The Future of Fishing for Fun: The Economics and Sustainable Management of Recreational Fisheries

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Abstract

The management of recreational fisheries has received relatively little research attention from economists. Nevertheless, recreational fisheries generate substantial economic benefits and ecological impacts in many freshwater and marine systems, although they frequently face a range of management challenges. In this article we consider the endogenous feedbacks and exogenous stressors within the coupled human-natural system of recreational fisheries that threaten their efficient and sustainable management, and we review the potential role of economics in addressing these challenges. We discuss key similarities and differences between commercial and recreational fisheries and the implications of the differences for the theory and practice of managing recreational fisheries. Finally, we identify important research gaps that must be addressed to enable policy makers to more accurately weigh the costs and benefits of changes to recreational fishery policies.

JEL codes: Q26, Q22, Q51

INTRODUCTION

Seafood serves as an important source of nutrition worldwide. However, fishing is also an important source of fun. It has been conservatively estimated that 220 million recreational fishers (i.e., anglers) fish worldwide (World Bank 2012), outnumbering commercial fishers 5 to 1 (FAO 2020). Over half of anglers reside in industrialized nations, where 1 in 10 fish recreationally (Arlinghaus, Tillner, and Bork 2015). Participation in recreational fisheries is generally lower in developing countries, although estimating participation is a challenge due to a lack of data and the conflation of recreational and subsistence fishing. Nevertheless, recreational angling is on the rise in many middle-income countries, including China, as incomes rise and demands for nature-based tourism expand (Freire et al. 2020). However, recreational angling can have significant impacts on fish stocks in both saltwater and freshwater, and can lead to overfishing (Coleman et al. 2004; Radford et al. 2018; FAO 2012).

Recreational fishing also provides an important source of income and employment in coastal communities (Lovell et al. 2020). Moreover, anglers derive welfare from the overall recreational experience that extends beyond the market values of harvested fish. Despite the importance of recreational fisheries, environmental and resource economics research on recreational fisheries has been limited and narrow in scope compared to the voluminous literature on commercial fisheries. Most economic research on recreational fisheries has focused on valuation – using recreational fisheries as a means to value aspects of the aquatic environment (Fenichel, Abbott, and Huang 2013). Relatively few papers have focused on the specific management challenges of recreational fisheries. This lack of research is an issue for policy makers because recreational fisheries have many unique features that make it difficult to directly apply successful policy approaches from commercial fisheries.

This article, which is part of a symposium on The Future of Seafood,[1] examines the economic literature on recreational fisheries in light of the current and likely future challenges facing the sector and provides recommendations for how economists can orient their research to better address these challenges.

The article is organized as follows. First, we briefly describe the non-market valuation techniques that have been used to measure the value of the services provided by recreational fisheries. Next, we describe the structure of recreational fisheries and the endogenous stressors and market failures that undermine sustainable benefits from managed and unmanaged recreational fisheries. This is followed by a discussion of exogenous stressors that provide both opportunities and challenges for mangers; these include environmental stressors such as invasive species and climate change as well as technological innovations. The penultimate section examines opportunities for improving the management of recreational fisheries, with a particular focus on adapting rights-based management approaches, which are more commonly applied in commercial fisheries, to the recreational context. We conclude with a discussion of research priorities.

THE VALUATION OF RECREATIONAL FISHING SERVICES

[1] The other articles are by Kroetz et al. (2022), who focus on the future of wild-caught fisheries, Asche et al. (2022), who focus on aquaculture, and Cojocaru et al. (2022), who provide a synthesis of the other three articles in the symposium and discuss key issues concerning the seafood system overall.

Although billions of dollars are spent on recreational fishing (Cisneros-Montemayor and Sumaila 2010), these expenditures are not sufficient for estimating the welfare value of recreational fishing because many of its benefits and costs occur outside normal market transactions (Edwards 1991). Thus, non-market valuation methods play an important role in the benefit-cost analysis of fishery and water quality regulations (Freeman 1995; Kaoru 1995) and stocking programs (Rhodes et al. 2018), natural resource damage assessments (Alvarez et al. 2014), and decisions about the allocation of harvest and access between the commercial and recreational fishery sectors (Lipton et al. 2014).

The value of recreational fishing, including both the food attributes of fish and the recreational fishing experience itself, can be estimated using either revealed preference (RP) or stated preference (SP) methods.[2]

Revealed Preference Methods

RP methods rely upon the actual or, in some cases, the recalled trip-taking and site choice behavior of anglers to identify their preferences. The travel cost method is the primary RP approach for estimating the economic value of recreational fishing (Lupi, Phaneuf, and von Haefen 2020). Under this approach, the implicit price of a recreational fishing trip is calculated based on the costs of travel and other trip-specific costs. Anglers tend to choose sites with low travel costs, but when choosing sites further away, they tend to be those that offer more attractive characteristics (e.g., greater expected catch, ease of access, or better weather conditions).

[2] In a review of the non-market valuation literature for site choice in recreational fishing, Hunt et al. (2019) find that 114 studies were published between 1988 and 2017, with about twice as many RP studies as SP studies.

Site selection is the primary angler decision analyzed with the RP approach. Fishing quality is incorporated into site-selection models through the variation in catch rates and other attributes across sites (e.g., Larson and Lew 2013, Hindsley, Landry, and Gentner 2011). Catch can be measured either as averages at the site level or individually, where catch depends on both local fish stocks and angler inputs such as capital and skill (McConnell, Strand, and Blake-Hedges 1995). Perhaps due to a lack of variation across sites in RP data, with the exception of possession (bag) limits, RP models rarely incorporate the effect of fishery regulations on the value of the recreational experience (Scrogin et al. 2004). This suggests a need for SP methods.

Stated Preference Methods

SP methods, such as contingent valuation (CV) and discrete choice experiments (DCE), elicit preferences through carefully constructed survey questions. Respondents are typically presented with hypothetical fishing trips that vary in their cost and/or quality attributes. In a CV survey, respondents are asked whether they would take a trip with higher costs or different quality (Cameron and James 1987). With DCE, respondents are asked to choose between multiple trips with various combinations of attributes as well as a no-trip option.

Many of the limitations of RP studies of recreational fishing can be addressed through SP studies' experimental presentation of attributes. It is often difficult to estimate the value of fishing attributes with RP methods. For instance, boat ramps and piers are often located near more productive fishing locations, which makes it difficult to untangle preferences for these correlated attributes. However, it is relatively straightforward to disentangle these attributes with a carefully constructed SP experimental design. This approach has been used to estimate the effects of bag and size limits on fishing values and to value consumptive harvest separately from catch and release fishing (Carter and Liese 2012a; Lew and Larson 2015; Lew and Larson 2014); these studies generally find that willingness to pay (WTP) is higher for harvested fish than for released fish.

Although estimated values can vary substantially across studies, there are some logical reasons for this variation. For example, WTP is greatest for salmon and "big game" (e.g., billfish, tuna) species; marine species have higher values than freshwater species; and the valuation methods used (e.g., RP versus SP) affect WTP estimates (Johnston et al. 2006). It is important to note that Johnston et al. (2006) found that SP methods often produce lower WTP values than RP studies, a difference that is also found in other non-market valuation applications (e.g., the value of statistical life; see Kochi, Hubbell, and Kramer 2006; Robinson and Hammitt 2016). Studies that combine RP and SP data (Cameron 1992; Gillig et al. 2003; Whitehead and Lew 2020) can provide insight into the differences in values recovered by each approach and help resolve them. Thus RP and SP methods are complementary approaches for estimating anglers' valuations of recreational fishing services and examining how those values differ across management options.

RECREATIONAL FISHERIES: STRUCTURE AND ENDOGENOUS STRESSORS

To understand the role of economics in addressing recreational fishery management challenges, it is important to first understand the structure of recreational fisheries and the sector's various stressors. Figure 1 presents recreational fisheries as a coupled human-natural system, in which the dynamics of fish stocks and other aspects of the biophysical environment are impacted by the behavior of stakeholders. These biophysical variables then influence stakeholders' perceptions and preferences, which are then influenced by constraints and incentives before ultimately resulting in in stakeholder behaviors. These internal feedbacks are also subject to external trends and shocks from both the human and biophysical systems that may be stabilizing or destabilizing.

Fisheries management institutions incorporate informational signals from both the biophysical system (e.g., stock assessments) and stakeholders (e.g., participatory management institutions) to alter feedbacks within the coupled human-natural system by: 1) allocating resource access to conflicting user groups; 2) altering the constraints and incentives of resource users; and 3) directly investing in natural capital through stock and habitat enhancement. Critically, fishery managers have only partial control of the system; the policy tools at their disposal can only indirectly steer the many dimensions of stakeholder behavior and are calibrated based on noisy and incomplete information about relevant feedbacks within the system.

We deliberately include recreational, subsistence, and commercial fishers as stakeholders in Figure 1 to highlight their structural similarities. Nevertheless, recreational and commercial fishing differ in several ways that are important for our discussion of recreational fisheries management. These differences include:

1. Markets for harvested fish often place a homogeneous value on the use of fish stocks by profit-maximizing commercial fishers, but recreational anglers are free to value this natural capital as they wish, as one of the components of the recreational "bundle" they enjoy. These heterogeneous valuations can result in

diverse behaviors across anglers (e.g., fishing for consumption vs. 'catch and release') that have distinct effects on the ecosystem.

2. Heterogeneity in fishing skill tends to persist more in recreational fishing than in commercial fishing. In commercial fisheries, competition excludes inefficient vessels, while in recreational fisheries, there is no reason to expect low-skilled anglers to abstain from fishing. Furthermore, depending on the correlations between anglers' skill, income, and preferences, the assumption (based on experience in commercial fisheries) that more skilled anglers will value additional harvest more highly than low-skilled anglers may not hold.
3. Relative to commercial fisheries, managers of recreational fisheries face substantial barriers to measuring biological feedbacks (i.e., fish mortality from fishing) and human feedbacks (preferences, behavior) and to managing anglers' impacts on aquatic resources. These challenges arise from the sheer number of anglers, the widespread nature of launch points and landing locations, and anglers' heterogeneity in preferences and skill. Thus, just as the control of pollution from nonpoint sources (such as automobiles) is less efficient than control of pollution from point sources (such as power plants), the management of recreational fisheries is generally second-best when compared to the management of commercial fisheries (Shortle and Horan 2002; Fenichel and Abbott 2014).

Now that we have established the structural features of the recreational fishery system, we next turn to the endogenous stressors that concern fishery managers.[3] Endogenous stressors to the recreational fishery emerge from feedbacks within the coupled human-natural system of the fishery itself. These stressors include within-sector stressors, which originate from and affect the recreational sector, and inter-sector stressors, which are due to interactions between the commercial and recreational sectors.

Within-sector Stressors

The greatest challenge to the efficient and sustainable provision of recreational fishing services is their dependence on multiple common-pool inputs (e.g., fish stocks, scarce fishing spots).[4] This means that without cooperation or effective regulation, individual anglers will tend to undervalue these inputs when making their fishing decisions. This results in a commons 'dilemma' (Ostrom 1990), whereby individually optimal but collectively irrational decisions result in degraded natural capital and inefficient allocation of harvested fish and trips across anglers. We examine these outcomes in both unregulated (open access) fisheries and regulated fisheries (which are more common).

The unregulated fishery

Consider an open access single stock recreational fishery, where insecure rights to fish cause anglers to ignore the full cost of their harvest and discard decisions on fish mortality. In this case, participating anglers will take more trips than is collectively optimal, and some anglers will be induced to participate, even though they would not have participated had they

[3] We discuss exogenous stressors in the next section.

[4] Common-pool resources are characterized by both rivalry in consumption (i.e., my use of the resource limits its availability or usefulness to others) and a high difficulty of excluding users.

borne the full cost (McConnell and Sutinen 1979; Anderson 1993). Anglers will also tend to fish too long and over-invest in fishing tackle to enhance their catch and retain more catch than is optimal (Anderson 1993). The distortion of retention incentives will be most consequential when released fish have a low rate of mortality. These equilibrium outcomes are similar to the outcomes for commercial fisheries; the undervaluation of fish 'in the water' results in too many participating anglers taking too many trips, catching too many fish per trip, and retaining a larger fraction than is optimal, thus resulting in a depressed stock. However, unlike in commercial fisheries, where profit-seeking behavior under open access results in an equilibrium prediction of zero rents, the welfare loss in an open access recreational fishery will depend on several factors. These include the number of potential anglers and their proximity to the fishery, the distribution of heterogeneous preferences and income, and the availability of fishing and non-fishing substitutes (Fenichel and Abbott 2014).

Abbott and Wilen (2009) consider the special case of the recreational for-hire sector, where anglers pay for trips on vessels owned and operated by recreational service providers. They find that, in addition to the externalities discussed above, the underpricing of fish mortality in open access will be reflected in anglers' trip demand, leading vessel owners to overinvest in catch-augmenting inputs (e.g., bait, tackle). If catch rates are a function of crowding on the boat, owners may place too few passengers onboard individual vessels, shifting angler-days to additional trips. Finally, there will be a tendency toward excess capacity in the industry.

There may be other angler-induced externalities. For example, the congestion of scarce fishing grounds may directly reduce the welfare of anglers that prefer solitude, or indirectly reduce welfare by reducing harvest rates (Phaneuf, Carbone, and Herriges 2009). In addition, water quality and habitat may be degraded through cumulative overuse and discarded tackle, and anglers' movements may spread invasive species (Timar and Phaneuf 2009). Finally, simply catching and releasing fish may affect their vulnerability to catch by subsequent anglers. Indeed, some released fish adapt and become more cautious over their lifetime, while the selective removal of less cautious fish may create evolutionary selection toward greater timidity (Lewin et al. 2019). Although these externalities are exacerbated by the underpricing of fishing mortality, their underlying causes are distinct, suggesting that there may be a need for targeted policies to address them.

The regulated fishery

Many recreational fisheries nominally limit entry by requiring an annual or short-term license. However, these licenses are primarily priced to raise revenue, deterring only those anglers with a low WTP for the option to fish, while providing no marginal incentive to reduce harvest for those that purchase a license (Abbott and Fenichel 2013, Whitehead, Clifford, and Hoban 2001). As a result, fishery managers primarily use output and input controls to limit the impacts of recreational fishing. This approach, known as regulated open access (Homans and Wilen 1997), typically relies heavily on bag limits and seasonal fishery closures, supplemented by size limits and restrictions on gear and tackle.

Bag limits restrict fishing mortality per trip and indirectly dampen trip demand for some harvest-oriented anglers that expect to exceed the bag limit. However, they have little behavioral effect on anglers for whom the limit is unlikely to bind and thus have little effect on total harvest (Cox, Beard, and Walters 2002; van Poorten, Cox, and Cooper 2013). Moreover, bag limits do not control harvest mortality effectively in catch and release settings that have significant discard mortality (e.g., deep sea fisheries) and may even induce “high-grading” behavior, whereby anglers continue to fish after reaching their limit, discarding previously retained fish so they can target larger fish (Woodward and Griffin 2003).

In fisheries with modest angling demand, or where stock enhancement can maintain stocks at low cost, bag limits may support achievement of biological management targets. However, managers often combine bag limits with more direct curbs on effort, including seasonal closures for anglers’ targeted species. Closures may indirectly suppress demand by prohibiting retention of the species (Abbott et al. 2018). More specifically, if barriers to intertemporal substitution are high, the value of species retention is low, and there are close substitutes for the recreational experience during the closed season, then seasonal closures may rein in fishing effort. However, seasonal closures may simply shift trips into the open season, with little effect on total fishing effort.

The potential for such inefficiencies has been well documented for the Gulf of Mexico red snapper fishery, where between 1994 and 2014, the length of the recreational season in federal waters was reduced from the full year to a few days and the bag limit declined from 7 to 2 fish as anglers flooded into the fishery in response to stock rebounds (and hence higher catch rates).[5] These reductions in access occurred despite increases in recreational quota in these years (Gulf of Mexico Fishery Management Council 2014). This skyrocketing demand during increasingly shorter seasons may overrun managers’ informational capacity (or political will) to

[5] An increase in catch size over this period also contributed to the biomass-based quota being met more quickly.

set seasons that limit fishing mortality, encouraging persistent overfishing of the recreational allocation.

Even if biological targets are achieved, there are disadvantages to regulated open access management. First, regulated open access may undermine angler welfare by shifting demand toward sub-optimal seasons for some anglers and inducing congestion during open seasons (Abbott et al. 2018). It may also jeopardize the ability of for-hire providers to provide a high-quality customer experience and limit their livelihoods to a narrow season (Abbott and Willard 2017). Finally, bag limits and closed seasons impose non-price rationing of scarce harvest (Holzer and McConnell 2014). Rather than allocating fish based on the highest marginal valuation, fish are allocated to anglers that have the lowest costs of adaptation to the regulations.

The efficiency losses of regulated open access are generally poorly understood. However, in a simulation for Gulf of Mexico red snapper, Abbott et al. (2018) predict large welfare losses to anglers if regulated open access management is maintained by lowering trip quality, forcing substitution toward trips with lower net benefits for some anglers (while excluding others entirely), and inefficiently allocating catch and harvest across heterogeneous anglers.

Inter-sector Stressors

Conflict between commercial and recreational fishers, as well as between the recreational for-hire sector and private anglers, may arise from direct technological interactions such as gear entanglement or congestion, stock depletion, or discard (or bycatch) externalities (Kearney 2002; Samples 1989). However, the most common inter-sector stressor, at least in

North American mixed-use marine fisheries, is the allocation of total allowed fishing mortality across sectors (typically denominated in terms of catch, see right side of Figure 1). Total catch is frequently divided into explicit allocations to the commercial and recreational sectors (and sometimes between private recreational anglers and the for-hire sector). Competition for a larger slice of the "pie" has led to heated conflicts that must be resolved by fishery managers because of the lack of mechanisms for transfers of allocations between sectors. Ironically, conflict has often intensified as management of the commercial sector has become more efficient through implementation of rights-based management (RBM) policies such as individual transferable quotas (ITQs) or cooperatives. These policies have created an organized constituency for commercial interests, while the recreational sector, faced with tightening regulations under regulated open access, has often sought additional allocation.

These conflicts have created a demand for economic analyses to support policy decisions. Most analyses have adopted static allocative efficiency (i.e., maximization of net benefits within a season) as their goal, typically relying on the `equimarginal principle' to justify partial reallocation to the sector with the highest estimated marginal valuation for landings (e.g., Gentner et al. 2010; Agar and Carter 2014). These valuations rely on landings prices net of harvest costs (or ITQ lease prices) for the commercial sector and data from RP or SP valuation studies for recreational fishers to identify and compare a point or a small region of each sector's demand curve as the basis for changes in the allocation. For example, if the recreational sector's marginal valuation of allocation exceeds that of the commercial sector, then a shift of allocation to recreational anglers is recommended.

Despite its simplicity, this approach has been criticized for several reasons, including the inability of static valuations to assess the efficiency of long-run changes in allocations (Schuhmann and Easley 2013; Woodward, Wui, and Griffin 2005). Most recently, the credibility of the equimarginal principle itself has been undermined (Abbott 2015; Holzer and McConnell 2014). Reallocation to the sector with the highest marginal valuation assumes that the allocation *within* each sector is rationed preferentially to those with the highest valuations, as in a well-functioning market. However, Holzer and McConnell (2014) argue that this assumption is often violated, especially for recreational fisheries under regulated open access. The value of "one more fish" to a sector is inseparable from how that fish is actually rationed to fishers within the sector (e.g., through a relaxation of bag limits vs. a longer season for recreational anglers). Thus, without incorporating a great deal more information about how policy allocates across the spectrum of anglers' valuations, comparisons of estimated marginal values across sectors provide little insight about whether a change in allocation actually enhances economic efficiency.

EXOGENOUS STRESSORS

Fishery managers' decisions about how to manage endogenous stressors occur within a context that is largely beyond their control. Thus, while variability in harvest is an expected and even appealing feature of recreational fishing, changes in the natural environment (e.g., water pollution, invasive species, climate change) and technological developments are both exogenous stressors to which anglers and managers alike must adapt (see Figure 1). In this section, we discuss how the recreational fishing sector is affected by and responds to these exogenous changes in the natural environment and technology.

Exogenous Changes in the Natural Environment

From the earliest days of nonmarket valuation (Bockstael, Hanemann, and Strand 1984) to the latest and largest studies (Alvarez et al. 2014; English et al. 2018), recreational fishing behavior has been used to place a value on water quality. Indeed, through their adaptive choice of fishing sites and frequency of trips in response to changing water conditions, anglers demonstrate a willingness to pay for improved water quality.

The recreational fishing experience can also be affected by invasive and exotic (non-native) species, which have become more common due to climate change and globalization (Rahel and Olden 2008). The impact of exotic species on recreational fisheries may vary from catastrophic (if the invading species decimates valuable native species) to economically beneficial (if the new species becomes an attractive recreational target).

Some of the most interesting cases of exotic species affecting recreational fishing come from the Great Lakes region of North America. After invading in the early 1900s, the sea lamprey upset the lakes' ecology by decimating native lake trout and other species, leading to explosive growth and die-offs of alewife, another exotic species. Two important management actions were taken in response. First, a variety of lamprey control techniques were implemented, which significantly benefited anglers (Lupi, Hoehn, and Christie 2003). Second, managers stocked exotic salmonid species. Although the introduction of exotic species is often opposed by ecologists due to their potentially profound effects on native species, they may also become an attractive recreational alternative. This occurred in the Great Lakes, where nonnative Chinook salmon have become among the most valued target species (Melstrom and Lupi 2013).[6]

Another interesting invasive species case concerns the lionfish, which has expanded rapidly through the U.S. east coast and the Caribbean, seriously disrupting reef ecosystems. Recreational fishing has been negatively affected, but it may also be part of the solution. For example, spearfishing derbies have been used to help control lionfish populations (Malpica-Cruz, Chaves, and Côté 2016). However, such an approach is effective only where the invasive species is already well established, which means more drastic, and often expensive, measures will be needed if the goal is eradication (Frazer et al. 2012).

In terms of exogenous environmental stressors, climate change may have the greatest impact on anglers. Some studies have found that rising temperatures may benefit anglers (Whitehead and Willard 2016). However, Dundas and Von Haefen (2020) find that in the U.S. Atlantic and Gulf Coast regions, the welfare losses from an increase in the number of extremely hot days are greater than the gains to anglers from a decrease in the number of extremely cold days. Climate change will also affect the species available to anglers, especially highly migratory fish that are often among the most prized recreational target species (Fujiwara et al. 2019; Pinsky et al. 2018). However, there has been limited analysis of the implications for angler welfare of climate-driven shifts in fish range and abundance (Hunt et al. 2021).

[6] However, Chinook abundance is dependent on the alewife. As a more natural balance has been restored to the Great Lakes, Chinook abundance has declined (Raynor and Phaneuf 2020).

Exogenous Technological Change

Technology has become an increasingly important aspect of the fishing experience for some anglers. Although only 3-5% of anglers purchase electronic devices such as depth finders and fish finders, the average amount anglers spend on these technologies has increased from $286 per year in 1996 to $686 in 2016 (U.S. Department of the Interior, U.S. Department of Commerce, and of the Census. 1996; U.S. Fish and Wildlife Service et al. 2018).

These high-tech gadgets are often viewed as inputs to the catch production function, and therefore cause increased fish mortality (Cooke and Cowx 2006). However, it may be more appropriate to view some fishing technology as an additional consumption good rather than as a catch-augmenting input, so that its effect on total landings may be ambiguous. Indeed, some technology may be a substitute, rather than a complement, to more or longer trips or other catch-augmenting inputs such as fuel and bait. While complementarity seems plausible in many circumstances, increased expenditures on gear and tackle may not always imply higher fishing mortality. For example, some anglers pay extra for barbless or circle hooks designed to reduce mortality rates for catch-and-release fishing. Thus, the overall impact of technological change on fishing mortality is unclear and likely to vary by fishery.

Another technological change that has affected marine recreational fishing is the manipulation of the fishing environment through artificial reefs, which provide alternatives to natural reefs threatened by ocean acidification and climate change, and fish aggregating devices, which attract and concentrate fish in known locations (Sutton and Bushnell 2007). As with stocking, which directly manipulates the species mix to favor preferred species, anglers will respond to these technological interventions by targeting areas where such technologies are available or avoiding them if a more natural or uncongested fishing experience is desired.

IMPROVING MANAGEMENT OF RECREATIONAL FISHERIES

Fostering economic efficiency in recreational fisheries management requires policies that adjust the constraints and incentives of stakeholders to internalize the social costs of recreational fishing and minimize the creation of additional externalities. In this section, we examine how recreational fishery policies can be used to ensure efficient management of endogenous stressors, while remaining robust to exogenous stressors.

Management of Endogenous Stressors

RBM systems that impose strong excludability – by limiting fishery access to a small group of users or by allocating durable individual rights to shares of harvest itself (i.e., ITQS) – are often proposed to internalize the common pool externalities of recreational fisheries. While some small-scale inland recreational fisheries are harvested by members of angler clubs (Arlinghaus, Mehner, and Cowx 2002), strong exclusion is rarely feasible or desirable for fisheries in public waters. Moreover, ITQs and other RBM policies, while common for commercial fisheries, are very rare for recreational fisheries.

Cultural traditions of open access often make recreational RBM politically infeasible (Borch 2010). Even when feasible, RBM policies face the challenge of the diffuse nature of recreational participation and ecological impact. Anglers often participate from a wide array of access points and modes (e.g., shore-based, private vessel, or for-hire vessel) for the nominal cost of a license. Because the angler population is large and diffuse, fishery managers use surveys to collect information on catch and effort. However, limited budgets and the sheer scale and spatial scope of many recreational fisheries may lead to unreliable tracking of landings, with even less reliable data on discard mortality (Cooke and Suski 2005). Given these features of recreational fisheries, recreational RBM must determine how to assign, monitor, and enforce rights to participants in ways that are feasible and provide efficient incentives. We consider three categories of policies that address aspects of this challenge: angler management organizations, short-term output and input-based rights, and RBM policies tailored for the for-hire recreational sector.

Angler management organizations

Sutinen and Johnston (2003) suggest a co-management approach to incorporating the diffuse angler population into management through the creation of an angler management organization (AMO), a for-profit, non-governmental organization composed of individuals from the recreational fishing community who own shares in the AMO and engage in its governance. The AMO would be allocated a share of the total allowable catch (TAC) and have the exclusive right to determine how to use its allocation to provide the greatest benefit to its shareholders. The for-profit nature of the AMO and tradability of AMO shares would provide collective incentives to maximize the value of the AMO's TAC allocation to the anglers it serves, helping align private and social interests. Another advantage of an AMO is that it creates an institutional mechanism for reallocating quota between the recreational and commercial sectors via transactions (Abbott 2015). To our knowledge, no AMO has been implemented, although private angler clubs and commercial fisheries cooperatives share similar features. Thus, AMOs face many unresolved design questions, including the scope of external regulation, membership rules, whether the AMO should be a for-profit or non-profit organization, the design of internal mechanisms for allocation monitoring and enforcement, and how to obtain political support in an environment where any restriction on access is viewed with skepticism.

Short-term output and input-based rights

Allocating multi-season harvest rights across a diffuse angler population (through an approach analogous to commercial ITQs) poses a formidable challenge. An alternative is for managers to annually create a limited number of far more restricted and short-term use rights. These rights could be based on outputs (harvest) or inputs (e.g., days of fishing), thus providing anglers a signal of the current scarcity value of these outputs or inputs (Kim, Woodward, and Griffin 2009).

Output-based use rights require either a physical harvest tag placed on harvested fish or a stamp appended to the fishing license specifying the maximum harvest of a species within a given time period (Johnston et al. 2007). If limited in quantity and well-enforced, and if discard mortality is negligible or occurs in known proportion to landings, then harvest tags can achieve recreational fishing mortality goals. Tags could be sold, allocated by lottery, or auctioned, depending on the objectives of managers. However, if tags are also tradeable in a secondary market, then harvest will flow toward its highest-valued use, fostering efficiency. While tags and stamps have been used in a number of fisheries, they have rarely been constrained by a hard cap on landings. Rather, they are often bundled with licenses, thus providing a cap on landings per angler, but not overall landings (Johnston et al. 2007). Moreover, when tags are scarce, they are typically allocated by lottery with resale prohibited, which undermines allocative efficiency.[7]

Another option is for managers to create a seasonal right to an observable fishing input that is tied to fishing mortality. For example, information on the correlation between fishing days and fishing mortality can be used to cap the total number of angler days in a season as an approximation of a target fishing mortality. Day passes can then be allocated to anglers (i.e., similar to harvest tags). A secondary market could allocate fishing days to those that value them most highly, although efficiency in the allocation of fishing mortality is unlikely to result unless fishing skill and discard practices are homogenous across anglers (Fenichel and Abbott 2014). While we know of no quantity-constrained day pass programs, short-duration fishing licenses are common, and these might be adapted to allocate rights more efficiently.

Neither harvest tags nor day passes will foster the levels of accountability and efficiency observed in commercial ITQ fisheries. Nevertheless, these approaches would substantially improve individual angler accountability and economic efficiency relative to bag and size limits and seasonal closures. The relative advantages of input versus output-based policies depend on 1) their ease of monitoring and enforcement and 2) the magnitude of the distortions created by their imperfect targeting of the externalities of fishing. While day passes are likely easier to monitor and enforce than harvest tags, anglers may respond by fishing more intensively to increase their landings per day. However, the link between harvest and total fishing mortality may be weak if harvest tags are used when discard mortality is high or if scarce tags induce

[7] Tags for trophy hunting are often allocated by auction (sometimes in combination with a lottery) to raise revenue for resource management (Johnston et al. 2007).

catch discarding. In fact, neither harvest tags nor day passes provide sufficient incentives for avoiding discards (Abbott 2015). Thus, the relative merits of input vs. output-based policies are context-dependent. Moreover, it is likely that any real-world RBM system will need additional input or output controls to achieve management objectives.

Recreational RBM in the for-hire sector

Given the challenges of RBM for private anglers, it is not surprising that there has been more progress on recreational RBM in the for-hire sector than in the private angler sector. For example, under a pilot program for the Gulf of Mexico red snapper and gag grouper fisheries, members of a for-hire cooperative were allocated a proportion of the TAC, which they could utilize to target these species over the entire year (rather than only for the short derby season). The pilot program benefited participating vessels through increased revenues, longer fishing seasons, and reduced discards (Abbott and Willard 2017). There were also welfare gains for anglers because vessel owners spread scarce red snapper and gag grouper catch over more anglers and trips (Abbott et al. 2018). Nevertheless, the benefits from the program may have been unusually large due to the extreme shortness of the season prior to establishment of the for-hire cooperative.

Another effort to include the for-hire sector in RBM is the catch sharing plan for Pacific halibut in Alaska, which allocates fish between the for-hire sector (managed under regulated open-access) and the ITQ-managed commercial fishery. For-hire businesses are allowed to lease quota for the season from the commercial sector, but they are not full participants in the ITQ system and cannot buy or hold quota. Kroetz et al. (2019) found that after its first two years, this program led to greater flexibility for commercial quota holders, especially those holding smaller vessel quota; however, the benefits to the for-hire quota lease holders were less clear.

Adapting Management to Respond to Exogenous Stressors

Even as they seek to manage endogenous stressors, recreational fisheries managers must also adapt to an ever-changing exogenous context (Figure 1). Environmental stressors such as oil spills, water pollution, and climate change impact fish stocks and the quality of the fishing experience, while changes in angler demographics and preferences, macroeconomic trends, and technological innovations alter demand and its impacts. Many of these exogenous forces unfold relatively slowly, giving managers time to learn and adapt. However, there are also exceptions, such as the prompt closure of recreational fishing across the Gulf of Mexico in response to the Deepwater Horizon oil spill.

Optimal management responses to exogenous shocks would require coordination across multiple governmental and non-governmental agencies, and account for the dynamics of and uncertainties inherent in the complex human-natural system (see Figure 1). In practice however, management is often constrained by a lack of information, the limited mission and power of resource managers, and bureaucratic inertia (Crosson 2013). For example, while in theory, recreational fishing interests should be represented when developing national climate change policies, it is unlikely that fisheries managers will actually play a significant role in that process. Nonetheless, recreational fishing managers and stakeholders can and do participate in regional efforts to address factors that would usually be considered outside their scope. For example, recreational fishing interests are represented on the Gulf of Mexico Fishery

Management Council's Coral Advisory Panel, which reviews scientific studies of coral habitat and makes management recommendations. Similarly, in areas with a strong recreational fishing economy, recreational fishing interests should be integrated into any plan for regional economic development (Ditton, Holland, and Anderson 2002).

Fisheries are stochastic dynamic systems. Thus, efficient recreational fisheries management requires that decisions made today incorporate the potential consequences of these decisions for future states of the system. However, this does not mean that policy makers should always try to dampen natural variation or treat the system as fully controllable. Indeed, as shown by Carpenter et al. (2017), a strategy aimed at reducing short-term variation can make the system less resilient to exogenous and unanticipated changes.

Finally, efficient management of recreational fishing would also include embracing the role of management in reducing uncertainty by pursuing an *adaptive* management perspective (Walters 1986), whereby policies are viewed as an opportunity to both improve outcomes for the sector and experimentally alter the environment to learn about system feedbacks. Nonetheless, few managers have an incentive to adopt such an adaptive management perspective because it requires that managers be willing to strategically increase rather than suppress variability in the system.

CONCLUSIONS AND RESEARCH PRIORITIES

Recreational fisheries are a fascinating and complex area for economic research. Indeed, they comprise systems for which the definition of efficiency itself is often not transparent, and in which user preferences can be both conveniently visible (allowing the estimation of values) and hidden and heterogeneous (confounding efficient management). Moreover, recreational fisheries are embedded in a stochastic-dynamic natural environment where regulations are highly constrained and monitoring is difficult. As discussed above, recreational fisheries face an array of endogenous and exogenous stressors that complicate their management, degrade angler welfare, and potentially threaten fishery sustainability. Given the heterogeneous and largely non-market orientation of anglers' behavior and the diffuse nature of recreational harvest, insights from commercial fisheries policy cannot be easily transferred to recreational fisheries. Thus, recreational fisheries provide opportunities for researchers to produce impactful and scalable research focused on angler behavior and welfare and the design and evaluation of policy instruments that are specific to the recreational fishery context. We conclude with a discussion of priorities for research aimed at achieving these objectives.

First, improvements are needed in both data and methods. Here, exogenous developments in technology present an opportunity for better management. Increased adoption of technologies like smart phone apps and remote sensing have facilitated new ways of collecting data on fishing behavior and environmental conditions (Venturelli, Hyder, and Skov 2017; Provost et al. 2020), while Internet search volume may be useful to "nowcast" recreational harvest (Carter, Crosson, and Liese 2015). The use of digital licenses and permits also holds tremendous potential for facilitating RBM approaches like harvest tag programs. These electronic tools may offer a cost-effective alternative to traditional survey methods by facilitating more regular data collection and shedding light on previously difficult to observe behaviors (e.g., targeting and discard decisions within trips). However, they must be adopted cautiously to ensure they yield valid estimates that are robust to design and sampling biases.

Recent studies have highlighted the need to improve RP (Lupi, Phaneuf, and von Haefen 2020) and SP (Johnston et al. 2017) valuation methods. Many of these improvements could simultaneously address important knowledge gaps in recreational fishery management, including (1) integrating RP and SP data in order to improve insights about the behavioral and welfare effects of *prospective* policy changes (e.g., Whitehead and Lew 2020); (2) expanding the portfolio of policy tools examined in existing recreational fishing SP studies; and (3) applying insights from behavioral economics to improve the modeling and estimation of recreational fishing preferences, values, and behavior (Lew and Whitehead 2020). Behavioral economics may also provide insights for fisheries management, including the use of nudges to influence regulatory compliance for diffuse populations of anglers (Mackay et al. 2020).

Further research is also needed to integrate recreational fishing demand models with biophysical models; this is a promising, but underutilized, approach for evaluating the short- and long-term effects of stressors and policy mechanisms on welfare and ecosystem conditions (Lee, Steinback, and Wallmo 2017; Massey, Newbold, and Gentner 2006). The development of bioeconomic models to evaluate multiple policy alternatives while also incorporating the feedbacks of endogenous stressors (e.g., congestion) and exogenous stressors (e.g., climate change) poses a major challenge. Meeting this challenge will require the strategic use of joint RP-SP approaches to provide the necessary data to calibrate models to handle scenarios beyond those based on recent historical conditions.

Concerning fisheries management, we have highlighted both the current lack of RBM approaches in recreational fisheries and the potential for realistic forms of RBM to enhance welfare and meet fishing mortality objectives in the sector. The encouraging results of the for-hire pilot program in the Gulf of Mexico (Abbott and Willard 2017) suggest a need for additional RBM policy experiments that focus on other RBM approaches (e.g., AMOs, harvest tags, input-based RBM) and that target the private recreational sector.

There are a number of other ways in which economists can inform emerging issues in recreational fishery management. For example, as state legislatures withdraw financial support from wildlife management agencies, these agencies increasingly depend upon revenue from fishing and hunting licenses. However, this approach creates policy tradeoffs between the goals of raising revenue and controlling resource use. There is also a growing need to understand the within-sector allocation consequences of changes in recreational fishing policies. For example, how do changes in a bag limit or a transition from licenses to a combination of license fees and harvest tags affect both the efficiency and the distributional impacts of access to fishery resources (Abbott and Fenichel 2013)? Finally, differences in angler tackle and in retention and congestion preferences may foster conflict between anglers; this presents opportunities for managers to increase welfare by utilizing regulations and incentives to create spatially and temporally differentiated fishing opportunities for distinct angler types. Spatial bioeconomic models can help managers anticipate the consequences of anglers' adaptations to such policies (Phaneuf, Carbone, and Herriges 2009).

Exogenous stressors, like climate change, are likely to become increasingly important for recreational fisheries. Pinsky et al. (2018) estimate that by 2080, almost 60 countries' territorial waters will be impacted by the climate-induced movement of fish stocks. These movements may have important consequences for future transboundary cooperation in fishery management. Although economics has a long history of game-theoretic analyses of transboundary commercial fisheries agreements, surprisingly little attention has been paid to recreational fisheries (Oinonen et al. 2016).

Finally, given the numerous recreational fisheries in developed countries and the growth of recreational fishing in transitioning economies, it is important for researchers to continue efforts to understand the impact of recreational fishing behavior on fish stocks and economies. As governments increasingly adopt ecosystem-based management approaches for recreational fisheries that embody multiple competing goals related to stock sustainability, social welfare, and equity, economics can play a key role in providing a framework for evaluating the trade-offs between different policy approaches.

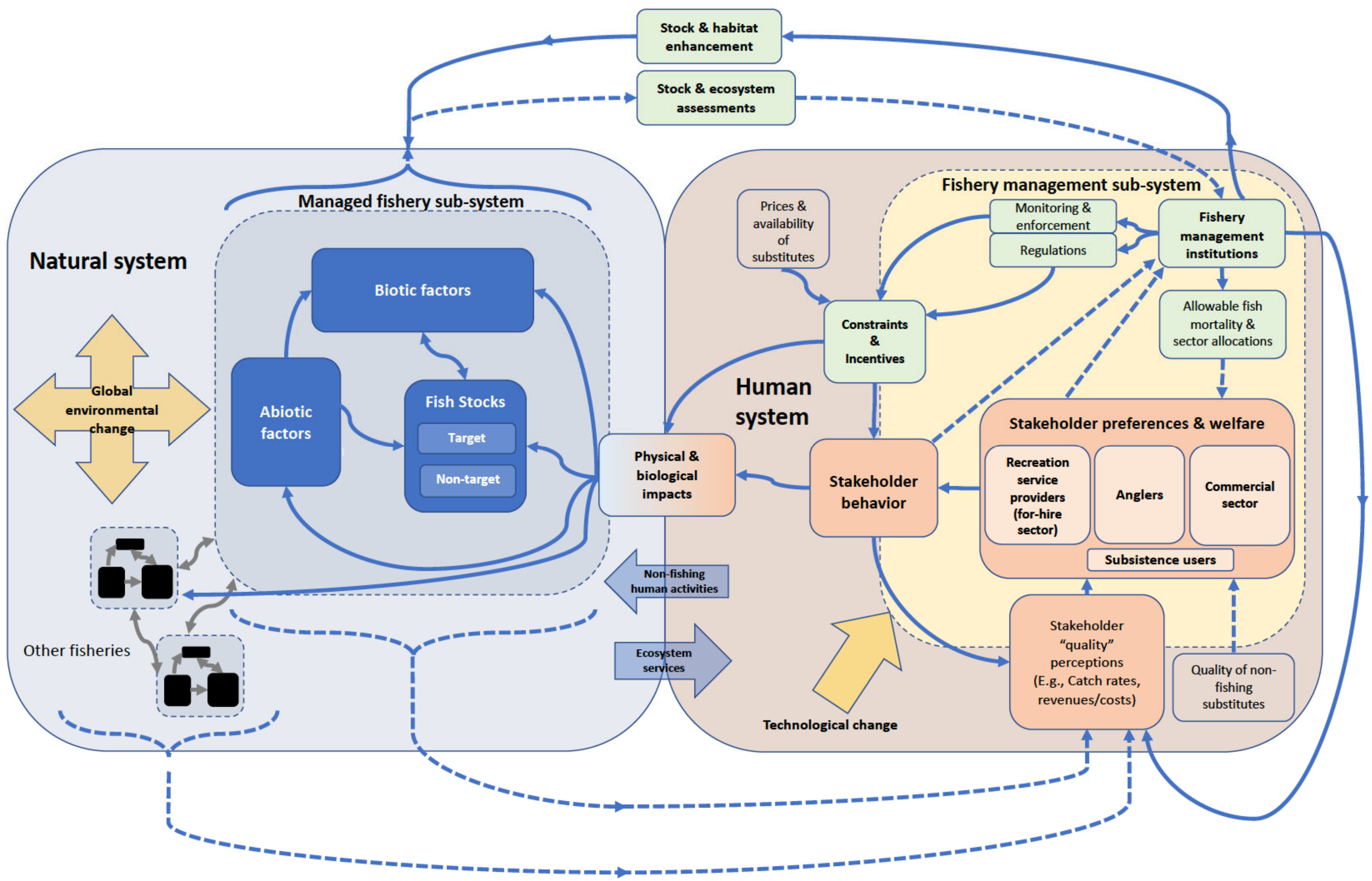

Figure 1: The recreational fisheries management system, embedded in a larger coupled human-natural system. Broken lines represent flows of information.

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