INTEGRATING STAKEHOLDER KNOWLEDGE INTO THE MANAGEMENT OF A SOCIAL-ECOLOGICAL SYSTEM:
MENTAL MODELS, RISK, AND TRUST IN ATLANTIC COAST FISHERIES

By

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ABSTRACT OF THE DISSERTATAION

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Dissertation Director:
Rebecca C. Jordan

Historical approaches to natural resource management have largely viewed resource managers, resource users, and the resources as distinct and separate components. This perspective has highlighted the conceptual boundaries between management, social systems and ecosystems. Recent failures in this normative approach however, such as major declines in fisheries, have challenged this traditional perspective. Many management institutions are now adopting a systems perspective which embeds resource management within the human system, and the human system within the broader ecosystem. This new paradigm has produced new frameworks like ecosystem-based management and theoretical tools such as coupled social-ecological systems (SES). These new frameworks are thought to be more beneficial for natural resource management decision-making since they acknowledge important links between social and eco- systems and include more complexity. This complexity, however, presents new challenges as managers and researchers now seek ways to characterize the components, relationships, and dynamics within these systems as a way to inform natural resource policies. To address some of these challenges, this dissertation research seeks to better understand the role that stakeholder knowledge plays in influencing natural resource management in a model SES, mid-Atlantic marine fisheries. I begin by characterizing the SES and outlining differences in knowledge systems by evaluating representations of stakeholder mental models. Next, through interview data collected from fishery managers and scientists, I categorize the conceptual risks within the SES to outline the goals of management and what policies in SES seek to address. Then, I evaluate factors which affect trust of fishery management institutions from the perspective of resource users. Finally, I offer recommendations on how to align knowledge systems between resource users and resource management toward shared goals.

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Introduction

Human societies and ecosystems are inextricably linked and comprise Social-Ecological Systems (SES) (Dietz et al 2007). Linkages between ecosystems and the human communities that rely upon them are often mediated by ecosystem services, i.e., the goods and services that are generated by functioning ecosystems (Daily 1997; Leslie 2009). The essential connection between these environmental goods and society are individual and collective human actions and interventions (Lui et al 2007, Millennium Ecosystem Assessment 2005; Resilience Alliance 2007). Human interaction with natural systems is nothing new and the connections between these systems have long been recognized (Daily 1997; Marsh 1864). Questions, however, about the complex patterns and processes involved in such interactions have not been well characterized, let alone fully understood (Dietz et al 2007).

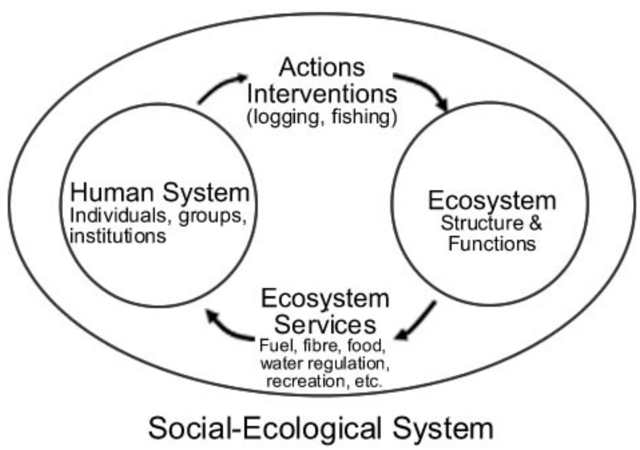
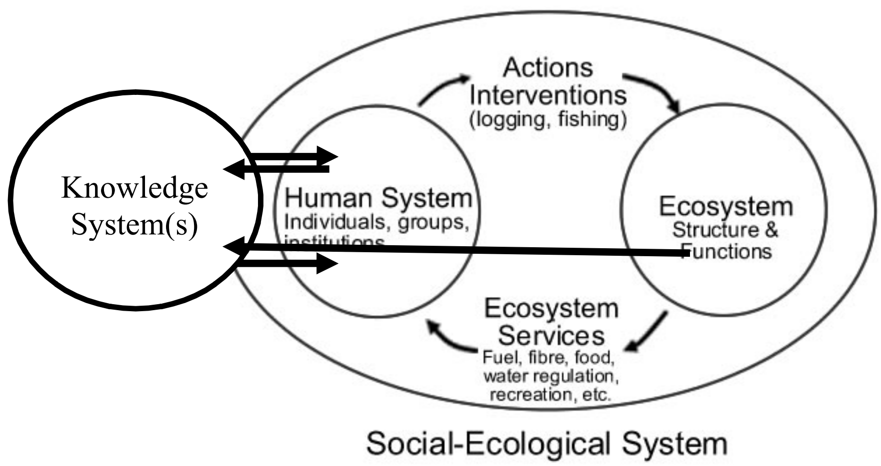


Figure 1. Conceptual diagram of elements of a social-ecological system. Human systems, comprised of individuals, groups, networks and institutions (rules, regulations and procedures) intervene to obtain goods and services from ecosystems. Actions and interventions include the removal or planting of vegetation, harvest of animals, irrigation of landscapes, and construction of systems to control floods. These interventions directly and indirectly modify ecosystem structure and function (from Resilience Alliance 2007)

This dissertation research seeks to understand how interactions within a SES are shaped, influenced and determined by various stakeholder knowledge systems. A knowledge system refers to a coherent set of mental constructs, cognitions, and practices held by individuals within a community (Richards, 1985). These systems can be internal representations of the external world (mental models) or can be a series of beliefs about the external world or components within it (risk and trust judgments). Knowledge systems are endemic to human systems and may offer a way to explain aspects of human interactions with ecosystems since these systems guide some aspects of human decision-making. Using Atlantic coast marine fisheries as a model SES, this research (1) evaluates the differences in stakeholder knowledge systems involved in an SES (2) outlines risk and trust as important beliefs which emerge from knowledge systems of resource managers and resource users within an SES and (3) offers recommendations by which resource managers and resource users knowledge systems might better be aligned to collectively manage the SES toward shared goals.

Theoretical Framework

As Garret Hardin wrote in his famous *Tragedy of the Commons* paper in 1968, individuals acting in their own self-interest have the ability to ultimately destroy commonly held natural resource goods since individuals benefit from maximum exploitation and do not benefit from harvesting restraint (Hardin 1968). The addition of institutionalized management and participatory decision-making in SES has added layers of complexity to commons theories since it expands the consideration of stakeholders beyond those that actually harvest the resource to include others that capitalize on the idea that these environmental goods are commonly held property. Stakeholder groups in many SES now include harvesters, members of the pre- and post-harvest sectors, assessment scientists, managers, and environmentalists that lobby on behalf of resources. Each of these groups generates their own conceptions of the dynamics between social and ecological systems as they interact within their communities and within the ecosystem over long periods of time (Folke 2004). The result is multiple, often competing, stakeholder interests (Nelson and Wright 1995) which have their roots in the distinct knowledge systems (Figure 2).



The ways in which these different knowledge systems are organized, socially influenced and useful for institutional resource management has seen increasing attention in recent years (Kellert et al. 2000, Gadgil et al. 2000, Armitage 2003, Brown 2003, Davis and Wagner 2003). Researchers generally agree that promoting the integration of diverse knowledge systems leads to more resilient outcomes since it makes knowledge structures less rigid and more malleable (Folke 2004; McLain and Lee 1996, Ludwig et al. 2001). Ecosystems are complex adaptive systems, and their management requires similar flexibility, continuous learning and knowledge acquisition for institutions, organizations, and individuals to remain adaptable in the face of unforeseen changes in SES (Berkes et al. 2000, Dietz et al. 2003, Folke 2004).

However, establishing SES management around the integration of stakeholder knowledge systems is not without its difficulties. Integrating distinct and valid perspectives into decision-making may slow down the management process and can promote hostile relationships between groups (Banjade et al 2007; Folke 2004). In many cases, the actual deliberative interface has been negatively affected by conflicts among different knowledge systems which have developed historically and independently from one another (Ojha 2008). Although many stakeholder groups may share some similar goals, their individual agendas, time-frames, focus within the system and proposed management policies may vary considerably. This variation is reflected by differing valuations of the components within the SES, how the SES operates, and what they ultimately derive from SES operation (Edmunds and Wollenberg 2001; Leeuwis 2000, 2004). For example, in a summary of six case studies of the management of forest, agriculture and water SESs in Nepal, Ojha (2008) found four typologies of knowledge systems; formal political agents, civil society groups, techno-bureaucrats, and development agencies/processionals. Depending on the context of SES, these groups utilize different information and offer separate perspectives on the system which can result in positive incremental change within the system. However, as Ojha points, out, this progress may be hindered by power struggles, problems in communication, and a history of antagonistic relationships between groups.

Social-Ecological Systems, Knowledge Systems and Marine Fisheries

Marine fisheries offer an ideal opportunity to evaluate different knowledge systems, decision-making, and conceptions of both social and ecological systems.

Fisheries management in the United States is a hybrid of federal and state-level management, guided by legislation which integrates various aspects of stakeholder participation throughout the decision-making process. Since these decisions are made in open and transparent forums where stakeholder groups articulate competing viewpoints and values, understanding the knowledge systems that individuals and groups bring into the decision-making process are relevant to understanding how human interventions and actions are formed within SES. To add clarity to this research, I adopt Jordan et al (2009) view of social and ecological knowledge systems as a diverse knowledge space comprised of cognitive (concepts and connections) and affective (self knowledge) components (Figure 3). The first chapter begins by characterizing the structure and function of the Atlantic coast fisheries SES from the perspectives of fishery stakeholder groups (fishery managers, fishery scientists, harvesters, pre and post harvest sectors and environmental NGO representatives) to characterize differences between knowledge systems and establish an overall view of the SES. In the next two chapters, I outline risk and trust as important components of knowledge systems of resource managers and resource users which guide interventions and actions in the human system. Finally, chapter four offers recommendations by which resource manager and resource user knowledge systems can better be aligned to outline shared goals and increase the efficacy in SES management.

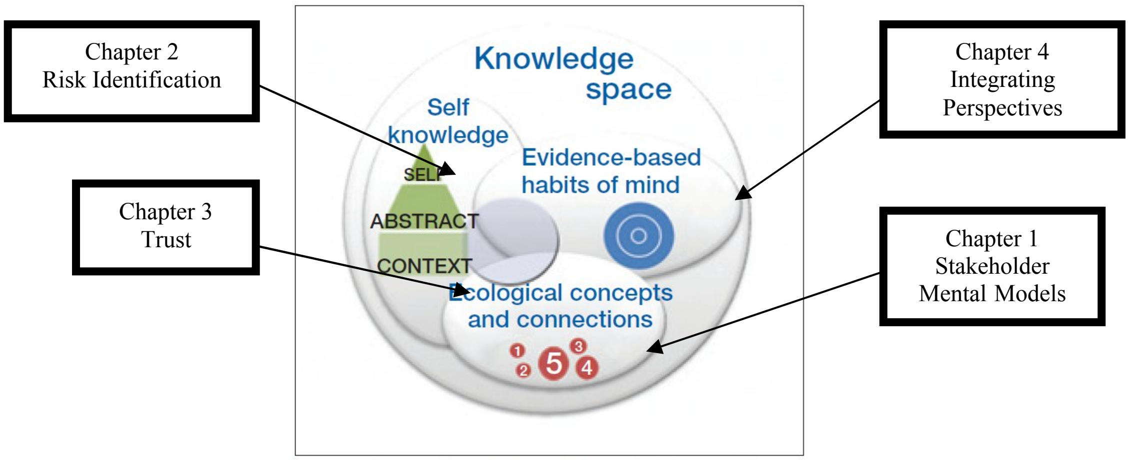


Figure 3. Jordan et al 2009 Model of Ecological literacy with Dissertation Chapters superimposed

Chapter 1: Stakeholder Conceptions of the Structure and Function of a Social-Ecological System
(Formatted for *Ecology and Society*)

ABSTRACT

Integrating stakeholder knowledge into natural resource governance is considered to add flexibility to social-ecological systems (SES) because knowledge diversity reduces rigidity, represents multiple perspectives, and promotes adaptability in decision-making. Characterizing difference between knowledge systems, however, is not easily accomplished. There are few metrics readily available to compare one knowledge system to another. This paper characterizes knowledge about a model SES, the summer flounder fishery in the Mid-Atlantic, to evaluate differences and similarities in the structural and functional characteristics of stakeholder mental models. To measure these differences, we collected Fuzzy-Logic Cognitive Maps (FCM) from several stakeholder groups (managers, scientists, harvesters, pre and post harvest sectors, and environmental NGOs) which comprise social agents within the SES. We then compared stakeholder groups' maps using graph theory indices to characterize the structure and function of the model system. We then combined stakeholder FCM to generate a community map which represents a theoretical model of the combination of stakeholder knowledge. Our results indicate that knowledge integration increases the ability of decision-maker to anticipate system stability, increases understanding of components in system and increases opportunities to change the system. However, knowledge integration may also decrease precision in the ability of decision-makers to understand the outcome of a proposed decision since the number of connections increases, making outcomes of forcing components less certain.

INTRODUCTION

As a way to manage and organize the complexity found in social-ecological systems (SES), many researchers have highlighted the benefits of integrating diverse types of knowledge systems. A knowledge system refers to a coherent set of mental constructs, cognitions, and practices held by individuals within a particular community (Richards, 1985). This knowledge can be internal representations of the external world (e.g. mental models) or can be a series of beliefs about the external world or components within it. The ways in which different knowledge systems are organized, socially influenced and useful for institutional resource management has seen increasing attention in recent years (Kellert et al. 2000, Gadgil et al. 2000, Armitage 2003, Brown 2003, Davis and Wagner 2003). Promoting diversity in the types of knowledge considered in management is thought to lead to more resilient outcomes in SES because it makes knowledge structures less rigid and more adaptive to change (Folke 2004 McLain and Lee 1996, Johannes 1998, Ludwig et al. 2004).

The most common way natural resource managers have to promote knowledge integration is including the public in decision-making. The term public participation refers to a number of activities and ranges from after-the-fact education programs to environments in which decision-making power resides solely with stakeholders (NRC 2008; Arnstein 1969; Berkes 1992). The benefits of integrating stakeholder knowledge into resource management have inspired a number of management strategies which are aimed at reducing traditional boundaries between knowledge sources (Berkes 2004) and highlighting the importance of two-way learning between participants (Chase et al., 2004; Johnson et al., 2004; Lynam et al., 2007). When different types of knowledge are included in resource management, reliance on experts and elites is decreased, making the system more adaptable (Agurwal 1995). Knowledge integration allows the local context and behaviors of individuals to be better understood so that uncertainty can be reduced (NRC 2008). Since ecosystems are complex, diverse, and adaptive, it has been suggested that the knowledge used to guide management decisions should also be complex, diverse, and adaptive (Berkes et al. 2000, Dietz et al. 2003, Folke 2004).

Although integrating knowledge through participation has been reported to create higher quality and more durable decisions (Reed 2008), it does present some difficulties. Dietz and Stern (2008) summarize three basic arguments that critics of public participation cite: (1) the costs are not justified by the benefits (2) the public is ill-equipped to deal with the complex nature of analyses and (3) participation processes seldom achieve equity in process (NRC 2008). These criticisms highlight that knowledge systems are neither easily reconciled nor integrated. Knowledge systems are unique to communities and often develop historically and independently from one another (Banjade et al 2007; Ojha 2008; Folke 2004). The costs of knowledge sharing are in terms of potential conflict and management resources because it may take considerable time to build common understandings between disparate stakeholder groups and institutions (Webler and Renn 1995).

Understanding the benefits and limitations of knowledge-sharing is not easily accomplished (Raymond et al 2010). Questions about the types of knowledge and the degree to which they are complimentary or incongruent are not easily answered. Although knowledge integration through participation has become standard in environmental policy, there are concerns about the biases (NRC 2008) and lack of empirical evidence which support some of the beneficial claims (Reed 2008). In a comparative study of knowledge integration in three environmental management contexts, Raymond et al (2010) found that knowledge integration is inherently complex, classification of knowledge is arbitrary and perspectives on the process are qualitatively very different. Additionally, categorizing what constitutes different types of knowledge has led to additional confusion (Fazey et al., 2006). Most often, knowledge systems are coarsely defined and can be placed into two main bins: local knowledge and scientific knowledge. Local knowledge reflects individual experiences (Fazey et al 2008) or non-expert or localized information (Jones, 1995). Local knowledge includes, traditional, indigenous and lay knowledge, each describing a particular point on a continuum of knowledge mediated by personal or cultural experiences. Scientific knowledge refers to knowledge created by more systematic means. Scientific knowledge utilizes agreed principles and process of study, including reliability and validity to generate new information (Gunderson et al 2005; Turnbull 1997)

These knowledge categories, however, have been criticized for being overly simplistic since they do not account for the way in which people process different types of information or the role that social contexts may play in influencing knowledge development (Raymond et al 2010). Further, knowledge classification does not inform the way in which stakeholders view important structural and functional aspects of the social-ecological system of which they are a part. These categories do little to explain how or why individuals or groups may anticipate environmental or social change. In this paper, we investigate the differences in knowledge systems by analyzing the mental models of stakeholders involved in the management of a model SES, the summer flounder fishery in the mid-Atlantic. We begin by characterizing the structure and function of stakeholder group knowledge. Next, we compare knowledge by stakeholder group to uncover differences and similarities. We then combine stakeholder knowledge into a community knowledge system which represents the integration of several different stakeholder groups during the decision-making process. Finally, we compare the community knowledge system to individual stakeholder knowledge systems to better understand the benefits and drawbacks of integrating knowledge in natural resource management.

Model system: mid-Atlantic summer flounder fishery

Marine fisheries offer an ideal opportunity to evaluate stakeholder knowledge in the context of a resource management debate. Fisheries management in the United States is a hybrid of federal and state-level management, guided by legislation, which integrates various aspects of stakeholder participation throughout the decision-making process. Since many fishery decisions are designed to be made in open and transparent forums, understanding differences in mental representations about the system may give insight into the way discourse develops as stakeholder knowledge is integrated through participation.

The summer flounder fishery in the mid-Atlantic was chosen as model system for multiple reasons. Summer flounder is a highly valuable resource to the region and debates about how to best manage ecological and social aspects of the fishery vary considerably. Over the last several years, the stock has been in recovery or “rebuilding” which has placed strict annual limitations on its harvest. Further, management decisions which determine these harvest levels, affect a range of stakeholder groups which include harvesters, coastal communities, and environmental NGO representatives. These stakeholders meet routinely throughout the year with fishery managers and fishery scientists to discuss the scientific assessment of the stock and potential management strategies meant to sustain both the social communities which rely on fishing and the summer flounder population.

METHODS

Structure and function of systems

To understand how knowledge may vary, it is important to examine how individuals internally organize knowledge about the external world. To accomplish this, we sought to collect explicit representations of stakeholder mental models of the SES. Since SES are complex systems, we wanted to understand the structure and function of individual and group mental models. In our study, the structure and function of mental models correspond to the structure and function of the SES.

Structures are the parts that define a system. The observational and conceptual recognition of structures has been linked to nearly every mode of inquiry and discovery in science, philosophy, and art (Pullan 2000). The relationships between structures are what give a system its shape which can be hierarchical or networked. Understanding structures is analogous to the "whats" of the system and has been shown to be the foundation of observational learning about complex systems (Hmelo-Silver et al 2004). In ecological systems, structures exist across varying scales of organization, from molecular to ecosystems, in a hierarchy. In social systems, structures refer to organizations which are networked by connections between groups of individuals. Functions are the outcomes of the system. The functions of complex systems have been defined in value-laden terms to indicate the purpose of the system. In biological terms, function has been referred to as the purpose of a chain of causal reactions (Dusenberry 1992) such as adaptations which aid in a species survival. In social terms, the function of ecosystems has been defined in terms of ecosystem services, or what human societies ultimately derive from ecosystem operation. Understanding structure and function is important to understanding systems since these aspects define the form and the outcome of system operation.

Fuzzy logic cognitive mapping

To better understand the structural and functional aspects of knowledge systems, we collected Fuzzy Logic Cognitive Maps (FCM) from stakeholder groups involved in the summer flounder fishery. FCM have been called simplified mathematical models of belief systems (Wei, Lui, and Yanchun 2008) and have been used to represent individual (Axelrod 1976) and group (Ozesmi and Ozesmi 2004) knowledge systems. Cognitive maps have been used in a number of disciplines to indicate relationships among variables as well as to understand system dynamics. Anthropologists have used signed digraphs to represent different social structure in human societies and systems of operation (Bauer 1975; Bougon et al. 1977; Carley 1990; Hage and Harary 1983; Klein and Cooper 1982; Malone 1975; Palmquist et al. 1997) and ecologists have used them to understand relationships between organisms and their biotic and abiotic environment (Hobbs et al.

2002; Özesmi 1999; Puccia 1983; Radomski and Goeman 1996). Here we use FCM to develop individual representations of the concepts and causal relationships in social and ecological systems. FCMs are models of how a system operates based on defined components and the causal links between these components. These components can be quantifiable constructs like temperature or abstract constructs such as happiness. The individual participating in developing a FCM decides what the important components are that comprise the system in question (see A,B,C and D in Figure 1) and then draws causal relationships among the components with numbers between -1 and +1. These numbers indicate the amount of positive or negative influence one factors has on another (see directional arrows and numerical influence Figure 1).

[Insert Figure 1]

Data collection

For this case study, five stakeholder groups from the summer flounder fishery created FCMs of the fishery system following best practices as outlined by Özesmi and Özesmi (2004). These groups include harvesters, members of the pre and post harvest sectors, fishery managers, fishery scientists, and representatives of environmental non-government organizations (ENGOs). These groups were chosen a priori since they represent the social actors routinely included at fishery management meetings. In total, 35 individuals engaged in drawing FCMs. Participants included ten harvesters, seven members of the post or pre-harvest sectors, seven state and federal fishery managers, seven scientists and four individuals employed by an ENGO. In total, 27 maps were generated for analysis (Table 1).

As methodological papers have suggested, map collection took between 45 – 180 minutes, averaged about one hour and included individuals and groups of individuals in map construction. Participants were shown an unrelated example of a FCM and then asked to list the important components within summer flounder SES. After an initial list was developed, they were asked to organize the components within the system by drawing relationships between the components. Finally participants were asked to provide quantitative values on the causal links between components (between -1 for strong negative relationship to +1 for strong positive relationship). All maps were completed to the satisfaction of the participant.

[Insert Table 1]

Data analysis

FCM are subject to a range of analytical techniques (Eden et al 1992; Ozesmi 2004 and Kosko 1993). Maps can be analyzed to represent individual knowledge or aggregated to represent stakeholder groups or entire community knowledge (Ozesmi 2004). In this study, we analyzed FCMs to examine knowledge about the structure and function of a SES. First, we present structural measurements of the FCMs. The structure of individual maps were determined by developing adjacency matrices, determining the types of components included in the maps, and developing indices which indicate the amount of adaptability and complexity each stakeholder represented in their map.

Second, we present functional measurements of the FCMs. The function of the maps were analyzed in two ways: (1) by aggregated individual maps to examine stakeholder group function and (2) aggregated stakeholder groups maps to examine function of entire community map. The differences in these measurements were then compared to draw conclusions about major the differences in stakeholder knowledge systems and to compare the benefits and limitations of integrating knowledge systems.

Analyzing structure

Since FCM are based in graph theory, the structure of FCM is easy to determine. The structure of a FCM is determined by establishing a matrix. This allows the complexity in a hand-drawn map to be reduced, and system structure to become more apparent. The structure of an individual FCM is determined by listing the variables *vi* on the vertical axis and variables *vj* on the horizontal axis. The amount of influence one component has on another is then listed in the on the row and column in the matrix. All stakeholder maps were transcribed and examined for their structure.

Determining types of components

All components within FCM were then categorized in one of three ways: driver, receiver, or ordinary. Driver variables are seen as having significant influence over system operation, receiver variables represent the end result of the system operation and ordinary variables are links in between. All components in an individual FCM were binned in one of these three groups (Eden et al 1992). To accomplish this, we used the structural analysis matrix (Kosko 1986; Ozemsi and Ozemsi 2004). The variables *vi* are listed on the vertical axis and variables *vj* are listed on the horizontal axis to form a square matrix. To determine the type of variable, the outdegree [*od(vi)*] and indegree [*id(vi)*] values for each variable is calculated. Outdegree is determined by the summed row sum of the absolute values of a variable. The indegree value is determined by adding sum of absolute values of a variable in the rows. These values indicate the cumulative strength of the influence to other variables (outdegree) as well as the influence on a variable (indegree). To determine whether each variable is a driver, receiver, or ordinary variable, the outdegree and indegree variables are compared (Bougon et al 1977). Driver variables have a positive outdegree and zero indegree. Receiver components have a zero outdegree and a positive indegree. Ordinary components (in terms of conceptual system function) have both positive outdegree and indegree (Bougon et al.1977; Eden et al 1992; Ozemsi and Ozemsi 2004).

Amount of change and level of complexity

Density and complexity values were calculated for each individual stakeholder map and then averaged for each of the five stakeholder groups. To calculate the density, the number of components (N) and number of connections (C) in each individual map was determined. The density of a cognitive map (D) is an index of connectivity: $D = C/[N(N-1)]$ or $D = C/N^2$ if a variable can have a causal effect on itself (Hage and Haray 1983). Density within a cognitive map indicates whether the system is hierarchical (some components are perceived to have more influence) or fully democratic (all system components are tightly linked) (Özesmi and Özesmi 2004). Next, centrality for stakeholder group maps was calculated (Ozesmi and Ozesmi 2004). Centrality is the ratio of receiver variables to driver variables (R:D). The higher the number of receiver variables, the more complex a map is considered to be since it considers many possible outcomes of a system, rather than fewer end points (Eden et al 1992). Conversely, a larger number of driver variables has been said to indicate thinking in more top-down manner where there a map represents more forcing functions initially, but elaboration of the resulting consequences of these functions are not well articulated (Eden et al 1992).

Stakeholder and community cognitive maps

Maps were also combined to generate a representation of combining knowledge systems. All stakeholder groups' maps were weighted equally and combined by (1) individual maps within a stakeholder group to characterize each of the five stakeholder groups and (2) all five stakeholder groups to develop a large-scale community model of the SES. Combining stakeholder maps involves overlaying individual maps and averaging all influential connections between components. Summing relationships between components allows for repeating fuzzy logic understandings to be reinforced, where rarely mentioned components and influences identified by smaller contingencies are included, but not reinforced. For example, Figure 2 shows a hypothetical example of the combination of two stakeholder group maps. Stakeholder Map 1 includes variables A,B, C, and D and Stakeholder Map 2 includes A,B, C, D, and E. For the combined map, these two individual maps are simply added together, holding equal weight in the final map. Notice, certain influences, for example A → C, A → D, and A→ B, are reinforced in combined map while others, for example D → E, are included but are not reinforced since it was not mentioned by both participants. These summed values of reinforced influence values between components are then averaged to allow for fair comparison across groups.

[Insert Figure 2]

Aggregating stakeholder maps

FCM were aggregated to ease analysis. Aggregation of stakeholder maps can be done qualitatively or quantitatively to reduce and standardize the dataset (Ozemsi and Ozemsi 2004). After all maps were collected, variables included in all maps were listed by frequency of mentioned to determine most often reoccurring structures. Further, we subjectively combined similar variables into categories in order to standardize maps. To validate aggregation, subsuming variables were validated by at least one member of each stakeholder group. For example, different types of fishery regulations were mentioned by several harvesters such as “size limits”, “bag limits”, and “total allowable catch”. These three variables combined into one variable “management measures”. After aggregation, follow-up conversations with stakeholder representatives verified new components. Aggregation of stakeholder maps reduced 124 variables into 27 final system components. Similar studies have reduced large amounts of variables into smaller and more manageable components (Ozesmi 2001).

Analyzing function

After map aggregation and structural measurements, the dynamics of stakeholder and community maps were determined using the matrix calculation for the stakeholder group and community maps. This allows for the function of the map to become clear. Further, matrix calculation also allows for artificial “what if” scenarios to be run to see how the system might change under a range of conditions (Ozemsmi and Ozemsi 2004 Ozemsni 2003) First, the steady state vector was created by placing a value of 1 for each of the elements in the vector. Second, the steady state vector was then subject to matrix multiplication with the adjacency matrix of the desired cognitive map and a new vector was created. Third, subject each of the elements within this vector to a logistic function (f(x) = (1/(1+e^(-x))) to keep the values in [0,1]. Fourth, the new vector was applied to matrix multiplication with the adjacency matrix and the elements were subjected to a logistic function. Past studies have indicated that the resulting values can either, 1) go into a steady state, 2) go into a limit cycle, or 3) go into a chaotic pattern (Kosko 1985). For our analyses, however, all of the calculations resulted in a steady state with less than 15 iterations.

The steady states of the stakeholder maps or community cognitive maps were then used to test different SES scenarios. Kosko (1985) first proposed the clamping method in which a value of 1 is “clamped” for the desired variable in the steady vector from a cognitive map. Clamping a variable allows us to determine how the function of the system might change under certain conditions. While using the same cognitive map, this value remains clamped at each time iteration before the matrix multiplication step to achieve the next vector. The following iterations are then calculated using the same methods, but again the variable of interest in again set to a value of 1. The final vector of the clamp is then compared to the original steady state vector of the corresponding cognitive map by taking the difference between the clamped vector and the steady state vector. Thus, the resulting values for each variable show the amount of relative change given the SES operation under artificial conditions.

Although researchers have written about the inherent limitations in predicting system states in SES (Walker et al 2002; Folke 2004), we developed a possible scenarios for our stakeholder and community maps. The scenario was developed as a way to highlight differences between functional knowledge systems of stakeholder groups and create a theoretical model of the community SES knowledge system. It was not developed as a way to predict specific structural and functional change in the SES in the real world. The scenario artificially increased the summer flounder population as continuously high. Six models were run in total, one for each of the five stakeholder group maps and one for the community map.

RESULTS

Structural and functional measurements uncovered several differences between stakeholder knowledge (Table 2). Based on these measurements we summarize the knowledge by stakeholder group and for the community map. For graphs of functional response see appendix one.

[Insert Table 2]

Differences in structure and function

Harvesters

Harvesters indicated a high number of transmitter variables, with a lower number of receiving variables. This is an indication that they consider many outside forces to affect the function of the system. Compared to other stakeholder groups harvesters indicated mid-level structural opportunities for change of the SES when compared to other groups. This indicates neither a rigid system that is difficult to change nor a large amount of opportunities for change in the SES. Under the functional analyses, increases in summer flounder population resulted in increases in recreational fishing (0.02), economic development (0.01), summer flounder reproduction (0.01), fishing pressure (0.003) and commercial fishing (0.009).

Pre and Post-Harvest

Analysis of pre and post harvesters sectors saw similar results to harvesters, however indicated far more room for change within the system relative to other groups. This was as evidenced by the group's high density score. Additionally, members of the pre and post harvest sector also saw high numbers of receiving variables compared to driver variables, an indication that pre and post harvest sector are equally aware of the driving and resulting actions of the SES dynamics. Finally, on average this group identified the least amount of variables in the system, therefore designate the system to be comprised of the least amount of components. The functional analyses indicated the highest increase in the economic sector (0.02), followed by increases in recreational (0.01) and commercial fishing (0.01) and fishing pressure (0.003).

Managers

Our results indicate that fishery managers fall in the middle of the range of stakeholders, however, had less somewhat less diversity in their maps as indicated by their standard deviations relative to other groups. The amount of components designated to be in the system, their maps density, complexity and numbers of connections included in their maps were all mid-range values relative to other groups. Functional scenarios indicated the highest increase in recreational fishing (0.03), economic development (0.01) and reproduction/spawn (0.01) with smaller increases in commercial fishing (0.002), fishing pressure (0.002) and prey (-0.001).

Scientists

Scientists' maps viewed less room for change within the SES, yet represented the most complexity within their maps. This was indicated by two measures. First, scientists included more receiver variables than any other group, an indication that scientists may consider the results of a dynamic system more often than other groups. Second, scientists' density score was the lowest of those evaluated, an indication that scientists view the SES as more rigid than other groups with less opportunity for change within the system. Functional response to summer flounder population increase resulted in highest increases in reproduction/spawn (0.02) predators (0.009), fishing pressure (0.009), and decreases in prey (-0.004).

Environmental NGO

Members of the environmental sector had the least complex maps, however, included the highest number of variables and connections between variables. Additionally, ENGO representatives seemed to view more structures driving the system which was evident by the highest number of driving variables. This group also indicated the second highest score for density (or change) and indication they see the more room for potential changes to the system compared to all other groups, except the pre and post harvest sectors. Functional scenarios indicated increase in summer flounder population (0.03) and decreases in fishing pressure (-0.01).

Community Map

Compared to stakeholder group maps, the community map resulted in the highest number of variables, and connection between variables (Figure 3). This included a high number of transmitter variables and a low number of receiver variables. This suggests the community map represents many outside forcing components and relatively fewer outputs of the system. Combing stakeholder maps also resulted in highest number of connections between components and therefore the highest indication of room for change in the system, however also resulted in the lowest complexity score. Functional analyses resulted in highest positive response in recreational (0.01) and economic development (0.01), reproduction/spawn (0.008), commercial fishing (0.005), fishing mortality (0.0003), fishing pressure (0.003), predators (0.002), and decreases in prey (-0.0009).

[Insert Figure 3]

DISCUSSION

Differences between stakeholder knowledge

We attempted to compare representations of mental models across stakeholder groups. In our study, harvesters' the pre and post harvest sectors' FCM indicated somewhat similar knowledge systems by our measures while scientists and ENGO representatives seem to be divergent when compared to all groups. Managers, on the other hand, seem to be located in the middle of all stakeholder groups. This is an interesting finding since managers are both appointed officials which are meant to reflect the interests of fishery constituents (i.e. belonging to any of the other stakeholder groups) or, on the state-level, are career bureaucrats. Ideally, managers are expected to represent a range of fishery interests. Therefore, in theory their knowledge would be as diverse as the stakeholders they represent. Our results support the notion that their knowledge does seem to fall in between the other groups as their mental models were in the middle all measures, and the function of their system was similar a combination of harvesters/pre and post harvest sectors and scientists.

The most divergent groups were scientists and ENGO representatives. Scientists see the summer flounder SES as somewhat rigid and saw with less opportunity for manipulation of the system than other stakeholders. This may be because scientists often focused on the ecological components of the fishery which potentially were seen as less malleable than social components. Scientists' maps were also shown to be the most complex since they represented both the forcing functions of the system and the end results of those processes. ENGO representatives identified the highest number of components within the system and the highest number of driving components. This is an indication that they perceive the SES to be subject to several driving functions which largely influence how the system functions.

Benefits and limitations of knowledge integration

Perhaps the most important finding from our study is that integrating diverse knowledge systems increases understanding of how the system may react to change and the dynamics of stability. This was indicated by the amount of higher level functional change in stakeholder maps when compared to lower level functional change found in the community map. Our findings indicate that a major strength of knowledge integration is combining separate focuses on subsystems which may inform more comprehensive representation of the system. For example, scientists included more ecological components in their maps while harvesters focused more heavily on social components. Both, however, included links between these systems. When maps were combined, changes in the system were more widely distributed resulting in less relative change overall. Additionally, knowledge integration increases overall understanding of the components in the system and the relationships between them. The community map density score was considerable higher than that of individual stakeholder groups, an indication of representing more opportunities in which desirable states can be promoted and undesirable states can be discouraged.

However, our results indicate some limitations. Knowledge integration may also decrease precision in our understanding of how a system functions, be overly focused on driving components and decrease understanding of the resulting actions of a decision. In a comparison of the community map to stakeholder maps, our results indicate the complexity of the system may be hindered by increased noise from multiple perspectives. Integrating knowledge may reinforce the driving forces within the system, but limit the articulation of the results of those forces. In practice this may make anticipating the results of a policy more difficult to characterize and increase implementation uncertainty.

CONCLUSIONS

Institutional and scientific knowledge on their own are inadequate guides to determining how SES should be managed (Agurwal 1995; NRC 2008). Instead, input from those affected by environmental decision-making should be invited into the process so that institutions can learn from stakeholders and stakeholders can learn from institutions as the groups work toward a decision (Chase et al., 2004; Johnson et al., 2004; Lynam et al., 2007). This is especially true in complex environments that include both social and ecological systems where predictive ability is low and uncertainty is high (Folke 2004). In these situations, stakeholder input is particularly valuable to decision-making since adaptability requires a range of perspectives and options (Holling 1992). The mechanics behind integrating different types of knowledge, however, are not well understood (Raymond et al 2010) and increasingly research is shifting focus from assuming better outcomes when knowledge is integrated- to the mechanisms involved in the process (Reed 2008). As a starting point, recent research has identified that the differences in stakeholder knowledge should be clearly articulated (Raymond et al 2010) so that conflict among knowledge systems can be reduced (Banjade et al 2007; Ojha 2008) and the benefits of integrations can become better understood (Walker et al 2002).

While there are benefits to integrating knowledge in resource decision-making, it also has costs associated with it. Our analysis indicates that including explicit stakeholder knowledge may lead to increased understanding of system since it increases knowledge of components and the connections between them, therefore more widely informing anticipated changes across the system. However, at any given time, stakeholder are unlikely to be able to articulate the results of these changes, since there is a tendency to focus on the driving components that effect the system and increased connections result in decreased precision of dynamic changes.

Figures and Captions

Figure 1. Example of a FCM

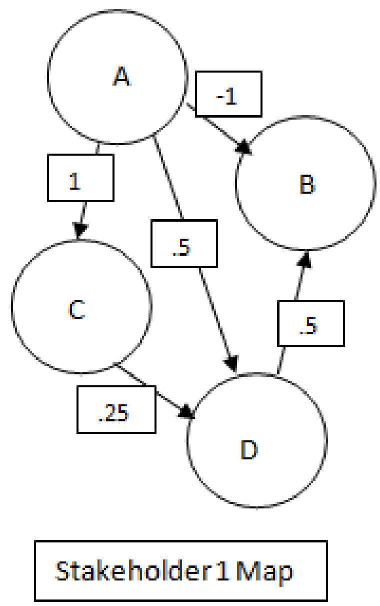


Figure 2. Example of combining stakeholder maps were components and relationships
are reinforced.

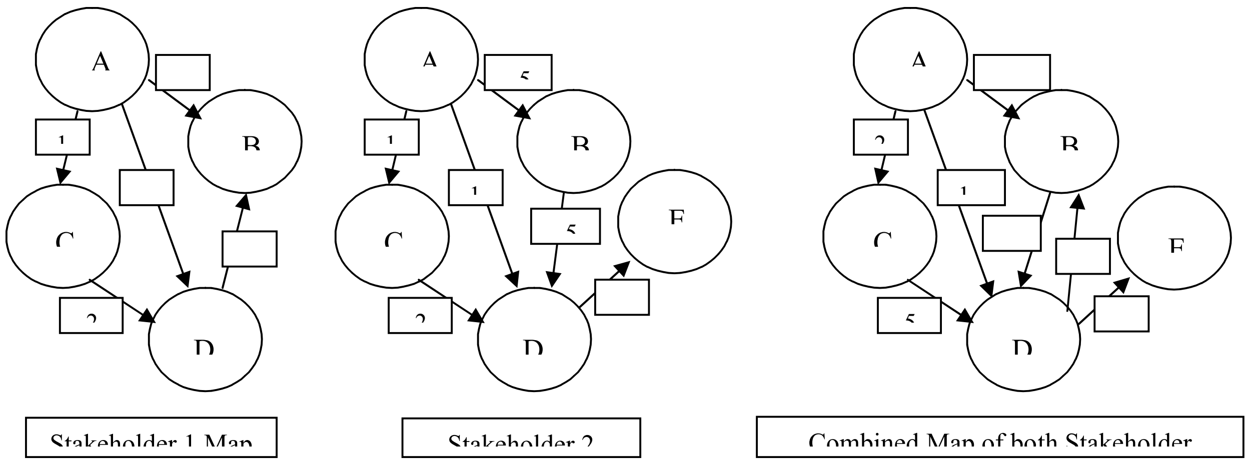
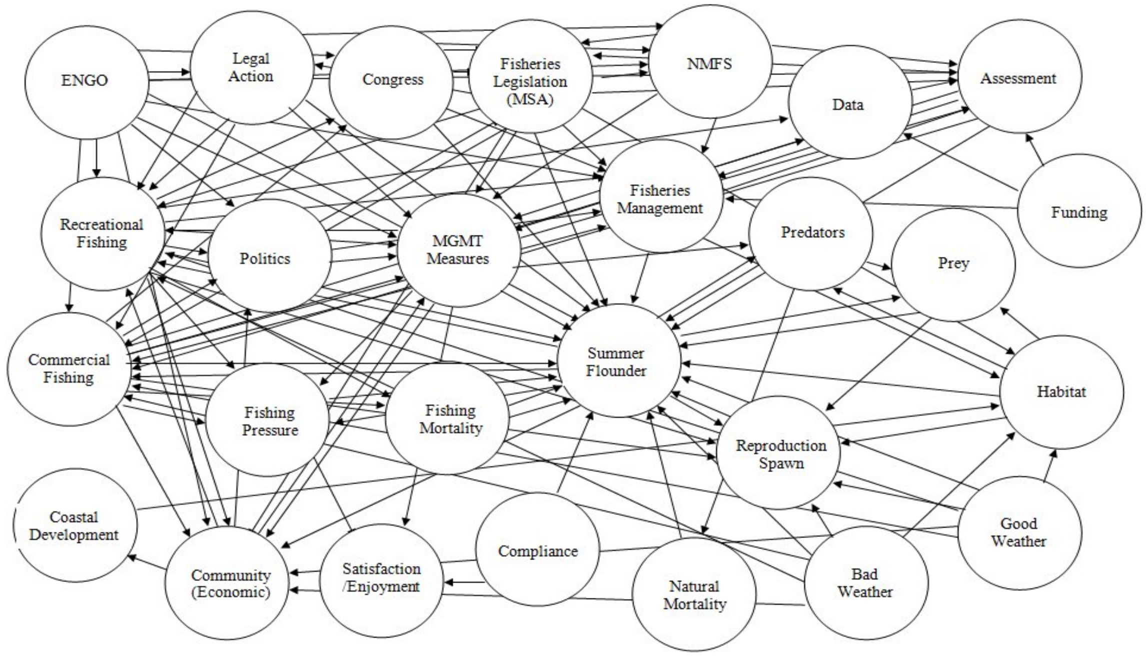


Figure 3. Community FCM for summer flounder SES, including all negative and positive relationships between components.



Tables and Captions

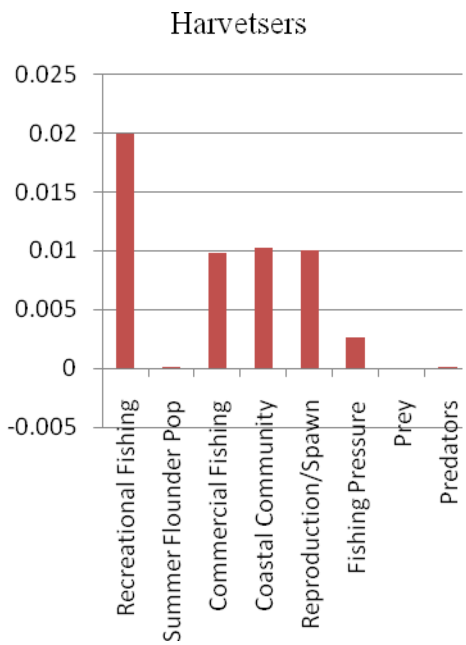
Table 1. Stakeholder groups involved in Summer Flounder Fishery in the mid-Atlantic

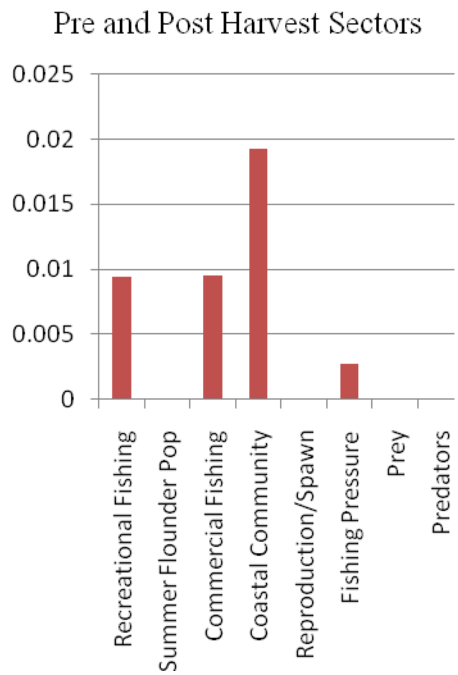
Stakeholder Group	Maps(*N*)	People(*N*)	Occupation/Organization/Social Group
Harvesters	9	10	Commercial fishermen, charter boat captains, headboat captains, recreational fishermen
Post and Pre Harvest	4	7	Bait and tackle shop owners, fishery trade magazines, seafood wholesalers/retailers
Managers	5	7	State and federal fishery managers
Scientists	6	7	Academic scientists, federal management scientists and state management scientists
Environmental NGOs	3	4	National environmental non-profits
Total	27	35	

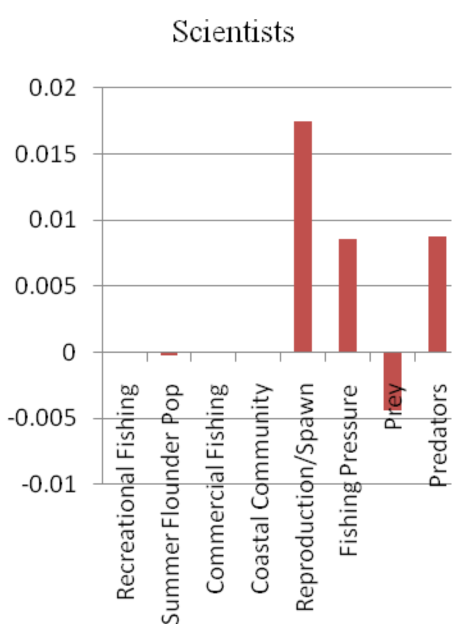
Table 2. Mean and Standard Deviations by Stakeholder Group and Community Map

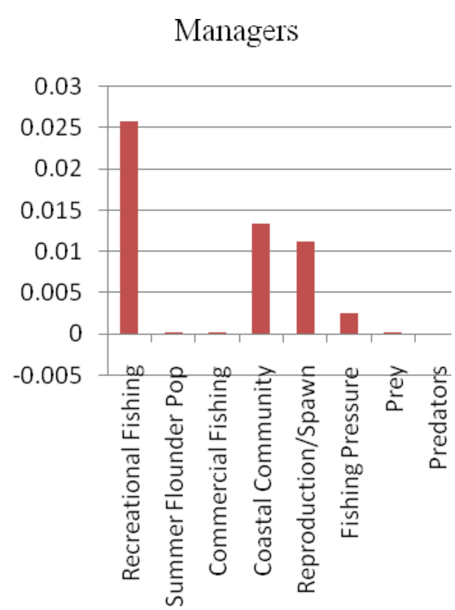
Stakeholder Group	Harvesters	Pre and Post Harvest	Managers	Scientists	Environmental NGO	Community Map
Maps (N)	9	4	5	6	3	27
Number of Variables	16.2(3.0)	12.8(2.1)	15.4(5.8)	19.2(1.71)	19.7(5.5)	27
Number of Transmitter	6.33(3.08)	2.75(1.71)	5.8(3.27)	6.33(1.75)	7.67(3.51)	6
Number of Receiver	1.44(0.88)	2(1.41)	0.8(0.45)	2.33(1.87)	1.67(0.58)	1
Number of Ordinary	8.55(3.16)	8(3.47)	8.8(3.90)	10.33(3.72)	10.67(4.50)	20
Number of Connections	26.22(7.70)	22.5(13.80)	25(13.80)	27.33(7.60)	40.67(19.00)	117
C/N	1.65(0.30)	1.66(1.24)	1.42(0.23)	1.41(0.30)	2.56(1.02)	4.34
Complexity (R:D)	0.34(0.40)	0.38(0.49)	0.27(0.22)	0.50(0.58)	0.17(0.29)	0.17
Density	0.11(0.02)	0.14(0.01)	0.11(0.04)	0.09(0.02)	0.12(0.08)	0.17

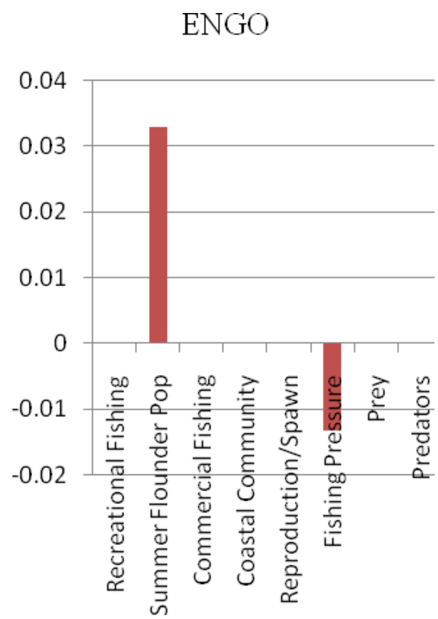
Appendix 1

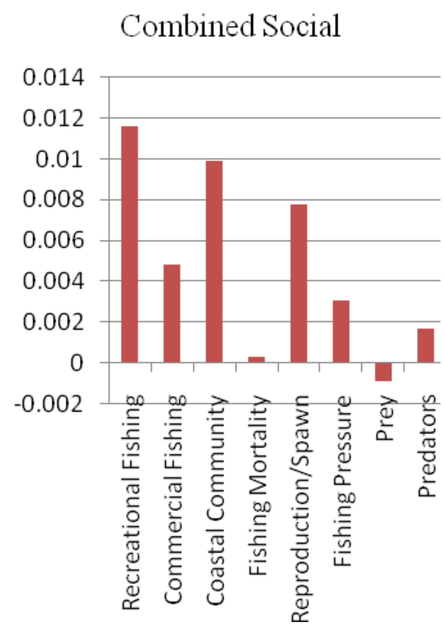

Harvetsers
0.025
0.02
0.015
0.01
0.005
0
-0.005
Recreational Fishing
Summer Flounder Pop
Commercial Fishing
Coastal Community
Reproduction/Spawn
Fishing Pressure
Prey
Predators


Pre and Post Harvest Sectors
0.025
0.02
0.015
0.01
0.005
0
Recreational Fishing
Summer Flounder Pop
Commercial Fishing
Coastal Community
Reproduction/Spawn
Fishing Pressure
Prey
Predators


Scientists
0.02
0.015
0.01
0.005
0
-0.005
-0.01
Recreational Fishing
Summer Flounder Pop
Commercial Fishing
Coastal Community
Reproduction/Spawn
Fishing Pressure
Prey
Predators


Managers
0.03
0.025
0.02
0.015
0.01
0.005
0
-0.005
Recreational Fishing
Summer Flounder Pop
Commercial Fishing
Coastal Community
Reproduction/Spawn
Fishing Pressure
Prey
Predators


ENGO
0.04
0.03
0.02
0.01
0
-0.01
-0.02
Recreational Fishing
Summer Flounder Pop
Commercial Fishing
Coastal Community
Reproduction/Spawn
Fishing Pressure
Prey
Predators


Combined Social
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
-0.002
Recreational Fishing
Commercial Fishing
Coastal Community
Fishing Mortality
Reproduction/Spawn
Fishing Pressure
Prey
Predators

Chapter 2: Categorizing the Risks in Fisheries Management
(formatted for, and in press in *Fisheries Management and Ecology*)

Abstract

The many risks associated with fisheries management can be attributed to the substantial uncertainties that exist within fishery systems and their numerous possible consequences for fishers and fish stocks. Compounding these risks are the possible disparities between different fisheries professionals on the nature and source of these risks. This paper attempts to categorise the risks as reported by fishery scientists and managers in Australia and along the US Atlantic Coast. Through the use of semi-structured interview data, this paper attempts to provide a categorisation of the risks identified by fisheries professionals; and to compare the identified risks by professional group and by country. The analysis yields three broad categories and 12 subcategories of risk found in both nations. Results indicate that: (1) fisheries management risks can be broadly categorised through interview data; (2) the frequency of identification of a particular risk category reflects the management system in which they operate; and (3) risk categorization could be useful from a risk management perspective as risks in different categories may be evaluated and managed using different risk management approaches.

KEYWORDS: Atlantic coast fisheries, Australian fisheries, political risk, risk management, semi-structured interviews, uncertainty

Introduction

Research into risk in fisheries management has grown, possibly with the increasing realisation that exploitation of marine resources has lead to lower productivity and, in some cases, stock collapses (Charles 1998; Dulvy *et al.* 2003, Hutchings & Reynolds 2000; Roberts & Hawkins 1999; Walters & Maguire 1996). Although risk within fishery systems has been widely acknowledged by researchers (Charles, 1998; Francis & Shotton 1997; Harwood & Stokes 2003; Peterman 2004), a comprehensive understanding of the risks identified by the different professional groups involved in fisheries management is not available (Smith 1988). Methods of risk management are contingent on the types of risks being identified, which can change over temporal and spatial scales and vary between individuals and groups (Althaus 2005; Delaney & Hastie 2007; Harms & Sylvia 2001; Peterman 2004). Research has highlighted the importance of articulating definitions of potential risks within fisheries management. For example, Peterman (2004) stressed that "to avoid misunderstandings, fisheries scientists, managers, and stakeholders should always clearly state what they mean by the term risk" (p 1332). Francis and Shotton (1997) stressed the informal, non-quantitative, undocumented and loosely linked way in which risk management is connected to risk assessment in fisheries management. They attributed the lack of explicit direction for managers and scientists on how to deal with different risks to the often conflicting (but rarely articulated) way in which risks are managed.

A number of quantitative (Groger *et al.* 2007; Hilborn *et al.* 1993; Hilborn *et al.* 2001; Pearsons & Hopley 1999; Puga *et al.* 2005; Punt & Hilborn; 1997; Punt & Walker 1998; Rosenberg & Restrepo 1994; Touzeau *et al.* 2000; Walters 1986) and qualitative

(Astles *et al.* 2006; Astles 2008; Fletcher 2005; Francis 1992; Hobday *et al.* 2004) risk-based methods have been used in fisheries management as a way to mitigate potential undesirable outcomes associated with harvesting activities and extreme events, and as a means to prioritise research and management. Each of these methods are, at their core, an attempt to identify and rank the risks associated with the different uncertainties found within fisheries and articulate the consequences of these uncertainties for the associated human and environmental systems. Previous research has organised the various sources of uncertainty common to fisheries systems, ecology and conservation biology (Francis and Shotton, 1997; Charles 1998; Harwood & Stokes 2003; Peterman 2004, Regan *et al.* 2002). Categorising uncertainty in this way has proven useful in the development of strategies for management as it has allowed separate fields of expertise to develop to consider different forms of uncertainty. A similar "divide and conquer" approach may be employed to understand the various sources of risk in fisheries management and thus provide the groundwork for the development of a comprehensive risk management framework for fisheries.

A key problem in any such categorisation of "risk" lies in the ambiguity associated with the differing usage of this term across the multiple disciplines that fisheries professionals may be associated with (Adams 1995; Hokstad 2006; Althaus 2005). Any categorisation of risks in fisheries management must therefore take into account the risks identified by fisheries professionals that are involved with on-the-ground management of marine fisheries and should examine the extent to which these identified risks vary between fisheries professionals. This paper investigates such 'on-the-ground' categorisation of the risks in fisheries by examining the most commonly identified risks in responses from semi-structured interviews with fisheries professionals in Australia and the United States .

Fisheries management in Australia and the United States

Modern industrial countries manage marine fisheries in similar ways, usually by limiting fishing activities through a top-down approach, with overall control given to a central governing institution (Acheson & Wilson 1996; McCay & Jentoft 1996). Fisheries management in both Australia and the United States is a hybrid of federal and state-level management, guided by legislation but integrating various aspects of stakeholder participation or co-management throughout the process. This strategy raises the possibility that risk becomes a much broader and more complex issue given the diversity of the groups involved. Additionally, both the U.S. and Australian systems place emphasis on the scientific assessment of the resource and the use of harvest regulations and limits to control fishing pressure - both requiring extensive cooperative interaction between scientists and managers. The interpretation and role of risk within fishery management is expected to differ among management participants because the goals, priorities and values of the players differ (Adam *et al.* 2000).

Methods

A qualitative research design based on in-depth personal interviews and grounded theory data analysis (Strauss and Corbin 1990) was chosen to capture the various ideas of risk held by fishery professionals in the two countries. Exploratory qualitative research methods like those used in this study are appropriate when exploring phenomena like risk

(Marshall & Rossman 1998) and have been used routinely as a measure for complex social issues in natural resource management such as trust (Davenport *et al.* 2007). Further, grounded theory is an inductive method which allows for complexity in the interview data to be maintained while still allowing for distinct categories to be developed.

Study participants were chosen from publically funded fishery management institutions on the Atlantic Coast of the United States (15 states from Maine to Florida, including Pennsylvania) and in all six Australian states as well as the Northern Territory and the Commonwealth (ACT). While the sample size is not intended to be statistically representative of the entire population in either country, it does represent a cross-section of fishery professionals since all state and federal institutions along the Atlantic coast were included in US interviews and all state or territory and federal institutions were included in Australia. Interviewees included 12 fisheries scientists and 10 fisheries managers in Australia, while the U.S. Atlantic coast interviews consisted of 10 fisheries scientists and 8 fisheries managers (n = 40). All fisheries professionals interviewed were involved in the management or scientific assessment of fish stocks in state (0-3 nautical miles) and/or federal (3-200 nautical miles) waters. Interviews were audio-recorded using the same list of questions as a guide to semi-structured conversations (see Appendix 1 for a copy of the interview pro forma).

The term “fisheries scientist” refers primarily to stock assessment scientists while the term “fisheries manager” refers to those professionals who play a formal role in making decisions (usually in terms of developing regulations) about marine fishery resources. Fisheries professionals are generally expected to have a working knowledge of both biological science and fisheries management and policy. This can make the classification of profession unclear. Past studies have indicated that even within designated professional groups, perceptions of fisheries management may vary (see Delaney & Hastie 2007 and Wilson *et al.* 2002). However, for the purposes of this study, participants were asked to identify the risks they encountered within their current professional role, which was self-identified as either a fisheries scientist or a fisheries manager.

Survey instrument

A semi-structured interview tool (see Appendix 1) was used to assess: (1) in what capacity the participant was involved in fisheries management or science; (2) how the concept of risk was used in their assessment/management work and whether they found the concept useful; and (3) if there was any formal process for determining what risk assessment technique or techniques are used on the fisheries they are involved with. The first two questions were designed to uncover specific identifications of risk within their professional schema and the third question was designed to elicit identification of specific risks with which they were engaged. Only the answers to these three questions were used for this present study. The full interview included 24 questions and was used as part of a separate project designed to develop national risk management guidelines for data poor fisheries (Scandol et al. 2009).

This analysis focussed on: (1) categorising the risks identified by fisheries professionals from the two international jurisdictions; (2) comparing risk identification between professional groups and international jurisdictions and; (3) examining where risks are identified most often after the risks were categorised. Individual participants remained anonymous but each individual was identified as either a manager or scientist from either Australia or the U.S.

Analytical methods

Participant responses were categorised using post-coding (Miller 1983) to identify emergent themes which followed Strauss and Corbin's (1990) interview data interpretation techniques. Based on a review of field notes and transcribed texts, categories of risk were developed by grouping similar themes, phrases, and words into categories. These categories were grounded on the participants own words collected during interviews. A sample of the transcribed interviews from both nations was then reviewed to verify the initial categories and identify additional subcategories. All transcribed interviews were then scored by two different researchers using the risk categories. Any differences between the two researcher's scoring results were discussed until agreement was reached.

Quantitative comparisons were then undertaken between countries and between professions to determine to what extent the identification of risk varied between groups. Twelve separate non-exclusive categories emerged through data analysis, so the highest possible score for any contribution to a risk category would be 40 (since n = 40), whereas the highest possible score for any one individual's identification of risk would be 12 (since 12 categories emerged). Fisher's exact tests were used to determine whether the scores were significantly different between groups.

Coding example

In one of the responses to the question “How do you see the concept of “risk” being used in your fisheries assessment/management work?” one manager answered:

“As a fisheries manager, we have to evaluate the resources available and the benefits that we can obtain from those resources without putting that fishery at risk. By putting at risk, I am talking about sustainability of the fisheries, the industry, and how it is going to affect the environment. To what point is human activity going to be putting a fishery at risk, including the fishers, the species, and the environment?”

This participant was coded as identifying risk in three ways; namely species-level (IIa), ecological (IIb), and social (IIc) since the answer explicitly mentions risk in his work associated with individual species, the environment and the fishers, respectively.

Results

Qualitative categories of risk in fishery management

The three broad categories and twelve subcategories of risk in fisheries management are presented in Table 1. Fisheries management in Australia and the U.S. involves a system of scientists, managers and stakeholders contributing in various capacities to develop a plan of how harvested marine resources are to be managed. In a complex system such as fisheries (which involve multiple dynamic components interacting at various temporal and spatial scales), the identified categories are not exclusive because many categories are linked and influence each other to varying degrees. However, for the purposes of this study, three main categories are presented to describe the way risk is identified by fishery professionals into (I) Uncategorised Risk,

(II) Managed Risk, and (III) Institutional Risk. An explanation of each of these categories and sub-categories follows.

Insert Table 1.

Category I. Uncategorised: risk is everywhere, informal or implicit. Uncategorised risks were those that arose informally or were implicit in discussions of risk. This category reflects responses that emerged from interviews that stated that the reason that management institutions exist is to manage potentially undesirable outcomes related to fisheries. Discussing risks in uncategorised terms is reflective of general societal uncertainty of future events combined with the notion that negative outcomes are possible when natural resources are shared collectively and individuals do not benefit from harvesting restraint (Hardin 1969). This category was divided into two subcategories, (a) unarticulated and (b) broadly defined, based on the manner in which participants discussed risk.

Ia. UNARTICULATED RISK- THE RISK OF LOSS ASSOCIATED WITH COMMON-POOL RESOURCES. The unarticulated risk subcategory includes statements that alluded to risk being discussed in informal terms (e.g. risk is implicit) and did not involve the phrases "risk is", "risk to", "risk from" or "risk in" explicitly. Additionally it was not clearly articulated that risk was found in any specific step of the fisheries management process. Unarticulated risk refers to risk being inferred in institutional process, but never explicitly handled through any definable mechanism, like risk management. Unarticulated risk was identified by 22.5% (rank 3) of interviewees. An unarticulated risk example was: "We beat around the bush with risk, but it is not explicit in the way or sense that other areas might be. It is more implicit than explicit. I don't think we have gotten to the point where we talk about "risk" in terms of the outcome of the assessment." -U.S. Manager

Ib. BROADLY DEFINED RISK- THE EXISTENCE OF RISK IS THE REASON FOR MANAGEMENT. Broadly defined risk included the interviewee defining "risk" as the catalyst for fisheries management; or found everywhere throughout the system; or it was defined in terms of likelihood and consequence (or as an outcome probability). This subcategory of risk is reflected by research that proposed that society expects science-based policies to manage environmental uncertainties to improve decision making (Funtowicz & Ravetz 1990). Broadly defined risk was identified by 35% (rank 8) of interviewees. An example of broadly defined risk was: "There is always risk present, but whether people quantify it or not is another story" – U.S. Scientist

Category II. Managed risk: Risk to the biological and social systems. Managed risks were those risks fisheries management is designed to mitigate. These risks encompass both the biological and social systems. Potential loss of productivity of these systems is arguably the impetus for the development of institutional fisheries management in both countries as they reflect components of the system that are considered valuable and expected to be maintained or sustained (Hatton *et al.* 2006). The identification of these risks is attributable to the nature of ecosystems, populations, and social systems that fisheries encompass and the associated losses to human and environmental systems. When interviewees mentioned this risk, many participants discussed specific stock assessments, stakeholder groups, or other case studies that pertained to a particular fishery decision as a way to articulate risks that they encountered.

IIa. SPECIES/STOCK-LEVEL RISK- THE RISK OF POPULATION DECLINE. Species/Stock-level risk was identified as the potential harm to the sustainability of a species or stock. Since fisheries in both nations are most often managed on the basis of fish stocks, study participants often discussed the risks to the specific stocks they were involved in managing and the uncertainty involved in that process. All mention of potential loss to specific stocks as species-level risk. Species or stock-level risk was mentioned by most (75%) (rank 1) of the study group. An example of species/stock-level risk is: "There is a risk to the biological impact to the fish" – U.S. Manager

IIb. ECOSYSTEM-LEVEL RISK- THE RISK OF LOSS OF ECOSYSTEM-FUNCTION. Ecosystem risks included potential harm to the general ecosystem, including species not targeted by fishers (such as by-catch), and habitat impacts of fishing activities. This risk was mentioned by 42.5% (rank 5) of the interviewees. An example of ecosystem-level risk is: "[There exists] a risk of ecological damage and risks to the entire ecosystem" – Australian Scientist

IIc. SOCIAL RISK- THE RISK OF LOSS TO THE ECONOMIC OR CULTURAL SYSTEMS (BOTH INDIVIDUALLY AND COMMUNITY). Any mention of socioeconomics, individual livelihood or individual risk was coded as social risk. Social risks included mention of socioeconomic disruption as well as potential risks that effect loss of economic viability due to either the implementation of fishing restrictions, changing economic conditions or the decline in the abundance of stocks. Social risk was identified by 40% (rank 6) of interviewees. An example of social risk is: "… the assessment of risk is the measure of benefit of the mortality control versus the potential impact in the fishing community that you are governing." -U.S. Manager

Category III. Institutional: Risks that arise from the practice of fisheries management

Institutional risks are those created by the formal processes of managing marine fisheries and include such issues as making incorrect decisions based on misinformation, poor management, and problems in implementation. Institutional risks are mitigated through various management techniques such as diversification, quality assurance procedures and precautionary approach (Hilborn *et al.* 2001). The institutional risk category is divided into seven subcategories.

IIIa. LEGISLATIVE RISK - THE RISK OF NOT MEETING REQUIREMENTS AS OUTLINED IN U.S. FEDERAL OR AUSTRALIAN STATE OR COMMONWEALTH LAW. Legislative risks include the identified risk of not meeting legislated objectives as well as the ability of fisheries managers to evaluate risks against these legislated objectives. The latter risk is due to legislated objectives sometimes being ambiguous from problems with normative or unscientific language and due to society's uncertain expectations (Duarte-Davidson & Pollard 2006). Participants that identified legislative risks often referred to specific laws (most notably the 2006 Re-Authorization of the Magnuson Stevens Act) and the challenges that are inherent in translating written statutory requirements into management. Legislative risk was identified by 42.5% (rank 5) of interviewees. An example of legislative risk is: “With the new Magnuson [Act] we have to develop recommendations to meet the letter of the law” –U.S. Manager.

IIIb. Data Collection risk – the risk associated with the incorrectness of data collected for assessment work. Data collection risks are those associated with the uncertainties involved in the collection of quantitative and qualitative data used to assess the status of the biological or social systems. Data collection risk is the risk of gathering incorrect, inappropriate, misguided, biased, or sparse datasets for risk/stock assessment work. It was identified by 55% (rank 3) of interviewees.

IIIc. Data Analysis risk – the risk associated with the correctness of scientific assessments. Data analysis risk relates primarily to quantitative assessment work and refers to the risks associated with the methods used to analyse data, such as stock assessments. The risks include assessments that are inaccurate, imprecise or are extrapolated beyond their utility, and thus lead to incorrect advice being given to managers. Risks associated with data analysis arise from imperfect modelling practices, ignorance of the system to be modelled or a lack of calibration tools. Data analysis risks were identified in 62.5% (rank 2) of the interviews. An example of collection and data analysis risk is: “We need to identify the limitations of our stock assessments from the absence of data or particular types or lack of data which may not be representative. There is a risk of over-interpreting the data for our assessments.”-Australian Scientist.

IIId. Management Objective risk – the risk associated with not meeting management objectives. Management objective risks are those associated with the uncertainties inherent in the day-to-day management of fisheries. They differ from the legislative risks in that management objectives may be more specific than broader legislative requirements. In some cases, management objectives may attempt to meet legislative requirements while taking into account current institutional arrangements. Not meeting management objectives was usually discussed in terms of not simultaneously balancing biological and social interests such as preventing overfishing whilst maintaining fishery profits. The risks associated with not meeting management objectives was identified by 55% (rank 3) of the respondents. An example of management objective risk is: "Ultimately for fisheries the risk they should be concerned with is the risk of not meeting your management objectives." - Australian Scientist.

IIIe. Political Influence risk – the risk associated with political influences compromising current management objectives. The fifth subcategory of institutional risk involves risks associated with political influence over the decision-making process. This risk includes the mention of factors that influence or bias management decisions in the direction of a stakeholder group(s). The risk involved here is that of disproportional influence to favour one stakeholder group over another. It arises as a result of institutional uncertainty and irreducible biological/social process uncertainty in such systems (Bammer & Smithson 2008). Political risk was identified by 47.5% (rank 4) of the participants. An example of political influence risk is: "Risk is basically assessed by walking this line of political pressure; on one hand you have constituents and the other following scientific advice from stock assessments." - U.S. Scientist .

IIIf. Science/Management interface risk – the risk associated with the communication or understanding of scientific assessment. Science/Management interface risk is that of inappropriate communication or understanding when information is exchanged between scientists and managers. These risks were primarily identified as those of misinterpretation or misunderstanding by managers of the information provided by scientific assessments. This type of risk has also been characterised by the "linguistic uncertainty" outlined by Regan, Colyvan and Burgman (2002). These authors attribute communication between conservationists as a source of potential uncertainty due to vagueness, context specificity, underspecificity and ambiguity of ecological issue under discussion. The risks that arise from the science/management interface were mentioned by 35% (rank 8) of interviewees. An example of science/management interface risk is: "The risk estimate is based on a single value presented to managers and there is a lack of desire for most managers to figure the uncertainty" – U.S. Scientist.

IIIg. Implementation risk – the risk associated with the management actions not producing the desired effect. This risk category is associated with implementation and the risk that the management measure chosen will not have the planned effect on the fishery. Participants that identified this risk discussed such issues as the effectiveness of tools available to managers, as well as fisher compliance and monitoring and the lack of retrospective methods needed to evaluate whether past decisions have satisfied their original intent. The risks associated with implementation was mentioned by 37.5% (rank 7) of participants. An example of implementation risk is: "Risk is to make sure that the actions that have been selected have the desired effect." – U.S. Manager.

Comparison between Australia and the U.S. Atlantic Coast

Coded responses were also compared between Australia and the U.S. Atlantic Coast (Figure 1.). The following ratios are listed as percentages (AU: US) for comparison, since participants of the two countries varied similarly by proportion (i.e. AU managers comprised 45% of AU total, US managers comprised 44% of US total).

Insert Figure 1.

In the three main categories of risk, the American interviewees reported more uncategorised risks than did Australian interviewees (Australian 5%:US 44%) while broad risk was identified more frequently by Australians (45:22). The following ratios are listed as percentages by country, which varied proportionally (Australian: US). Managed risk was identified more often in all categories by Australians with regard to species (86:61), ecosystem (68:11) and social (50:28) systems. Most institutional risks, however, were identified more often by Americans including: legislative (36:50), data analysis (45:83), management objectives (45:67), political (45:50), science/management interface (18:56), and implementation uncertainty (27:50) with the exception of data collection (68:39), which was mentioned by Australians more often. Quantitative analysis indicated that Australians and Americans differ in the risk categories of managed ($P < 0.001$; Fishers Exact Test - FET) and institutional risk ($P = 0.003$, FET), but uncategorised risk were not different ($P = 0.14$, FET).

Comparison between scientists and managers

Coded responses were also analysed by professional role in the same manner for each category and subcategory of risk. The following ratios are listed as percentages by professional role in management, which varied proportionally (Scientist: Manager). Uncategorised risk scored similarly between scientists and managers with unarticulated (23:22) and broadly defined risk (32:39) comparable. Managed risk was also similar for species (73:78) and ecosystem (41:44), although social risks were recognised more often by scientists (45:33). Institutional risk diverged with fishery scientists identifying data analysis (73:50), management objectives (59:50), and science/management interface (58:17) more frequently while managers identified data collection (45:67) and implementation uncertainty (27:50) more often. Overall, scientists and managers responses were not significantly different in their identification of unarticulated (P = 0.081, FET), managed (P = 0.144, FET) or institutional risk (P = 0.08, FET).

Organising the risks

The 12 subcategories that emerged from the coding can be organised within the 3 broad categories into a schematic diagram of the risks associated with fisheries management as perceived by managers and scientists (Fig. 1). The bar charts identify the count of the interviews in which a subcategory was identified by each of the country's professional groups including a count of interviews in which respondents did not identify the subcategory (RNI).

Discussion

The most important finding from this study is that almost every subcategory of risks was identified by each of the two national groups and the two professional groups (with the exception of Australian managers who did not mention "unarticulated" risk and U.S. managers who did not mention ecosystem risk). This indicates that although variation in risk identification was found between groups, based on the interview data, similar risk categories emerged. Further, these risk categories strongly reflect typologies of uncertainty outlined by previous studies of risk in fisheries (Charles 1998; Francis & Shotton 1997; Harwood & Stokes 2003; Peterman 2004, Regan *et al*. 2002). However, these identified categories and subcategories refine the concept of risk to incorporate the consequences for economies, ecosystems and fish stocks, as well as to reflect how fishery professionals communicate and discuss risk. Differences in risk identification are most likely attributable to subtleties that exist on finer scales of fisheries management in both countries since there was some variation by country but not by profession. For example, the U.S. respondents identified risk more often in uncategorised terms than did Australians. This is possibly caused by Australia's recent integration of qualitative risk-based frameworks (Astles *et al.* 2006; Astles 2008; Fletcher 2005, Hobday *et al.* 2004) into assessments following the requirements of the Environment Protection and Biodiversity Conservation Act (1999). This strategic assessment process promoted risk management in fisheries and defined risks (at least to some extent) in explicit terms. By contrast, American respondents mentioned institutional risks, such as legislative risks, more often than Australians. This is possibly attributable to recent developments within the U.S. system such as the 2006 Re-Authorization of the Magnuson Stevens Act and the increasingly large number of fishery management actions that are being challenged in U.S. federal courts (Powers 2004).

Beyond species, ecosystem-level and stock assessment risks; risks of not meeting management objectives and the risks associated with political influence were identified with high frequency regardless of professional role or nation. The risks associated with political pressure have many points of influence within institutional risk (as presented by the arrows in Fig. 1) and are difficult to isolate within one step of the management process - given the many roles of stakeholders. While participatory management is considered to increase transparency, accountability and robustness of management decisions by incorporating stakeholder knowledge and concerns into the process (Kaplan & McCay 2004), it has also been shown to change support and direction of management decisions and contribute to unfavourable or "risky" outcomes (Dudley 2008). Further, political influence may have the power to decrease the efficacy of other risk-based methods since the risk arising from investment in a more participatory process may marginalise risk management applied in other areas – such as presenting arguments around uncertainty as a way to influence decision-making. A common approach to dealing with uncertainty is to delay management action in the hope of reducing uncertainty through research and deliberation. Delaying fisheries management decisions, however, has not usually resulted in a reduction to the risk of species decline (Shepherd & Rodda 2001) and past research and many policy frameworks recommend that the precautionary approach should be adopted at times of high uncertainty and serious consequences (Hutchings 2000) instead of delayed action. Additionally postponing decisions to undertake more research can actually increase uncertainty by revealing more complexity than was previously understood, such as spatial variance in growth rates (e.g. McShane & Naylor 1995). This is not to say that a participatory process does not mitigate implementation risks. For example, allowing high levels of uncertainty to continue can result in a decline in social trust over time (Bammer & Smithson 2008). If conditions of low social trust prevail they can pose major challenges and additional costs to decision-makers. More in-depth analysis focused on refining the categories and subcategories identified here might give further insight into possible risk-based methods for areas of fisheries management such as political risk where few data are being collected and few or no standardised procedures exist (Underwood 1998).

The categorisation of uncertainty was an important step in the development of methods for the management of uncertainty in fisheries (Charles 1998). In a similar fashion, categorisation of the risks may help fisheries professionals break down the risk problem into separate manageable components. For the majority of the categories identified in this study, risk management methods have already been developed. For instance, data collection risks are managed through good experimentation and project management methods, such as data validation, and through incorporation of observation error into models (Solow 1998). More complex fisheries management controls have been suggested as a means of reducing risks to species and fisheries (Butterworth & Punt 2003; Edwards *et.al* 2004; Peterson & Smith 1982; Stefansson & Rosenberg 2005), however such controls generally fall short of accounting for all sources of risk as identified in this study. Risk categorisation is therefore an important first step in the process of developing a comprehensive risk management system that covers each of the different risks present in fisheries management (e.g. Astles 2008; Fletcher 2005; Hobday *et al.* 2004). Future research is needed to further refine these categories; to incorporate them into theoretically based classifications schemes; and to align them with appropriate risk management strategies.

As fisheries continue to move towards formalised methods to address issues associated with the potential impacts of harvesting, it is also important to define the risks that various stakeholders bring into this debate (Francis & Shotton, 1997; Harms & Sylvia, 2001). This paper provides a categorisation of risks from the perspective of fishery professionals. It does not, however, address risks identified by other groups involved in fisheries systems such as commercial or recreational fishers, members of the seafood industry, suppliers of fishing equipment and non-governmental organisations. For example, through an analysis of interview data with commercial fishermen, Smith (1988) concluded that commercial fishermen's perceptions of risk arise primarily from non-fishermen (e.g. sports fishermen, economists, politicians, biologists, environmentalists, and bureaucrats). Therefore, the risks identified from commercial fishermen would be expected to be considerably divergent from the risks discussed in this study. More research is needed to further refine how other groups involved (beyond those engaged in professional management) articulate and perceive risk in fisheries. This becomes increasingly important the more that risk becomes the vernacular by which fisheries management issues are discussed.

Interview-based analyses, such as those presented here, are subject to a number of possible biases (Converse & Presser 1986; Fink 2006; Fowler 1984; Sarantakos 2005). The questions and interview format used for this study was designed to reduce biases as much as possible. All interviews were conducted on individuals to avoid social conformity bias. Biases associated with leading questions were minimised by ensuring that the questions were designed for a larger study and both interviewee and interviewer were unaware that this information would be used for a categorisation of risk. However, interviewer bias could have occurred since U.S. interviews were conducted by different interviewers than the Australian interviews. This bias was reduced by extensive consultation between the interviewers from both countries. Possibly the most important source of bias was in the form of personal cost bias. Even though each respondent was told that the interviews would be anonymous, their answers could have been biased by the respondents' awareness that they were being tape recorded and thus may have tailored their answers to reduce any possible risk to their job or professional standing.

Conclusions

The complexities found within fisheries has long been acknowledged but have proven difficult to consider in routine fishery management decisions (Dudley 2008; Garcia & Charles 2008). It is therefore important for fisheries professionals to work toward a shared understanding of the different conceptions of risks so that divergent and convergent concepts can be articulated to the best extent possible. Refining the identification(s) of risk from the perspective of the groups involved adds clarity to such an abstract concept such as risk (Francis & Shotton 1997). The primary lessons learned from this study are:

(i) fisheries management risks can be broadly identified based on frequency of identification through interview data;

(ii) risks identified by individuals are reflective of the management system in which they operate, but significant differences were not found between professional roles within that system; and

(iii) risk categorisation can be a valuable tool from a management perspective as each type of risk may be assessed and managed using different risk management approaches.

Table and Figure Captions

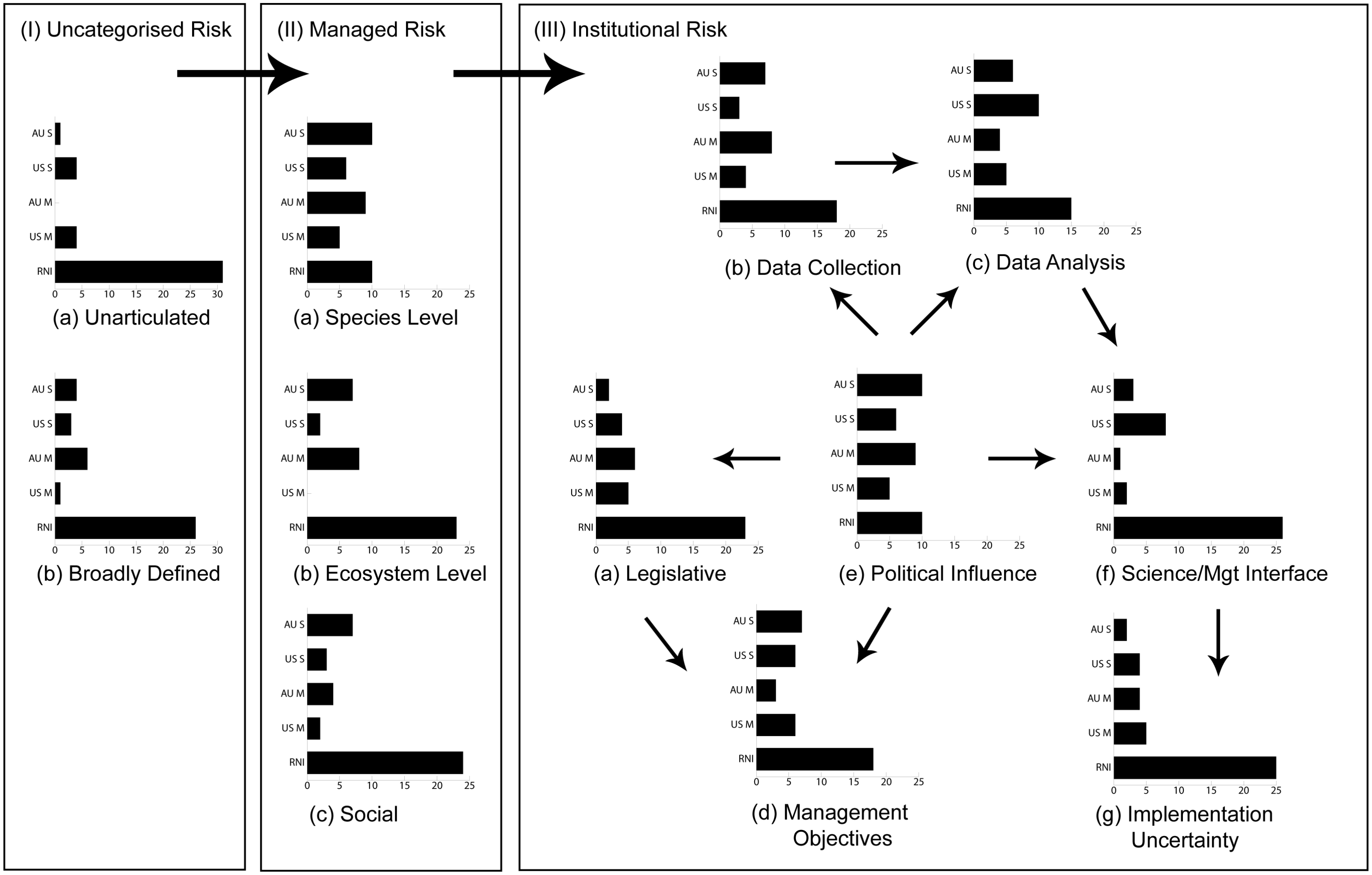
Table 1. Summary of risk categories and rank of by frequency of response. Transcribed interviews yielded 3 main categories of risk in fisheries management and 12 subcategories. The risk category identified most often was the risk to the species being managed (IIa) while the category mentioned least often was that of unarticulated risk (Ia)

Figure 1. A schematic diagram of the risks associated with fisheries management as perceived by managers and scientists in Australia and the U.S. Bar charts indicate the counts of respondents for each risk subcategory by country and professional groups including respondents that did not identify the particular risk subcategory (RNI).

Table 1.

Risk Category and Subcategory	Definition	Rank by frequency of response
I. Uncategorised Risk		
A. Unarticulated	The risk of loss associated with common-pool resources.	9
B. Broadly Defined/Likelihood and Consequence	The existence of perceived risk is the reason for institutional management.	8
II. Managed Risk		
A. Species/Stock-level	The risk of a decline to a species/population.	1
B. Ecosystem-level	The risk of loss to ecosystem function.	5
C. Economic or Individual	The risk of loss to the economic or cultural systems (both to the individual and community).	6
III. Institutional Risk		
A. Legislative	The risk of not meeting legislative objectives or requirements as outlined by law.	5
B. Data Collection/Management	The risk associated with incorrectness of data collected for assessment (not appropriate, misguided, biased, sparse).	3
C. Data Analysis	The risk associate with correctness of scientific assessment (wrong methods, high degree of uncertainty in the output).	2
D. Management Objectives	The risk associated with not meeting management objectives.	3
E. Stakeholder Influence/Political Influence	The risk associated with political influences compromising management objectives (risk of politicizing the process and clouding judgment).	4
F. Science/Management Interface	The risk associated with communication or understanding scientific assessment.	8
G .Implementation Uncertainty	The risk associated with management actions not having the desired effect (e.g. risk of lack of stakeholder compliance or incorrect policy enacted).	7

Figure 1.


(I) Uncategorised Risk
(II) Managed Risk
(III) Institutional Risk
AU S
US S
AU M
US M
RNI
(a) Unarticulated
(b) Broadly Defined
(a) Species Level
(b) Ecosystem Level
(c) Social
(b) Data Collection
(c) Data Analysis
(a) Legislative
(e) Political Influence
(f) Science/Mgt Interface
(d) Management Objectives
(g) Implementation Uncertainty

Chapter 3: Understanding factors which influence stakeholder trust of fisheries science and institutions

(submitted to *Environmental Management*)

Abstract

Building trust between resource users and natural resource institutions is essential when creating conservation policies that rely on stakeholders to be effective. Trust can enable the public and agencies to engage in cooperative behaviors toward shared goals and address shared problems. Despite the increasing attention to trust in the environmental management literature, the influence that individual cognitive and behavioral factors may play in influencing levels of trust in resource management institutions and their associated scientific assessments remains unclear. This paper uses the case of fisheries management in the northeast to explore the relationships between an individual's knowledge of the resource, perceptions of resource health, and participatory experience on levels of trust. Using survey data collected from 244 avid recreational anglers in the Northeast U.S., we test these relationships using structural equation modeling. Results indicate that participation in fisheries management is associated with increased trust across all aspects of fisheries management. In addition, higher ratings of resource health by anglers are associated with higher levels of trust of state and regional institutions, but not federal institutions or scientific methods.

Keywords: cooperation, fisheries management, recreational anglers, science trust, structural equation modeling, trust

1. Introduction

The benefits of developing and maintaining trust between natural resource management agencies and natural resource users have been well documented (Earle and Cvetkovich 1995; Beierle and Cayford 2002; Davenport 2007). Fostering trust between managers and those managed has been shown to decrease public perception of risk (Eiser and others 2007; Needham and Vaske 2008), increase the likelihood of compliance behaviors (Dickson and others 2009) increase coordination across diverse stakeholders (Owen and Videras 2008) and increase the overall resilience of coupled social-ecological systems (Ostrom and others 2008). These positive outcomes are attributable, in part, to the ability of trust to minimize social disorder by facilitating cooperation among individuals and groups (Barber 1983).

Past research has highlighted the importance of learning which enables trust to be built as individuals gather information about the motives, objectives and behaviors of others over time (Beratan 2007). Ultimately, the collection of this information results in the acceptance or rejection of another's goals which then determines whether cooperation is an appropriate response. Trust has also been framed in terms of mental assessment of costs and benefits of cooperation. According to Rousseau and others (1998) trust is best defined as a willingness to accept vulnerability based upon positive expectations of the intentions or behaviors of others. In these terms, individuals are rational actors and the trust outcomes are carefully considered to determine whether the benefits of cooperation outweigh the potential costs to vulnerability. These definitions emphasize rational responses and the role that knowledge, internalizing information and learning plays in influencing trust, which may result in the decision to work together toward common goals or to seek out an individually beneficial plan of action.

Studies have shown that not all trust judgments, however, are rational and learned appraisals. Rather, in the absence of information about the motives and objectives of others, emotions and heuristics seem to fill the knowledge gap. In an experimental setting, Schwarz and Clore (1983) found that people use their momentary affective states as information. Building on this work Dunn and Schweitzer (2005) determined that these "affect-as-information" heuristics and familiarity with the trustee have a significant influence on trust judgments. When the trustee is well known, information is directly processed and evidence or associations influence the trust decision. However, when there is little information about the trustee, affect-as-information and emotional associations may determine the level of trust afforded to a trustee.

1.1 Trust in Natural Resource Management

Trust between individuals, groups, and institutions is central to the effective management of shared natural resources. In both experimental and field research, trust appears to be a core variable explaining why in some settings participants tend to cooperate and tend not to cooperate in other settings (Ostrom and Walker 2003). This cooperation is especially important in common-pool resource management because profit maximizing by harvesters has the capacity to threaten the sustainability of a resource (Ostrom 2007). On short timescales, harvesting restraint does not benefit the individual and trust and cooperation are counter-intuitive responses when the alternative response is to maximize returns (McAllister and others 2005). Yet, considerable evidence from past studies have indicated that trust and cooperation are an appropriate response when the likelihood of encountering the trustee again is high (Barclay 2004) and the benefits of cooperation are clearly communicated (Ostrom and Walker 2003). The mechanism for building trust in a natural resource context is most often discussed in terms of fostering shared values between management agencies and stakeholder groups (Johnson 1999; Cvetkovich and Winter 2003; Needham and Vaske 2008). Aligning values increases cooperation by increasing the perceived likelihood of accruing benefits. Shared values are made explicit by reciprocity norms between individuals, groups and institutions which are socially reinforced (Ostrom and Walker 2003). These experiences and interactions result in understanding the values of others which then leads to trust judgments. As Johnson (1999) points, however, evidence of shared values are not necessarily easily identified. Further, values are often complex and multi-dimensional and are likely to vary across and within stakeholder groups (Hoppner 2009).

Investigations of trust in a natural resource context overwhelmingly examine case studies between local communities and government agencies. For example, in a study investigating water-resource decision-making, Leahy and Anderson (2008) qualitatively describe the importance of trust between local community members and the U.S. Army Corps of Engineers. In a review of three case studies from river systems across the United States, Carroll and Hendrix (1992) outline trusts contribution to collaborative management when local and affected citizens were involved. Cvetkovich and Winter (2003) studied trust between a range of local forest stakeholders and the U.S. Forest Service management for the protection of endangered species. All studies found that similar values between local communities and agencies influenced level of trust in management decisions and describe frameworks for agencies to engage stakeholders through collaboration.

Research has also uncovered impediments to trust building with local communitiesl. In an investigation of U.S. Forest Service and stakeholder groups, Davenport (2007) found that low levels of community engagement, unclear communication and a history of adverse relationships between communities and agencies can constrain and limit collaboration between communities and agencies. This constraint can make it difficult, if not impossible, to understand the values of stakeholders and communicate the goals of the agency. A history of distrust in the federal government, an agency, or in the management of a particular public resource can create a negative atmosphere that is difficult to dispel (Lawrence and others 1997). Additionally it is much easier to destroy trust than for trust to be built since negative events have much greater impact on self reported trust than do positive events (Slovic 1993)

1.2 Public Participation

Although the benefits and outcomes attributed to trust are somewhat clear, promoting and maintaining trust between institutions and stakeholders is not an easily accomplished goal (Johnson 1999). The most common tool available to most natural resource policy-makers to promote trust is the inclusion of stakeholders in the decision-making process. However, neither trust nor participation is one size fits all. Measurements for success of these public engagements vary and general typologies of participation are not easily developed (Chess and Purcell 1999). The term "public participation" refers to a diverse set of activities which range in the terms of who is involved, how early and often in the process, and who has influence in the final outcome (NRC 2008). Over the years, a set of general guidelines for public participation have emerged (Rowe and Frewer 2000) highlighting the importance early contact and information exchange between both parties in the planning process. Researchers have also drawn attention to the importance of increasing the perception of procedural justice (Webler and Tuler 2000) by promoting fairness and offering multiple opportunities and methods for engaging public audiences to minimize perceived barriers, increasing the likelihood that the public feels their input is valued. In a natural resource context, Smith and McDonough (2001) outline six themes which emerged from focus group conversations regarding ecosystem management project and call attention to the importance of representation, voice, consideration, logic, and desired outcomes when including the public in ecological decision-making.

1.3 Trust and Participation in US Fisheries Management

This paper uses the case of fisheries management in the northeast to explore the relationships between an individual's knowledge of the resource, perceptions of resource health, and participatory experience on levels of trust. Using survey data collected from 244 avid anglers in the Northeast U.S., we test these relationships using structural equation modeling. Recreational marine fisheries in the U.S. offer an ideal model to investigate individual factors which may influence trust in natural resource institutions beyond the local community case study approach since recreational fishermen are a loosely-connected and diverse group of stakeholders.

Additionally, marine fisheries management in the U.S. is designed around public participation. Outlined by the Magnuson Stevens Act (1976), resource managers consult with stakeholder groups throughout all phases of management, from the initial scoping process to selecting harvest regulations, as a way to align the goals and for management to integrate stakeholder knowledge into the management process. Stakeholders are even invited to participate in some aspects of scientific assessment (Kaplan and McCay 2004) which has been shown to increase industry buy-in of management procedures (Johnson and van Denson 2007). Further, members of the management bodies (regional fisheries management councils) are comprised of appointees who reflect the stakeholder make-up of the fisheries under management (e.g. commercial fishermen, recreational fishermen, environmental NGO representatives). Designing the fisheries management system in this manner is deliberate and expected to increase legitimacy in decision-making and produce more effective regulations by increasing cooperation in common property management (Wilson and others 2003).

1.4 Study Objectives

Even with an extensive and ongoing participatory system in place, levels of trust between fishery stakeholders and management are not well understood. This is especially true of geographically dispersed recreational anglers for which there is little data to support both their ecological and political impact in modern fisheries management (Arlinghaus 2005). Further, factors which affect levels of trust are also not well known in a recreational fisheries context. Trust in institutions may be influenced by many recent scientific reports of dwindling fishery resources, significant stock declines, and high-profile cases where biological extinction has been predicted (Worm and others 2006). Conversely, trust in institutions could be influenced by personal fishing experiences that anglers have when they fish and whether they consider the resource to be healthy. Currently, there is no evidence to support either claim. Additionally, fisheries decision-making, like many environmental policy decisions, relies heavily on the scientific assessment of the resource (population estimates) and fishing pressure (amount and frequency of fishing activity) to set seasonal regulations. These estimates are often made under conditions of uncertainty yet have very direct implications for anglers since they are used as a reference point for setting harvest limits. Therefore, expanding the examination of trust to include scientific methods underpinning used to create management decisions may also be a useful step forward for the trust literature.

2. Materials and Methods

Here, we focus our investigation on stakeholder trust as influenced by cognitive factors, specifically angler familiarity about fundamental fisheries management processes and science concepts. Additionally, we compare how fishers rate the current state of fisheries resources as another form of potential evidence used to make trust judgments. Finally, we compare the relative amount of these influences with angler reports of participation in fisheries management and its influence on trust of institutions and scientific methods used to create fishing regulations. To investigate these issues quantitatively we used structural equation modeling (SEM) which is a type of multivariate analysis used to determine strength of associations between latent constructs. SEM is an advantageous technique because it allows for simultaneous testing of the measurement and structural models and adjusts for measurement error. Two types of latent variables can be measured through SEM, endogenous or variables which are used to predict a response in the model and exogenous or variables which are the response variables.

We hypothesize that all of these factors: high familiarity with fishery science and management processes, high resource ratings, and participation in fisheries management will result in higher levels of trust of management institutions (state, regional, and federal), and science (scientific assessments used to create recreational and commercial harvest limitations) (Figure 1) . To test these ideas empirically, we propose to test the following hypotheses:

H1: High ratings of knowledge of fisheries science influence higher level of trust in state, regional, federal institutions and recreational and commercial science

H2: High ratings of knowledge of fisheries management influence higher level of trust in state, regional, federal institutions and recreational and commercial science

H3: High ratings of fishery resource health influence higher levels of trust in state, regional, federal institutions and recreational and commercial science

H4: Participation in fisheries management will influence higher level trust in state, regional, federal institutions and recreational and commercial science

[Insert Figure 1]

Our model was constructed on the basis of qualitative research and initial stakeholder interviews which has been shown to be an effective two-tiered approach to constructing latent variables for SEM (Chung and Kim 2009). We used ordinal scales and several individual questions to measure most latent variables in the model except participation which was binary. Both ordinal and binary data have been shown to be appropriate measures for SEM (Dietz and others 2007). Additionally, our survey development was guided by past SEM studies which used scaled instruments to measure similar latent constructs such as risk (Needham and Vaske 2008) trust, (Chung and Kim 2009; Dietz and others 2009) beliefs (McFarlane, Stumpf-Allen and Watson 2007) and knowledge and familiarity (Skogen and Thane 2008).

2.1 Exogenous Variables

Components of Fisheries Management and Science

We divide the exogenous variables into five separated components: three levels of fishery management institutions (state, regional, and federal) and two components of fisheries science (methods used for assessment of recreational stocks and pressure, and those used for commercial stocks and pressure). Although these institutions and scientific methods are related and rely on one another to make decisions, they can be considered discrete entities since management jurisdictions and decisions do vary by state, region (there are eight regional Councils in the U.S.), and federal levels.

2.2 Endogenous Variables

Familiarity of Fisheries Management and Science

Rival knowledge systems (Dobbs 2000; Skogen 2001) and familiarity with concepts key to fisheries management and may contribute to the level of trust between users and institutions. Knowledge systems are mental constructs held by individuals and refer to a coherent set of cognitions and practices endemic to a community (Richards 1985). This potential disconnect between the often quantitative scientific assessment of resource health and users' qualitative assessment of resource health may account for different preferences for management. Schisms originating from the tension between scientific knowledge and lay knowledge may increase resource conflicts (Skogen and Thrane 2008) and decrease trust. Additionally, low levels of knowledge or familiarity with institutional practices increases the difficulty individuals have in making direct and adequate assessments about the risks and benefits of various environmental management policies. Thus, the amount familiarity and knowledge stakeholders may have about an institution and its practices are likely to influence the amount of trust in a decision-making institution (Dietz and others 2007).

Rating of the Resources

Evidence of institutional success or failures, whether accurate or not, is expected to influence trust of natural resource management institutions. Recreational anglers spend a great deal of time interacting with nature and their evaluation of the current resource conditions, or productivity of these areas, may influence whether they trust the performance of management bodies. Evidence of ecological health may also influence risk perception. In other wildlife contexts, hunter stakeholder groups who perceived less ecological degradation reported higher ratings of trust of management institutions (Needham and Vaske 2008). We contend that similarly rating the harvested resources highly will result in higher levels of trust while low ratings of harvested resources will result in lower levels of trust.

Participation in Fisheries Management

Trust has been repeatedly highlighted as an indicator of success criteria in participatory decision-making and planning (Beierle and Konisky 2000; Chess 2000; NRC 2008). Participation in management processes is thought to increase trust of management institutions. The term public participation refers to a number of activities and ranges from after-the-fact education programs to environments in which decision-making power resides solely with stakeholders (Arnstein 1967; NRC 2008).

2.3 Study Participants

Participants in this study were attendees at two northeastern US saltwater fishing expositions in the winter and spring of 2008. These are large trade shows typically held in convention centers or similar venues with attendance averaging between 5,000 and 10,000. Exhibitor booths at these events range from recreational fishing services and equipment to non-governmental and governmental organizations. They are usually held in late winter in the northeast US when conditions for fishing are poor. Study participants were general audience attendees over a period of three days. Survey response rates were similar at both 3 day events in New Jersey (n = 118) and in Rhode Island (n = 122).

Although some typologies of recreational fishermen exist based on consumptive behavior (Fedler and Ditton 1986) and fisheries policy support (Arlinghaus 2005), recreational anglers remain a diverse group who are not easily divided into categories. Our sample represents a cross-section of coastal anglers who were predominantly male (~95%). Most reported to fish from personal boats in coastal waters at least 6-12 times per year (~79%) and most (64%) fished on average more than once a week. According to recent assessments, the average recreational angler effort is 13 days per year in New Jersey and 11 days per year in Rhode Island (US Fish and Wildlife 2006). Thus, the majority of our study participants reported well above average fishing effort compared to the general population of recreational fishermen in both states and can be thought of as avid or frequent marine anglers.

2.4 Survey Instrument

Prior to surveying, local interviews were conducted and a pilot questionnaire was developed and administered to a subsample of 34 recreational fishermen at a recreational fishing club in New Jersey. Questionnaire items were validated through informal interviews for face validity and Confirmatory Factor Analysis (CFA) was used to increase construct validity. The final survey instrument was administered in person (either computer-based or pen and paper) at the two events. Researchers manned a booth and anglers were solicited to take part in the study. To address knowledge about fishery science, we measured angler confidence in fundamentals of fishery assessment knowledge such as understanding the relationship between size and age and how to determine healthy habitat for larval or juvenile fish. To address knowledge about civic literacy, we measured confidence with fishery management procedures such as how to be involved in the management process and how fishery management plans are determined. To address their knowledge of the state of fishery resources, we measured their current ratings of the health of the fisheries they participate in most and other regionally important species. Finally, we asked if they participate or do not participate in fisheries management. The relationship between angler responses to these categories and level of trust was then evaluated using a SEM (see Table 1).

[Insert Table 1]

3. Results

To validate and compare the factors affecting recreational angler's level of trust of fisheries institutions and science, factor analysis from the survey results were used to minimize the dataset which validated the latent constructs hypothesized to influence trust in fisheries management. Next, a hypothesized SEM was developed. Although SEM requires a larger sample size than most statistical methods, our respondent number of 244 is sufficient to run a model.

To validate the latent variables and questions, we carried out a reliability analysis using Cronbach's Alpha. Under the analysis, items which had low factor loadings (< 0.6) or low Cronbach alphas (<0.6) were omitted as suggested by Kim (2004) and Salisbury and others (2001). Using this reliability analysis, the final latent variables and questions which comprise these constructs are shown in Table 1. Ultimately, fisheries science knowledge included three variables, fisheries management knowledge included five variables, rating of the resources included four variables, and participation included one variable. To test the hypothesized model, maximum likelihood estimates were obtained using AMOS 17 software. The covariance matrix used to fit the proposed model was calculated using survey data collected in both New Jersey and Rhode Island and parameter estimates were obtained.

Confirmatory factor analysis validated question categories and Cronbach's alpha for all latent variables indicated reliability between 0.84 - 0.91. Several model fit measures are usually used to determine goodness of fit (Table 2). The most common of which being the chi-square fit index which should reflect no significant difference and the model would ideally yield a value of between 2.0 and 5.0. The root mean square error of approximation (RMSEA) provides an indication of the discrepancy between the observed and model generated covariance. A RMSEA value >.05 indicates a good fitting model where a value between .05 and .08 indicates a reasonable model fit and >.08 indicates an ill fitting model. Goodness of Fit Index (GFI) and Adjusted Goodness of Fit Index (AGFI) measures fit compared to no model at all (Jöreskog and Sörbom 2001) and both values should be >0.9 (GFI) and >0.8 (AGFI).

[Insert Table 2]

Knowledge of Fisheries Management and Science

Survey responses indicate similarities between New Jersey and Rhode Island recreational fishermen in rating their familiarity with fishery science and fishery management on a scale from (1) very knowledgeable to (5) very unknowledgeable. Overall, recreational fishermen hovered around the slightly knowledgeable side the middle designation (3.0) with determining age class based on size (2.45), healthy habitat designation for larval andjuveniles fish (2.63) and determining sex of a fish when caught (2.98). Similarly, recreational fishermen had higher, but similar mid-range ratings of familiarity with civic aspects of fisheries management such as how size (2.13) and catch (2.12) limits were determined with less reported familiarly with how to be involved in the fisheries management process (2.66) familiarity in the development of fisheries management (2.66) plans and fishery legislation (2.60).

Ratings of the Resource

Overall, recreational fishermen rate the current state of fisheries resources as fair to good in all categories on a scale from (1) Excellent to (5) Very Poor. The bluefish fishery was most highly rated (2.05), followed by the fishery the individual participates in most (2.30), followed by overall regional (either Aid-Atlantic or New England) resources (2.67) with similar ratings for the summer flounder fishery (2.66).

Trust by Management Construct

Survey results indicate that trust in fisheries science and management varies by scale. Survey responses for amount of trust for state, regional, federal, recreational science and commercial science were averaged. Only state (2.82) and regional (2.90) institutions were more trusted than not trusted while recreational (3.01) science, federal level management (3.08) and commercial science (3.38) all fell on the distrust side of the spectrum.

Structural Equation Modeling

The SEM standardized multiple regression indicated that participation had the most influence in determining level of trust (Table 3). In fact, participation predicted strong positive correlations with state (0.72), regional, (0.77), federal (0.79), recreational science (0.79) and commercial science (0.82). These were all found to be statistically significant. Ratings of the resources were also found to have positive correlations and strongly influence trust, but only significantly for state (0.26) and regional (0.26) levels of management and not for the other constructs. Further, fisheries science and management knowledge were found to be negatively correlated with both types of science meaning the more confident anglers report being in these areas, the less trust they had for these areas. This negative correlation, however, was not found to be significant, but do highlight a general trend.

[Insert Table 3]

4. Discussion

Of the variables investigated, participation in fisheries management was the most significant predictor of trust in both fishery management institutions and fisheries management science in avid recreational angler groups in the Northeast U.S. These findings are important since previous studies have long supported that trust increases as the level of participation in decision-making increases (Beierle and Konisky 2000; Chess 2000; NRC 2008). Less is known, however, about how level of trust of scientific methods of environmental assessment may vary with participation. Science plays a unique role in environmental decision-making and ideally assessments are guided by the knowledge, values and preferences of the affected parties (NRC 2008). However our results indicate that stakeholders may also learn to trust scientific assessments as they become more familiar with the assessment techniques, questions, and the institutions charged with conducting them through participation. As Beratan (2007) points out, shared understanding and trust are built through many personal interactions over time which facilitates learning. Participating in decision-making may allow for opportunities for this type of learning. As stakeholders gain a better understanding of institutional values and practices, the goals and intent of scientific assessments may become more familiar, therefore increasing trust.

Our survey results also showed overall low levels of trust in scientific assessments. Previous studies of the general public have linked these low levels with the inability of the public to differentiate between science and the resulting policies (Haerlin and Parr 2001). Past researchers have linked declining trust in science to a lack of credibility in scientific institutions based on the inadequacies of science to develop clear solutions to contemporary societal issues (Haerlin and Parr 2001). These failures, however, are more likely attributable to imperfect policies rather than imperfect science and the public may not clearly see the difference between the two. Low levels of trust in science have also been linked to conflicts of scientific interest (Friedman 2002). Although the scientific method is ethically neutral, participants in our study rated commercial scientific assessments as less trusted than recreational scientific assessments. This is an indication that recreational anglers see a difference in the processes or outcomes in the two. During fisheries decision-making process, outcomes of these assessments are susceptible to influence from counter viewpoints from other resource users, like commercial fishermen or environmental NGOs, which may influence the policy adopted based on the science- but most likely not the assessment itself. Low levels of trust in science have also been attributed to the ability of science to limit personal freedoms (Lidskog 1996). In a fisheries context, scientific assessments are used to limit recreational and commercial harvest. Trust, then, may decrease when the public feels that scientific assessments will directly limit their fishing behaviors. Exact reasons for low ratings of trust in science, however, are still unclear and are an area that would benefit from further research.

Higher ratings of fishery resources were found to indicate higher levels of trust in state and regional management. These ratings indicate that resource health may be attributed to the decisions and actions of smaller scale management institutions. Further, trust appears to decrease overall by scale. Past research has indicated that familiarity is thought to affect trust (Dunn and Schweitzer 2005) and local level governance is often more trusted than higher levels of organization (La Porta and others 1997). In a natural resource context, our data indicate that when there is evidence that the resources are doing well, resource user may consider it to be the result of smaller scale management decisions. This may be problematic since assessing many ecological problems requires understanding large spatial scales using evidence beyond local experiences (Jordan and others 2009). Further, significant resource declines may take long periods of time for stakeholders and managers to notice. This has already been witnessed with the slow but constant decline in some of Canada's recreational fisheries which has been called the "invisible collapse" (Post and others 2002) since declines in resources have gone largely unnoticed by both managers and the general public.

There are still many questions regarding other reliable predictors of trust in natural resource management. In our study, familiarity with scientific concepts used to make regulations was not a significant predictor in trust judgments in fisheries science. Likewise, familiarity with fishery management processes did not yield significant positive associations with trust judgments of institutions. These results indicate that trust is not affected by how knowledgeable individuals might be about the abstract components and processes of environmental management. Rather, it is much more important that stakeholders have an opportunity to interact with these components. These findings uphold criticisms of the 'deficit model', since our data show that familiarity with technical aspects (either scientific or civic) has no association with stakeholder trust. As Rowe and Frewer (2000) point out, there is not only a need for institutions to learn how to effectively communicate complex ideas to stakeholder groups, but also to create opportunities where these complex ideas can be discussed and debated (Frewer and Shepherd 1998)

It is important to note that building trust is a dynamic and evolving process. Trust in our study was measured at a particular point in time; however these levels are not likely to remain constant. Rather, they are likely to change with new developments within fisheries and their management. Trust is fragile, slow to grow and easy to break and as stakeholders learn about potential changes in management action, stakeholder trust may change (McKnight and Chevany 1996; Beratan 2007). However, the process of building trust is also seen as self-reinforcing where existing trust may maintain trust in the absence of new events or information (Blomqvist

1997). Therefore, although we report the levels of trust at a certain point in time, we can only expect these levels to remain as constant as new significant developments in the fishery.

5. Conclusions

The results of our investigation on trust can be interpreted as both a learned and affective responses. As many have pointed out, participation in decision-making by those affected by the decision is thought to increase trust (Beierle1998; Beierle and Cayford 2002; Dietz and others 2003; NRC 2008). This is the result of institutions and users forming relationships where the goals of both groups are clearly articulated (Rousseau and others 1998; Beratan 2007). In these cases, trust is the result of active information processing and relies less on emotions and more on a learned experience. However, in large-scale environments where there few interactions between institutions and stakeholders, stakeholders will rely more on evidence generated from their own experiences and associations to determine the intentions of institutions. Dunn and Schweitzer (2005) found that when there is little history or experience between individuals and a trustee, emotions supplant information to form trust judgments. Thus, higher ratings of trust can be expected with smaller scale institutions and when experience indicates to stakeholders that the resources and the environment are healthy.

It may be more difficult, however, to build trust in the scientific methods used to make resource management decisions. Although our study indicates that participation in environmental decision-making is positively associated with trust in science, low ratings of trust in science were reported overall. Previous studies have linked distrust to science to stakeholder conflation of scientific assessment, the resulting policy, and the outcome of policy (Haerlin and Parr 1999). Therefore, natural resource managers should clearly outline the scientific questions being asked, the methods, knowledge produced, and how this knowledge informs natural resource management decision-making.

Acknowledgements

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Tables and Captions

Table 1. Summary of latent variables, measurement instrument, question loadings, validation and averages to questions responses for NJ and RI

Latent Variable Survey Questions	NJ Mean (SD)	RI Mean (SD)	T Mean (SD)	alpha**(α)** loadings
*Knowledge of Fisheries Science**				**.89**
Habitat conditions needed for larval or juvenile fish	2.60(1.3)	2.65(1.3)	2.63(1.3)	.75
Determine age class based on size	2.37(1.1)	2.54(1.0)	2.45(1.0)	.71
Determine sex of a fish caught	2.8(1.2)	2.9(1.2)	2.98(1.3)	.70
*Knowledge of Fisheries Management**				**.91**
How size limitations are determined	2.07(1.1)	2.20(1.1)	2.13(1.1)	.78
How catch limitations are determined	2.11(1.1)	2.15(1.1)	2.12(1.1)	.77
How to be involved in the management process	2.66(1.4)	2.66(1.4)	2.66(1.4)	.74
The development of Fishery Management Plans	2.72(1.4)	2.62(1.4)	2.66(1.4)	.72
The Magnuson Stevens Act	2.65(1.5)	2.5(1.6)	2.60(1.6)	.69
*Rating of the Resources***				**.84**
Overall fishery resources	2.61(1.1)	2.71(1.1)	2.67(1.1)	.72
Fisheries in which you participate most	2.25(1.1)	2.35(1.1)	2.30(1.1)	.67
Summer flounder fishery	2.42(1.3)	2.9(1.2)	2.68(1.3)	.73
Bluefish fishery	2.04(1.0)	2.07(1.0)	2.05(1.0)	.66
*Institutional Trust ****				**.90**
State Fisheries Institutions	2.84(1.4)	2.78(1.2)	2.82(1.2)	.73
Regional Fisheries Management Councils	3.08(1.4)	2.84(1.1)	2.9(1.3)	.79
Federal Fisheries Management (NMFS)	3.27(1.5)	2.7(1.4)	3.01(1.5)	.81
*Scientific Trust****				**.90**
Assessment science used to set seasonal limits for Commercial fishermen	3.66(1.4)	3.13(1.3)	3.38(1.4)	.81
Assessment science used to set seasonal limits Recreational fishermen	3.33(1.5)	2.87(1.2)	3.09(1.4)	.80
Participation				
Do you participate in Fisheries Management in some way?	Yes: 48% No: 52%	Yes: 38% No: 61%	Yes: 43% No: 57%	n/a

*Scale of (1) Very Knowledgeable to (5) Very Unknowledgeable
**Scale (1) Excellent to (5) Very Poor
***Scale (1) Fully Trust to (5) Fully Distrust (3 is neutral)
α derived Cronbach's Alpha reliability test and factor loadings derived from Principle Components Analysis (PCA)

Table 2. Summary of model fit indices, recommended, and obtained values for hypothesized model

Statistic	Recommended value	Obtained value
X^2	-	286.95
d.f.	-	116
X^2/d.f.	P > .05**	2.47
Goodness of Fit (GFI)	>.9**	.900
AGFI	> .8**	.829
CFI	>.9**	.932
NFI	>.9**	.900
RMSEA	.05 - .08**	.078

**surpasses recommended value

Table 3. SEM coefficients, and standardized multiple regression coefficients**.*****indicates significance at $p > .05$

	Trust of Fishery Management Institutions			Trust of Fishery Science	
	State	Regional	Federal	Recreational	Commercial
	Coefficient (Standardized β)	Coefficient (Standardized β)	Coefficient (Standardized β)	Coefficient (Standardized β)	Coefficient (Standardized β)
Fishery Science Knowledge	.06(.04)	-.05(-.04)	-.03(-.02)	-.04(-.03)	.19(.12)
Fishery Management Knowledge	.01(.01)	.12(.09)	.08(.06)	-.05(-.03)	-.08(-.05)
Resource Ratings	.36(.26)***	.37(.26)***	.18(.11)	.10(.07)	.10(.06)
Participation	6.99(.72)***	7.53(.77)***	9.19(.79)***	8.56(.79)***	9.02(.82)***
R^2	.58	.68	.69	.64	.68

Figures and Captions

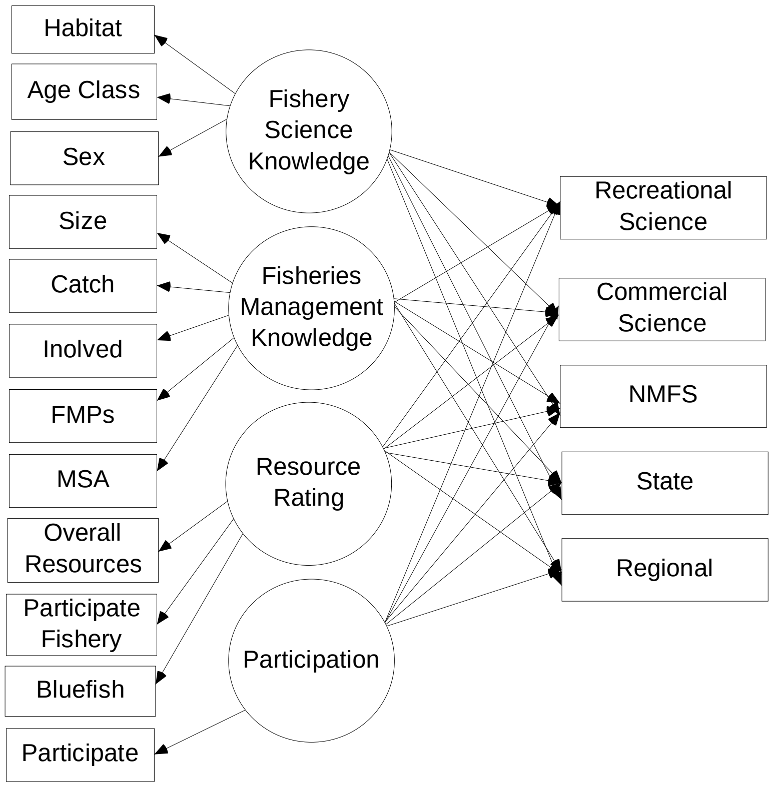


Figure 1. Hypothesized SEM. Rectangles indicate measured variables and ellipses indicate latent variables

Chapter 4: Ecosystem-based Angling: Incorporating Recreational Anglers into Ecosystem-based Management

(in press *Human Dimensions of Wildlife*)

Abstract

Coastal management institutions and recreational fishermen share concerns about the current state of marine fisheries. This article provides coastal managers with an outreach framework for recreational fishers that contextualizes social and ecosystem information toward the goals of ecosystem-based management. Based on a survey of anglers conducted at saltwater fishing expositions in the Northeast US and on the literature, we report data on perceptions of recreational anglers about potential threats, individual fishing impacts, preferred modes of communication, conceptions, and behavior. We conclude that outreach campaigns should (a) focus on the perceived threats to the resource, (b) contextualize and justify the recommended pro-ecological target behaviors, (c) include topics of general interest to anglers and (d) communicate through socially trusted sources.

Key Words: Ecosystem-based Management, Recreational fishermen, Education, Outreach, Stakeholder communication, Recreational Marine Fisheries

Introduction

Ecosystem-Based Management (EBM) has been championed by many as the future of fisheries management (Dulvy, Sadovy, & Reynold, 2003; Francis, Hixon, Clarke, Murawski, & Ralston, 2007; Murawski, 2007; NRC, 2006; Pauly et al., 2002; Pauly et al., 2003; Pikitch et al., 2004). EBM is an integrated and science-based approach to the management of natural resources that focuses decision-making on sustaining the health of an ecosystem, rather than solely on the goods and services derived from an ecosystem. Shifting paradigms from traditional single species or sector management towards a more holistic strategy has obvious merits. This shift, however, relies heavily on inter-institutional arrangements, increased knowledge of stochastic variation in ecosystem processes, and the integration and collection of copious amounts of continuous biological, ecological, and social data. Scholars and scientists are currently struggling to identify management policies that move EBM from a theoretical framework into an actionable plan (Tallis et al., 2010).

Although complete institutional implementation of EBM for fisheries is yet to come, we contend that fishery management agencies can begin to formalize ecosystem stewardship by providing educational resources to recreational fishermen about their role and potential impact within ecosystems. Encouraging understanding and engagement with ecosystem processes and management procedures is likely to increase aspects of fishery science literacy, alter negative resource-user behaviors, and potentially create partnerships between managers and stakeholders to respond to social-ecological problems. For example, in a review of case studies of invasive species, Browne, Pagad, and Poorter (2009) concluded that resource stakeholders need shared collective access to

(a) science-based biological and ecological information about target species, (b) prevention strategies and management techniques, and (c) case studies from other regions facing similar problems. Based on studies like these, conservation scientists have initiated calls to action for biologists from academic, NGO, and government institutions to increase their efforts to publically communicate the science underlying contemporary environmental issues and management action (Barbour, Poff, Norris, & Allan, 2008; Brewer, 2001; Brewer, 2002; Jordan, Singer, Vaughan, & Berkowitz, 2008). Given that providing stakeholder groups with key information under certain circumstances is likely to increase effective responses to social-ecological problems, we seek to target information that can be disseminated to recreational fishers in an effort to increase pro-environmental behavior consistent with EBM.

Methods

To build this framework, we present (a) data from a survey administered to 244 marine recreational anglers in the Northeastern US with the intent to characterize marine recreational anglers as a stakeholder group, ecosystem component, and audience; and (b) a review of relevant literature regarding the relationship between recreational fishing behavior and ecological issues facing many coastal systems.

Study Participants

Participants in this study were attendees at two northeastern US saltwater fishing expositions in the winter and spring of 2008. These are large trade shows typically held in convention centers or similar venues with attendance averaging between 5,000 and 10,000. Exhibitor booths at these events range from recreational fishing services and equipment to non-governmental and governmental organizations. They are usually held

Friday through Sunday in late winter in the northeast US when conditions for fishing are poor. Study participants were general audience attendees over a period of three days. Number of survey responses were similar at both three day events in New Jersey (n = 118) and in Rhode Island (n = 122).

Although some typologies of recreational fishermen exist based on consumptive behavior (Fedler & Ditton, 1986) and fisheries policy support (Arlinghaus, 2005), recreational anglers remain a diverse group who are not easily divided into categories. Our sample represented a cross-section of coastal anglers who were predominantly male (~95%). Most reported to fish from personal boats in coastal waters at least 6-12 times per year (~79%) and most (64%) fished on average more than once a week. According to recent assessments, the average recreational angler effort is 13 days per year in New Jersey and 11 days per year in Rhode Island (US Fish and Wildlife 2006). Thus, the majority of our study participants reported well above average fishing effort and can be thought of as avid or frequent marine anglers.

Survey Instrument

Because EBM requires assessment and understanding of how social (e.g., harvesters and management institutions) and ecological systems (e.g., communities, stocks) operate together (Tallis et al., 2010), the survey was comprised of three main categories (a) angler perceptions (b) angler behaviors and (b) present and preferred modes of angler communication (Table 1). Prior to data collection, a pilot questionnaire was developed and administered to a subsample of 34 recreational fishermen at a recreational fishing club in New Jersey. Items were validated through informal interviews about the survey questions. The survey instrument was administered in person (either computer-based or pen and paper) at the two events. Survey responses were then analyzed. Open-ended participant responses were categorized using post-coding (Miller, 1983) to identify emergent themes following Strauss and Corbin's (1990) data interpretation techniques. Categorical data were summed to determine frequencies of response.

Given the diffuse nature of collective recreational fishermen pressure (Post et al., 2007), and high value recreational anglers place on fish stocks as an ecosystem service (Feddler & Ditton, 1986) survey questions were developed to test the following two main hypotheses:

H1: The majority of avid recreational fishers do not consider their individual fishing behaviors to have an effect on the ecosystems in which they fish.

H2: The majority of avid recreational fishers will be open to receiving information about low cost behavior changes that can be adopted to better care for the ecosystems in which they fish.

[Insert Table 1.]

Results

Results from the survey and the literature are integrated and presented in three sections. In the first section we compare recreational fishermen perceptions of threats to- and perceived effect on- marine fisheries with those issues currently being dealt with by fishery management institutions. In the second section, we present content based on the literature that might be covered when outreach programs are developed. In the last section we discuss angler present and preferred modes of communication.

Understanding Recreational Fishermen

Past research has highlighted the importance of aligning environmental values and current level of stakeholder understanding with strategies for communicating behavioral change (Dietz, Fitzgerald & Shwom, 2005; Shiller et al., 2001; Stern, Dietz, Kalof, & Guagnano, 1995). Caron and Johnson (2006) recommend that shared values of institutions and stakeholders be clearly discussed so the information communicated might be integrated within the existing beliefs of stakeholder groups. For recreational anglers, this requires developing an understanding of what components potentially pose a threat to marine fish stocks, the perceived impact that an angler might have on the system and where these align with management objectives.

Threats to Marine Ecosystems.

The threat to marine fisheries mentioned most often by recreational anglers was that of commercial fishing practices (48%) (Figure 1). Commercial fishing includes commercial discards, gear technology, and increasing commercial fishing pressure. The second threat mentioned most often was overfishing (17%). This category is included separately from commercial pressure and includes recreational take and non-compliance of management control measures. The third most frequently mentioned threat was that of decreasing water quality (9%). Although in fisheries, water quality is most readily linked to habitat conditions, it also represents the abstract idea of point and non-point source pollution, which was evident in responses like “pollution,” “industrial pollution,” and “run-off”. The fourth most mentioned threat was risks that arise from “bad”, “misinformed”, or “politicized” management decisions (9%). This threat was seen as arising from political pressure from other stakeholder groups which bias management decisions or the lack of coordination across local, state, and regional institutions. Fifth, was the perceived threat of disruption to ecological balance resulting from selective fishing pressure (6%). This threat also includes mention of loss of forage fish (e.g., mainly attributed to increasing commercial pressure over the years for species like menhaden, *Brevoortia tyrannus*) and the protection of top trophic species (e.g., spiny dogfish (*Squalus acanthias)* in the geographic area surveyed). Five additional threats by decreasing frequency of mention were habitat degradation (3%), uncertainty in biological assessments (3%), political influence (2%), global warming (2%), and environmental groups (1%).

[Insert Figure 1]

Perceived effect on ecosystem processes. Forty-nine percent of the recreational fishermen surveyed felt that their fishing behaviors had no effect on the ecosystems in which they fished while 38% felt that their fishing actions had an effect on the ecosystem. Thirteen percent reported that they did not know. When those that did not feel their behaviors had a negative effect were asked a follow-up question to justify their answer, responses fell into three categories. Most, (54%) reported engaging in catch-and-release as their primary fishing practice and 37% attributed their non-impact to engaging in responsible fishing practices. The remaining (8%) explained that as recreational fishermen, their influence on the ecosystem was insignificant when compared to that of commercial fishermen and other sources of other environmental problems like "pollution". When those that considered their fishing behaviors to have an effect were asked the follow-up question, 61% attributed their effect to initiating small perturbations like leaking oil from their boat engine or losing debris overboard. The remaining 39%

report that removing individuals from a population will have some affect on the ecosystem as a whole.

Receptiveness to education and outreach. When asked about openness to receiving information about altering behaviors which promote ecosystem health, recreational fishermen overwhelmingly (86%) said they would be receptive to receiving new information. Only 9% said they would explicitly not like to receive any additional information and the remainder (5%), were unsure one way or the other.

What do Recreational Fishermen Need to Know?

Research has indicated that recreational fishing practices (in addition to direct fishing pressure) and other types of recreational marine use may have measurable impacts on coastal ecosystems. Recreational fishing activities such as catch and release (Danylchuk et al., 2007; Wilde, & Sawynok, 2009), leaving debris (Danner, Chacko, & Brautigam, 2009), and fishing gear choice (Fobert, Meining, Colotelo, O'Connor, & Cooke, 2009) all have the potential to have an indirect effect on fish populations and overall ecosystem health. Other activities associated with recreational fishing, such as boating (Lloret, Zaragoza, Caballero, & Riera, 2008; Pielhar, Maloney, & Paerl, 2002) and increasing development in coastal communities, have also been shown to have significant negative impacts (Smith, 2000).

Inspired by practical recommendations provided to fishery scientists and managers that aimed to remove EBM from an ambiguous construct and place it within a decision-making context (Francis et al., 2007), we attempt to provide similar guidelines for recreational anglers. Using these past recommendations as a foundation, we contextualized important ecosystem concepts for recreational anglers using the survey described above combined with a review of the recent literature about the negative impacts of recreational fishing. Although fishing behaviors, methods and their associated problems vary by region and ecology, we sought to provide management institutions with a starting point for developing resources meant to support integrated marine stewardship. Like EBM, content covered should largely reflect information collected about social and environmental factors endemic to the ecosystem being managed. The tips provided here are by no means exhaustive and are meant to be illustrative. The content covered is based on a review of recent human cognition and behavior literature as it relates to recreational fisheries. The content recommended here is divided into (a) conceptual information about fisheries science and EBM framework and (b) applied information meant to outline potential target behaviors for recreational anglers. Although studies in environmental education have outlined several additional factors beyond knowledge that influence pro-environmental behavior such as habits of mind, locus of control, and world-view (Hines, Hungerford, & Tomera, 1986; Stern 1995), we sought to focus on contextualizing information about EBM target behaviors which are grounded in the coastal management literature.

Recommended Concepts for EBM

Promote a Perspective that Embraces Complexity.

Humans are not good at estimating long-term changes over space and time (Sterman, 2008) and individuals may be biased by anecdotal or personal experiences even in light of larger-scale information (Slovic, 1979) . However, it is important for managers, scientists, and the public alike to keep a perspective that acknowledges that human activity both directly and indirectly affects biological productivity (Francis et al., 2007). Even though it is assumed that a recreational fisher's goal is to seek one specific type of fish when fishing (e.g., ~ 97% surveyed indicated they fished most often for one of three different species of fish), the factors that affect whether that fish is available to catch relies on other factors. In short, it is important to communicate systems-thinking to anglers so that it might guide their actions and promote reflection of individual behaviors when they are on the water and at home. Promoting understanding of complex systems and indirect effects, however, is not an easily accomplished goal (Sterman & Sweeney, 2002). Research has indicated that the use of qualitative models, like concept mapping and flow charts, may be useful when attempting to communicate inter-related connections between system components (Plate, 2010). Additionally, the Structure-Behavior-Function or SBF ontology has been shown to facilitate learning about complex biological systems (Hmelo, Holton, & Kolodner 2000) through explicit articulation of the what (structures), the how (behaviors), and the why (functions). This mental framework allows learners to organize their mental representations about a given system and reduce its complexity into more manageable components.

Larger and Older Fish may Play a Disproportionate Role in Population Structure

Many fishers seek to catch "trophy" fish. This process has largely been supported by traditional fisheries management based on two major assumptions. The first is that eggs and spawning behavior of females belonging to long-lived species are of identical quality and quantity (Beverton & Holt, 1957). Second, the removal of larger members in the population is acceptable since these larger and older adults have already recruited and are therefore considered surplus production. Recently, however, these assumptions have been challenged. As Francis et al. (2007) point out, information to the contrary

(Niklosky, 1953) has long been available. In particular, it is widely acknowledged that larger and older individuals, especially females, might play a disproportional role to promote stock resilience given environmental fluctuations and sex-selective take (Hislop, 1988; Lauer, Shroyer, & Kilpatrick, 2005; Wilderbrauer & Turnback, 2009). Convincing sportsmen not to seek out the largest fish is no easy task, but providing information about the significance that older fish provide for the larger population may offer some appreciation for stock dynamics and highlight the complex nature of fish biology.

Understand the Relationship between Size and Age

Knowing why fishing restrictions are based on demographic data may shed some light on why it is important to follow the size and catch limitations established by fisheries management. When asked, most (89%) of our sample group knew why these regulations were established, however, many could not determine the sex of a fish (67%) or determine its age class based on length (57%). These individuals may not recognize what population based assessment may reveal for the health of the stock since they only experience a very local perspective (i.e., abundance at their fishing sites). It is also likely that these individuals do not encounter data on the varying demographics of a population or are aware of the relationship between size, age, and condition. Educational materials might do well to integrate some of these basics in to their guides and regulations. For a useful educational introduction to fisheries science in lay terms, see *Understanding Fisheries Management*, (Wallace & Fletcher, 1996).

Understand the Role of Juvenile Habitat

Many marine fish rely on healthy estuary and coastal areas for reproduction and these areas need to be maintained to ensure the viability of future generations. Increased development in coastal areas means a change in ecosystem function because of an increase in impermeable surface (e.g., roofs, parking lots) and human activity resulting in greater runoff that may adversely affect juvenile and adult habitat (Blann et al., 2009). When asked, most recreational fishers (67%) reported knowing how to determine in a visual survey if an area provides healthy habitat for adult fish, however, less (50%) reported knowing how to determine whether habitat is suitable for juveniles. Survey responses indicated that education efforts should include information on life cycle processes and associated qualitative ecological indicators of habitat health for both adults and juveniles.

Recommended Behaviors to Support EBM.

Reduce Boating Impact

Recent research has indicated that boating may have considerable negative impacts on ecosystem function (Smith, 2000). Boats produce harmful noise (Haviland-Howell et al., 2007), leak oil and gasoline (Pielhar et al., 2002), spread invasive species (Johnson, Bossenbroek, & Kraft, 2006; West, Davis, Barnes, & Wright, 2009) and disrupt species assemblages (Herbert, Crowe, Bray, & Shearder, 2009). These negative impacts, however, are largely preventable and researchers in this area have called for environmental education as a method by which to promote precautionary behaviors to mitigate potentially harmful outcomes associated with boating (Lloret et al., 2008). Potential solutions to these issues have been addressed through the promotion of speed zones, performing engine maintenance in controlled areas, routine hull cleaning (without antifoulants or biocides if possible), and attention paid to anchoring techniques in spatially explicit areas.

Carry in / Carry out.

It is estimated that about 20 states have promoted a "leave no trace" philosophy in their state parks by encouraging resource users to carry out any garbage or debris they carry in (Ohio Department of Natural Resources). While recreational fishermen are most likely aware that there is a negative effect of leaving plastics and other debris at their fishing sites, they may not be aware that releasing unused bait or organic material into these areas may also have a negative effect (Danner, Chacko, & Brautigam, 2009). Promoting awareness of absolute removal may be an effective way to curb unwanted material being left behind in fishing areas especially when outcomes are unknown.

Reduce Post-Release Mortality

Studies indicate that stress caused by harsh handling of fish can result in severe harm and death post-release through soft flesh tears (Fobert et al., 2009, Wilde, & Sawynok, 2009), removal of protective skin coating, and fatigue leading to easier predation (Danylchuck et al., 2007). It is important for anglers to remember that fish are subject to a variety of injuries when caught. Lack of working knowledge about post release mortality may be associated with our survey responses that indicated that recreational fishing ecological impact was low because many fishermen engaged in catch-and-release practices.

To minimize fish stress, choice of gear and appropriate methods for handling should be provided. For example, studies have indicated that when a fish is gut-hooked, cutting the line is expected to have less negative impact than removing the hook by force (Fobert et al., 2009). Promoting the use of new technology such as circle hooks may curb lethal or sublethal effects. If benefits are made clear, the adoption of stock-sustainable methods might be followed. In our survey, for example, 73% of fishermen said they used circle hooks when appropriate because they were easier to remove and were considered to cause less damage to the fish since they are specifically designed to snag the jaw.

Participate and Share Knowledge in Management

Fisheries scientists and managers recognize the need for help from fishermen, including cooperation in research, provision of experience-based and traditional knowledge, participation in crafting appropriate management responses, and compliance with regulations (Kaplan & Kite-Powell, 2000). State, regional, and federal systems in the US are designed for stakeholder participation and for communication flows in a variety of ways. Although approaches to co-management are varied, research in the social sciences indicates that participation in the management process by those who are to be regulated should greatly improve cooperation and efficacy (Jentoft, McCay, & Wilson, 1998; Kaplan & McCay, 2004). For an example of an educational document aimed at promoting participation in fisheries management see Fish or Cut Bait: A guide to Magnuson Stevens (McCay, Creed, & Gray, 2009).

Lines of Communication

Choosing how the information is communicated is as important as what is communicated. How information is framed and where is comes from will likely determine how, or even if, a message is received (Griffin, 1967). Studies of environmental risk communication have outlined that trust and credibility (Peters, Covello, & McCallum, 1997) are important factors that influence the likelihood of whether a message is ultimately accepted or rejected (Trettin & Musham, 2000). It is important to understand what type of information your audience is motivated to learn more about so that the content communicated can be paired with information of general interest (Krapp, 1999). Therefore, it is important to understand from where stakeholders are currently receiving their information, how they prefer to receive new information, and what type of information they are interested in learning more about.

According to our survey results, recreational fishermen are currently receiving their information about fisheries management from a variety of sources (Table 2). Fishery trade magazines in print and online were reported as the most consulted source of information (53%) closely followed by bait and tackle shops (49%). Also popular were other online sources (40%) which included both state and federal fishery websites and recreational angler "message boards" or fishing club sites. Additionally, one-third of fishers (33%) reported also getting information informally from other anglers. When asked where they would prefer to receive marine fisheries related information, most indicated they would like to received information online (85%) which was preferable to printed or mailed material (10%). The disparity between the response of preferring to receive information online (85%) and the current trends of receiving information online (40%) is unclear. This inconsistency, however, may be attributable to the lack of definition of the term "online" in the survey instrument. For example, "online" could refer to email updates sent directly to anglers or could refer to the existence of a website which can be accessed electively. When asked about fisheries topics they would like to know more about, 50% listed individual species by name (i.e., primarily the species they fish for most-often), 15% responded they would like to know more about fisheries management procedures or management decisions as they happen, while general fish behavior (feeding, habitat, spawning) and migration were both mentioned by 8% of the fishermen surveyed.

[Insert Table 2.]

Discussion

Based on our survey results, we can neither clearly reject nor accept our first null hypothesis about angler perception of their impacts on the ecosystems in which they fish. Rather, the perception of their role appears to be much more nuanced and complex. When survey responses are viewed within the context of EBM, we can synthesize two ideas about recreational fishers' understanding of marine fisheries dynamics and their role within the system. One, there is a general awareness that there are multiple factors, both consumptive (e.g., advances in commercial fishing technology, non-compliance) and non-consumptive (e.g., water quality, habitat availability) that may lead to degradation in ecosystem function and may affect stock availability. Two, survey results show that recreational fishers are divided as to their perceived effects on the ecosystem. The justification for viewing their effect as negligible varies slightly, however, coded responses indicate that most fishers already engage in what they consider "responsible" or "low-impact" fishing, especially when compared to the perceived negative effect associated with commercial fishing activity. Similar results have been shown in research evaluating individual behaviors and their relationship to other diffuse environmental problems such as climate change (Dietz, Dan, & Shwom, 2007). This finding is not surprising given that we surveyed individuals who are drawing from their own individual experiences and not from a knowledgebase that includes an understanding of aggregate-level recreational fishing behavior or effects. It is troubling, however, because the loosely connected nature of recreational angler effort has been linked to the “invisible collapse” and significant decline of some freshwater recreational fisheries (Post et al., 2002).

Our survey results, however, do allow us to draw clearer conclusions regarding our second hypothesis regarding angler openness to altering their current behaviors to align with more sustainable practices. Even with some disparity in terms of perceived effect, recreational fishers are overwhelmingly open to receiving information about behaviors that can minimize their impact on the marine fisheries they value. This finding is promising since education and outreach programs to stakeholder groups can be costly in terms of time and other resources and maybe difficult to maintain. Given their receptiveness, providing avid anglers with key information may be at least a partially effective strategy to manage ecosystems or alter the associated negative behaviors exhibited by recreational fishers. It is important to note that simply providing stakeholders with information does not necessarily lead to the adoption of new target behaviors that are in-line with management objectives (Chess & Johnson, 2006). Past studies indicate that prior beliefs and values have more influence on behavior than simply providing audiences with new information (Sturgis & Allum, 2004). Further, what is communicated should also be framed in terms of what is valued by the audience and not what “should” matter (Reardon, 1991). In the case of recreational fishermen and EBM, this requires that outreach strategies first understand anglers as a group so that similar goals and perceptions shared by managers, scientists, and anglers can be highlighted. Assemblers of content to be covered in outreach programs should steer away from a complete “deficit model” approach, which regards the lay audience as an empty vessel to be filled with the knowledge of experts. Rather, the information presented should be relevant and relate to the education need of the stakeholder. For example, when assessing the self-rated knowledge of recreational anglers, it appears that on average, fishers are aware of the reason that underlies seasonal catch and size restrictions; however, they are uncertain as to how these restrictions are developed. These results indicate that anglers recognize the purpose behind the scientific assessment of the resource but are unclear as to the biological and ecological information required to make these decisions. At the same time, recreational anglers have indicated that most would be interested in receiving more information about biological and management aspects of the fish they fish for most often. Thus, we advise designers of education programs to communicate information about the scientific assessment process of highly valued recreational fisheries that includes life history and ecological information outlining potential behaviors which affect the population and how they may be affected by fishermen.

Last, it appears that anglers are receiving their information about fisheries management from a number of sources which include a mixture of online and print sources and through interpersonal interactions (bait and tackle shops and other fishermen). Where anglers get their information may determine what type of information they receive, and further, how they formulate their ideas about marine ecosystems and their management. For example, Stamm, Clark and Ebacas (2000) found that information about environmental problems from mass media and interpersonal communication generally lead to misconceptions about the issue, its causes, consequences, and potential solutions. Although recreational fishermen form their ideas about marine fisheries over time from a variety of these information sources, providing targeted information through a trusted venue (Peters, Covello, & McCallum, 1997) may provide improved support for management initiatives and outline the context behind how and why decisions are made.

Conclusions

We believe that recreational anglers can serve as a resource for EBM efforts when education and outreach programs are situated within a broader ecological and social context that promotes a more comprehensive systems understanding. However, to increase the likelihood that these partnerships are successful, education and outreach programs must be situated within a framework which includes several components. Based on the results from our survey and a review of the literature, we offer the following recommendations to institutions seeking to provide information to marine recreational anglers toward the goals of EBM:

a) Align recreational fishers' perceived threats with those management institutions seek to address.

b) Articulate pro-ecological fishing behaviors within an ecological and management context so that they may be justified.

c) Combine information to be communicated with other information of interest such as individual species profiles or information on species behavior.

d) Provide these resources online through recreational fishing trade magazines or in print at fishery related businesses in coastal areas like bait and tackle shops.

Tables and Captions

Table 1. Anlger survey included 3 question categories; angler perceptions, behaviors, and comminucation. Dashes indicate open-ended responses which were coded and * indicates scale response of (1) very knowledgeable to (5) not knowledgeable. All values reported as Mean(SD).

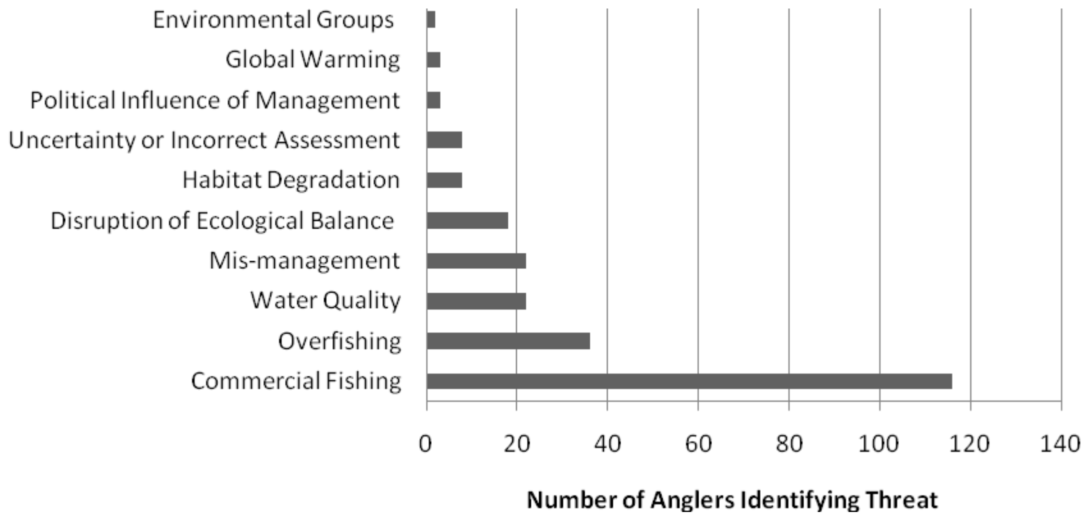
Angler Survey Questions	NJ	RI	Total
Angler Perceptions			
Do you think your fishing behaviors have an effect on the ecosystems in which you fish?	Yes 37% No 55%	Yes 44% No 44%	Yes 38% No 49%
Why or why not?	-	-	-
What are the top three threats to marine ecosystems?	-	-	-
Angler Behaviors			
How often and in what manner do you fish?	-	-	-
What fish species do you fish for most?	-	-	-
*How would you rate your knowledge in the following areas of the fish you fish for most:			
Determining Sex of fish caught	2.8(1.2)	2.9(1.2)	2.9(1.3)
Determining Age of fish caught	2.3(1.1)	2.5(1.0)	2.4(1.0)
Why there are catch and size limitations	1.7(1.0)	1.6(.7)	1.6(.8)
How to tell if a habitat is healthy for a particular fish species	2.1(1.3)	2.3(1.3)	2.2(1.3)
Determining healthy habitat for juvenile fish	2.6(1.3)	2.6(1.3)	2.6(1.3)
Do you use circle hooks?	Yes 77% No 23%	Yes 69% No 31%	Yes 73% No 27%
Why or why not?	-	-	-
Angler Communication	-	-	-
Where do you currently receive information about marine fisheries (such as seasonal size and catch limitations)?	-	-	-
What types of information regarding marine fisheries would be interested in learning more about?			
Would you be open to receiving information about small changes you could make while fishing to take better care of the ecosystem?	Yes 87% No 8%	Yes 84% No 9%	Yes 86% No 9%
How would you like to receive this information?	-	-	-

Table 2. Current and preferred information sources for recreational fishermen.

Where do you currently receive marine fisheries information (check all that apply)?		**How would you like to receive marine fisheries related information?**	
Fishermen Magazines	53%	Online Source	85%
Bait and Tackle Shops	49%	Newsletters (post mailed)	10%
Online	40%	Fisheries Club Meetings	2%
Other Fishermen	33%	Magazines (print)	2%
Government Publication or Newsletter	11%	Other	1%

Figures and Captions

Figure 1. Top ten threats to marine fishery resources by frequency of mention.



Conclusions

This dissertation research sought to understand how some of the interactions within a SES can be shaped, influenced and determined by stakeholder knowledge systems. In the first chapter, I investigated the internal representations of the external world (mental models) of several groups involved a model SES, the mid-Atlantic summer flounder fishery. This research constructed a structural and functional representation of individual stakeholder groups' models and a collective community model of the mid-Atlantic fisheries SES. Further, it highlighted some of the major differences and similarities in stakeholder knowledge and outlined some of the benefits and limitations of integrating stakeholder knowledge into SES decision-making. In the second and third chapter, I outlined important beliefs in stakeholder knowledge which may influence how decisions are made within an SES. Chapter 2 evaluated risk identification as a component in institutional knowledge (manager and scientist) to address questions of the negative outcomes in a SES management seeks to address. Results yielded 3 main categories of risk and 12 sub-categories of risk. Chapter 3 evaluated trust as an important component in stakeholder knowledge (recreational anglers) and addressed questions of factors which may influence how resource managers and resource institutions work together toward shared goals in SES management. Results indicated that participation was the highest predictor of increasing trust and therefore an important indicator of cooperation. Further, the results from this chapter highlighted that stakeholders are more likely to trust management institutions in SES compared to the scientific assessment of resources within an SES. Finally, Chapter 4 outlined recommendations to how institution and stakeholder knowledge systems can be aligned to increase the likelihood of cooperation in marine fisheries management. It outlines specific perceptions of ecological pressure from recreational fishing and their management from and aligns scientifically assessed ecosystem goals with survey assessed angler perception.

Understanding the dynamics of coupled social-ecological systems (SES) is difficult given the vast complexity that exists within subsystems (e.g. economies and biological communities) and their behavioral components (animals, plants, harvesters, nutrients). Adding to this difficulty is a lack of working knowledge of how social and ecological systems operate together and the important factors which influence overall system function. This complexity hinders our ability to easily manage SES since we cannot easily predict how changes in systems' components influence social or ecological change. Here I present data that support the potential importance of integrating knowledge systems in the management of SES and in establishing expectations of the system. My research suggests that creating opportunities for knowledge-sharing between resource managers and resource users can (1) increase overall understanding of the complexity of SES components and their dynamics, (2) articulate potential opportunities for increasing positive system change and decreasing negative change (3) increase trust and cooperation toward shared goals.

Acknowledgment of Previous Publications

Portions of this dissertation are already slated for, or pending, publication elsewhere. Chapter two has been accepted for publication as it is presented here in a forthcoming issue of the journal of *Fisheries Management and Ecology* (Gray, S., M. Ives, J. P. Scandol, and R.C. Jordan. 2010. Categorizing the risks in fisheries management. Fisheries Management and Ecology. 17(3)). Chapter four has been accepted for publication in its present form in the journal of *Human Dimensions of Wildlife* (Gray, S. and R.C. Jordan. 2010. Ecosystem-based angling: incorporating recreational fishermen into ecosystem-based management. Human Dimensions of Wildlife. 15(4)). Finally, Chapter three has been submitted for publication to the journal of *Environmental Management* (Gray, S., R. Shwom, and R. C. Jordan. Understanding factors which influence stakeholder trust of fisheries science and institutions, in review).

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