERVATIONS OF RIVER DARTER (*PERCINA SHUMARDI*) IN HISTORICAL AND NEW LOCATIONS THROUGHOUT NORTHWESTERN ONTARIO.

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River Darter (*Percina shumardi*) is a native yet cryptic species in Canada that has been collected haphazardly throughout northwestern Ontario since the 1930's. In 2013 we sampled the Rainy River in northwestern Ontario using several gear types and in 2014 we used a Herzog- Armadillo Trawl to sample 10 historical and 5 new locations throughout northwestern Ontario. The Rainy River appears to support a robust population of River Darter. We also found River Darter in all of the historical locations and in 3 of the 5 new locations. In all locations stomachs were examined to discern major diet items. In the Rainy River stomachs were also examined to determine the prevalence of *Bythotrephes longimanus*, a newly invaded zooplankton in the system. Generally diet in River Darter consisted of Trichopterans and Dipterans. Ephemeropterans and Odonates were found in fewer guts. Ages of the River Darters collected ranged from 1 to 4 years and were similar to that found in other areas of their range.