ICES Journal of
Marine Science

ICES Journal of Marine Science (2020), 77(6), 2344–2353. doi:10.1093/icesjms/fsz234

Contribution to the Themed Section: '*Marine recreational fisheries – current state and future opportunities*'

Original Article

The importance of fishing opportunity to angler utility analysis in marine recreational fisheries

Erik G. Young [1]*, Michael C. Melnychuk [1], Leif E. Anderson[2], and Ray Hilborn[1]

[1]*School of Aquatic and Fishery Sciences, University of Washington, Seattle, Box 355020, WA 98195–5020, USA*
[2]*Fishery Resource Analysis and Monitoring Division, Northwest Fisheries Science Center, National Marine Fisheries Service, National Oceanic and Atmospheric Administration, 2725 Montlake Boulevard East, Seattle, WA 98112, USA*

**Corresponding author: tel: +1-206-681-5148; e-mail: eyoung@uw.edu*

Young, E. G., Melnychuk, M. C., Anderson, L. E., and Hilborn, R. The importance of fishing opportunity to angler utility analysis in marine recreational fisheries. – ICES Journal of Marine Science, 77: 2344–2353.

Received 29 January 2019; revised 10 November 2019; accepted 15 November 2019; advance access publication 17 December 2019.

Managers of recreational fisheries make assumptions about what anglers value, often emphasizing factors directly related to catch. Evaluations that include both catch and non-catch aspects of recreational fishing, as well as the trade-offs between attributes that are trip-based and those that measure opportunity over a season, are rarely be incorporated into management objectives and the design of management frameworks. A study of two marine recreational fisheries in the United States, Pacific halibut in central Oregon and red snapper in northeast Florida, comprised local interviews and a limited survey of recreational anglers to evaluate the relative importance of catch rates, season length, and the uncertainty around early closures. National meeting reports, interviews, and stated-preference survey results suggested that angling opportunity in the form of longer seasons may be more important to anglers than either catch rates or the uncertainty that results from mid-season changes to fishery closure dates. Results suggest that researchers evaluating economic benefits to anglers should consider including opportunity attributes directly in angler surveys. Issues associated with limited sample sizes and a lack of intermediate attribute values limit the use of this study for direct regulatory guidance, but it instead offers a potential methodology to be applied in future analyse.

Keywords: fisheries management, fisheries policy, recreational fisheries management, sportfishing management, stated-preference survey

Introduction

Fishery managers must consider human behaviour as well as ensuring sustainable fish populations in designing and implementing management measures (Fenichel *et al.*, 2013a). Anglers, fishery managers, and fish populations comprise a coupled, dynamic, social-economic system (Ward *et al.*, 2016). Thus, fisheries managers should carefully consider economic and social issues and develop management responses by including the input of groups impacted by management decisions (Fenichel *et al.*, 2013b). This will facilitate the cooperation of recreational sector stakeholders (Hilborn, 2008; Ihde *et al.*, 2011) through the incorporation of socio-economic information that identifies factors, which provide angler satisfaction.

Angler utility has been defined as the extent to which an angler's desires are matched by their perceived fulfilment of those desires (Holland and Ditton, 1992). It consists of many components (Holland and Ditton, 1992), including both catch and non-catch attributes with varying levels of relevance to management (Fedler and Ditton, 1994; Arlinghaus, 2006). Because catch-related attributes vary across fisheries, angler utility should be specific to the species involved, and should cover the geographically relevant population of anglers (Haab *et al.*, 2012; Schroeder and Fulton, 2013). For example, in the Southeastern US coastal areas, an angler's willingness to pay for a red snapper caught and retained is more than eight times higher than the value of a red snapper released (Carter and Liese, 2012). Similarly, on the West Coast, anglers place a much higher value on the retention of Pacific halibut relative to catching and releasing (Anderson and Lee, 2013). On the other hand, many anglers are willing to spend thousands of dollars simply for the experience of landing a catch-and-release fish such as a marlin (Pine Iii *et al.*, 2008). This need to measure context-specific utility presents challenges from a practical perspective. It requires a detailed experimental design to capture the complexities generated by including multiple individual species, local areas, and stakeholder groups. Such a broad design has the potential to be cost-prohibitive.

When measuring angler utility, focus has commonly been placed on trip-based factors, such as catch rates, the size of fish caught, and bag limits. However, recreational anglers also value opportunity and stability (NOAA Fisheries, 2018). These factors have been discussed at a number of national meetings held in recent years that have included representatives from NOAA Fisheries, State and Federal regulatory agencies, and recreational fishing stakeholders. The wide array of interests represented at these meetings formed a broad constituency capable of formulating an effective strategy that will later promote the cooperation of anglers in its implementation (Ihde *et al.*, 2011).

Stakeholder objectives include improving opportunity and stability (NOAA Fisheries, 2018). What comprises opportunity and stability? Opportunity is provided through the number of days available (Abbott and Fenichel, 2013) as well as the number and distribution of sites accessible for fishing (FCRC Consensus Center, 2010; American Sportfishing Association, 2014). Restricting opportunity can have limited impact on reducing mortality, since anglers may simply relocate effort to unrestricted areas or open-season days (Powers and Anson, 2016; Chagaris *et al.*, 2019). It may also increase bycatch mortality of the target species in a multiple species fishery, muting the biological benefit expected from any closure (Chagaris *et al.*, 2019).

Stability is attained by a predictable set of allocations, seasons, and regulations (Commission on Saltwater Recreational Fisheries Management, 2014; NOAA Fisheries, 2014). Stability in the case of for-hire boat owners allows planning in advance for the subsequent season (FCRC Consensus Center, 2010). Stability also means minimizing or avoiding in-season adjustments to season length; basing catch limits on multi-year moving averages; and minimizing year-to-year regulatory changes if feasible.

In addition to these meetings and conferences, in 2013, NOAA conducted a national survey regarding fisheries management practices to anglers in 22 coastal states and received 9200 responses. Results were generally consistent in both the West Coast and South Atlantic coastal fisheries (Brinson and Wallmo, 2017). On the West Coast, anglers preferred strategies that protect and restore degraded fish habitat, and, if tighter regulations were necessary, favoured trip-level measures such as minimum size limits and bag limits over a reduction in season length. In the South Atlantic, anglers preferred measures to improve natural habitat, establish artificial habitat, and, if tighter regulations were necessary, favoured imposing more restrictive minimum size limits over shortening the season (Brinson and Wallmo, 2013).

Also, there have been two studies of angler behaviour in these two specific fisheries. A prior stated-preference survey indicated that Pacific halibut anglers prefer larger fish, but marginal utility declines as fish size increases, and importance is placed more on retained fish than released fish (Anderson and Lee, 2013). Another stated-preference survey for red snapper showed that increases in catch have declining marginal utility, and that most value was realized by retaining fish, not simply catching them (Carter and Liese, 2012).

The overarching goal of our study was to develop a framework that could be used to assist fisheries managers in devising a successful governance strategy. For this purpose, we developed stated-preference questions that included those framed on a season-long basis, rather than framing questions at the trip level. By tending to focus on trip-level utility, most stated-preference surveys that are used to develop a utility function have not directly evaluated the relative importance of a key component of angler satisfaction—how many days in a year an angler is able to go fishing for the species—which is affected by season length, the timing of season days, and the possibility of early closures.

Here, for each of the two case study fisheries, we conducted focused person-to-person interviews with individuals representing different fishery segments and consulted other background information to identify three key management-relevant attributes of angler satisfaction. Next, we developed and administered a stated-preference survey to a limited sample of anglers as a proof of concept to help identify the relative importance of these three attributes to overall utility. The two case studies were Pacific halibut (*Hippoglossus stenolepis*) in central Oregon and red snapper (*Lutjanus campechanus*) on the Atlantic coast of Florida. Each is a preferred target in a large regional recreational fishery. Using survey results for each of the three attributes, we developed utility curves to examine how angler utility varies as the value of these attributes increase.

Methods

Case studies

The US states of Washington, Oregon, and California comprise International Pacific Halibut Commission (IPHC) Area 2A and receive an aggregated allocation of the overall United States and Canadian Pacific halibut catch limit. Within Area 2A, the regulatory strategy used to divide this allocation is set by the US National Marine Fisheries Service with input received from these three states. In 2018, the sport fishery in Oregon received 29.7% of the Area 2A non-tribal allocation. Of this allocation, the Oregon Central Coast subarea received 93.79% of the Oregon sportfishing allocation. The Oregon Department of Fish and Wildlife assigns allocations and separate season days for the Central Oregon subarea to a nearshore (inside 73.2 m depth) fishery and an all-depth fishery, which allows offshore (outside 40 fathom contour) fishing. In nearshore waters, halibut catch rates are much lower, weather and ocean conditions are less likely to preclude fishing on any given day compared to the offshore fishery, and bycatch rates of yelloweye rockfish (*Sebastes ruberrimus*) are lower (ODFW, 2019). Retention of most species is permitted in the nearshore fishery, but on all-depth days, regulations prohibit retention of most species, except salmon, sablefish, Pacific cod, flatfish species, tuna, and other offshore pelagic species. For Pacific halibut, the bycatch of endangered yelloweye rockfish has a very large effect on management decisions. The fishing season may be halted once yelloweye quota has been reached, which impacts the utility associated with season length. Charter operations operate primarily offshore during all-depth days as a result of the higher catch rates. Each recreational fishing group—

nearshore private boat anglers, offshore private boat anglers, and charter operations—has interests that potentially differ.

Red snapper is one of the most popular species for offshore anglers throughout the US South Atlantic and Gulf of Mexico regions. In the South Atlantic, it is managed by the National Marine Fisheries Service in Federal waters in consultation with the South Atlantic Fishery Management Council, which is currently reviewing its recreational regulatory strategy for the snapper/grouper fishery. A Snapper/Grouper Fishery Plan Amendment is being developed for consideration in 2019 that will set catch limits for red snapper, address recreational permitting and reporting for private recreational fishermen, and identify best fishing practices. A rebuilding plan was adopted in 2010 that allows for limited harvest as the red snapper population grows. The season was closed in 2010 and 2011, open with limited harvest in 2012–2014, closed in 2015–2016, and again open with limited harvest in 2017–2018. With respect to State waters nearer to shore (within three nautical miles) Florida regulations permit fishing for red snapper year-round, but red snapper generally do not frequent the nearshore along the Florida Atlantic coast.

Focused interviews and qualitative analysis

In-person interviews were conducted with recreational fishing individuals for the two selected fisheries. Interviewees were identified via referrals from various sources such as tackle shops, fishery associations, fishery agencies, and from prior interviewees. The interviews were semi-structured, focusing on:

(1) What the individual likes about fishing in general;

(2) What the individual likes about fishing for the target species;

(3) The context in which they go fishing;

(4) What the individual does not like about the fishery;

(5) How the individual feels about alternative forms of regulation; and

(6) Their fishing practice relating to releasing fish.

We then transcribed the in-depth interviews and combined, sorted, and arranged themes using NVivo software (version 10.1.3) as part of an overall approach that combined both qualitative and quantitative methods (Yin, 2014) to identify important recreational fishing attributes to anglers. Subjects included major segments comprising anglers participating in the fishery—onshore and offshore for Pacific halibut, and both private boat owners and charter operators and customers.

For Pacific halibut, individuals who were willing to participate in personal interviews were identified from a recreational fishing electronic bulletin board; through personal referrals; through conversations at landing ramps, bait and tackle stores; or onboard a charter vessel. Seven of these anglers were interviewed in Newport and the Portland metropolitan area during May 2014. Interviewees included representatives of a regulatory agency, a tackle shop owner, customers of party boats, private boat anglers, and party boat owners and operators. Participants included people who primarily fished offshore (outside 40 fathoms) and those who primarily fished nearshore (inside 40 fathoms).

For red snapper, six face-to-face interviews were conducted with charter captains, recreational anglers, and bait and tackle shop owners and employees, in locations along the Florida coast between Port St. Lucie and Port Canaveral. Interviews occurred in person during late August to early September 2015.

Interviews were transcribed and then qualitatively analysed using an inductive approach with NVivo software (version 10.1.3). The use of qualitative methods accomplished three objectives. First, this method served as a means of triangulation to cross-check results generated from other relevant studies of these fisheries and angler utility. Second, it was used to design the questions posed on stated-preference surveys, described next. Third, it was used as a source of complementary data for the quantitative analysis of stated-preference surveys (Yin, 2014).

Development of a pilot stated-preference survey specific to each fishery

Identifying and measuring angler utility can be approached in a variety of ways (Fenichel *et al.*, 2013a). A common approach is the use of a stated-preference survey (Aas *et al.*, 2000; Carter and Liese, 2012; Lew and Larson, 2015). In the United States, stated-preference models have been used in studies of the Northeast US recreational summer flounder fishery (Massey *et al.*, 2006); the Oregon and Washington recreational salmon fishery (Anderson and Lee, 2013); the Southeast US recreational grouper, red snapper, dolphinfish, and king mackerel fisheries (Carter and Liese, 2012); the US Gulf of Mexico recreational red snapper fishery (Abbott *et al.*, 2018); the Alaska halibut charter boat fishery (Lew and Larson, 2015); and the groundfish fishery in the Northeast (Lee *et al.*, 2017). Based on interviews and outcomes of national stakeholder meetings, we selected the three most salient, management-relevant attributes for the stated-preference survey: (i) days available to go fishing (a proxy for season length and fishing opportunity), (ii) the catch rate for retained fish, and (iii) the unpredictability associated with early season closure (a proxy for stability). To have considered more than three factors would have required a longer survey (the number of choice combinations varies not linearly with the number of factors, but geometrically), which may have reduced the level of participation. The choice of retained fish, rather than caught fish, was selected as a result of prior surveys performed for these two fisheries (Carter and Liese, 2012; Anderson and Lee, 2013). With respect to season uncertainty, in the halibut fishery, currently the largest factor contributing to mid-season overrun and cancellation or under-run and the addition of days is the setting of "fixed" spring all-depth season dates. If take during the season overruns the spring all-depth quota (which represents the majority of the total quota), the remaining spring all-depth days will be cancelled, followed by summer all-depth days, followed by nearshore season days. Conversely, if the fixed days fall short of quota, then days will be added on to the spring all-depth season. Early season closure risk may increase given the adoption of proposals to use yelloweye rockfish bycatch as a trigger for season closure.

The stated-preference survey for Pacific halibut was distributed in October 2015 to individuals via two methods. The Oregon Department of Fish and Wildlife included the survey by providing a link at the end of the annual survey sent out via email to people who have indicated an interest in recreational halibut fishing. This yielded few responses, so the distribution was broadened by posting the link to the survey on a local web-based bulletin board (www.ifish.net).

Table 1. Utility attribute values used for northeast Florida red snapper and central Oregon Pacific halibut utility surveys.

Utility attribute	Attribute level	Red snapper	Halibut nearshore	Halibut offshore anglers	Halibut charter owners, operators, employees
Retained catch (number of fish per trip)	Low	1	0.5	0.5	0.5
	High	5	2	2	2
Available fishing days (number of days)	Low	10	1	1	5
	High	50	6	6	15
Season certainty (per cent chance that the	Low	50%	50%	50%	50%
season length will not be shortened mid-season)	High	90%	90%	90%	90%

The Pacific halibut survey generated responses for the following fishery subgroups:

(1) Charter owners, operators, and employees ($n = 14$).

(2) Offshore private and charter anglers ($n = 11$).

(3) Nearshore private boat anglers ($n = 8$).

These subgroups for Pacific halibut were created and individually analysed because of their differing fundamental characteristics, which became apparent following interviews with anglers participating in those subgroups. As discussed above, the nearshore and offshore (all-depth) fisheries have different season dates and attract anglers with distinct motivations. As a result, we present results for nearshore anglers (nearshore season), offshore anglers (all-depth season), and charter operators and employees separately. Pooled results for these groups are also provided in the Supplementary materials.

The stated-preference survey for South Atlantic red snapper was developed and distributed via email through a network of contacts in Florida involved with recreational fishing in March and April 2016. There were 68 respondents. Although the fishery consists of both charter and private boat segments, they share the same season and a clear justification for the analysis of subgroups was not apparent. Nonetheless, both aggregated and unpooled subgroups are provided in the Supplementary materials.

In a series of nine choices, survey participants were offered a choice between two hypothetical alternatives, which varied in the number of fish caught and retained, the number of days available to fish over the season, and the chance the season would be closed early. A full factorial approach generated the list of combinations. Duplicates were removed, as well as those combinations where one of the alternatives was superior to the other over all three attributes based on the assumed sign of the utility parameters. This resulted in nine sets of paired alternative choices, drawing from the low or high utility attribute levels listed in Table 1.

The survey methodology used in connection with both fisheries serves as a pilot approach, since anglers did not have an equal probability of selection. The sampling methodology resulted in a low number of completed surveys and may have produced selection bias (Barrett *et al.*, 2017). However, it met a management goal of being cost-effective (NOAA Fisheries, 2018) and was focused on a single species and a local geographic area.

Construction of utility curves

Stated-preference survey data were used to generate utility curves for each of the three utility attributes in each fishery segment. Two attribute levels (low and high) for each attribute were presented in combinations of preference options. Although only two values were used, non-linear utility curves were constructed by assuming an inverse hyperbolic sine relationship (Layton, 2001; Carter and Liese, 2012) between the attribute value (α) and the resulting value of the utility component (C). For example, the utility derived from fish caught and retained was not a linear relationship with increasing number of fish; this model implicitly assumes diminishing marginal utility:

$$C = \beta_v * \ln\left(\alpha + \sqrt{1 + \alpha^2}\right) \quad (1)$$

Estimated coefficients (β_v) under the inverse hyperbolic sine model were determined from random-parameters logistic models. We modelled the utility that an individual receives from selecting a season (a set of options) in the stated-preference questions as a function of the number of days available to a respondent to fish in the season (*Available fishing days*), catch rates (*Retained catch*), and the probability of avoiding an early season closure (*Season certainty*). To account for potential heterogeneity across the preferences of anglers and charter operators, we allowed parameters to follow a specified distribution instead of fixing the values across respondents. To account for potential heterogeneity across the preferences of anglers and charter operators, we allowed parameters to follow a specified distribution instead of fixing the values across respondents. A symmetric triangular distribution was chosen to ensure a consistent sign across the population for each of the three attributes. This approach acknowledges heterogeneity in preferences while imposing an intuitive restriction that an attribute cannot have a positive impact on utility for one individual while having a negative impact for another individual. We imposed this constraint by fixing the spread of the distribution during estimation. For any attribute with parameter estimate β, we estimated a triangular distribution that is bounded by 0 and 2β and rises linearly to its peak at β from each of these bounds (Greene and Hensher, 2003). We estimated model parameters using simulated maximum likelihood with 10 000 random draws in LIMDEP. See Train (2003) for an in-depth discussion of simulation methods for choice models. Identical modelling approaches were used for both species. The model for Pacific halibut was further broken out into three subgroups to accommodate different motivations among different participant types: (i) offshore private anglers, (ii) offshore charter owners and operators, and (iii) nearshore private anglers. Although the model for red snapper was estimated by combining two potential sub-groups [(i) private and charter anglers and (ii) charter boat owners, operators, and employees], unpooled estimates for these sub-groups are provided in the Supplementary materials.

Values for C (Equation 1) for each component were calculated and used to construct utility curves for the three variables in each of the four fleet segments. These represent the utility to anglers at any given value of the variable. Marginal utility, on the other hand, represents the additional utility provided by an increment of the variable and typically declines as values of the variable increase (i.e. diminishing returns). Although tracking total utility for each attribute is instructive, the utility of any fishery management action should be evaluated relative to the baseline level of utility in the absence of the action, and therefore, marginal utility values are provided alongside total utility values. Marginal utility (M) at any given value of the variable is calculated as the derivative of C with respect to a:

$$M = \frac{dC}{d\alpha} = \frac{\beta_v}{\sqrt{1 + \alpha^2}} \quad (2)$$

Results

Personal interviews and social media

Overall, personal interviews and communications and review of recreational comments on a media bulletin board (www.ifish.net) shared certain common results while also highlighting several differences between the two fisheries, suggesting potential differences in preferred management strategies. The iFish electronic bulletin board was useful for two purposes. First, its discussion forums provided a robust discussion between anglers on topics important to them in each of the two case study fisheries. Season length and timing, catch limit, and other subjects were debated and discussed, providing another data point of angler points of view. Second, the bulletin board provided a method for distributing the surveys.

When queried during personal interviews about fishing in general, individuals in both fisheries noted the importance of similar attributes including being out on the ocean or in nature, spending time with friends, and, especially for private boat anglers, the satisfaction derived from strategizing and preparation associated with fishing. These factors were not included in our survey, because they are only indirectly related to management actions.

With respect to fishing for the target species, individuals in both fisheries valued bringing home food. Red snapper anglers were more likely to cite the excitement associated with the catch, since red snapper can put up a good fight. They also enjoyed the ability to fish for other species when fishing for red snapper. Halibut anglers, on the other hand, enjoyed the fact that halibut is the first fish available in the spring.

With respect to their dislikes, individuals in both fisheries mentioned overcrowding and a derby mentality. Red snapper anglers were particularly unhappy with season restrictions or cancellations when they are observing what they believe is an abundant population. Halibut anglers were more likely to cite weather and ocean conditions as a concern. Individuals in both fisheries would be willing to accept minimum size or bag limit restrictions if they led to a longer season. Halibut anglers were especially concerned with how season days are allocated within a season and some favoured a tagging system.

With respect to the uncertainty associated with potential early season closures, the response depended on the individual. It was more of a concern for those who are for-hire owners or operators, and others who need to plan well in advance because they have to consider their work schedules, or who travel long distances to the fishing grounds. It seemed to be less of a concern to retirees or to those who live locally. Of note, those opinions may change due to recent regulatory changes in Oregon that now allow for in-season modifications to the sport halibut seasons based on yelloweye rockfish impacts (ODFW, 2017a).

Stated-preference survey results

All estimated parameters from logit models had signs that matched expectations; in both fisheries, anglers and charter operators preferred longer seasons, higher catch rates, and a lower probability of an early season closure (Table 2). With the exception of the Pacific halibut nearshore private anglers sub-group, all estimated parameters were statistically significant. We observed strong similarities in the relative preferences for the *Available fishing days*, *Retained catch*, and *Season certainty* attributes across all user groups. However, we also found significant heterogeneity among respondent preferences in both fisheries and among all three Pacific halibut sub-groups. This heterogeneity suggests that changes in management designed to increase the utility of fishery participants are unlikely to completely avoid decreasing some anglers' utilities.

Estimated total and marginal utility illustrate the trade-offs anglers are willing to make between attributes. Whether the average angler would prefer a baseline season described by season days, retained catch, and certainty relative to an alternate season depends on the difference between total utility evaluated at the baseline levels of these attributes and total utility evaluated at the levels put in place by the alternate season.

For northeast Florida red snapper, the three curves for total utility (Figure 1a) can be used to determine the relative increase

Table 2. Parameter estimates from mixed logit models applied to stated-preference surveys in four fleet segments using the IHS transformation.

	Pacific Halibut			Red Snapper
	Nearshore	Offshore	Charter	
Retained catch (number of fish per trip)	0.97	7.62**	5.32***	1.62***
Standard error	1.03	3.09	1.48	0.22
Available fishing days (number of days)	3.46**	5.59**	6.42***	2.22***
Standard error	1.68	2.23	1.81	0.26
Season certainty (per cent chance that the season length will not be shortened mid-season)	4.90	6.92**	9.72***	6.21***
Standard error	3.10	3.11	2.79	0.85
Respondents	8	11	14	68
Log likelihood at zero	−49.91	−67.93	−85.26	−413.81
Log likelihood at convergence	−26.66	−33.16	−61.44	−321.10

Limits of the symmetric triangular distributions used to model heterogeneous preferences are constrained to be equal to zero on one side and twice the mean on the other and, therefore, are not presented separately.
**$p < 0.05$, ***$p < 0.01$.

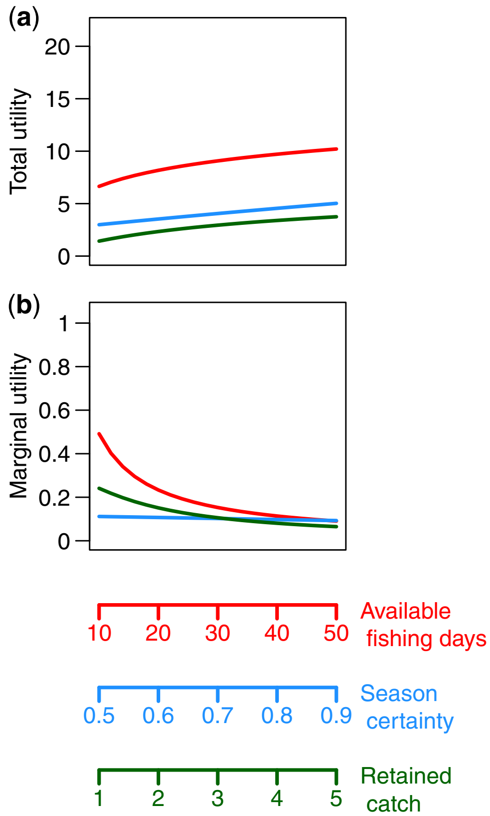

Figure 1. Northeast Florida recreational red snapper total (a) and marginal (b) angler utility for days fishing, season certainty, and fish caught. Utility curves show outputs of a logit model applied to stated-preference surveys. Endpoints of the curved lines represent low and high values of the attributes presented to respondents in surveys.

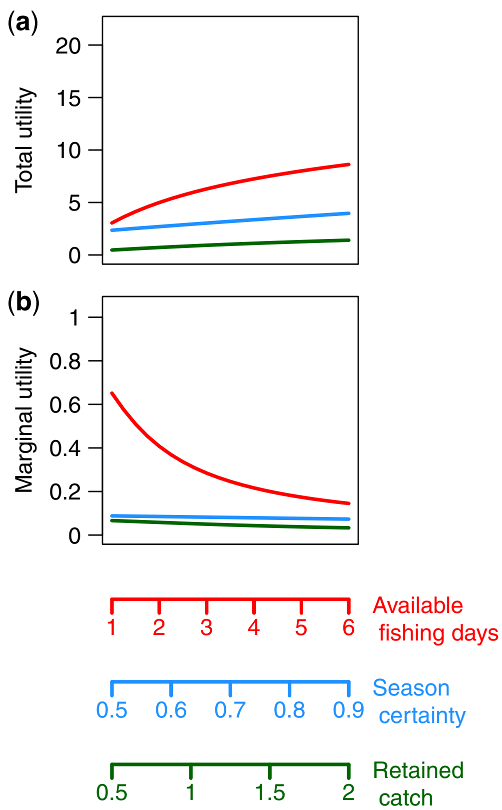

Figure 2. Central Oregon recreational Pacific halibut nearshore anglers total (a) and marginal (b) utility for days fishing, season certainty, and fish caught. Utility curves show outputs of a logit model applied to stated-preference surveys. Endpoints of the curved lines represent low and high values of the attributes presented to respondents in surveys.

in utility for each attribute for any given change in the attribute's level. Because of the non-linearity assumed for utility functions, the utility gain resulting from one additional retained fish is greater between zero and one fish than between four and five fish. In assessing trade-offs between the three attributes, at low values of the attributes, marginal utility associated with increases in the number of days available for fishing exceeds the marginal utility for either the catch rate or season certainty (Figure 1b). In contrast, at higher attribute levels, marginal utility converges across the three attributes. As an illustrative example, Figure 1a and b together suggests that an angler would be reasonably indifferent to choosing between an increase in the number of available fishing days from 40 to 50, an increase in season certainty from 80% to 90%, or an increase in the average daily retained catch from four to five, as utility gains are similar between these scenarios. However, at lower values of these attributes, an angler would favour an increase in the number of available fishing days from 10 to 20 over an increase in season certainty from 50% to 60%, with an increase in average daily retained catch from one to two being intermediate between these (Figure 1b).

For central Oregon Pacific halibut, survey results from nearshore anglers again illustrate how a given change in attribute level affects the level of total utility for that attribute (Figure 2a). The trade-offs implied by marginal utility (Figure 2b) are similar to those observed in the snapper fishery (Figure 1b).

We observe a different pattern for the offshore for-hire halibut fleet. Here, available fishing days has a much higher total utility compared to the other two attributes across the full ranges of attribute values (Figure 3a). The marginal utility for available fishing days does not diminish rapidly as the number of available fishing days increased, like it did for the other two halibut fleets and the snapper fishery (Figure 3b).

The offshore private halibut fleet shows a similar relative importance of available fishing days to anglers, but for this fleet retained catch is the next-most important attribute (Figure 4a). Similarly, marginal utility at low values of attributes is greatest for available fishing days, intermediate for retained catch, and lowest for season certainty (Figure 4b).

A change in utility associated with one of the attributes is dependent not only on the magnitude of change in the attribute value but also on the baseline values of the three attributes. Table 3 shows several examples for the red snapper fishery of baseline scenarios of the three attributes along with expected changes in utility resulting from small changes in the values of each attribute. Percentage changes in utility are based on the total utility across all three attributes before and after the change in a single attribute. All three attributes show diminishing marginal returns in utility as baseline values of the attributes increased. Based upon the

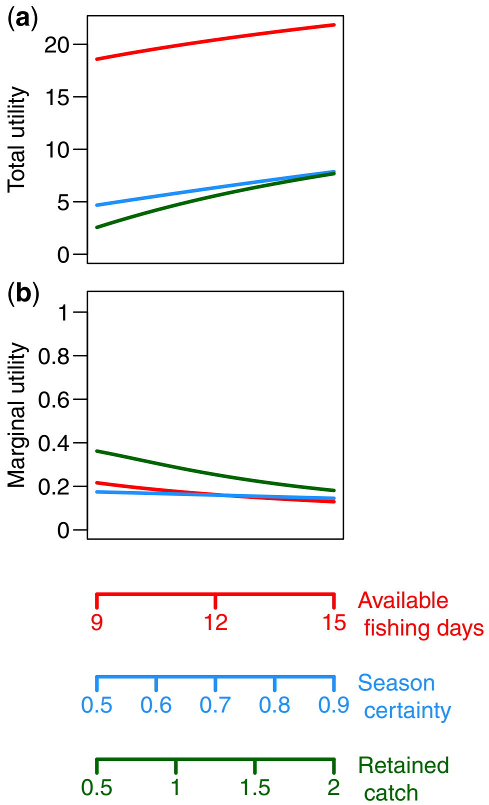

Figure 3. Central Oregon recreational Pacific halibut for-hire owners, operators and employees total and marginal utility for days fishing, season certainty, and fish caught. Utility curves show outputs of a logit model applied to stated preference surveys. Endpoints of the curved lines represent low and high values of the attributes presented to respondents in surveys.

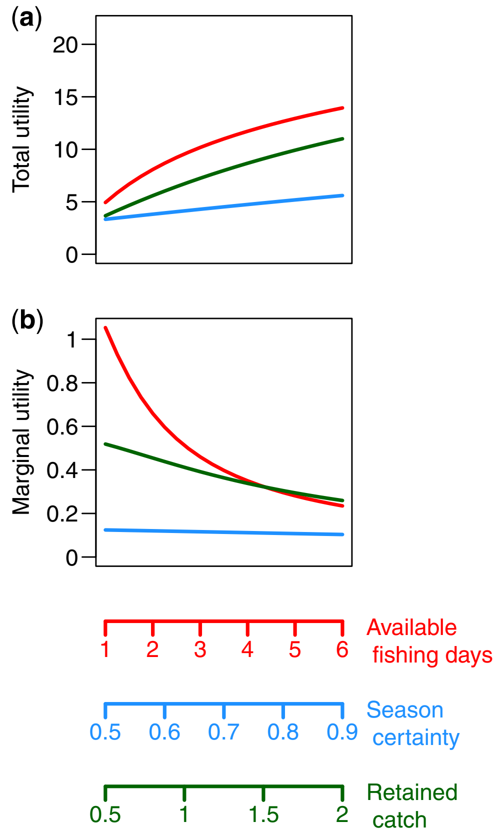

Figure 4. Central Oregon recreational Pacific halibut offshore anglers total and marginal utility for days fishing, season certainty, and fish caught. Utility curves show outputs of a logit model applied to stated-preference surveys. Endpoints of the curved lines represent low and high values of the attributes presented to respondents in surveys.

Table 3. For the Florida red snapper recreational fishery, the expected percentage gain in total utility from all three attributes derived from specified increases in those attributes when compared to specified baseline values.

Baseline scenario			Expected percentage increase in utility		
Days fishing	**Fish retained**	**Season certainty (%)**	**From four more available fishing days**	**From one more fish retained per trip**	**From a 4% increase in certainty**
10	1.0	50	28.82	8.63	1.80
14	1.4	55	4.79	6.63	1.68
18	1.8	60	3.61	5.34	1.60
22	2.2	65	2.88	4.45	1.56
26	2.6	70	2.39	3.80	1.52
30	3.0	75	2.04	3.32	1.50
34	3.4	80	1.78	2.94	1.49
38	3.8	85	1.57	2.64	1.48

illustrative changes and baselines considered, the diminishing pattern of marginal returns was strongest for fishing days; the marginal utility of season certainty declined but not as rapidly.

Discussion

National meetings, one-on-one interviews and this study's stated-preference survey (Table 4) all show the need to consider and weigh season-related variables (season length and season certainty) in addition to per-trip variables commonly perceived to be of greatest importance to anglers (i.e. catch rates). When evaluating alternative season scenarios using marginal utility rates, at low attribute values anglers may be willing to sacrifice retained catch rates and certainty in these two fisheries in order to increase available fishing days. At those low attribute values, regulations in

Table 4. Summary of attribute importance based on multiple data sources.

Data source	Attribute
National conferences	Opportunity and season certainty
National surveys	Minimum size and bag limit restrictions acceptable; shorter seasons are not.
Personal interviews	Non-catch attributes, bringing home food, willingness to accept minimum size or bag limit restrictions for longer seasons, desire to avoid derby style fishing. Red snapper adds more of a sport element to the catch.
Local species-specific surveys	In general, more season days. At higher attribute values, catch rates may provide slightly higher marginal utility.

recreational fisheries management systems may be adjusted to increase overall angler satisfaction even as retained catch rates decrease.

For Pacific halibut charter owners, operators, and employees, an increase in season length generates additional utility that exceeds a corresponding change in catch rates or season certainty. This might be explained by two factors. First, their incomes are a linear function of the number of days fishing, not a function that implies diminishing marginal returns. For-hire owners, operators, and employees are motivated by revenue from trips taken, which accrues in a linear fashion with respect to trips, i.e. not with diminishing returns. Second, during May at the beginning of the halibut season, salmon and tuna seasons have not commenced (ODFW, 2013). This latter point suggests that a longer season may be of less importance because of the availability of alternative targets later in the year.

For offshore Pacific private boat halibut anglers, any conclusions to be drawn from the total utility curves (Figure 4a) require conditioning on the underlying attribute values of any season scenarios being analysed (Table 3). Whereas a change in retained catch rates generates utility that rivals that of available fishing days, it might be explained given the expense involved in pursuing a species that is located far offshore and which may be desirable to eat but which may not provide as much excitement when it is hooked compared to other species. Season certainty may generate lower marginal utility, which would be consistent with feedback from interviews that suggest offshore anglers in the past have been able to gauge season length fairly closely by watching weekly catch totals online.

For the nearshore fleet, total utility for retained catch was lower than total utility for the other two attributes throughout the ranges of attribute values. This lower relative importance may be because, unlike days open to offshore halibut fishing, anglers in this fishery are allowed to retain a much wider variety of other substitute groundfish species (ODFW, 2017b). Meanwhile, when examining marginal utility curves, the steep initial decline in the marginal utility of season days for offshore anglers (Figure 4b) likely reflects the fact that the large majority of offshore halibut anglers in Oregon only choose to make one or two trips per year (ODFW, 2013).

Recent studies have either used angler models of utility based on trip-level factors (Carter and Liese, 2012; Anderson and Lee, 2013), or have not fully incorporated elements of fishing opportunity into a bioeconomic model (Abbott and Fenichel, 2013). With respect to Pacific halibut on the West Coast, an extensive recreational fishing discrete choice survey was conducted by NOAA in Oregon and Washington during 2006 and 2007 (Carter and Liese, 2012; Anderson and Lee, 2013). Pacific halibut was one of the species included within the survey, which asked anglers to choose between trips based on the species caught, the size of fish caught, and varying bag limits. An analysis, which focused on comparing the recreational value of wild and hatchery salmon (Anderson and Lee, 2013) provided partial insight on recreational angler preferences in these two states for species including halibut, but angling opportunity was not explicitly included in the model.

In the South Atlantic in 2003, NOAA's Southeast Fisheries Science Center Office conducted a survey of anglers in several recreational fisheries, including red snapper. The survey measured anglers' relative preferences for different regulatory strategies, based on a discrete choice experiment methodology. The utility attributes included the target species, number of fish caught per trip, the bag limit, the minimum size limit, catch at or above the minimum size, trip cost, and catch of species other than the target species (Carter and Liese, 2012).

Both of the above studies measured utility using trip-based factors. Here, we used a similar stated-preference survey methodology that is context-specific with respect to geography and species (Beardmore *et al.*, 2015). However, in contrast to many existing studies, our approach considers and includes attributes that are both catch and non-catch related (Fedler and Ditton, 1994). Also, unlike much of the existing literature, our model of angler utility is not restricted to trip-based motivational factors, as it also incorporates motivational factors that stretch over a season, and therefore, assists in predicting overall fishing intensity (Fenichel *et al.*, 2013a). Increased season length can generate both trip-based utility factors if it results in less crowding in the fishery through avoidance of a derby fishery (Cox *et al.*, 2002), but it also includes increased opportunity that stretches over an entire season.

These results are not intended for direct regulatory guidance in managing these two fisheries. Instead, they suggest an approach to identifying and prioritizing the elements of angler satisfaction at a local level. The limitations of this study are several. First, the non-linear relationships between the three chosen attributes and their associated utility rely on an assumption that, while in line with economic theory, should be tested with a survey that includes intermediate levels of attributes in the experimental design. Second, other attributes beyond the three selected may be significant. However, the effect of potential omitted attributes should be tempered by the use of an experimental design that produces minimal correlation between attributes. Third, the selection of survey respondents may have resulted in characteristics of respondents being correlated with our outcomes of interest, and the sample sizes might not be adequate to expand the calculated utility and marginal utility curves from the sample to the full population of all anglers in these fisheries. Future-related work should consider a more robust sampling plan. Fourth, season days are not generic. The days of the week and the calendar days selected for the season days are likely to be important in determining utility and are not captured by the survey. Finally, as noted above, for Pacific halibut, the bycatch of endangered yelloweye rockfish has a very large effect on management decisions.

Despite the limitations of this study, the identified importance of season length; even at the expense of retained catch; is consistent with the results of personal interviews for these two fisheries, the priorities identified in stakeholder meetings (NOAA Fisheries, 2018), and with other studies (Abbott and Fenichel, 2013). Future work should not only include a larger sample coupled with a survey administration less subject to potential selection biases but also compare models that explicitly incorporate season length with trip-based models that do not, the latter requiring aggregation over different sets of choice occasions to evaluate the effect of season length. The results of our surveys can be incorporated within bioeconomic models to quantify how management policies may affect overall utility across all attributes. Results from these same stated-preference surveys have been merged with an age-structured population dynamics model to generate a bioeconomic model for these two fisheries. This merging of population models and angler utility models provides a framework for predicting changes in both biological attributes and angler utility measures in response to changes in management parameters. This may assist fishery managers in developing successful regulatory strategies for recreational fisheries.

Supplementary data

Supplementary material is available at the *ICESJMS* online version of the manuscript.

Acknowledgements

Four anonymous reviewers provided helpful comments on a previous version of this manuscript. Many individuals graciously shared their time and input in the interviews and surveys conducted during this study. We are grateful for the input provided by the Oregon Department of Fish and Wildlife, Michael Nussman, President and CEO, American Sportfishing Association, Gary Jennings, American Sportfishing Association, Rob Southwick, Southwick Associates, Jim Martin, Conservation Director, Pure Fishing, Dr Larry McKinney, Executive Director, Harte Research Institute for Gulf of Mexico Studies, and Ken Haddad, Marine Fisheries Advisor, American Sportfishing Association.

Funding

This research was supported by the National Marine Fisheries Service through a Saltonstall-Kennedy grant (No. NA14NMF427005). This article and its findings do not necessarily reflect the views of the National Marine Fisheries Service.

References

Aas, Ø., Haider, W., and Hunt, L. 2000. Angler responses to potential harvest regulations in a Norwegian Sport Fishery: a conjoint-based choice modeling approach. North American Journal of Fisheries Management, 20: 940–950.

Abbott, J. K., and Fenichel, E. P. 2013. Anticipating adaptation: a mechanistic approach for linking policy and stock status to recreational angler behavior. Canadian Journal of Fisheries and Aquatic Sciences, 70: 1190–1208.

Abbott, J. K., Lloyd-Smith, P., Willard, D., and Adamowicz, W. 2018. Status-quo management of marine recreational fisheries undermines angler welfare. Proceedings of the National Academy of Sciences, 115: 8948–8953.

American Sportfishing Association. 2014. Oregon Marine Protected Areas. American Sportfishing Association, Alexandria, VA.

Anderson, L. E., and Lee, S. T. 2013. Untangling the recreational value of wild and hatchery salmon. Marine Resource Economics, 28: 175–197.

Arlinghaus, R. 2006. On the apparently striking disconnect between motivation and satisfaction in recreational fishing: the case of catch orientation of German anglers. North American Journal of Fisheries Management, 26: 592–605.

Barrett, B. N., van Poorten, B., Cooper, A. B., and Haider, W. 2017. Concurrently assessing survey mode and sample size in off-site angler surveys. North American Journal of Fisheries Management, 37: 756–767.

Beardmore, B., Hunt, L. M., Haider, W., Dorow, M., and Arlinghaus, R. 2015. Effectively managing angler satisfaction in recreational fisheries requires understanding the fish species and the anglers. Canadian Journal of Fisheries and Aquatic Sciences, 72: 500–513.

Brinson, A. A., and Wallmo, K. 2013. Attitudes and preferences of saltwater recreational anglers: Report from the 2013 national saltwater angler survey. ICES Document NOAA tech. memo. NMFS-F/SPO. 135 pp.

Brinson, A. A., and Wallmo, K. 2017. Determinants of saltwater anglers' satisfaction with fisheries management: regional perspectives in the United States. North American Journal of Fisheries Management, 37: 225–234.

Carter, D. W., and Liese, C. 2012. The economic value of catching and keeping or releasing saltwater sport fish in the southeast USA. North American Journal of Fisheries Management, 32: 613–625.

Chagaris, D., Allen, M., and Camp, E. 2019. Modeling temporal closures in a multispecies recreational fishery reveals tradeoffs associated with species seasonality and angler effort dynamics. Fisheries Research, 210: 106–120.

Commission on Saltwater Recreational Fisheries Management. 2014. A Vision for Managing America's Saltwater Recreational Fisheries. Theodore Roosevelt Conservation Partnership, Washington, DC. 1–15. pp.

Cox, S. P., Beard, T. D., and Walters, C. 2002. Harvest control in open-access sport fisheries: hot rod or asleep at the reel? Bulletin of Marine Science, 70: 749–761.

FCRC Consensus Center 2010. 2010. 2010 Recreational Saltwater Fishing Summit. Florida State University, Tallahassee, Florida. 1–150 pp.

Fedler, A. J., and Ditton, R. B. 1994. Understanding angler motivations in fisheries management fisheries. 19: 6–13.

Fenichel, E. P., Abbott, J. K., and Huang, B. 2013a. Modelling angler behaviour as a part of the management system: synthesizing a multi-disciplinary literature. Fish & Fisheries, 14: 137–157.

Fenichel, E. P., Gentner, B., and Arlinghaus, R. 2013b. Normative considerations for recreational fishery management: a bioeconomic framework for linking positive science and normative fisheries policy decisions. Fisheries Management & Ecology, 20: 223–233.

Greene, W. H., and Hensher, D. A. 2003. A latent class model for discrete choice analysis: contrasts with mixed logit. Transportation Research Part B: Methodological, 37: 681–698.

Haab, T., Hicks, R., Schnier, K., and Whitehead, J. C. 2012. Angler heterogeneity and the species-specific demand for marine recreational fishing. Marine Resource Economics, 27: 229–251.

Hilborn, R. 2008. Knowledge on how to achieve sustainable fisheries. *In* Fisheries for Global Welfare and Environment. Ed. by K. Tsukamoto, T. Kawamura, T. Takeuchi, J. T.D. Beard, and M. J. Kaiser. World Fisheries Congress 5, Tokyo, Japan. pp. 45–56.

Holland, S., and Ditton, R. 1992. Fishing trip satisfaction: a typology of anglers. North American Journal of Fisheries Management, 12: 28–33.

Ihde, T. F., Wilberg, M. J., Secor, D. H., and Miller, T. J. 2011. FishSmart: Harnessing the Knowledge of Stakeholders to Enhance U.S. Marine Recreational Fisheries with Application to the

Atlantic King Mackerel Fishery. *In* American Fisheries Society Symposium.

Layton, D. F. 2001. Alternative approaches for modeling concave willingness to pay functions in conjoint valuation. American Journal of Agricultural Economics, 83: 1314–1320.

Lee, M.-Y., Steinback, S., and Wallmo, K. 2017. Applying a bioeconomic model to recreational fisheries management: groundfish in the northeast United States. Marine Resource Economics, 32: 191–216.

Lew, D. K., and Larson, D. M. 2015. Stated preferences for size and bag limits of Alaska charter boat anglers. Marine Policy, 61: 66–76.

Massey, D. M., Newbold, S. C., and Gentner, B. 2006. Valuing water quality changes using a bioeconomic model of a coastal recreational fishery. Journal of Environmental Economics and Management, 52: 482–500.

NOAA Fisheries. 2014. 2014 recreational saltwater fishing summit summary report. *In* 2014 Recreational Saltwater Fishing Summit, pp. 1–123. NOAA Fisheries, Alexandria, VA.

NOAA Fisheries. 2018. 2018 National Saltwater Recreational Fisheries Summit Report. Meridian Institute, Arlington, VA, pp. 1–68.

ODFW. 2013. Public Meetings to Discuss the Pacific Halibut Catch Sharing Plan for 2014. pp.1–33. Oregon Department of Fish and Wildlife. Salem, Oregon.

ODFW 2017a. Fish and Wildlife Commission Adopts Ocean Salmon, Pacific Halibut, Game Bird Hunting Regulations; Hears Public Testimony on Draft Wolf Plan. p. 1. Ed. by ODFW. Oregon Department of Fish ad Wildlife, Salem, Oregon.

ODFW 2017b. Public Meetings to Discuss the Pacific Halibut Catch Sharing Plan for 2017, pp. 1–27. Oregon Department of Fish and Wildlife, Salem, Oregon.

ODFW 2019. Just for the Halibut: Fish Soft Bottom Areas for Lower Yelloweye Rockfish Bycatch. Oregon Department of Fish and Wildlife, Salem, Oregon.

Pine Iii, W. E., Martell, S. J. D., Jensen, O. P., Walters, C. J., and Kitchell, J. F. 2008. Catch-and-release and size limit regulations for blue, white, and striped marlin: the role of postrelease survival in effective policy design. Canadian Journal of Fisheries and Aquatic Sciences, 65: 975–988.

Powers, S. P., and Anson, K. 2016. Estimating recreational effort in the Gulf of Mexico Red snapper fishery using boat ramp cameras: reduction in federal season length does not proportionally reduce catch. North American Journal of Fisheries Management, 36: 1156–1166.

Schroeder, S. A., and Fulton, D. C. 2013. Comparing catch orientation among Minnesota Walleye, Northern Pike, and Bass Anglers. Human Dimensions of Wildlife, 18: 355–372.

Train, K. E. 2003. Discrete Choice Methods with Simulation, 2nd edn. Cambridge University Press, New York, NY. 385 pp.

Ward, H. G. M., Allen, M. S., Camp, E. V., Cole, N., Hunt, L. M., Matthias, B., Post, J. R., *et al.* 2016. Understanding and managing social–ecological feedbacks in spatially structured recreational fisheries: the overlooked behavioral dimension. Fisheries, 41: 524–535.

Yin, R. K. 2014. Case Study Research Design and Methods, 5th edn. Sage Publishing, Thousand Oaks, CA. 282 pp.

Handling editor: Kieran Hyder