Size-Based Models of Aquatic Ecosystems: Theory and Practice
- A Symposium in Honour of Rob Peters.

American Fisheries Society Annual Meeting, Quebec City, PQ August 18-19, 2014
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The symposium will focus on how size-based ecosystem models can be used to understand and manage marine and freshwater aquatic systems. Body size is a ubiquitous trait of organisms determining virtually all important physiological and ecological functions. Size-based models of marine ecosystems have been studied for at least 4 decades, however over the last 10 years there has been much new work demonstrating the utility of this approach in describing, managing and forecasting the behaviour of many aspects of both marine and freshwater systems. For example, such models have provided useful tools for exploring the responses of aquatic systems to exploitation, eutrophication and climate change. Topics to be covered in the symposium include: (i) theory underlying model structure and behaviour – links to the macro-ecology literature and the pioneering work of Rob Peters; (ii) applications to exploitation management at both the community level and the population level; (iii) new methods (eg hydro-acoustics) for estimating size structures in the field; (iv) empirical studies of size structure variation along several (eg climate, nutrient) environmental gradients. We expect participation by ~ 20 scientists actively working in this field. Presentations will cover new research results from North American, South American, European and African systems. AFS members will benefit from this symposium because it will provide a comprehensive overview of this promising approach to aquatic ecosystem management, covering (i) why the approach is effective, (ii) what it can be used for; (iii) its data needs and how to meet them.

Organizers
Brian J. Shuter, Ecology and Evolutionary Biology, University of Toronto, ON M5S 3G5
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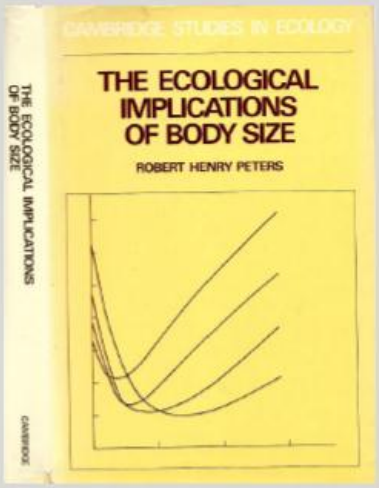
Dr. Robert Henry Peters 1946-1996



Published in 1983 – 4500 citations and counting ....

PRESENTATIONS

Surfing the Biomass Size Spectrum: Some Remarks on History, Theory, and Application
W Gary Sprules and Lauren Barth, University of Toronto Mississauga (Keynote)

Following upon their prior Coulter Counter observations on the size distributions of small particles in the ocean, RW Sheldon and colleagues published a seminal paper in 1972 in which they proposed as a first approximation that concentrations of marine particles in logarithmic size intervals “from bacteria to whales” were roughly equal. This concept was quickly expanded both empirically and theoretically by a small group of researchers, and before long the biomass size spectrum caught the attention of a much broader diversity of scholars. The underlying theory describes a community in which body size increases with trophic level, predators consume prey smaller than themselves, and material flow up the size spectrum is modelled by size-dependent ecological and physiological processes. We will briefly review the development and application of the size spectrum and focus on some more problematic aspects of the theory including what it means when the structure of a community does not fit size spectrum predictions; whether the normalized size spectrum is best described by a linear or non-linear model and how this affects predictions of productivity in parts of the food web; and the importance of spatial, temporal and biological scales in applications of size spectrum theory.

Supply-Demand Models and the Evolution of Body Size
John DeLong, University of Nebraska

Body size is of fundamental importance to the structure and function of natural systems, yet the factors selecting for certain body sizes are still not well understood. I developed a simple optimization model for adult (or asymptotic) body size where the optimal size is that which balances the bodily demand for resources with the environmental supply of those resources. These resources are typically food but may also be nutrients or oxygen. The model easily integrates with population dynamics models and can account for a wide range of body size patterns in space and time. Recent experimental work provides quantitative support for model predictions on the effects of temperature on body size, links between body size and growth rate, and dynamic changes in predator body size during predator-prey cycles. The simplicity and quantitative nature of the model sets the stage for understanding a wide array of patterns as well as for making quantitative predictions about body size evolution under novel scenarios, including those related to climate and land use change.

A Size-Based Theory for Inferring Global Change Impacts on Food Web Structure
Dominique Gravel, Camille Albouy and Claire Jacquet, Université du Québec à Rimouski

Global changes induce deep modifications in species distribution worldwide. However, the consequences of such changes on community structure are still poorly understood. Here, we propose a new framework, coupling species distribution and trophic models, to predict global change impacts on food-web structure. We first present a new method, inspired from the niche model of food web structure, to infer the matrix of potential interactions among a pool of species. The method applies to both local and regional scales. We find that this method gives robust predictions of the structure of food webs and that its efficiency is increased when the strength of the body–size relationship between predators and preys increases. We then study the consequences of this relationship on the body-size distribution at the biogeographic scale. We find that trophic interactions significantly impact individual species distribution, and ultimately the body-size structure of ecological communities. The theory is illustrated with applications to the Mediterranean Sea and Pacific coral reefs. Our study highlights large-scale impacts of global change on marine

Allometric Constraints to Food Webs within a Metacommunity Context
Matias Arim, Facultad de Ciencias & Centro Universitario Regional Este (CURE), Universidad de la República Uruguay, Ana Borthagaray, Facultad de Gobierno and Marcelo Loureiro, Facultad de Ciencias, Universidad de la República Uruguay

Advancing in the connection between global change and communities structure and function has become a pressing issue. Food web and body size structure of communities are interrelated by the trophic position-body size relationship (TP-M). While gape limitation promotes a positive relationship, energetic constrain force a negative one, mutually determining a hypothetic humped TP-M association. Here, we explicitly modeled the effect of community isolation and the mass-dependent individual movement on the TP-M relationship. Our result indicates that in spite of their greater abilities to move among communities, larger species could be particularly sensible to ecosystem fragmentation. The analysis of alternative meta-community networks congruently points to larger constraints to trophic positions and species viability, among larger species inhabiting isolated communities. Different components of global change mutually reinforce to impact larger species at higher trophic position. This impact could reduce or enhance the interaction between large-size species and species with lower body size; determining not evident changes in community structure. The body size and food web structure of communities are particularly sensible to global change. The analysis of allometric trends in energy demands, resource acquisition, and movement abilities, provides testable predictions about the association between food web structure and global change

Understanding and Predicting Marine Ecosystem Responses to Climate and Fishing
Julia Blanchard, University of Sheffield (Keynote)

Marine ecosystems are dynamic and complex. Understanding the consequences of change from multiple human and environmental pressures can be challenging, but this knowledge is needed to assess the ecosystem effects of human activities. Many ecological indicators and models have been developed to address these goals and size-based food web models are emerging as a powerful approach due to their simplicity and well-established theory. I will give an overview of recent work showing how size-based food web models can be used to help us understand the structure of marine ecosystems, establish abundance baselines of marine communities and their responses to the potential effects climate and human activity. Looking across a range of applications from global to local scales, I will focus on how we can confront size-based models with data and the challenges that exist for their potential use to support ecosystem-based management.

The Impact of Active Metabolism on the Dynamics of Size-Structured Food Webs
Henrique Giacomini and Pedro Peres-Neto, Université du Québec à Montréal

Active metabolism is a major component of the energy budget of many consumer organisms, especially those relying on active foraging to find and catch prey. Nevertheless, most models of ecosystem dynamics applied to fisheries assume that consumption rate is the single factor varying with prey density, and that metabolic rates are constant instead. Here we propose a systematic evaluation of the dynamical effects of active metabolic responses to prey density, using a Generalized Modeling approach and size-based rules to determine food web structure. In the absence of metabolic costs, increasing activity with prey density is always stabilizing as it leads to more accelerating functional responses, although this effect is inverted for larger metabolic costs. These in turn tend to be stabilizing for negative activity responses and saturated functional responses, especially in systems with few species or low connectance. Species with negative metabolic responses, particularly satiated large-sized top predators, tend to be more resistant to direct increases in fishing mortality. However, they are more susceptible to exploitation of their prey. These results call for a more careful evaluation of fishing at low trophic levels, whose impacts up in the food chains can be more drastic than forecasted by traditional models

Estimating the Potential Effects of an Invading Species, Lionfish (Pterois volitans), in Biscayne Bay through a Size-Structured Model
Nicholas Bernal and Donald DeAngelis, University of Miami

The lionfish (*P. volitans*) is a recent invader of benthic habitats in Biscayne Bay. Prior studies suggest the lionfish consumes a wide range of prey items. This generalist diet may have significant overlap with that of native fishes, such as those from the Snapper-Grouper complex, occupying a similar niche. Therefore it is important to estimate the potential impact of this invader on the native community. Lionfish can tolerate a wide breadth of environmental conditions, but quantification in terms of its long term fitness across this range of conditions has yet to be determined. We address the question of whether lionfish are likely to survive and flourish in Biscayne Bay. We apply a bioenergetics model to better understand how ambient environmental variables across newly invaded habitats impact metabolic function leading to growth and reproduction. This model incorporates estimates of effects of stress from low salinity, which is highly variable in Biscayne Bay and acts as a limiting environmental stressor for native species. Studies of environmental scenarios on individual lionfish are helping us refine our understanding of thresholds of prey availability and environmental conditions necessary to sustain individuals across environmental gradients

A Size-Based Approach to Examining Predator-Prey Relationships in Aquatic Predators
Francis Juanes, University of Victoria

Aquatic populations are generally size-structured and length-based processes are rapidly becoming the basis of aquatic ecosystem level management. Predator-prey relationships are especially constrained by allometric patterns in morphology and behaviour of both predators and prey. We have used size-based approaches to understand general allometric patterns in predator-size prey-size relationships across piscivorous and teuthivorous species ranging in size from 20 cm to 2m. Using this approach we have learned that predator-prey length scatters are generally wedge-shaped (minimum sizes independent of predator length and increasing mean sizes driven by the maximum), species-specific, and upper bounds often determined by mouth gape. Trophic niche breadths (relative prey size as a function of predator size) are generally converging so that average trophic niche breadth declines as a function of predator body size. We have also shown that cannibal gadid predator select larger prey than non-cannibal predators, and that predator species with wide distributions and site-specific diets exhibit similar predator-size prey-size scatters suggesting that prey size is more constraining than prey type. The ecological generalities produced by this size-based approach provide a powerful method with which to produce predictions about ecosystem responses to exploitation and climate change

The Lake Superior Biomass Size-Spectrum

Peder Yurista 1 , Daniel L. Yule 2 , Matthew P. Balge 3 , Jon VanAlstine 4 , Jo Thompson 1 , Allison Gamble 5 , Thomas R. Hrabik 6 , John R Kelly 1 , Jason Stockwell 7 and Mark R. Vinson 8 , (1)US Environmental Protection Agency, (2)USGS Great Lakes Science Center, (3)Normandeau Associates, Inc., (4)US Forest Service, (5)Minnesota Department of Natural Resources, (6)University of Minnesota, Duluth, (7)University of Vermont, (8)U.S. Geological Survey

We combined data from multiple sampling programs to describe the Lake Superior pelagic biomass size structure. The data represented phytoplankton, zooplankton and prey-fish that spanned over 10 orders of magnitude in size and two time periods separated by five years. The biomass size-spectrum was stable over the 5-year time frame. The primary scaling or overall slope of the normalized biomass size-spectra (NBSS) for the combined years was -1.113. The slope was consistent with a previous estimate for Lake Superior (-1.10) that was based on phytoplankton and zooplankton (Sprules and Munawar 1986). Periodic dome structures within the overall biomass size-spectrum were fit to polynomial regressions. The regressions described observed sub-domes that occurred within the classical taxonomic positions (algae, zooplankton, and fish). This more restricted interpretation of periodic dome structure was aligned more closely with predator-prey size relationships that existed within the zooplankton (herbivorous, predacious) and fish (planktivorous, piscivorous) taxonomic positions. Domes were spaced approximately every 3.78 Log units along the axis and with a decreasing peak magnitude of -4.1 Log units. The relative position of the algal 1010 and herbivorous zooplankton domes predicted well the subsequent biomass domes for larger predatory zooplankton and planktivorous prey fish.

Biomass Size Spectra As Ecological Indicators Across Broad Environmental and Anthropogenic Gradient

Cindy Chu 1 , Nigel P. Lester 2 , Henrique Giacomini 1 , Brian J. Shuter 3 and Donald A. Jackson 1 , (1)University of Toronto, (2)Ontario Ministry of Natural Resources, (3)Ontario Ministry of Natural Resources/University of Toronto

Biomass size spectra (BSS) provide a means of summarizing fish community production. In lakes, abundance decreases as body size increases, that is, larger species such as Walleye are less abundant than the smaller species they forage upon such as Cisco or minnows. This relationship represents the underlying processes of energy transfer and predator-prey dynamics, which determine the abundance of taxa at different trophic levels. It approximates community production and the slope can be used to document impediments to production. This study evaluated the utility of BSS as an ecological indicator of community health and fisheries production in hundreds of lakes throughout Ontario. The relative influences of lake and watershed characteristics, community composition, climate and anthropogenic stress including exploitation on BSS were also determined. A general linear model indicated that BSS were related to lake morphometry, angler activity, climate, the presence of large predators and aquatic invasive species and water quality. Identification of regional patterns in BSS and an understanding of the factors influencing BSS will improve our ability to manage fisheries across large spatial scales

Impact Assessments of Fishing Using Size-Based Models
Ken Haste Andersen, Technical University of Denmark (Keynote)

Implementation of the ecosystem approach to fisheries management requires impact assessments of how fishing on one part of the ecosystem affects the rest of the ecosystem. This should be done with models of various complexity. I will introduce the size- and trait-based approach to designing models of intermediate complexity of a fish community. In the models, individual fish are characterised by size, and their interactions by the simple rule: big fish eat smaller fish. As an example of an impact assessment I simulate the consequences of optimising ecosystem protein yield or economic rent while avoiding collapse of individual stocks. Finally I will show how a failure to resolve the stock structure of the individual components of the system will lead to models that are either too unstable or that have too strong indirect interactions in the community. The modelling framework has been implemented in three web-applications, available from http://ken.haste.dk.

The Adaptive Capacity of Aquatic Food Webs
Kevin McCann, University of Guelph

Aquatic food webs are size-structured with organisms eating across a range of size. As such they are webs with extremely generalized feeding strategies. The scale of movement of aquatic organisms also generally increases with size/trophic position, suggesting that spatial coupling of these webs often increases, on average, with increasing trophic level. These webs thus tend to have relatively distinct pathways that are increasingly coupled by mobile generalist foragers as one goes up in trophic position. Here, we argue that this food web architecture makes for a complex ecosystem that is inherently “flexible” or “adaptive” in that lower level changes are mediated by adaptive responses of higher level species. We argue that empirical, theoretical and applied research needs to embrace this inherently flexible architecture. Towards this goal, we review and synthesize empirical patterns in aquatic food web

Hydroacoustic measurements of fish community size spectra in a boreal reservoir
Laura Wheeland and George Rose, Memorial University, Newfoundland

Acoustic size spectra of fish communities have been determined in both freshwater and marine ecosystems using digital methods. In general, the empirical spectra fit ecological theory. In freshwater ecosystems, the majority of fish are typically distributed individually and can be distinguished as acoustic “single targets”. Using examples from research conducted at Lac du Bonnet in Manitoba, it will be shown that acoustically-determine spectra have potential to provide year to year assessments and a monitoring tool for measuring spring production and relative fish size structures for fisheries management. In addition, within year sequential spectra may have potential to provide estimates of mortality along the size spectrum. In marine ecosystems, in contrast, the majority of fish are typically distributed in aggregations, wherein the distinguishing of single targets is problematic. This imposes a bias on marine spectra determined acoustically. Nevertheless, marine acoustic size spectra may provide key information on size structures of fish communities or stocks. Examples and the potential of size-based acoustic measures will be drawn from research on the Grand Banks and northeast Newfoundland Shelf

The Seasonal Variation in Size-Spectrum Slopes within Lakes and the Capacity to Detect Environmental Change

Derrick T. de Kerckhove, University of Toronto, Scott Milne, Milne Technologies and Brian J. Shuter, Ontario Ministry of Natural Resources/University of Toronto

The mid-point heights, y-intercepts and slopes of size-spectra linear relationships between log-scaled fish abundance and body size have been studied in primarily marine fisheries as potentially useful indicators of community change arising from fishing. As larger individuals are harvested the high end of the size-spectrum is diminished, and as prey species are released from predation higher abundances increase at the low end of the spectrum, thus steepening slopes and increasing y-intercepts. Here we investigate three potentially confounding factors to this scenario including: 1) shifts in prey sizes following the release from predation, 2) temporal variation from the seasonal and decadal dynamics of fast-growing species, and 3) the generally high coefficients of variation associated with monitoring abundances and sizes in fisheries. The relevance of these factors are presented using time-series data of the fish community in the pelagic zone of Lake Opeongo from gill netting, trawls and hydroacoustic surveys spanning over a 40 year period, over which time the Lake Trout population experienced overfishing, and experienced decreasing body sizes in both the Lake Trout and their prey, Cisco. Last, we compare Lake Opeongo's size spectra with over 30 hydroacoustic lake surveys from across Canadian lakes containing Lake Trout

Fish Size Structure in European Lakes: Variations Along Continental and Regional Gradients and Implications for Lake Management

Sandra Brucet 1 , Thomas Mehner 2 , Matthias Emmrich 3 , Ian Winfield 4 , Pietro Volta 5 , Christine Argillier 6 , Kerstin Holmgren 7 , Lluís Benejam 8 , Ignasi Arranz 8 and Erik Jeppesen 1 , (1)University of Aarhus, (2)Leibniz-Institute of Freshwater Ecology and Inland Fisheries (IGB), (3)Leibniz Institute of Freshwater Ecology and Inland Fisheries, (4)Centre for Ecology & Hydrology, (5)CNR-Istituto per lo Studio degli Ecosistemi, (6)Irstea, (7)Swedish University of Agricultural Sciences, (8)University of Vic

Variations in the size structure of fish communities were explored at European scale along gradients of climate, morphometry, productivity and fish community structure in more than 1800 lakes. Size metrics used were average fish body size, individual size distributions and size diversity. Analyses were conducted at both continental and regional scale. We found changes in fish community size structure across temperature gradients in correspondence with the dominant thermal fish guild. Lakes located in the warmer European lowlands were dominated by eurythermic cool- and warm-water fish communities with small-sized individuals characterised by linear individual size distributions. Lakes located in cold regions and dominated by stenothermic coldwater salmonids with larger-sized individuals were characterised by unimodal or bimodal size distributions. Our results show that temperature modifies fish community size structure uniformly within the thermal fish guilds and different ecoregions. The importance of temperature in explaining variability in fish size increased when moving from warm to cold regions. After controlling for the natural factors, productivity negatively influenced average fish size. At a macro-ecological scale, the strong effect of environmental temperature suggests future changes in fish size structure as a consequence of climate change, whereas eutrophication effects become more apparent at a regional scale.

Maximizing Fisheries Yields While Maintaining Ecosystem Structure
Jeppe Kolding 1 , Nis Sand Jacobsen 2 , Ken Haste Andersen 2 and Paul van Zwieten 3 , (1)University of Bergen, (2)Technical University of Denmark, (3)Wageningen University

Under the Ecosystem Approach to Fisheries an optimum fishing pattern is one that gives the highest yield while causing the least structural impact on the community. Unregulated, overall non-selective open access African inland fisheries have been observed to sustain high sustainable catches by harvesting a broad spectrum of species and sizes, often in open conflict with current management regulations in terms of mesh and gear regulations. We use a size based trophic model to theoretically explore the optimal fishing pattern in terms of the effort on a given size range. The results are validated and compared with long term multispecies data from man-made Lake Kariba under fished and unfished conditions. Both model and observations show that the highest yields with the least structural impact on the ecosystem is obtained by predominantly targeting the smallest components of the community. These results call for a re-evaluation of the size based management regulations that are ubiquitous in most fisheries

Testing Biomass-Size Spectrum Theory with Whole-Lake Experiments
Michael D. Rennie, Fisheries and Oceans Canada, Michael Paterson, International Institute for Sustainable Development and David Findlay, Fisheries and Oceans Canada, Emeritus

Aquatic freshwater ecosystems are changing at a dramatic pace, as a result of a range of anthropogenic stressors including species invasions, climate change and eutrophication. However, it is not always immediately clear how these community-level changes resulting from disturbance impact rates of energy transfer or overall ecosystem productivity. Whole aquatic ecosystems at the Experimental Lakes Area have undergone dramatic community-level change in response to acidification, eutrophication and biomanipulation, both during manipulation and recovery. Data from many of these manipulations lend themselves to analysis of normalized biomass size spectra (NBSS) to better understand how community changes have affected energetic transfer efficiency in ecosystems. Preliminary NBSS analyses focused on phytoplankton and zooplankton indicated a significant resilience in the fitted slopes around the expected slope of -1, but that residual variance around the slopes tended to increase during manipulations. Here, we amend these analyses by including fish size spectra to help improve NBSS assessments, and provide a more complete analysis of how community changes in response to experimental disturbance affect NBSS fits and parameter estimates, and in turn how that informs our interpretation of the effects on energy transfer rates in these systems

Dynamic Models of Size Spectra: Insights into Productivity and Exploitation of Fish Communities
Richard Law 1 , Gustav Delius 1 , Jeppe Kolding 2 and Michael Plank 3 , (1)University of York, (2)University of Bergen, (3)University of Canterbury (Keynote)

This talk outlines a model for the dynamics of size spectra in which fish increase in body size by eating other organisms, including other fish. The model starts with bookkeeping of biomass at the level of individual predation events, and builds up to biomass flow at the macroscopic level of fish populations and communities. This helps understanding of ecosystem processes, such as the balancing of mass at steady state. Productivity typically decreases with increasing body size in these models. When fishing mortality is brought more in line with productivity, the models show that biomass yields can be substantially increased. At the same time, coexistence of exploited species is enhanced, disruption to size structure reduced, and resilience to perturbations increased. We suggest that the relatively benign effects of balanced harvesting could stem from fishing mortality tending to replace predation mortality, rather than adding to it.

Size Spectra of Fish Assemblages: Longitudinal and Temporal Variation in a Small Neotropical Reservoir
Mateus Ferrareze, Sao Paulo State university and Henrique Giacomini, University of Toronto

Size spectrum approaches have been increasingly used as an indicator of aquatic ecosystem structure. In this study, we estimated the size spectrum slopes of fish assemblages at three different longitudinal zones of a recently formed reservoir in Southeastern Brazil, at two different points in time: in the first and in the second year after closing the dam. We show that the size spectrum slope, given by the maximum likelihood estimator of the Pareto type I distribution, has not changed from the first to the second year only in the lotic, more preserved zone. The lentic zone, representing the more altered habitat, had a much steeper size distribution in the first year, implying in relatively higher dominance by small fish, but then showed the greatest change in slope in the second year towards the values typical for the lotic zone. The transition zone showed intermediate trends in slope. These results can be explained by concomitant changes in phytoplankton production, water transparency and occurrence of piscivorous fish observed between the two years, suggesting that the fish size distribution can readily track changes in environmental conditions following major perturbations

The Roles of Climate and Community Size Structure in Shaping the Life Histories of Limnetic Top Predators: An Empirical Assessment Using Several Continental Data Sets
Brian J. Shuter 1 , Henrique Giacomini 2,3 , Cindy Chu 2 , Erin S. Dunlop 4 , Ander Finsatd 5 and Nigel P. Lester 4 , (1)Ontario Ministry of Natural Resources/University of Toronto, (2)University of Toronto, (3)Université du Québec à Montréal, (4)Ontario Ministry of Natural Resources, (5)Norwegian Institute for Nature Research

The relative importance of environmental temperature and prey availability in shaping somatic growth rate and reproductive allocation in freshwater fish has been the subject of much recent theoretical and empirical work. In this paper, we use extensions of the biphasic growth model of Lester et al (2004) to make a quantitative assessment of: (i) the nature of the constraints that the seasonal water temperature cycle places on juvenile somatic growth rate; (b) the nature of the constraints that the prey size spectrum places on reproductive allocation and the consequences for adult somatic growth. We use six data sets that document continent-wide variation in the life-time somatic growth patterns of 2 cold water species (lake trout in North America, brown trout in Europe), 3 cool water species (walleye and yellow perch in North America, European perch in Europe) and 1 warmwater species (smallmouth bass in North America). Comparative analyses of these data reveal many similarities and some differences in the degree to which variation in observed growth patterns can be linked to environmental differences in seasonal temperature patterns and ecological differences in prey size distributions

Simulation of Lake Ontario Benthification
James E. McKenna Jr. 1 , Marc A. Chalupnicki 2 and Dawn E. Dittman 2 , (1)US Geological Survey, Great Lakes Science Center, (2)USGS Great Lakes Science Center

Benthification of Lake Ontario has converted it from a pelagically-focused productivity engine to a more benthic system. Large-scale filter-feeding is new to this system and much about mass and energy transfer through the benthic subsystem is unknown. We developed an individual-based, spatially-explicit simulation model of carbon flow through the Lake Ontario benthic system and tested hypotheses of food competition and differential mortality rates to explain the pattern of community change associated with Dreissinid mussel invasion and benthification. The model simulates the physiological processes and population dynamics of three benthic feeding guilds, Filter-feeders [FF] (mussels), Deposit-feeders [DF] (e.g., oligocheates), and Surface Deposit-feeder [SDF] (amphipods), with different larval dispersal strategies. After 150 years of stabilization, FF were introduced, the simulation continued for 10 years, and then FF mortality was increased (due to Round Goby *Neobogius melanostomus* invasion) for another 10 years. The SDF mortality was either held constant or elevated (representing unknown mortality e.g., disease) during the invasion period. The model was stable and predicted SDF and DF abundances similar to field observations during stabilization and

after FF invasion. The elevated SDF mortality scenario represented the spatial pattern of SDF abundance throughout the invasion period better than the constant mortality scenario.

Comparing Ecosystem Models As Fisheries Management Tools: A Case Study in the California Current
Nis Sand Jacobsen[1]**,** Ken Haste Andersen1 and Timothy E. Essington[2] , [1]Center for Ocean Life, Technical University of Denmark, Charlottenlund, Denmark; [2]School of Aquatic and Fisheries Sciences, University of Washington, Seattle, WA.

Ecosystem modeling is becoming a more integral part of fisheries management, and there is a need to quantify differences between various models currently being employed for scientific and management purposes. Using two models, Ecosim and a size- and –trait based model, we simulate ecological consequences of fishing to identify commonalities and differences in model predictions for the California Current fish community. We predict the maximum sustainable yield of each fish species and the fishing mortality required to reach it. Secondly, we investigate the fish community response to small perturbations, to find the most important components as well as bottom-up and top-down changes due to fishing. We find that the most important differences between models are 1) The fishing mortality needed to reach MSY differs systematically between models 2) competition in the trait-based model causes increased abundance of larger species when forage fish are removed, whereas bottom up consequences are more unpredictable in Ecosim, 3) diet matrices in Ecosim change the responses of individual species compared to a size based food selection approach. We conclude that the choice of ecosystem model critically influences the outcome of a given fishing scenario and conclusions from a single model should be drawn carefully.

Harvesting of Lake Trout Induces Alternative States in Lake Opeongo
Karin A. Nilsson 1 , Derrick T. de Kerckhove 2 , Kris Vascotto 3 , Kevin McCann 1 and Brian J. Shuter 4 (1)University of Guelph, (2)University of Toronto, (3)Nova Scotia Marine and Coastal Advisory Services, (4)Ontario Ministry of Natural Resources/University of Toronto

Cisco was introduced to Lake Opeongo as a forage fish for Lake Trout over 60 years ago. While the introduction had an initial positive effect on both Cisco and Lake Trout growth and abundance, over time the system changed resulting in the currently lower body and population sizes observed for both species. We use time-series data and life-history theory to disentangle a set of hypotheses on why this later change occurred. We find a strong correspondence withan Emergent Allee effect, which is driven by the predator's ability to create more profitable prey by feeding on it. This conclusion is supported by a drastic decrease in Lake Trout abundance in the late 1970s due to high fishing mortality. Prior to this event, Lake Trout foraging thinned the Cisco population, which reduced intraspecific competition that led to larger Cisco sizes. After the event, increased competition between Cisco slowed their growth rate. As the Lake Trout population recovered in size over the last few decades, there was no transition back to the previous state. Cisco appears to be locked in a state with small size at maturation and slow growth.

Could the Nile Perch Invasion in Lake Victoria Have Succeeded without the Preceding Decrease of Its Prey?
Jeppe Kolding, University of Bergen, Michael Plank, University of Canterbury, Paul van Zwieten, Wageningen University and Richard Law, University of York

The introduction of the Nile perch (*Lates niloticus*) into the largest tropical lake in the world and the following dramatic reduction in fish species diversity has made Lake Victoria in East Africa one of the paragon examples of man-made ecological blunders in the last century. The dramatic changes in Lake Victoria took place within a few years in the mid 1980s, almost 30 years after Nile perch was introduced. An unresolved question has always been why it waited so long when it could happen so fast. Long time series of environmental changes, eutrophication, productivity, and low and high trophic species changes and size compositions; indicate that the dramatic changes in the ecosystem encompassed areas of the ecosystem outside the control of the introduced top predator. Recruitment data indicate that Nile perch was strongly constrained when the abundance of the cichlids was high, and its explosive development did not take place until after these had nearly disappeared. With a size-based model we want to explore the alternative hypothesis that Nile perch was not able to become established when the abundance of the cichlids were high, and that its introduction therefore cannot be only explanation for the observed changes

Habitat Complexity and Human Presence Shape Pacific Coral Reef Size Structure
James Robinson 1 , Andrew Edwards 2 , Ivor Williams 3 , Jana McPherson 4 , Rusty Brainard 3 and Julia K. Baum 1 , (1)University of Victoria, (2)Fisheries and Oceans Canada, (3)Pacific Islands Fisheries Science Center, (4)Calgary Zoological Society

Human disturbances have wide ranging and diverse impacts on coral reef ecosystems. Reductions in biomass and biodiversity are well documented, particularly at local scales, and yet the impacts on community structure are less defined. Size-based analyses can be used to describe changes to community structure where, by quantifying the allometric relationship between body size and abundance, the size spectrum represents the distribution of body sizes in a community. Exploitation of large body sizes alters community structure and is reflected by a steepening of the size spectrum. Here, using an extensive dataset of fish abundance and body size at over 50 Pacific islands, covering several biogeographic regions, we explore the variation in community structure attributable to human impacts and environmental covariates. Size spectra of populated reefs are steeper than their near-pristine, uninhabited counterparts, indicating a consistent and ocean-basin wide effect of fishing on the reef fish community. In contrast, habitat complexity and reef isolation drive size structure when humans are absent. Size based analyses complement the use of diversity and biomass metrics in teasing out the impacts of human disturbances on marine ecosystems.

A Generic Sized-Based Model of the Effect of Habitat Loss on Freshwater Fishes
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Habitat loss has been identified as the greatest threat in freshwater environments. Endangered freshwater fishes tend to be smaller-bodied with habitat-related threats, whereas endangered marine fishes are predominantly larger-bodied and threatened by exploitation. Many attributes of fishes are related to body size. Larger fishes tend to grow slower, mature later, be more fecund and live longer. Here we present a generic size-based population matrix model, parameterized using published length-based allometries and relationships among life history traits. Our aim was to examine the sensitivity of fish populations and fisheries productivity to habitat versus exploitation perturbations. Our model predicts that small-bodied fishes (shorter maximum body length) are indeed more sensitive to the loss of habitat. Moreover, distinct stage-based trends show an increased sensitivity of smaller fishes to both habitat loss and changes to vital rates during pre-adult stages. This indicates that the pre-adult period represents a critical stage for the continued production of smaller-bodied fishes and an increased importance to the protection of habitat utilized by young-of-the-year and juvenile fish.