



## Symposium I: Understanding Angler Behaviour Through Human Dimensions and Economics Research

B1

### Understanding and Managing Freshwater Recreational Fisheries as Complex Adaptive Social-Ecological Systems: The Role of the Human Dimension

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The old adage that fisheries management is as much about people management as it is about fish stock management has for long motivated our research efforts to study the human dimension of recreational fisheries. However, the underlying justification for such research has evolved from a desired focus to simply understand “people” towards a more encompassing challenge to learn about how people and their behaviors shape key feedback processes in recreational fisheries as coupled social-ecological systems (SEs) and how in turn how ecological and managerial changes feedback to affect people and their behaviours. In this context, the emerging research agenda has to address three relevant qualities of recreational fisheries as complex adaptive SEs: i) diversity and individuality of components, ii) localized micro-scale interactions among system components (e.g., anglers interacting with single sites within a lake) leading to emergent, difficult-to-predict macro-scale patterns (e.g., regional overfishing across lakes), and iii) an autonomous, self-organized process that uses the outcomes of local interactions as feedback for adaptation through selection and evolution. In all three areas, research on the human dimensions is of key importance, but it can no longer be treated as tangential or even separate to the ecological dynamics of recreational fisheries.



B2

## A Shopper's Guide to Recreational Fisheries Human Dimensions' Research

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Many reasons exist to engage in studying recreational anglers. These reasons vary from the pedantic to the practical with most research falling between these extremes. The different ways of and reasons for studying anglers can result in tension among researchers from different human dimensions disciplines such as economics and social psychology. These apparent tensions are exacerbated by a lack of appreciation of each other's perspectives and enflamed by beliefs that some fisheries managers favor some perspectives above others. In an age of an increasing trend towards interdisciplinary-based research and policymaking, it is imperative for human dimensions researchers and perhaps, more importantly, fisheries scientists and managers to understand the strengths and weaknesses of these perspectives. In this talk, we map our understanding of these disciplinary-specific perspectives paying close to the contributions towards answering both positive and normative-focused questions. Then, we describe for non-disciplinary specialists, the relative strengths and weakness of the different perspectives. Specifically, we recognize and appreciate that all researchers engaged in studying anglers are passionate about the resource and /or the people whom benefit from using this resource. But, without clearly understanding the needs of fisheries managers and the perspectives and contributions from other researchers, this passion and eagerness can befuddle policymakers, managers, and other fisheries scientists. Therefore, we offer this shopper's guide to help researchers, policymakers, and managers find the right partners from within the human dimensions community.



B3

## Why Fisheries Scientists Have Long Ignored Human Dimensions and Why This is Now Changing

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The goal of fisheries science is to better understand the interaction between fishers (recreational, commercial, indigenous, artisanal) and fish populations and communities. As fisheries science developed as a field, great emphasis was placed on understanding how fishing impacted fish populations to prevent against overfishing and the problems related to population recovery (e.g. cultivation-dependence, Allee effects). However, the complexities driving fisher decisions on whether, where and when to fish were slow to develop. Early attempts were based on simple economic or ecological models where motives for fishing were usually driven by expected catch rates or abundance. More recent work has shown how misleading these models can be when the diversity of fisher motives and attributes are ignored. I will discuss the history of applying human dimensions in fisheries and explain why a more formal integration of the two fields was so slow to develop. This will include early attempts and misinterpretation of results by fisheries scientists, recognition by fisheries scientists that the greatest unknown element of fisheries is fisher response over time and formal integration of HD elements into fisheries models and decision making. Fisheries models incorporating HD concepts are still being developed and there are still difficulties in aligning these concepts. I will close by highlighting some of these issues and suggest ways to move forward to improve social and conservation outcomes.



B4

## The Goals for and Challenges of Incorporating HD Information into Fishery Management: A Great Lakes Perspective

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Recently, the Great Lakes Fishery Commission updated its “Human Dimensions of Great Lakes Fishery Management” research theme. The theme outlines the commission’s objectives for HD research and guides prospective investigators as they formulate proposals for funding. To update the research theme, the authors interviewed Great Lakes fishery managers and other key practitioners to identify barriers and opportunities for better use of social science information in decision-making. The research revealed that fishery managers face a number of barriers that impede them from applying social science to their management actions. Such barriers include limited training in social science; incomplete and skewed understandings of the nature of social science information; and logistical difficulties in integration. Subsequently, fishery managers identified multiple information needs that would allow them to better understand the human dimension of fishery management and incorporate that information into decision making. Those key information needs include a refined understanding of demographic changes, a better understanding of angler values and behavior, and an improved understanding of economic factors that help explain behaviour and justify management actions.



B5

## Using the Cognitive Hierarchy to Understand and Predict Angler Behavior: Its Promise and Limitations

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The cognitive hierarchy is a dominant conceptual framework within social psychology. The cognitive hierarchy suggests that at an individual level much of human thought is organized as an evaluative system that directs our appraisals of “good” and “bad” as well as our subsequent choices and behaviors. Key concepts within the cognitive hierarchy include values, value orientations, norms, attitudes, beliefs and behavioral intentions. Values are defined as broad goals and principles that guide human thought and behaviors across all life events and circumstances. Values operate as critical lenses through which we perceive, interpret and react to the outside world. They shape our world views and ideologies and help define our individual identities. Such values are learned early in life, reinforced by our environment, and tend to be relatively stable. Values also help shape our subsequent attitudes, or evaluative beliefs, of almost everything we encounter in our lives from other people, places, animals, events, activities and policies as well as our norms for behaving in different ways. As conceived, the cognitive hierarchy provides an essential framework for understanding our preferences and behavioral choices. Many more specific social psychological theories relating to attitudes and norms are derived from the cognitive hierarchy and have been applied with varying success in understanding human behavior related to fisheries and affiliated resources. We provide a critical examination of 1) the concepts in the cognitive hierarchy, 2) the predictive ability of the derived theories, and 3) suggestions for improving the approach in the context of recreational fisheries management.



B6

## Motivations Toward Recreational Fishing and Their Bearing on Predicting Angler Behavior

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The recreation experience preferences (REP) scales developed by Driver and associates contain 21 psychological domains encompassing most reasons individuals participate in outdoor recreational activities. Referred to as "activity-general" recreation motivations, measurement scales associated with them have been refined to confirm their reliability and validity. Not until researchers began using these scales in angler surveys did questions arise about the relevancy of activity-general motivations to understanding angler behavior. With the exception of consuming fish, many of the activity-specific motivation items developed to appease fisheries administrators appear to be just context specific motivations to an existing activity-general motivation. If that is the case, the question arises as to whether any motivations specific to fishing exist aside from the opportunity to keep fish (unique to fishing)? If they do exist, researchers need to make a concerted effort to define potential activity-specific domains, develop items, and test them with the same rigor that went into the development of the activity-general motivations. If they cannot be developed, then researchers are delaying our understanding of angler behavior and preventing the incorporation of human dimensions research into decision-making and recruiting new anglers, and reverting to the use of the original REP scales will likely best serve that purpose.



B7

## Angler Satisfaction: Measurement Approaches and the Importance of Catch Vs. Non-Catch Dimensions of Fishing

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Angler satisfaction constitutes the ultimate reward to anglers. Angler satisfaction is also a relevant management objective, although it has become commonplace to manage for surrogates of satisfaction, such as high catch rates or large sizes of fish in the stock. Two approaches to measuring angler satisfaction have been prominent: a) the gap score approach (where both expected and realized satisfactions are measured), and b) the sum-of-satisfaction approaches. Empirical research has shown that the non-catch components of the angling experience are generally much more easily satisfied than the catch components. In turn, variation in satisfaction among anglers has been found to be best explained by catch aspects or strong surrogates of catch (e.g., the intensity of stocking) in both European and North American studies. The contribution of catch-rates to satisfaction ceases to rise after some threshold (acceptable) catch rate is achieved; no such threshold exists for size of fish. Moreover, angler satisfaction has been found to affect attitudes towards and acceptability of management regulations and other management tools. Therefore, a continued focus on angler satisfaction for explaining behavior and other outcomes seems warranted. In certain situations, focusing on catch-related surrogates of angler satisfaction may be acceptable in management. However, which catch dimension matters (catch rate, or size of fish) to whom strongly depends on details and cannot be generalized.



B8

## The Role of Social Norms and Attitudes in Explaining Angler Behavior

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Studies of attitudes have been among the most common and popular in the history of human dimensions (HD) studies in recreational fisheries. Not surprisingly, since the term “attitude” is used in many contexts, among researchers and lay people alike. In HD research, the concept gained initial interest among managers and applied researchers since it suggested that with the provision of (new) knowledge (from experts), attitudes and behaviour would change (to the better). Studies of attitudes i.e. towards the importance of catch created important discussions between and among HD researchers and fishery managers, clarifying for instance that a) attitudes do not necessarily predict behaviour well, and that b) attitude studies need to be specific to have relevance in understanding people’s preferences and choices. Within the HD literature, norms have been approached both as standards (structural norms, i.e.) as well as in line with the more general social scientific definition of social norms. Norms have, compared to other HD concepts, a strong social component. The concept has provided important insights into understanding behaviour of anglers, especially contributed to how social norms act alongside and strengthen for instance formal regulations. We review the development of attitude and norms studies in fisheries research and related areas, and emphasize important theoretical, conceptual and methodological improvements during the last four decades. Finally, it is argued that we need to more strongly address social and cultural (as opposed to individual) approaches to better understand how stakeholders, including anglers and right holders behave towards fish and fisheries.



B9

## A Place for Place Within Recreational Fisheries Research

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While acknowledgement of the importance of place for understanding recreationist behavior and natural resource management has been prominent within the broader human dimensions literature for over 40 years (Lee, 1972), place's utility for understanding angling behavior and recreational fisheries management has received scarce attention. This is surprising given the setting's importance to the angling experience. In this review, I outline: (a) the varied conceptual orientations for understanding place across social science disciplines; (b) place concepts' intersections with other constructs that have informed our understanding of angling behavior and recreational fisheries management; (c) past empirical evidence providing insight on the utility of place for natural resource management, in general, and place's potential for informing recreational fisheries management, in particular; and (d) directions for future research exploring the implications of place for understanding angling behavior and recreational fisheries management.



B10

## Constraints to Angling: A Review and Recommendations for Recreational Fisheries Management

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Constraints theory has much to offer in understanding leisure behavior. This is especially true in the context of recreational fisheries, where a variety of situational, individual, and interpersonal factors interact to influence participation in the activity. Similarly, these factors have bearing on angler satisfaction and motivation, which are important psychological dimensions of participation in recreational fishing. A better understanding of the potential applications of constraints theory to recreational fisheries management can yield policy recommendations that sustain participation over the anglers' life-course, recruit new individuals to the sport, engage diverse and marginalized populations, and enhance angler experience and satisfaction. In this review, we provide a synthesis of the current state of the literature that has applied constraints theory to understand leisure behavior, especially in the context of recreational fisheries, and present recommendations for the use of constraints concepts in recreational fisheries management.



B11

## A Review and Synthesis of Angler Specialization and Behavior

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Specialization is a framework used to understand recreational involvement. Developed in 1977 by Hobson Bryan as a continuum for understanding anglers, the concept has grown and evolved over the following 40 years to represent a three-dimensional framework composed of anglers' behavior, skill, and commitment to their sport. Although it may be convenient to think of individuals moving over time from low to high levels of specialization, the vast literature on the concept has questioned the notion of progression, and has shown that specialization can prove to be a complicated construct. This talk will collect and synthesize specialization-related research by discussing three main topic areas: history and development of the construct, measurement of specialization, and the relationship between specialization and angler behavior. Specialization has experienced a number of notable evolutions since its inception and this presentation will seek to highlight research that pushed the concept to where it stands today. The measurement of specialization has varied wildly over the past 40 years. This presentation will discuss the available methods for measuring specialization. Best practices and appropriateness of various techniques will be explored using relevant literature. The discussion will conclude with a synthesis of the literature regarding the relationship between angler specialization and behavior. The level of specialization among anglers has demonstrated a relationship with motivations, place attachment, environmental behaviors, environmental attitudes, satisfaction and consumptive orientation. This final section will discuss these studies and their implications for fisheries management.



B12

## Factors Influencing Stakeholder Attitudes to Ending the Goliath Grouper Fishing Moratorium

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Stakeholder attitudes diverge when it comes to the Florida Goliath Grouper (*Epinephelus itajara*), a species that has been protected from fishery take for 26 years following precipitous population declines due to overexploitation. Recreational spear fishers and commercial fishers tend to strongly favor re-opening the fishery and view the giant grouper as a nuisance species. Recreational anglers have a more positive attitude toward the fish while also generally being in favor of re-opening of the fishery. Most sight-seeing (non-fishing) recreational divers, on the other hand, oppose any fishery on goliath grouper. In light of the recent decision by the Florida Fish and Wildlife Conservation Commission to explore options for a limited fishery, we present here an in-depth analysis of factors that underlie the divergent management attitudes of stakeholders. Our analysis is based on a 2013 internet survey of major fishing and non-fishing stakeholder groups. The survey provided information on respondent's personal experience with goliath grouper, views on the fish and its management, and general ecological value orientation (measured using the New Ecological Paradigm scale). We use structural equation modeling (SEM) to examine the relationship among value orientation, experience and belief constructs in determining attitudes toward the fish and management preferences.



B13

## Fisherman Tales: Comparison of Methods for Obtaining Actual Compliance Data from Anglers During Creel Surveys.

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Data regarding sensitive information such as recreational fisheries compliance is difficult to obtain and without the proper methodology, unreliable. Three different methods of obtaining this data during creel surveys were employed including the previously lauded Random Response Technique (RRT), the Ballot Box Method (BBM) and a truthful request (TR). To validate the results of each method, rock and surf fisherman were unknowingly observed during their outing with the use of night-vision, binoculars and spotting scopes and then interviewed as they left the fishing area. Results for the RRT indicated that the method is too complex for many anglers who often just “answer honestly” and also results in a significant loss of data due to probabilistic logic. The TR method provided a higher rate of contradiction to the observed data. The BBM performed best in obtaining honest answers to compliance questions and resulted in no loss of data due to filtering methods required by RRT. BBM is a more practical method compared to the often utilized RRT and should be employed by researchers in future creel surveys examining fisheries compliance.



B14

## Homo Economicus – Economics and Recreational Fisheries

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As part of the session 'Understanding human behavior through human dimensions and economic research', I was asked to provide a keynote-style presentation covering the different conceptual and empirical ways that economists have thought about behavior in recreation fisheries. I will begin by reviewing the types of rationality assumptions economists use – including full information and utility-maximization – for conceptualizing behavior in the fishery. I will then discuss the usefulness and limitations of these assumptions, and review how they are used to construct empirical models of behavior. From there my discussion will transition to a review of different econometric models, and the trade-offs between simple and transparent, versus rich and complex, models. This will also include discussion of the various data sources, means of gathering data, and prospects for improved data environments. I will end by reviewing different aspects of behavior in recreation fisheries that I believe to be important, but which economists have done a relatively poor job of modeling. Throughout, I will keep my remarks at the “horizon-scan” level, with the goal of providing a synthesis and overview upon which the later presentations can build.



B15

## Who is Smarter: Robert Arlinghaus or a Trout?

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Recreational fishers are some of the most sophisticated predators in aquatic systems. They respond to many other factors in addition to prey density. Yet within fisheries, efforts to understand and model fish predatory behavior greatly outnumber efforts to understand and model angler behavior. When fisher behavior is modeled it is often as a Holling-style (usually type I) functional response. Such models are useful as phenomenological descriptions of what fishers have done in the past under specific institutions. However, most fishery decision making is about changes in institutions, often to settings not yet experienced. Structural models are also often better suited to capture the heterogeneous preferences, demands, and behaviors of anglers. In this talk, I will review approaches to phenomenological and mechanistic modeling of angler behavior and discuss the advantages and disadvantages of each approach. For example, phenomenological models are well suited for assessing past policy interventions and for making ecological forecasts solidly within the range of existing data. Mechanistic models are better suited for considering the potential effects of novel policy interventions or environmental changes. Furthermore, mechanistic models are often important for understanding the impacts of changes in policy or the environment on angler wellbeing. I will also provide insight into how to bridge the two approaches. Finally, I will discuss how structural models are well suited to capture angler heterogeneity.



B16

## What do Studies Using Choice Models Tell Us About Recreational Fishers and Fisheries?

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Researchers often use choice models to estimate behaviors of recreational fishers and the associated benefits accruing to fishers from resource use. These choice models are relatively simple to estimate and only require data on choices (e.g., intended or reported fishing site choices), alternatives (e.g., plausible fishing sites), and attributes that describe the alternatives (e.g., catch-related quality and travel costs to the fishing sites). In fact, over a hundred choice model applications on recreational fishing have been conducted and published in primary literature. In this talk, we will describe the models and review the past studies in an effort to communicate typical approaches that researchers use to design research and draw meaningful conclusions from the results. Early insights suggest that researchers have made progress on several fronts including: (i) enhancing our understanding about the role of management actions on fishers' behaviors; (ii) accounting for heterogeneous preferences for attributes among recreational fishers; and (iii) better linking site choice and participation (effort) decisions by fishers. Despite this progress, researchers often use non-standard and context-specific approaches to measure attributes and invoke possibly unrealistic assumptions to characterize relationships between utility and travel cost/catch-related fishing quality.



B17

## Bioeconomic Trade-Offs in Recreational Fisheries- A Little Too Much?

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It is important that both biological and social aspects are taken into account when recreational fishery management decisions are formed. Bioeconomic models combine biological and ecological models and data in order to formulate management models. In this sense, bioeconomic modelling is one way to bridge the gap between biology and the social sciences. The ultimate aim of bioeconomic models is to maximize some objective function under certain constraints. The objective function is typically angler utility, landowner profit or social welfare, while the constraints are typically the biological capacity of the considered fish populations. There are two apparent challenges in formulating a sound bioeconomic model. First, one need to decide which objective to optimize (e.g. angler utility or social welfare?), and what aspects of the fishing experience that should be included in the chosen objective function. Second, one need to decide on the relevant biological information to be included. When is it sufficient with stylized biomass models and when do we need more realistic age- or stage-structured biological models? The challenge is to make bioeconomic models so realistic that both biologists and social scientists agree on the fundamental assumptions, but at the same time, simple enough to be informative and relevant for actual management decisions. As in all modelling, there are trade-offs between complexity and simplicity. This paper aims to discuss these trade-offs and point out the necessary areas of cooperation between biologists and social scientists in order to achieve the right balance for recreational fishing management.



B18

## Using Multiple Discrete-Continuous Extreme Value (MDCEV) Models to Understand Angler's Seasonal Fishing Behavior

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This talk will explore results from two different studies showing how both recall and contingent behavior data can be leveraged in productive new directions to model the seasonal behavior of anglers. Specifically, I demonstrate how a statistical modeling approach known as the multiple discrete-continuous extreme value (MDCEV) model – previously utilized in the environmental economics and transportation communities – can be used to better understand and predict the patterns of behavioral substitution across spatial sites and across sub-seasons of the year in response to changes in environmental conditions and regulations. This approach differs from the discrete-choice methodology that dominates much of the literature by 1) modeling the joint decision of whether and how much to fish at a given place or time in a theoretically consistent manner, and 2) explicitly estimating substitution parameters across fishing opportunities rather than relegating substitution to the “error term.” Using case studies from the Wisconsin Great Lakes and reef fish angling in the U.S. Gulf of Mexico I show how these models can serve as a useful platform for understanding how anglers are likely to respond to a wide range of scenarios including seasonal closures, retention restrictions, fees for trips (angling “day passes”) or increased permit prices. Finally, I demonstrate how contingent behavior (stated preference) data can be incorporated into MDCEV models to extend their predictive range to scenarios well beyond the status-quo – using the hypothetical case of implementing an ITQ in the Gulf of Mexico recreational red snapper fishery as a test case.



B19

## Pike (*Esox lucius*) Stock Management in Designated Brown Trout (*Salmo trutta*) Fisheries: Angler Conflict and Preferences

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A pressing need in recreational fisheries is the management of 'people conflicts' because such disputes hamper progress towards sustainability. Fisheries management is increasingly as much about people as it is about stock management and an important prerequisite for managing conflict is an understanding of each party's position and perspective. Angler engagement with fishery managers often comprises small numbers of vociferous groups, who can easily mute the voices of a more silent majority. In Ireland pike stocks are actively managed for the purpose of protecting brown trout stocks. Associated public discussion is increasingly polarized with a clear message that trout anglers favour and pike anglers oppose such management intervention. A first step towards successfully managing the tension between all stakeholders is a better understanding of the broad spectrum of anglers' views. We collected such data by means of choice experiments and use latent-class site-choice models to estimate anglers' preference functions. Not surprisingly model results show that pike anglers do not support pike stock control. However, contrary to the public discourse we find that the majority of trout anglers, 61%, are negatively disposed towards pike stock control and are more likely to choose fishing sites where pike stocks are not actively managed. A small minority of trout anglers (13%) are more extreme in their preferences favouring pike control, with site choice probabilities of such anglers being largely determined by the pike control management option, irrespective of the levels of catch rates, bag limits, or infestation by invasive weed species.



B20

## Inferring Site-Choice Behaviour of Lake Trout Anglers from Revealed Preferences

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Predictions of angler site-choice is an important component towards understanding best-management practices across an inland fishery landscape. Under a few assumptions (e.g., rational consumer), the revealed preferences of an angler population, in the form of creel intercept-surveys, can give insight on what drives angler site-choice behaviour. We used a Bayesian hierarchical approach that united a discrete logit model for site-choice with a Poisson model for time available to fish on a joint posterior, and estimated coefficients predicting angler site-choice from a variety of site- and landscape-characteristics for 2000+ individual trips and 27 lakes in Yukon. With this approach, we tested expectations that site-choice is a nested process that depends, in part, on characteristics like the time available for fishing, and site-characteristics like travel distance, management regulation, lodging, size and abundance of the catch, and the availability of nearby non-chosen fishing sites (i.e., the lake-district). We describe the shape and magnitude of these site-choice and site-characteristic relationships and how it influences the angler numerical response across fishing landscapes in the form of annual effort. We then discuss how using such an approach can help generalize landscape-scale fishery dynamics to advise management and conservation decisions.



B21

## Increasing the Realism of Choice Models: The Importance of Preference Heterogeneity and Context in Angler Decision Making

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Managers of recreational fisheries today are faced with the two goals of maintaining fish populations while simultaneously keeping anglers satisfied. This is no easy task since anglers can have complex and varied preferences that may lead to unanticipated behaviours. While models of preference variation or heterogeneity have become more common, so far, the impact of contextual factors which may influence decision making has not been widely (if at all) addressed in these models. We provide an empirical example of how different treatments of heterogeneity as well as accounting for contextual factors affect model robustness and conclusions. These treatments included the conditional logit (CL), a CL with interactions, a latent class logit(LC), a random parameters logit (RPL), and a RPL with central tendency parameters. Results indicated that addressing heterogeneity or context improved both model robustness and performance, but the greatest improvements were observed in models addressing both heterogeneity and the decision-making context (as in the RPL with central tendency parameters). Results revealed that preferences were highly variable and often dependent on context (trip duration or species preferences). This example illustrates the value of appropriately accounting for preference heterogeneity as well as the contextual environment in which decisions are made. Doing so increases the reality and thus the usefulness of choice models.



B22

## Economic Efficiency or Political Capture? The US Experience Allocating Fish Between Sectors.

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To economists, every fishery management decision is an allocation question. There is a long and well researched history on making economically efficient allocations. Unfortunately, allocations between sectors in the United States have been created using catch history, which rewards past behavior, however flawed, and ignores economic efficiency, distributional impacts or fairness. At the federal management level, allocation has become a hot issue for every fishery management council in the United States as hard TACs, rebuilding timelines and catch shares have increased conflicts between user groups. In fisheries with both a recreational and commercial component, recreational anglers have been seeking a higher percentage of the total quota. Because of pressures from recreational advocacy groups, the last Magnuson reauthorization included the requirement to examine economic values in making allocations. Additionally, the NMFS official Catch Share Policy requires the examination of allocation using economic metrics before the institution of a catch share program and an update of the allocation every five years. Recreational anglers have been very successful at the state level using political capture to change allocations in their favor for popular state level fisheries but have been able to shift the balance at the federal level. However, studies indicating an allocation shift to the recreational sector are warranted have been rejected, even in the face of market evidence of higher economic values. Instead, councils, bowing to pressure from commercial sectors, have recently began reallocating recreational fish from the recreational sector to the commercial sector without any mandated analyses.



B23

## HD as Surrogate Biology: Catch and Effort in Recreational Fisheries

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Fisheries management is the skilled application of scientific information to the development and implementation of guidelines and regulations that ensures the sustainable exploitation of fish populations. Monitoring changes in both the social and ecological components of recreational fisheries is critical to the management process. Historically, monitoring of the social component has been uncoupled from monitoring of the ecological component, and greater emphasis has been placed on the ecological component. There exist opportunities to couple these monitoring efforts by examining anglers' behaviors and associated outcomes, particularly catch and effort on specified spatiotemporal scales. Doing so requires a scientific understanding of angler composition and identity that drive angler motivations and trip contexts, of fish composition that drive predator-prey dynamics and vulnerability to capture, of manager composition and institutions that drive management actions and angling regulations, and of feedback mechanisms among anglers, fish and managers that are scale dependent.



B24

## Experimental Evaluation of Angler Effort Response to Fish Production in Spatially Structured Fisheries

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We manipulated stocking densities in 34 lakes and monitored angler effort, fish abundance, and fish size for up to seven consecutive years. We replicated our experimental manipulation in two geographic regions expected to differ substantially in latent fishing effort (i.e., total population of anglers). We hypothesized that angler effort would respond to variation in stocking density, resulting in spatial heterogeneity in angler effort but homogeneity in catch-based fishing quality within regions. We found that there is an intermediate stocking density for a given lake or region at which angler effort is maximized (i.e., an 'optimal' stocking density), and that this stocking density depends on latent effort and lake accessibility. Furthermore, we found no clear effect of stocking density on our measure of catch-based fishing quality, suggesting that angler effort homogenizes catch-related attributes leading to an eroded relationship between stocking density and catch-based fishing quality at the time-scale of annual surveys.



B25

## Angler App Data Provide Insight into Angler Site Choice and Anthropogenic Connectivity

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Mobile smartphone applications (apps) are a source of conventional and novel data describing angler behaviour. In this presentation, we use angler smartphone application (app) data from Ontario to gain insight into anglers' choices of fishing sites, and how these choices aggregate over individuals and time to form anthropogenic networks of connectivity. We modeled choice by applying random forest decision trees to seasonal lake visits and lake characteristics related to lake distance, access, and physical and biological properties. Results suggested that anglers are largely motivated by lake distance (i.e., cost) and morphometry. These results were largely consistent with the results of a parallel analysis that we ran using creel-based estimates of effort, and the literature. We also present preliminary network analyses that describe patterns of anthropogenic connectivity and how they change over time.



B27

## An Ecological-Motivated Theory About Angler Behaviour and Its Consequences for Understanding and Managing Competitive Races for Fish

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Forms of social behaviour within groups of resource users modify macro-scale resource use patterns and affect the risk of overexploitation. Accordingly, foreseeing social behaviour of recreational fishers as a function of ecological or technological variables is useful for the management of coupled social-ecological systems. We lack, however, a general framework to derive expected social behaviours of anglers. We propose three characteristic social behaviours – territorialism, collective searching and individualism – emerge on the foundation of a trade-off between the exploration difficulty and exploitation potential of a fishery resource from an individual recreational fisher's perspective. The exploitation potential may be defined as the fraction of the valued resource exploited once found (which is related to the catchability coefficient,  $q$ ). The exploration difficulty may be defined as the spatiotemporal difficulty in finding the resource. Based on these two axes, we developed a qualitative framework and tested it with two quantitative models. Both models independently supported the qualitative framework. We then confronted expectations against a diverse set of empirical fisheries cases. Our framework suggests, relative to commercial fishers, recreational fishers are prone to behave individualistically which fosters a race for fish. However, recreational fisheries with proportionally more specialized anglers and therefore greater exploitation potential may show increased territorial and reduced scrambling behaviour. Anglers targeting challenging to find and control fish (e.g., tuna) should show increasingly collective behavior, sharing information among peers. Further empirical studies are needed to test whether our framework captures real-life angler behaviours generally.



B28

## Landscape Scale Social-Ecological Dynamics: Optimizing Utility from Spatial Angler Behaviour and Management Policy

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We examined the outcomes of the behaviour of four segments of an angler population across a landscape of >500 rainbow trout populations distributed across a spatially complex road access network and climatological gradients for the British Columbia stocked Rainbow Trout fishery. We developed a spatial angler behaviour model based on discrete choice surveys, determined that there were four angler types, and simulated their site choice based on several key catch and non-catch attributes. Fish population dynamics of all populations across the landscape were simulated through a combination of empirical stocking rates, climate related growth rates and angler harvest. We simulated the spatial ecological and social outcomes of management policies on the fishery.



B29

## How Can Social-Ecological Models Help Us Respond to Management Challenges Posed by Aquatic Invasive Species?

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The development and application of social-ecological models for recreational fisheries has increased substantially over the past 20 years. These models now span a wide range of fisheries topics, including the response of fishers to harvest control roles, decisions to participate in poaching, and resource use as a function of linked biological and social factors. Given the widespread changes that aquatic invasive species (AIS) have on the ecological, social, and economic aspects of natural resource use, an increasing topic of interest involves the development of linked social-ecological models to determine the interactions between fishers and AIS. These models form the basis for understanding changes in resource use as a function of the presence of AIS, as well as the role that fishers play in facilitating the introduction and spread of AIS. In particular, social-ecological models that capture spatiotemporal aspects of fisher activity and the resulting intentional or unintentional uptake of AIS provide a logical framework for understanding how, why, when, and where AIS are introduced across the landscape, thereby providing an important component of ecological risk assessment for AIS. I will illustrate two scenarios in which social-ecological models have allowed the behavioural response of resource users (including fishers) to be predicted; namely, 1) the decisions for natural resource users to undertake risky behaviour involving AIS; and, 2) the identification of clear dose-response thresholds to manage propagule pressure of AIS across lake ecosystems.



B30

## The Costs and Benefits of Using Stock Enhancement Versus Harvest Regulations in Recreational Fisheries: Trade-Offs Among Biological, Social and Economic Objectives

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Fish stocking and harvest regulations are used in recreational fisheries to maintain or enhance fisheries, but their relative effectiveness for achieving biological, social and economic outcomes have rarely been evaluated. We examined how stocking various fish densities and sizes (fry, fingerlings and adults) performed relative to minimum-length limits alone in terms of augmenting the fish population, increasing catch rates and angler utility, minimizing per capita stocking costs, and producing a positive net economic benefit. Our model mechanistically integrated the dynamics of both angler and fish populations. The angler model was calibrated to a choice model from German anglers, and the biological model to two model species; naturally-recruiting northern pike (*Esox lucius*) and non-recruiting common carp (*Cyprinus carpio*). We found that outcomes depended on performance measure, species, stocking strategy, and latent fishing pressure. Stocking often augmented the overall fish population, but density-dependent bottlenecks minimized the number of fry and fingerlings surviving to a catchable size. Moreover, increases in catch rates resulting from management actions did not necessarily increase angler welfare, because of declines in marginal utility with increasing catch rates. Thus, stocking only lead to a positive net economic benefit when natural recruitment was impaired (e.g., overfished pike) or lacking completely (e.g., carp), stocking rates were low, and enough anglers benefited from stocking to offset the costs. Otherwise, minimum-length limits generated similar benefits without incurring the costs of stocking. Our study demonstrates how a utility-based approach to measuring performance is well suited to assess trade-offs in fisheries management.



B31

## A Linked Model of Animal Ecology and Human Behaviour for the Management of a Southern Stingray (*Dasyatis americana*) Recreational Tourist Attraction

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Mitigating negative recreational impacts on fish necessitates research into the ecology of the system and of the human dimensions, since plans aimed at optimizing wildlife fitness must also be acceptable to users. We developed an integrated systems dynamics model for the management of a recreational tourist attraction, 'Stingray City Sandbar' (SCS), Cayman Islands. The model predicts the state of the recreational activity over time in relation to stingray population size, stingray life expectancy, and tourist visitation under various management scenarios. Stingray population data in the model comprised growth rates and mortality estimates (from mark-and-recapture data), and were modified under different management scenarios based on accrued research. Changes in tourist population growth rates were based on heterogeneous demand for different management options, obtained from a stated preference choice model. We found that model predictions over a 25-year period were sensitive to the stingray population growth rate and alternate management options. It was possible to maximize the tourist segment in favor of no management and stingray numbers while reducing stingray health. The most effective relative strategy included a reduction in visitor density, restricted stingray-tourist interactions, and an imposition of a small fee. Over time, although fewer stingrays were predicted to remain at SCS they would live longer and experience fewer stochastic disease events, and the desirable tourist segment was predicted to predominate. By understanding how management will affect tourist activities and their subsequent impacts on both wildlife health and visitor satisfaction, one can explore the management alternatives that would optimize both.



B33

## Can We Predict A Priori Which Anglers Will Catch More Fish in a Novel Environment? An Experimental Approach in Nature

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Angling skill, or ability to catch fish, is typically measured by self-evaluations and used to index angler specialization. It is not known whether self-evaluated angling skill explains skill in real fisheries. If self-evaluated skill would be reliably related to catch rates, one could use self-reports in creel surveys or other catch reporting methods to control for skill-dependent variation in catchability unrelated to fish abundance. We assessed the accuracy of angling skill self-evaluations measured from a three-item index for rapid a priori assessment. Based on these data, volunteer anglers were classified as low-, middle- or high-skill anglers and asked to fish for acoustically-tagged large perch (*Perca fluviatilis*) in a lake unknown to all participants. Over 27 days, two members of each group were invited each day to fish for perch with standardized gear in an individual GPS-tracked boat. High-skill anglers indeed revealed significantly higher catch per unit effort of large perch (> 33 cm) than the other two skill groups, but all skill groups encountered large perch equally well on average. Therefore, angling success is determined by more than random chance, at least for perch anglers on a novel lake. In terms of mechanisms, our study suggests skilled anglers have an improved ability to “play the lure” rather than an improved ability to find the fish. A reliable a priori measure of expected catchability by certain angler types may be possible from three simple questions, but our index must be validated across other contexts.