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Illustrating the critical role of human dimensions research for understanding and managing recreational fisheries within a social-ecological system framework

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Abstract Effective management of recreational fishing requires understanding fishers and their actions. These actions constitute critical links between social and ecological systems that result in outcomes that feedback and influence recreational fishers' actions and the management of these actions. Although much research exists on recreational fishers and their actions, this research is often disconnected from management issues. One way to help to overcome this disconnect is to illustrate how past research on the social component of recreational fishing fits within an emerging coupled social-ecological system (SES) framework. Herein, a conceptual SES is first developed with specific attention to recreational fisheries. This SES is then used to illustrate the importance of considering human dimensions research for articulating, studying and ultimately managing key outcomes of recreational fisheries (e.g. fish population conservation, fisher well-being) using the example of harvest regulations and a brief review of past interdisciplinary research on recreational fishing. The article ends by identifying key research needs including understanding: how factors such as management rules affect the diversity of actions by recreational fishers; how governance and management approaches adapt to changing social and resource conditions; and how recreational fishers learn and share information.

KEYWORDS: harvest regulations, human dimensions, interdisciplinary research, recreational fisheries, social-ecological system.

Introduction

Recreational fishing is the fishing of aquatic animals (mainly fish) using one or more of several possible techniques in which aquatic animals do not constitute the individual's primary resource to meet basic nutritional needs and are not sold or otherwise traded on export, domestic or black markets (EIFAC 2008). Recreational fishing involves tightly coupled interactions among people and fish where an individual pursues fishing to help achieve a variety of desired psychological outcomes such as temporary escape from daily routines, meeting of fishing-related challenges or relaxation (Knopf *et al.* 1973). As recreational fishing is important to some people and

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fish populations are tightly linked to fishers' actions, recreational fisheries management often jointly addresses human (fishers and non-fishers) well-being and conservation issues (Cowx *et al.* 2010). One challenge of recreational fisheries management is to translate these vague management goals into operational objectives (Barber & Taylor 1990). Developing objectives for fisheries (resource) management requires answering normative questions about which dimensions of the system to focus on (e.g. human or non-human), how to measure human well-being and/or the state of aquatic ecosystems, and whether to seek satisfactorily good outcomes (e.g. management targets) or to optimise a measure such as well-being (e.g. Arrow *et al.* 2004; Fenichel *et al.* 2012). To help answer these social normative questions, research is needed on recreational fishers, their actions and outcomes from these actions.

Since the mid 20th Century, many fisheries social scientists have engaged in studies that describe fisher characteristics and their actions, thereby helping to understand the social side of recreational fishing. The maturing field of so-called human dimensions research activities has developed since the 1960s to become part of contemporary recreational fisheries science (Ditton 1996; Arlinghaus 2004). The goals of human dimensions research for recreational fisheries are to understand human thoughts and actions (i.e. cognitions, behaviours and relationships) regarding fish, fishing and fisheries governance and management, and the connections and feedbacks between the human and natural components of recreational fisheries systems. Such research builds on many social science disciplines, involving economics, social-psychology, sociology and political science (Aas & Ditton 1998). The units of social analyses in recreational fisheries usually include individuals, social groups, communities and institutions (i.e. the rules and norms that structure human and nature interactions; Ostrom 2005). For recreational fishing, human dimensions research is an applied field that provides information about fishers and their behaviours, preferences, perceptions, attitudes and well-being in support of fisheries management efforts.

Human dimensions research on recreational fishing has evolved considerably from early work that considered fishers merely as informants of the state of the biological resource (e.g. deriving fish catch information in standard creel surveys, Ditton 1996) or as a fixed non-responsive input parameter in biology-oriented fisheries population models, often collectively referred to as effort. One early evolution refocused research explicitly on recreational fishers to understand them as clients or stakeholders of the fisheries management system (McConnell & Sutinen 1979; Decker *et al.* 1996). Early human-dimensions research in this area was, however, mostly descriptive and focused on answering questions such as: Who are recreational fisheries stakeholders? Why do they fish? and What are their basic likes and dislikes? (e.g. Moeller & Engelken 1972; Knopf *et al.* 1973). Research has also examined recreational fishers' evaluations of policy and management issues such as the acceptability of decision-making processes, chosen methods for management and management outcomes (e.g. Dawson & Wilkins 1981; Ditton 1996). Understanding and predicting the behaviours of fishers is another important area of enquiry. Many applications have used economic theory to develop and estimate models to predict how management (and other) changes would likely affect recreational fishers' choices, such as where and when to fish and what to target, and, correspondingly, how the economic value of recreational fishing would change [see review by Hunt (2005)]. Therefore, human dimensions research has incrementally moved from describing the average recreational fisher to help understand and to account for diversity in fisher populations and their behaviours (Aas & Ditton 1998). This movement often involved attempts to understand the heterogeneity among the recreational fisher populations by developing concepts and theories to identify distinct types of fishers who share certain attitudes and behaviours (e.g. angler specialisation, Bryan 1977; Ditton *et al.* 1992).

Despite the volume and quality of human dimensions research produced over the past 40 years, the authors of the present article and others (Ditton 2004; Arlinghaus *et al.* 2008) believe that the existing human dimensions research has not been fully utilised in recreational fisheries management. Indeed, the gap in utilisation of human dimensions research in fisheries management seems to be widening (Fulton & Adelman 2003). The lack of awareness of relevant research findings and an overall low frequency of dedicated human dimensions staff in fish and wildlife management agencies (Fulton & Adelman 2003), constitute probably the most salient reasons for this development. Lack of awareness of human dimensions theory and research by recreational fisheries managers and biologists has resulted in two challenges. First, it can result in a reinventing of the wheel at best, and incorrect assumptions about human behaviour related to fisheries at worst. Fenichel *et al.* (2012) noted that although many biologists are keenly interested in understanding recreational fishers and their actions, publications seldom acknowledge the large body of research conducted on human dimensions. Second, selected beliefs that some human dimensions research results are relatively unimportant or simply too messy for use in recreational fisheries management further challenges

making research known to biologists and managers. Without understanding human dimensions theory, neglecting the connections between fishers and fish, and instead focusing on fisheries biology, one might view fishers' behaviours and reactions and outcomes from fisheries management (e.g. fisher dissatisfaction) as externalities or politics that only disturbs the biologically motivated management process (Arlinghaus *et al.* 2008). Likewise, many human dimensions researchers are unaware or unresponsive towards recreational fisheries management issues and/or biological considerations when conducting, interpreting, or presenting their research (see Matlock *et al.* 1988; Matlock 1991 for an informative case), thus contributing to the gap between human dimensions knowledge and its use in fisheries management.

Reframing human dimensions research approaches and results from a disciplinary, social-science perspective into an integrative social-ecological system (SES; Berkes & Folke 1998) framework might represent a significant step towards greater appreciation and consideration of human-dimensions information in recreational fisheries management. Fisheries researchers and managers have called for greater integration of human behaviour into recreational fisheries analyses (e.g. Larkin 1978; McConnell & Sutinen 1979; Royce 1983; Arlinghaus *et al.* 2008; Fulton *et al.* 2011; Post & Parkinson 2012). Indeed, human behaviour is increasingly included in recreational fisheries models by coupling fishers' behaviours and ecological dynamics (e.g. Johnson & Carpenter 1994; Massey *et al.* 2006). Although SES models are developed for many reasons, such as identifying policies to address management objectives (Johnston *et al.* 2010), SES frameworks are useful for illustrating and emphasising how human dimensions research fits within an integrative analytical framework for understanding and managing recreational fisheries. The SES framework for managing natural resources presented below and elsewhere (e.g. Fenichel *et al.* 2012; Schlüter *et al.* 2012) explicitly recognises the links and feedbacks between social and ecological systems, including the many diverse benefits that people derive from fish resource use and the effects that human activities have on those resources and the associated ecosystems (Ostrom 2009). In a SES framework, human and natural components are connected and embedded in webs of interactions that can result in complex and often surprising outcomes that one cannot predict by studying human or natural systems in isolation (e.g. Liu *et al.* 2007). The emphasis on the coupled SES refocuses attention from individual components to the connections and feedbacks within the system and, ultimately, to the outcomes from management actions (Schlüter *et al.* 2012).

A SES framework for a recreational fishery is developed and presented to help structure the article. The resulting framework is used to highlight the diverse human dimensions concepts that exist and how they can help to address key connections and feedbacks between social and natural systems and to identify future human dimensions research priorities. The following section illustrates the SES framework and discusses the associated components and connections. The SES is also used to organise and describe examples of past human dimensions research applications on harvest regulations. Although not exhaustive, the review attempts to exemplify key aspects of how humans influence the success of harvest regulation management. Finally, a brief review of interdisciplinary recreational fishing applications using an SES-like framework is provided to discuss how human dimensions research has benefited these applications and to identify pertinent research needs.

A coupled social-ecological system for recreational fisheries

The SES for recreational fisheries is first described with a general conceptual model consisting of two interacting systems: the social system and the ecological (resource) system (Fig. 1, after Ostrom 2007, 2009). In all SESs, human use of natural resources depends on ecological systems because these systems provide many valued and preferred ecosystem services that human actions can affect (Millennium Ecosystem Assessment 2003). Important services valued by humans include provisioning (e.g. food from fish), regulating (e.g. regulation of water clarity through top-predator rich food webs), cultural (e.g. recreation or aesthetic values) and supporting (i.e. those necessary for producing all other services such as nutrient cycling) (Millennium Ecosystem Assessment

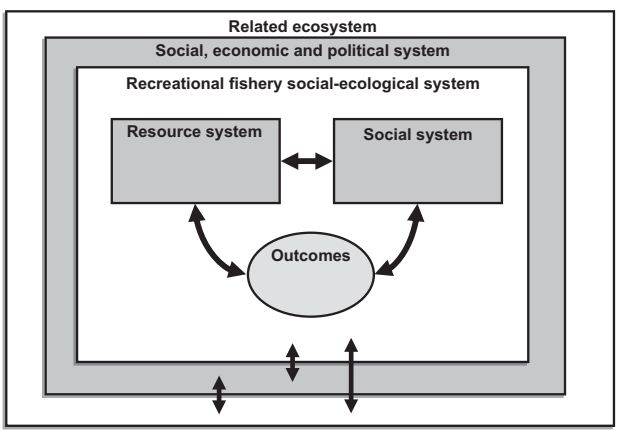

Figure 1. General coupled social-ecological system of recreational fishing.

2003). For individuals participating in recreational fishing, cultural services of recreation and aesthetics are usually most important followed by provisioning of food. Recreational fishing also generates relevant economic activity through the demand of goods and services to support recreational fishing.

As human use of fish and habitats affects the ecological system (Lewin *et al.* 2006), feedbacks and interdependencies exist between the social and ecological systems. The coupling of natural and social systems inherent in all SESs usually results in non-linear social-ecological dynamics that extend across scales in space and time, and affect the range of tangible SES outcomes (e.g. catch rates and harvest for desirable fish species, spawning stock biomass, fisher satisfaction). Some outcomes of a focal SES may be considered externalities that affect other SESs such as using water for irrigation can affect the SES for fisheries. All outcomes of human-nature interactions thus explicitly recognise that any SES is embedded within wider social and ecological settings (e.g. political system, climate patterns, ecological limits set by geomorphologic and geologic processes), and that any SES will influence and be influenced by those overarching settings and conditions that are components of other SESs (Fig. 1).

Against this background, a specific SES is conceptualised as an entity within nested hierarchies of other SESs that form complex webs of interaction across various spatial and temporal scales (Liu *et al.* 2007). For example, a community of resident people using regional fisheries resources for recreational purposes is likely nested within a broader regional SES in which people use aquatic resources for other and possibly competing purposes such as commercial fisheries, potable water, agriculture, flood control or electricity generation. This regional SES is ultimately nested within global SESs that are affected by combinations of human actions and natural disturbances arising from local and global processes (Liu *et al.* 2007). This complex nested structure often makes it difficult to define and delineate a focal SES because the spatial, temporal and institutional boundaries of any SES are vast and not always clear (Carpenter *et al.* 2009). A recreational fishery when viewed as a SES, usually involves a local to regional extent referring to resident or non-resident fishers using local or regional fish resources in aquatic ecosystems for recreation.

One important feature of the basic SES (Fig. 1) is that it helps to define and delineate the focal SES for analysis by allowing decomposition into subsystems and associated variables and interactions at multiple levels. Using Ostrom (2007, 2009) as a guide, the general model (Fig. 1) is decomposed into the components and interactions most relevant to study the recreational fisheries SES from a human dimensions perspective (Fig. 2). However, the resource system is equally decomposable, and other research might and should highlight other details within the SES.

Following Ostrom (2007, 2009), the ecological system consists of the resource system (or ecosystem) and the resource units (Fig. 2). The resource units desired by fishers refer to the individual fish of a given species (e.g. trophy individuals), the various stocks of a species in a particular area in multi-stock fisheries, or the species desired by recreational fishers. The resource system defines the resource units' extent, either spatially, biologically or administratively (e.g. a single lake, a region of

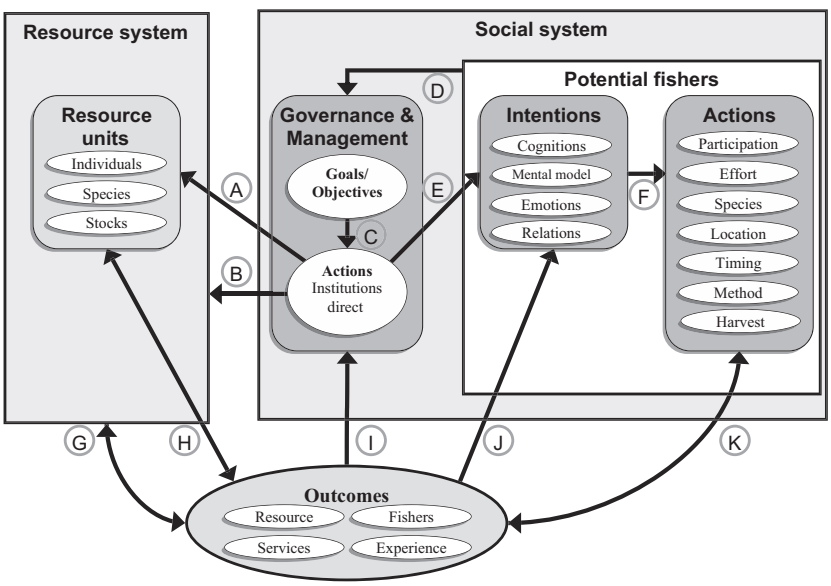

Figure 2. Coupled social-ecological system of recreational fishing with emphasis on the social system and interactions among various components.

lakes governed by an agency, an extended geographic area such as a marine area, or an area inhabited by widely-distributed or highly migratory species). Although not included in Figure 2, the wider resource system is characterised by general features such as habitat quality and structure, geomorphology, geology (resulting in background nutrient levels) and the natural or human-altered biotic community.

The social system is decomposed into governance and management and potential fisher components (Fig. 2). The governance and management component consists of subcomponents related to goals/objectives and management actions. Goals represent broad and general statements about the intent for management, such as achieving sustainable use or conserving a target species (Barber & Taylor 1990). Objectives are used to transfer these goals into specific operational statements related to management (e.g. fish mortality will not exceed some threshold, the catch rates per angler will increase by a predefined level). Sometimes, reference points (e.g. related to spawning biomass) will be established that trigger some management response. Management actions (Fig. 2, link C) are then used to develop approaches to either alter fishers (e.g. number of fishers or their actions such as harvesting patterns) or resource systems and units.

Developing institutions to guide human behaviour is one important recreational fisheries management action of the governance and management component. Institutions are prescriptions that people use to organise interactions among people, and between people and natural systems (Ostrom 2005). Institutions are developed formally often through centralised agency control or more informally through groups, clubs, associations or other aggregations of people. Institutions result in norms and/or rules that can influence the population of fishers along with their intentions and ultimately actions (links E, F, and K in Fig. 2, Cooke *et al.* in press). Crawford and Ostrom (1995) noted that rules and norms include an aim (i.e. description of actions or outcomes from actions), attributes (i.e. recipients for the rule or norm), deontic logic (i.e. communicating whether an action is permitted, obliged, or forbidden) and conditions describing where and when an action is permitted, obliged or forbidden. These authors note that a norm does not include formal sanctions although individuals whose actions deviate from a norm will experience informal sanctions such as social shunning or loss of reputation. Rules include formal sanctions and incentives (i.e. an or else condition) that describes consequences of not following a rule (e.g. payment of a fine) or rewards for following a rule (e.g. more fish in the next fishing season). The most common institutions in recreational fisheries are size-based harvest limits, bag limits and similar harvest regulations and voluntary catch-and-release, but institutions governing licenses and access to resources also exist. Ostrom (2005) noted that institutions are hierarchical with rules for operational (e.g. bag limit for recreational fishers), collective choice (e.g. developing operational rules from consensus among stakeholders) and constitutional situations (e.g. who are stakeholders? and how do stakeholders make decisions about operational rules?). The focus of the SES here is on operational and collective choice situations.

Resource management agencies, fishing organisations and clubs take other actions than institutional design. These direct actions that can influence the resource system, units and potential fishers (Fig. 2, links A, B and E) focus primarily on habitat rehabilitation, management of access or facilities, such as boat ramps, or supplementing the resource units via stocking or introduction of fish (Lewin *et al.* 2006). Although these actions do not occur in all recreational fishing contexts, they are highlighted because they provide a different approach to manage outcomes of recreational fishing than altering actions of fishers.

Potential fishers consist of individuals who are or might become active recreational fishers through their behavioural intentions, such as whether to buy a license and fish (Fig. 2). Although the population of fishers is influenced by resource conditions (e.g. catch rate), social conditions (e.g. crowding) and management actions (Hunt 2005), Bissell *et al.* (1998) noted that larger social processes including population and demographic change and urbanisation play important roles in affecting participation in recreational fishing.

Intentions of fishers are precursors to actions including actual behaviours that provide one entry point for human dimensions theory to explain the expectations and actions of fishers (e.g. Albarracín 2002). Underlying cognitions, mental models about system relationships, emotions, social relationships and formal and informal institutions can all modify behavioural intentions. Cognitions are a key concept in social-psychology, which include basic values, perceptions, beliefs, attitudes, rewards sought (e.g. utility) and general cognitive evaluations of given issues and objects such as endangered fish species or management regulations. Modified by experience and situational conditions, recreational fishers carrying certain cognitions will then develop preferences for specific species or sizes of fish, develop a tendency to release or to keep fish, or exhibit a psychological attachment or fidelity to specific fishing sites (Hunt 2008) that strongly affect their actions. Mental models relate to subjective knowledge about aspects of the systems and outcomes related to perceptions of how the

SES functions (Biggs *et al.* 2011). Recreational fishers can also learn over time about fishing opportunities, build their own perspective about where and when to expect certain catches and use information about catch and non-catch related qualities of fishing sites to assess the resource system and the success of different strategies for catching fish. Emotions are complex psychophysiological experiences that are part of the feeling states of individuals (Myers 2004). Emotions provide the affective component to attitudes and motivation, help to shape cognitions (e.g. attitude change) and along with cognitions affect preferences, intentions and ultimately actions (Manfredo 2008). Individuals are also embedded in a complex web of social relations that can modify their intentions and actions. Finally, institutions influence intentions and even actions of fishers. All relevant formal and informal rules of accepted behaviour on a fishing site are expected to influence most fishers' intentions and perceptions of social norms play an important role in mediating people's intentions and actions (Ajzen 1991). Heterogeneity in cognitions, mental models, emotions and norms among fishers is expected (Ditton 2004), and knowledge of this heterogeneity is useful for fisheries management.

At the coarsest scale, intentions of individual fishers result in a choice to participate in recreational fishing (Fig. 2). Given active recreational fishers, their intentions result in fishing strategies that they implement by mobilising resources such as time as revealed through their actions such as fishing site choices. These strategies describe the amount of effort expended by individuals on fishing along with context including the targeted species, the location, the timing (including duration), the method (i.e. fishing style including gear and equipment choices) and the decision to harvest caught fish on a given fishing trip. These fishing strategies can and do vary among fishers, and result in, and possibly from, different abilities among fishers to catch and harvest fish [see review by Hunt (2005)].

Many outcomes to the resource and social systems arise from fishing and fisheries management actions. Here, the focus is on the feedback of these changes on social outcomes at two levels: the recreational fisher and people involved in managing the recreational fishery (managers). An individual who takes a fishing trip will experience and learn about catch (species, number and size) and non-catch (e.g. encounters with other fishers) related expected outcomes for a particular fishing strategy. This catch and non-catch information can influence a fisher's cognitions, emotions and mental models that in turn affect future actions by the fisher. A recreational fisher also might share this information with others resulting in additional changes to intentions and actions of relevant others (e.g. Mueller *et al.* 2008). Finally, the fishing trip provides experiences that contribute to the well-being (e.g. utility or satisfaction) of the fisher, which one can use to evaluate the result of a trip or a fishing season (Arlinghaus 2006).

For individuals who manage the recreational fishery, outcomes usually become meaningful and measurable, after some aggregation of fishing trips acting on the ecological and the social systems (e.g. over a year). Biological outcomes to describe the resource system's state may be measurable through fishery-dependent or fishery-independent stock assessments. Other social outcomes that may be relevant to managers describe general information about fishers including the population of active fishers and their expenditure, willingness to pay, satisfaction, effort and catch and harvest rates. More thoroughly, the outcomes can describe changes in the well-being of fishers and non-fishers. This well-being depends not only on the quality of the cultural and provisioning services provided by fish stocks and ecosystems but may also include the perceived fairness of decision-making processes (procedural justice, Daigle *et al.* 1996) and associated social outcomes from these processes (distributive justice; Loomis & Ditton 1993).

A focus on the outcomes from the SES is critical for managing recreational fisheries. Although resource conservation goals are often translated into specific objectives (e.g. ensuring that fish population harvests are less than maximum sustained yield), many other goals are not (e.g. satisfaction of fishers, fairness of decision-making processes, or system-level properties such as resilience of the SES). Debate exists between researchers who advocate developing and maximising a single index (Fenichel *et al.* 2012) and those who advocate multiple objectives and associated targets and thresholds (e.g. Booth *et al.* 2002; for resource management issues). However, discussing the pros and cons of these optimising *vs* satisficing approaches is outside the scope of this study.

Harvest regulation management and coupled social-ecological interactions in recreational fisheries

Harvest regulations are formal institutional rules that are widespread in recreational fisheries. These rules are used here to illustrate how human dimensions research has helped and can help to understand better the dynamics and outcomes of the SES, including the links and feedbacks among and within the SES components. Fisheries managers often use harvest regulations (e.g. size-based harvest limits, daily bag limits, possession limits) to help achieve the management goal of resource conservation

(Noble & Jones 1999; Radomski *et al.* 2001). Considerations for designing many harvest regulations involve resource conservation issues (e.g. avoiding spawning stock size to fall below unacceptably low levels, with levels often serving as reference points) and at least implicitly, distributional issues (e.g. providing diverse opportunities for fishers and allocating fish between current and future generations, Radomski *et al.* 2001). Harvest regulations are a suitable example to explore past human dimensions research from an SES framework because: (1) they often involve controversy and uncertainty when revising or implementing new regulations (e.g. Radomski *et al.* 2001); (2) they directly connect social and biological outcomes in the SESs to the governance and management component by informing future management actions from feedbacks associated with past regulatory effects (e.g. fisher reaction to the implementation of a new policy); and (3) they affect recreational fishers' support for management, their well-being and individual or collective actions.

This section describes human dimensions studies that have primarily examined a single connection within the SES of recreational fisheries as highlighted in the arrows and associated letters in Fig. 2. Consequently, the reviewed studies are typically disciplinary in nature (see next section for interdisciplinary approaches).

In developed countries with centralised agencies, managers usually consult with recreational fishers when selecting fishing regulations (Lackey 1998). The consultations normally constitute key links between fishers and governance and subsequently management components of the SES (Fig. 2, link D). The consultations also provide opportunities to meet legally required responsibilities for many agencies and to allow fishers to have input on developing or even making goals, objectives and rules to match local conditions (Daedlow *et al.* 2011) (Fig. 2, link C). Human dimensions research in some regions and localities can and has provided reliable information about the expectations, needs, desires and preferences that a population of recreational fishers have for different regulatory approaches. For example, human dimensions research has provided insights into the relative acceptability of different regulations and/or how this acceptability varies among fishers (e.g. Dawson & Wilkins 1981; Salz & Loomis 2005). Although providing managerially useful descriptive information to gauge acceptability of planned future interventions, these attitudinal-rating approaches remove the overall fishing context and most of the salient trade-offs (e.g. expected fish size *vs* catch number) inherent in most regulations (Ditton 2004). Other survey approaches such as conjoint and choice models explicitly account for these tradeoffs by asking fishers to choose policies or policy outcomes that are jointly described by harvest regulations and the catch and non-catch outcomes of the fishing experience (Teisl *et al.* 1996; Gillis & Ditton 2002; Hunt & Morgan 2005). The choice model approach has allowed managers and others to predict support for different regulations from contextual factors related to catch and non-catch related outcomes from fisheries management. Human dimensions research has also used qualitative methods such as focus groups or participatory methods (e.g. Ritter *et al.* 1992; Irwin *et al.* 2011) to study preferences of fishers for management tools including harvest regulations. Along the same lines, research has investigated recreational fishers' perceptions of the adequacy and fairness of consultation processes, and provided information to agencies to engage recreational fishers better in decision making (Sutton 2006; Sutton & Tobin 2009).

A vital piece of information when choosing harvest regulations is the likely effect of regulations on fishers' actions such as effort allocation or fish harvesting decisions (Beard *et al.* 2003; Johnston *et al.* 2010). The feedbacks constitute the complex links between management and potential fisher populations through behavioural intentions and ultimately actions (Fig. 2, links E and F) given people's reactions to the regulation or to associated (perceived or real) changes in the resource system and resource units. Thus, understanding of how fishers react to new harvest regulations is crucial, yet often unknown information resulting in what is known in the commercial fisheries literature as implementation uncertainty (Fulton *et al.* 2011). This information can help managers design regulations in attempts to achieve management goals and objectives (Fig. 2, link C) by helping to ensure that unanticipated responses by fishers do not compromise the regulation's general intent (Radomski & Goeman 1996). Like research on regulation acceptance, human dimensions research has used trade-off based survey approaches whereby fishers make choices for pursuing fishing among sites that have different regulations and other attributes (Aas *et al.* 2000; Scrogin *et al.* 2004; Oh *et al.* 2005; Oh & Ditton 2006; Dorow *et al.* 2010). These behavioural models are crucial for many interdisciplinary applications that link fishers' actions to fish population dynamics (e.g. Johnston *et al.* 2010; Hunt *et al.* 2011). In multi-species fisheries, research has examined how regulations that affect fishers' access to one species may change the targeting or harvesting behaviour of fishers for other species (Sutton & Ditton 2005; Gentner & Sutton 2008).

Managers must also consider, address and potentially mitigate fishers' resistance and non-compliance that might result from different sets of harvest regulations (Pierce & Tomcko 1998; Sullivan 2003). This consideration of rules on paper vs rules in use (Young 2002)

requires an understanding of the comprehension and acceptance of regulations by fishers (Page & Radomski 2006; constituting the feedback link from governance and management to intentions, Fig. 2, link E) and monitoring the effectiveness of enforcement efforts to limit non-compliance (constituting a link from outcomes to governance and management; Fig. 2, link I). First, managers and others use various communication approaches to help increase fishers' understanding of harvest regulations and the rationale for them (Johnson *et al.* 2009). Human dimensions research can help managers and others study and subsequently develop and refine the most effective communications activities including associated outreach programmes (Li *et al.* 2010; Cardona-Pons *et al.* 2010). Second, managers can design communications in attempts to persuade fishers to change their actions and attitudes and beliefs towards such actions (see Albarracín 2002 for a potential model to apply). This soft harnessing can be as effective as hard-wired regulations because voluntary norms of proper behaviour (informal institutions) can strongly affect people's actions leading to effective fisheries management (Arlinghaus 2004; Cooke *et al.* in press). Third, managers can implement the regulations and if necessary encourage fishers to follow rules with enforcement activities, and formal and often graduated sanctions. Fishers might not always follow harvest regulations, and compliance levels depend on the catch-related quality of a fishery (Sullivan 2002), fishers' beliefs about the level of enforcement and penalties (Walker *et al.* 2007), the amount of time since a regulation change (Fujitana *et al.* 2012), the regulation itself, the agency and the beliefs of other fishers. Research has illustrated how to estimate fishers' compliance with regulations using methods such as random response and social surveys (Schill & Kline 1995) and creel survey data (Wilberg 2009).

Interactions among recreational fishers can strongly affect fishers' intentions, actions and the acceptability of regulations. Fishers' actions have the potential to affect other people in at least four ways. First, through their actions on the ecosystem, fishers experience varying resource conditions such as catch rates, fish size and fishing sites (link from outcomes to fishers, Fig. 2, link K). Some fishers will share this information with others potentially resulting in changes to intentions through cognitions (e.g. attitudes) and mental models, and actions of other fishers; thus, feedbacks constitute links from outcomes to potential fishers, intentions and actions (Fig. 2, links J and F). To date, little research has focused on social network analysis for harvest regulations specifically or for recreational fishing in general (for exceptions see Little & MacDonald 2007 and Mueller *et al.* 2008). Second, learning about resource conditions might change fishers' evaluations of management actions, which constitutes the link from potential fishers to governance (Fig. 2, link D) as fishers demand new regulations or become familiar with existing ones though custom and habit. For example, if fishers experience reduced levels of catch from a harvest regulation, they might change their attitudes towards that regulation (Dorow *et al.* 2010), which might change social norms about the regulation (van Poorten *et al.* 2011). Third, through their actions, fishers will learn about the expected encounter levels with other fishers at sites (links from outcomes to intentions, Fig. 2, link J). High levels of encounters at some sites might result in crowding concerns that could repel individuals to other fishing sites (e.g. Timmons & Murdock 2007). Fourth, fishers' actions can result in changes to norms for behaviours (links from actions and outcomes and from fishers to governance to intentions; Fig. 2, links K, D, E). For example, catch-and-release fishing can be a voluntary practice that has gained wide acceptance among some cultures and fisher types and, consequently, many managers have developed policies to encourage this practice voluntarily rather than developing a formal rule (Arlinghaus *et al.* 2007).

Of possibly the most interest to more biology-oriented fisheries managers is the question of how the fishers' actions (e.g. harvesting and even illegal stocking of fish, Lewin *et al.* 2006) change resource systems and subsequently, resource units (Fig. 2, links K, G and H). Although research largely addresses these topics in fisheries biology or integrated models of fish-fisher interactions (see next section), more traditional human dimensions research has also made important contributions. For example, human dimensions research can help identify groups of fishers with similar harvesting behaviours that are useful for estimating the degree of exploitation that some groups might induce from different harvest regulations (e.g. Johnston *et al.* 2010). Human dimensions research has also helped to understand the biological implications of harvest regulations by assisting with collecting catch and harvest information from fishers using creel surveys or diary studies (e.g. Pollock *et al.* 1994). To link actions of fishers quantitatively to fish resource conditions, human dimensions research has also estimated the importance of expected catch of fish and other attributes to shape site choices by different groups of fishers [reviewed in Hunt (2005)] or even compliance with harvest regulations (Sullivan 2002). This body of literature suggests that expected catch rates (and likely the catchability of fish) vary considerably across fishers, locations and fishing methods (e.g. McConnell *et al.* 1995; Massey *et al.* 2006). Finally, some human dimensions research has examined fishers'

knowledge and perceptions of their effects on the resource system and units, and their willingness to change their behaviour or affect certain regulations to reduce their resource impacts (e.g. Arlinghaus 2006; Dorow & Arlinghaus in press).

Some research about the effects of harvest regulations on the well-being of recreational fishers has also been undertaken constituting the link from the actions to outcomes (Fig. 2, links I and K). For example, research has estimated how different types of harvest regulations affect the economic value of a fishery (e.g. Teisl *et al.* 1996; Scrogin *et al.* 2004). Although no studies have empirically investigated aspects of distributive or procedural justice of recreational fishing decisions and decision-making processes, theoretical exceptions exist (Loomis & Ditton 1993; Daigle *et al.* 1996) along with more general frameworks that might address distributional concerns within fisheries management (Kellner *et al.* 2011). Ultimately, human well-being outcomes including resource conservation goals from the SES influence the future governance and management of recreational fisheries by matching outcomes to objectives (link from outcomes to governance/management, Fig. 2, link I). For example, one can evaluate the effectiveness of harvest regulation policies by monitoring outcomes related to human well-being including resource conservation and then match outcomes to pre-defined objectives that inform a structured decision-making process (Irwin *et al.* 2011). This approach recognises the inherent uncertainty of outcomes from policies apparent in SESs (Schlüter *et al.* 2012) and results in an active or passive adaptive management approach, whereby managers experiment with different harvest regulations and monitoring activities to assess the effectiveness of the regulations at achieving objectives.

Using human dimensions research concepts to guide interdisciplinary SES models on recreational fishing

Researchers (human dimensions and biologists) are moving from disciplinary research towards truly interdisciplinary studies that link the social and biological disciplines and models, often using tools such as integrative models of recreational fishing approached from a SES perspective (e.g. Biggs *et al.* 2008; Johnston *et al.* 2010). The review below highlights some ways that theories and concepts from human dimensions research have been used to examine recreational fisheries within SES-like frameworks while modelling aspects of the resource system and units. Fenichel *et al.* (2012) can be consulted for a more detailed review of these efforts.

Although many researchers (e.g. Larkin 1978; McConnell & Sutinen 1979; Royce 1983) have long called for integrated modelling of recreational fisheries, applications using empirical or simulated data that heavily draw from human dimensions-related theories and concepts are more recent. Early research focused on developing integrated models that were consistent with economic utility theory (e.g. McConnell & Sutinen 1979; Anderson 1993) or employed a coupled system that lacked feedbacks between fishers' actions and fish populations (Lupi *et al.* 2003). Carpenter and Brock (2004) presented one of the first complex simulation models of recreational fishers' behaviours based on economic utility theory and feedbacks to fish populations within systems models of recreational fishing. Subsequently, Massey *et al.* (2006) applied utility-theoretic models within a recreational fishing SES for studying the impact of environmental change on fisher well-being in a coastal fishery in the USA. Research has also used these utility-theoretical models in recreational fisheries SES to understand: how heterogeneous preferences of fishers might affect conclusions about preferred harvest regulations (Johnston *et al.* 2010); how accounting for multiple nested decisions by fishers (e.g. participation, duration of fishing) affect multiple outcomes from fisheries management (Gao & Hailu 2010); and how different assumptions of fishers and their behaviours influence outcomes from a landscape of fishing opportunities (Hunt *et al.* 2011). Other applications using human dimensions concepts have simulated the effects of information communication among networks and actions of fishers (Little & MacDonald 2007) and the use of social norms to examine stocking decision-making for a local recreational fishery (van Poorten *et al.* 2011).

Many studies above focused on optimising policies or management approaches given management goals and objectives while either not considering or fixing the institutional setting (Johnston *et al.* 2010; Fenichel *et al.* 2010). However, governance systems and institutions are dynamic and change, often slowly, in response to feedbacks by the fishers and others or the outcomes revealed to managers. Some research (Carpenter & Brock 2007; Horan *et al.* 2011) has begun exploring how institutions respond to feedbacks from fishers and resource systems and how the resulting managerial actions (e.g. changes to formal rules), connections and feedbacks affect outcomes from the SES.

Future research needs

Biologists and fisheries managers are slowly embracing human dimensions research as a critical part of recreational fisheries analyses and management. Hastening this

embrace requires increasing the awareness and appreciation for human dimensions research to these individuals. Viewing recreational fishing within a coupled SES helps to illustrate the important contributions by human dimensions research to recreational fisheries management. More importantly, the SES provides a framework to help integrate past human dimensions research results within a managerial context of considering how fishing actions affect resource systems and units and how these changes in turn affect recreational fishers' intentions, strategies and actions. Increasingly, research is adopting a coupled SES approach to conduct truly interdisciplinary research on recreational fishing that focuses on human and biological dimensions and their interactions. Evidence for this increase comes from the previous section where five research articles were published before 2010 whereas six were published in 2010 and 2011 (see also Fenichel *et al.* 2012).

Although human dimensions research activities are contributing towards recreational fisheries management, further progress is needed in several areas. First, consistent with the general call by Anderies *et al.* (2004), more research is needed to understand how institutions and their design affect fishers' actions and outcomes within an SES. Although some researchers have explored these effects (Carpenter & Brock 2007; Horan *et al.* 2011), future research should focus on at least two fronts. The first front involves understanding how rules and norms affect fishers' actions (Fenichel *et al.* 2012). Such studies should examine typical rules such as harvest regulations along with all rules and norms that affect the full range of fishers' actions including participation, strategy selection, behaviours and outcomes (Ostrom 2005). The second front involves studying how institutions change and adapt within an SES. Research could focus on how people redesign institutions when resource and social outcomes change and how and if these changes to institutions link and feedback through fishers' actions and outcomes. Such studies could examine not only agency managers' responses to changing outcomes but also how groups of fishers respond to these changes (e.g. develop and revise voluntary norms).

Second, more research is needed to understand the processes that recreational fishers use to select and implement their fishing strategies and subsequent actions. To date, much research that predicts the actions of fishers in relation to dynamic fisheries resources has relied on natural predatory-prey theory (e.g. Johnson & Carpenter 1994; Parkinson *et al.* 2004), atheoretical statistical models (e.g. Post *et al.* 2008), or utility maximisation theory (e.g. Massey *et al.* 2006; Gao & Hailu 2010). Some social scientists insist that humans do not optimise (maximise) their choices and are active in devising other ways to predict human actions [reviewed in Gigerenzer & Gaissmaier (2011)]. Research designed to evaluate the validity of different approaches to predict fishers' actions and the sensitivity of outcomes to these approaches could provide important information for future SES applications. Such research could produce better predictions from models of fishers' actions and assist in understanding and describing the heterogeneity in fishing strategies and actions taken by these fishers. This research is especially important given that heterogeneity in fishers can affect predictions about how fishing effort influences resource systems and units (Fenichel *et al.* 2012).

Third, understanding how recreational fishers learn and share information is an important need. On the one hand, cooperative actions such as sharing catch-related information can result in increased catch and harvest effects from recreational fishers (Mueller *et al.* 2008). Consequently, cooperation can result in increased effects on resource systems and units that will necessitate the development or redesign of institutions. On the other hand, understanding how information sharing affects intentions and actions through changes in cognitions, mental models and social relationships provides an avenue for governance of fishers. Managers, recreational fishers and others can design communications and outreach programmes that target ways that fishers learn, including through social networks. These targeted communications can help to increase fishers' awareness of actions related to their health (e.g. fish consumption advisories), related to the aquatic ecosystem (see Lewin *et al.* 2006), or to their attitudes and preferences for fishing strategies and actions. Any resulting changes to attitudes and preferences can result in changes to recreational fisher well-being even without changes to outcomes. For either of these, research should draw from a large body of literature on social network analysis that describes different ways to think about and model sharing and learning of information (e.g. Watts 2004; Carrington *et al.* 2005).

Human dimensions research on recreational fishing has largely been disciplinary in perspective, and this has likely contributed to the lack of awareness of the research by more biologically-oriented fisheries scientists and managers. Even for human dimensions researchers studying recreational fishing, little overlap exists among individuals who pursue research from different disciplinary lenses. Embedded within these disciplinary lenses are different epistemologies that influence the methods, writing, journal choice and conclusions of human dimensions research. Although the diversity of social science approaches is a strength, it further exacerbates awareness concerns by natural science-oriented managers and biologists and contributes to the perceived messiness and possibly the perceived

low utility of results from human dimensions studies. Simply put, if human dimensions researchers from different disciplinary perspectives do not understand and cite each other (see for example Fenichel *et al.* 2012), it is doubtful that many fisheries managers and biologists will understand this research.

Ultimately, an integrated approach that incorporates an understanding of the various sub-systems and their interrelationships is necessary and sorely needed, and the SES framework proposed here could help in fostering the integration. By situating recreational fisheries within an SES, it is hoped that research will be further encouraged to ensure that research activities contribute to solve recreational fisheries management issues without reinventing the wheel. Therefore, a benefit of situating research within an SES is potentially heightened awareness of other disciplinary perspectives within the social sciences, including earlier research results that may result in consilience (Wilson 1998) by unifying disciplinary specific theories and concepts that comprise human dimensions thinking.

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