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REVIEW

Catch and Non-catch-related Determinants of Where Anglers Fish: A Review of Three Decades of Site Choice Research in Recreational Fisheries

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ABSTRACT
Studies of where people recreationally fish were reviewed to understand which attributes influence these choices, to make this literature accessible to individuals who manage or rely upon recreational fishers, and to shape future research. Between 1988 and 2017, researchers published 114 studies and 189 distinct models of angler behaviors from 96 unique data sets. On average, costs such as travel were universally important while measures of catch-related fishing quality also generally and positively influenced choices of fishing sites. Although frequently omitted from studies, facility quality (e.g., boat launch presence), destination size (e.g., lake area), and measures of environmental quality (e.g., water quality) tended to positively influence choices of fishing sites by anglers. Finally, the influence of regulations and congestion on fishing site choices was more often a significant factor in the choice of hypothetical (i.e. stated preference) than actual (i.e. revealed preference) fishing trips. Researchers are also encouraged to facilitate future reviews by: (i) more clearly communicating details of their studies; (ii) enhancing comparability among studies by using where possible standardized attribute measures; (iii) explicitly testing alternate model specifications related to how anglers' tradeoff fishing site attributes and; (iv) expanding the scope and scale of research on where people fish.

KEYWORDS
Angler behaviors; meta-analysis; valuation; utility; stated preference; revealed preference

Introduction

Recreational fishing represents a dominant use of wild freshwater fish stocks in industrialized countries and is rising rapidly in importance in many economies in transition (FAO, 2012). Anglers are also becoming a key user of coastal and some offshore marine fisheries (Coleman et al., 2004; Ihde et al., 2011). At the intersection of a mobile population of anglers, other actors such as fisheries managers, and the natural environment lies a recreational fishery, which often encompasses multiple fishing sites (Ward et al., 2016). Like the case for commercial fisheries (Hilborn, 2007; Fulton et al, 2011), sustainably managing recreational fisheries demands a focus on people and their behaviors (Hunt et al., 2013; Arlinghaus et al., 2017). A better understanding of how attributes (e.g., catch rates) of sites typically affect individual anglers' behaviors like site choice may be useful for both anticipating outcomes, such as aggregate fishing effort or harvest, and for deciphering social-ecological linkages (Arlinghaus et al., 2017). For example, sustainable recreational fishery management is facilitated by anticipating anglers' responses to interventions by managers such as the implementation of new harvest regulations (Aas et al., 2000). Improved knowledge and representation of these responses will ultimately help fisheries scientists and managers to predict how regulations will likely affect fish, aquatic ecosystems, and in turn feedback to people.

The decision of where anglers fish is amongst the most studied behaviors of anglers. Beginning in the late 1980s, researchers began adopting choice-based models to understand better how anglers choose among competing fishing sites, often termed alternatives or destinations (e.g., Milon 1988a,b; Bockstael et al., 1989). These choice models are a theory-grounded approach (Lancaster, 1966; McFadden, 1974; Manski, 1977) to understand and predict angler

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behaviors by assuming that the relative attractiveness of a fishing site (i.e. utility of a site) arises from attributes that characterize fishing sites and anglers' preferences for these attributes. Therefore, by gathering information about fishing sites, attributes, and choices of fishing sites by anglers, researchers can estimate anglers' preferences for attributes and subsequently predict the likelihood that an angler will fish at a site given a set of available sites.

Despite the critical implications for fisheries management, integration of studies on angler behaviors by human dimensions specialists and economists into recreational-fisheries management approaches have been slow (Fenichel et al., 2013; Arlinghaus et al., 2017). The lack of rapid uptake is surprising given the interest of many fisheries biologists and managers in angling effort and the desire to provide quality fishing opportunities (e.g. Cox et al., 2003). Angling effort, as defined by the sum trips over some spatio-temporal frame, arises from the decisions by individual anglers (Fenichel et al., 2013). Consequently, an agency's capacity to provide quality fishing opportunities in an efficient way is facilitated by understanding which attributes provide positive utility to anglers.

Management agencies' slow incorporation of utility-theory-based descriptions of angler behavior has at least two causes. First, resource economists have largely published research on utility-based angler behavior and these publications may not be read or understood by managers primarily trained in fisheries biology (Fenichel et al., 2013). Second, resource economists and human dimensions researchers may be motivated to address more theoretical research questions such as valuing ecosystem changes or understanding angler behaviors. The results from these studies will likely not address specific fisheries management questions nor will the developed models likely be suitable for inclusion in quantitative ecological models of fish population dynamics. In these instances, the contributions of studies of angling behaviors might be difficult to interpret by fisheries managers and researchers (Peyton and Gigliotti, 1989; Fenichel et al., 2013).

Against this context, two goals are addressed through a review of research on published empirical models that predict where anglers fish. The first goal is to provide fisheries researchers and managers with an accessible summary of utility-theory-based research describing anglers' fishing site choices and the key attributes that drive related angler behaviors. This summary can help to lessen the disciplinary barriers that inhibit acceptance and adoption of human dimensions research by fisheries biologists and ecologists. The second goal is to provide advice for future researchers who study where anglers fish. Specifically, researchers are encouraged to conduct new research into novel fisheries, to communicate results clearly, to increase comparability among studies, and to challenge and test often implicit assumptions about how anglers make tradeoffs among attributes when choosing a fishing site.

Our work builds from an earlier effort on reviewing choice models in recreational fisheries by Hunt (2005) and complements a more recent review in commercial fisheries (Girardin et al., 2016). Recreational fisheries are sufficiently different from commercial fisheries to expect strikingly different patterns of attributes driving participant choice behavior (Arlinghaus et al., 2017). While expected catch, tradition, and fishing costs are primary drivers of what is known as fleet dynamics (e.g., behavioral choices of boats) in commercial fisheries (Girardin et al., 2016), fish are just an input within a multidimensional outdoor recreation experience in recreational fisheries (Fedler and Ditton, 1994; Fenichel et al., 2013). Thus, anglers may also select fishing sites characterized by low stock size and associated catch rate and/or small fish size if other attributes such as low crowding levels or low access costs provide enough compensatory utility to continue to attract anglers. In short, recreational fishing is only partly about catch, as a range of non-catch-related factors are relevant to anglers (Fedler and Ditton, 1994). A key unresolved question in recreational fisheries that has attracted considerable controversy over the years (summarized in Arlinghaus, 2006) is understanding the relative roles of catch (e.g., size of fish, catch rate) and non-catch-related factors (e.g., expected crowding, type of regulation in place, environmental quality, cost) in driving behaviors, such as site choice behavior in fisheries landscapes (Post et al., 2008; Hunt et al., 2011). This contribution is meant to provide novel insights into this understanding.

The methods and results sections are organized to answer three key questions related to the above-mentioned study goals. These questions include: (i) how have researchers typically studied where people fish for recreation; (ii) what general and specific attributes influence where people fish recreationally; and (iii) how do researchers link attributes and preferences for attributes to develop predictive models of where anglers fish? The answers to these questions provide the footing for addressing the research goals in the discussion.

Methods

A comprehensive review was conducted of all articles published through 2017 that focused on angler fishing site choice behaviors and employed methods using variants of stated (based on intended or hypothetical behaviors of anglers) or revealed choice models (based on actual behaviors of anglers). Studies using Kuhn-Tucker models that integrate both site selection and participation decisions by anglers given budgetary constraints of time and financial resources (e.g., Abbott and Fenichel, 2013) were also included in the review. Studies were not included that solely focused on whether, how often, or how long anglers fish, what species anglers target, how many fish anglers catch, what policies anglers support, or studies using the contingent valuation method. These exclusions were made to concentrate the review on similar, utility-theory-based methods used to evaluate factors that affect where anglers fish in terms of site-specific attributes driving the choice.

Conducting the review and database management

Studies were identified from a literature search using key terms including: angling, recreational fishing, and sport fishing in combination with choice experiment, choice model, effort, Kuhn-Tucker, latent class, nested logit, random parameters logit, random utility model, repeated nested logit, revealed preference, and stated preference. Relevant literature was not identified from a search of Web of Science as the Web of Science contained no record of the first three published articles that focused on fishing site choice models (Milon, 1988a,b; Bockstael et al., 1989) nor did it include articles published in important journals such as Marine Resource Economics. Consequently, relevant literature was identified from existing reviews (Hunt, 2005; Fenichel et al., 2013) and Google Scholar searches using the aforementioned search terms. During the process of reviewing each article, three additional articles were included that were missing from the search that were cited by authors in the original collection.

Each paper was reviewed, and pertinent information was recorded including: the data set, data type (revealed or stated preference data), species examined, considerations of heterogeneity among anglers (e.g., whether different anglers had different preferences for some catch and non-catch-related factors), context (e.g., marine or freshwater fishery), and detailed information and results for each group of anglers. These details included the attributes that were examined such as expected catch rates, the importance of an attribute at influencing where anglers fish, the assumed relationship among some attributes and behaviors (e.g., linear or non-linear), and parameter estimates for the attributes. The list of attributes from Hunt (2005) was used to group the specific attributes into themes. These general attributes included cost-related attributes, catch-related attributes, environmental quality, facility quality, regulations, congestion, and fishing destination size; the latter attribute was not included by Hunt (2005) but was relevant here and was included in earlier studies (e.g., Parsons and Kealy, 1992; Feather, 1994).

All analyses used the data set as the observational unit except for the marginal rate of substitution (MRS) for catch that used the fish species group and each data set (see below for explanation). This focus on a data set rather than a publication ensured that multiple publications from the same data would not unduly influence the conclusions. For each data set, each angling group studied was weighted equally. If two studies were published from one data set and one study reported a general model for all anglers while the other study reported a separate model for, say, resident and nonresident anglers, the weight of each angling group was 0.33.

All results were reported at the aggregate level and were compared by data set type (i.e. revealed vs. stated preference) and context (i.e. freshwater vs. marine). Data sets were defined by the type of fishing site choices with reported/observed choices being termed revealed preference and hypothetical/intended choices being termed stated preferences. Social-ecological context was crudely based on whether the data set focused on marine, freshwater, or both types of fisheries.

Answering the research questions

The first research question (How have researchers typically studied where people fish?) was answered in three ways. First, the tendencies and trends were summarized among the data sets for different data types (stated and revealed preference), different contexts (marine and freshwater fisheries), different approaches to account for diversity (heterogeneity) among anglers, and decisions to study both participation (total effort) and site choices decisions. Proportions based on these summaries were illustrated for six periods (1988 – 1992, 1993 – 1997, 1998 – 2002, 2003 – 2007, 2008 – 2012, 2013 – 2017) and Pearson correlation coefficients were estimated for these proportions

Table 1. Changes to attribute levels used to estimate marginal rate of substitution (MRS) between monetary cost and other attributes.

Attribute	Measure	Base level	New level
Catch rate ($n = 59$)	Catch or harvest per day (4 h day)	2	3
Boat launch ($n = 13$)	Presence	Absence	Presence
Water quality ($n = 5$)	Secchi depth (m)	1	2
Bag limit ($n = 10$)	Number of fish	2	3
Destination size ($n = 13$)	Water area (ha)	500	600
Fish consumption advisory ($n = 9$)	Presence	Absence	Presence

n = the number of unique data sets reviewed.

using mid-points for the periods. Second, locations of data sets by country and for the United States and Canada by state and province were mapped. Third, approaches used by researchers to account for preference heterogeneity were characterized as none, classic or observable (e.g., interactions with age, gender, fishing experience), random parameters, and latent classes. For studies using classic approaches to study preference heterogeneity, the relative frequency of the employed anglers' characteristics was communicated.

For the second research question (What general and specific attributes influence where people fish?), the original plan was to conduct a meta-analysis based on fixed or random effects to determine effect size (Higgins et al., 2009). This meta-analysis could not be conducted because parameter estimates for attributes in choice models are conflated with the inverse of the unobserved error variance (Train, 2003; Girardin et al., 2016). This conflation results in pathology in meta-analyses as applied to choice models because parameter estimates and standard errors for attributes tend to zero as the variance or noise in an estimated model increases. Therefore, the usual approach for meta-analyses of weighting parameter estimates by an inverse of standard errors will result in excessive weight given to parameter estimates near zero and a tendency to conclude that the impacts of all attributes are negligible (e.g., the odds ratio, which equals the log of the parameter estimate, will tend to one). For this reason, a standard meta-analysis was not appropriate for the data and thus, was not conducted.

The second research question was instead addressed using three metrics: prevalence of attribute inclusion, attribute effect, and attribute MRS. Prevalence of researchers to include different attributes into models that predict where anglers fish was measured as a proportion of data sets that employed a given attribute. The effect of attributes on angler behavior was measured by a significance score based on the reported null hypothesis statistical significance ($p < 0.05$) and the sign of the parameter estimate to measure effect. While this measure is like the one used by Girardin et al. (2016), nonsignificant results were retained when calculating these significance scores by coding the score as (1, 0, or −1) where zero represented a non-statistically significant parameter estimate. The sign on parameter estimates was reversed where necessary to make them comparable with other estimates within the same family of attributes (e.g., for the catch attribute, the negative indicator for time elapsed to catch a fish was reversed to be positive and thus, to relate to expected catch rates). When the authors did not report statistical significance of a parameter, it was considered significant if the parameter estimate, divided by the reported standard error, exceeded the critical t value for statistical significance. These prevalence and significance scores were presented for both general and specific attributes. Proportion tests were used to assess statistical significance ($p < 0.05$) about these scores among attributes using Holm-Bonferroni-adjusted probabilities for pairwise comparisons. Tests were also conducted between scores from different contexts (marine vs. freshwater fisheries) and data types (revealed vs. stated preference). To conduct the proportion tests for significance scores, the absolute value of the significance score was used. Finally, following Girardin et al (2016), the MRS between an attribute and monetary cost was reported. The MRS was estimated as $-\Delta B_k/B_c$, where B_k is the parameter estimate for an attribute in question, Δ is a change in the measure of an attribute, and B_c is the parameter estimate for monetary cost. This MRS is loosely interpreted as the amount that anglers are willing to pay for a change in an attribute such as catching one additional fish. The MRS puts parameter estimates on the same scale and thus allows direct comparisons of the effect of changes in attribute levels. The MRS was estimated by first converting all monetary cost parameters into $US 2017 by adjusting parameter estimates using online tools for inflation (https://data.bls.gov/cgi-bin/cpicalc.pl) and currency conversion (http://www.xe.com/currencytables/). To include studies with non-linear relationships between an attribute and utility, MRS was estimated for specific changes (Δ) to attributes such as from a 500 to 600 ha water body for the destination size of a water body (Table 1). Studies that reported parameter estimates were converted into costs by

Table 2. Fish species groups used to estimate the marginal rate of substitution of catching a third fish per trip by an angler.

Group name	Species
Big game (pelagic)	Ahi (*Thunnus albacares*), Atlantic blue marlin (*Makaira nigricans*), Dolphinfish (*Coryphaena hippurus,*), big game or billfish
Snapper	Northern red snapper (*Lutjanus purpureus*), snapper generic
Salmon (marine)	Atlantic (*Salmo salar*), Chinook (*Oncorhynchus tshawytscha*), Coho (*Oncorhynchus kisutch*), Sockeye (*Oncorhynchus nerka*), salmon generic
Salmon (freshwater - stocked)	Chinook (*Oncorhynchus tshawytscha*), Coho (*Oncorhynchus kisutch*), Kokanee (*Oncorhynchus nerka*), salmon generic
Flatfish	Summer flounder (*Paralichthys dentatus*), halibut generic, flatfish generic
Mackerel	King mackerel (*Scomberomorus cavalla*), Atlantic Spanish mackerel (*Scomberomorus maculatus*)
Trout (freshwater)	Brown (*Salmo trutta*), Lake (*Salvelinus namaycush*), Rainbow (*Oncorhyncus mykiss*), trout generic
Sander	Walleye (*Sander vitreus*), Zander (*Sander lucioperca*)
Bass	Largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), bass generic
Panfish	Yellow perch (*Perca flavescens*), panfish generic
Pike	Northern Pike (*Esox lucius*)
Other (marine)	Generic saltwater fish
Other (freshwater)	Generic freshwater fish

using the Internal Revenue Service established mileage rates for vehicles (https://currentmileagerate.com/). The median, mean, standard deviation, and range of MRS were recorded for each attribute. These values were estimated from only the mean reported parameters; consequently, they underestimate the actual range of MRS estimates. The MRS for the catch-related attribute was reported for fish species groups (Table 2) because of known MRS variability among fish species (Johnston et al., 2006; Melstrom and Lupi, 2013). Only attributes or species with MRS based on three or more unique data sets were reported.

The third research question (How do researchers link attributes and preferences among attributes to develop predictive models of where anglers fish?) was addressed by assessing the assumptions that researchers made about how to relate attributes and preferences for attributes to utility. For example, one might suspect a nonlinear effect of catch on utility as increasing catch numbers provide a reduced level of improvement to utility. It was believed that few researchers actually tested if nonlinear relationships predicted anglers' choices better than did linear relationships, hence the focus on this third research question. Given the extensive use of cost and catch rates in the models, the descriptions here focus on these attributes.

Results

A total of 114 papers and book chapters were published between 1988 and 2017 that used choice-based models to understand and predict where anglers fished (see Appendix 1 for full listing and references). Of these papers, 96 unique data sets were represented by 66 revealed preference and 31 stated preference data types, with two studies using both revealed and stated preference data. A total of 189 unique models of angler groups were estimated from these 96 data sets. Angler behavioral models were based on an average of 1,136 anglers (1,920 standard deviation) and 5,971 observations such as trips (12,379 standard deviation). Three (3%) data sets had no explicit information about the sample while 14 (15%) and 37 (39%) other data sets had no explicit information about the number of sampled anglers and observations, respectively.

Question 1. How do researchers typically study where people fish for recreation?

Over the 30-year period, most data sets were based on reported (revealed preference) fishing site choices (70%), accounted for preference heterogeneity (57%), and focused on freshwater fisheries (63%; Figure 1). Over the review period, there was a decline in the relative abundance of revealed preference data sets ($r = -0.96$, df $= 4$, $p < 0.01$) and studies that examined participation (avidity of effort) with site choice decisions ($r = -0.92$, df $= 4$, $p = 0.01$). Increases over the review period were observed for studies accounting for preference heterogeneity ($r = 0.94$, df $= 4$, $p = 0.01$) and based on stated (hypothetical) fishing site choices ($r = 0.96$, df $= 4$, $p < 0.01$). In fact, by 2017, data sets used to estimate stated preference models represented over 30% of all data sets despite the first publication of a stated preference model of where anglers fish being published in 2000 (Aas, Haider and Hunt, 2000). No significant trends were observed for the tendency to study marine ($r = 0.56$, df $= 4$, $p = 0.25$) or freshwater fisheries ($r = -0.53$, df $= 4$, $p = 0.28$) over time.

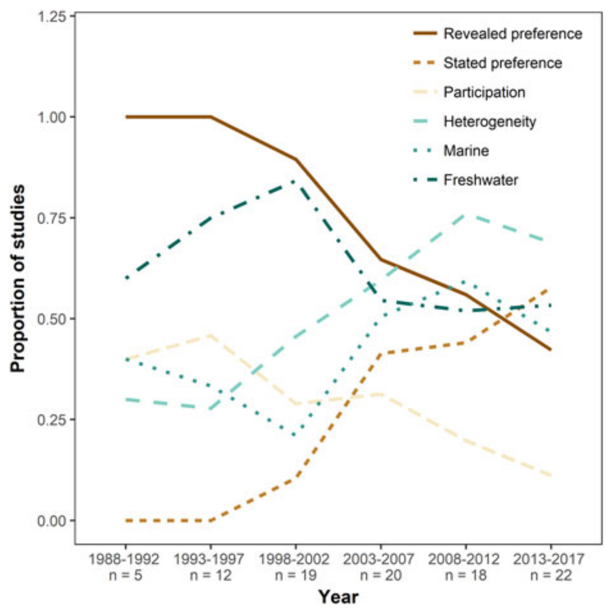

Figure 1. Trends in characteristics (proportions) used within models of where anglers fish. (characteristics are based on unique data sets and not studies; stated and revealed preference – the type of data used to estimate the models; participation – models jointly estimating where and whether/how often anglers fish; heterogeneity – models accounting for heterogeneity in angler preferences for attributes; marine and freshwater – type of fishery studied).

Most data sets were based on United States fisheries with the remaining data sets focused on fisheries from other industrialized nations in North America, Western Europe, and Oceania (Figure 2a). Notably, no published studies of site choice were conducted on recreational fisheries in Asia, South America, or Africa. Where data sets were associated with specific states or provinces in North America, the studies were concentrated around the Laurentian Great Lakes, Pacific coastal states, selected Atlantic and Gulf Coast states (i.e. Maine, North Carolina, Florida, and Texas), and a few inland areas such as Tennessee, Oklahoma, Montana, and Alberta (Figure 2b).

Among the data sets that researchers used to study anglers' preference heterogeneity ($n = 55$), researchers most often (76%) examined heterogeneity in a classic way by interacting angler characteristics and attributes of the fishing sites (Figure 3a). The other main way (38%) researchers accounted for heterogeneity was a random parameters logit model that assumes that anglers' preferences for an attribute vary according to a distribution such as Gausian. Like random parameter logit models, latent class choice models account for preference heterogeneity that is unobservable to the researcher. For latent class choice models, preference heterogeneity is assumed to be distributed among discrete groups (classes) of anglers. Some data sets (24%) were estimated with more than one approach such as a random parameters logit along with interactions of angler characteristics.

The interactions that researchers employed to account for the classic way of explaining preference heterogeneity largely focused on socio-demographic characteristics (e.g., age and income), equipment available (boat ownership), target species, and commitment of the individual to angling (Figure 3b). Commitment was usually measured by recreation specialization (Bryan, 1977) although other researchers used angling avidity and skill as proxies for commitment.

Question 2. What general and specific attributes influence where people fish for recreation?

Researchers almost always examined the effects of catch-related fishing quality and/or costs when explaining where anglers fished (Figure 4a, Table 3). Environmental quality and the destination size (often defined by the size of a waterbody) were the next most often studied attributes being represented in <40% of the data sets. Facility quality (e.g., boat launch or docking facilities), regulations, and congestion were not included in many of the data sets (between 14 and 28%).

Four attributes were used at different rates between data sets based on revealed and stated preferences. Revealed preference data sets were relatively more likely to employ environmental quality ($Z = 2.76$, $p = 0.01$) and destination size ($Z = 4.39$, $p < 0.01$) as attributes to explain anglers' site choices. Regulations ($Z = -5.32$, $p < 0.01$) and congestion ($Z = -2.46$, $p = 0.02$) were used relatively more often to explain anglers' fishing site choices for stated preference than revealed preference data sets. Environmental quality ($Z = -3.25$, $p < 0.01$), destination size ($Z = -2.10$, $p = 0.04$), and facility quality ($Z = -1.98$, $p = 0.05$) were relatively used more often to explain choices in data sets describing freshwater as opposed to marine fisheries.

In terms of significance scores (effect), parameter estimates for the cost-related attribute were almost always universally significant and negative (Table 4; Figure 4b). The next set of attributes in terms of strength of significance scores were destination size, catch-related fishing quality, facility quality, and environmental quality ranging from positive effects of 64 to 89% (Table 4; Figure 4b). Regulations and congestion were much less often found to be significant attributes at influencing angler behaviors and each

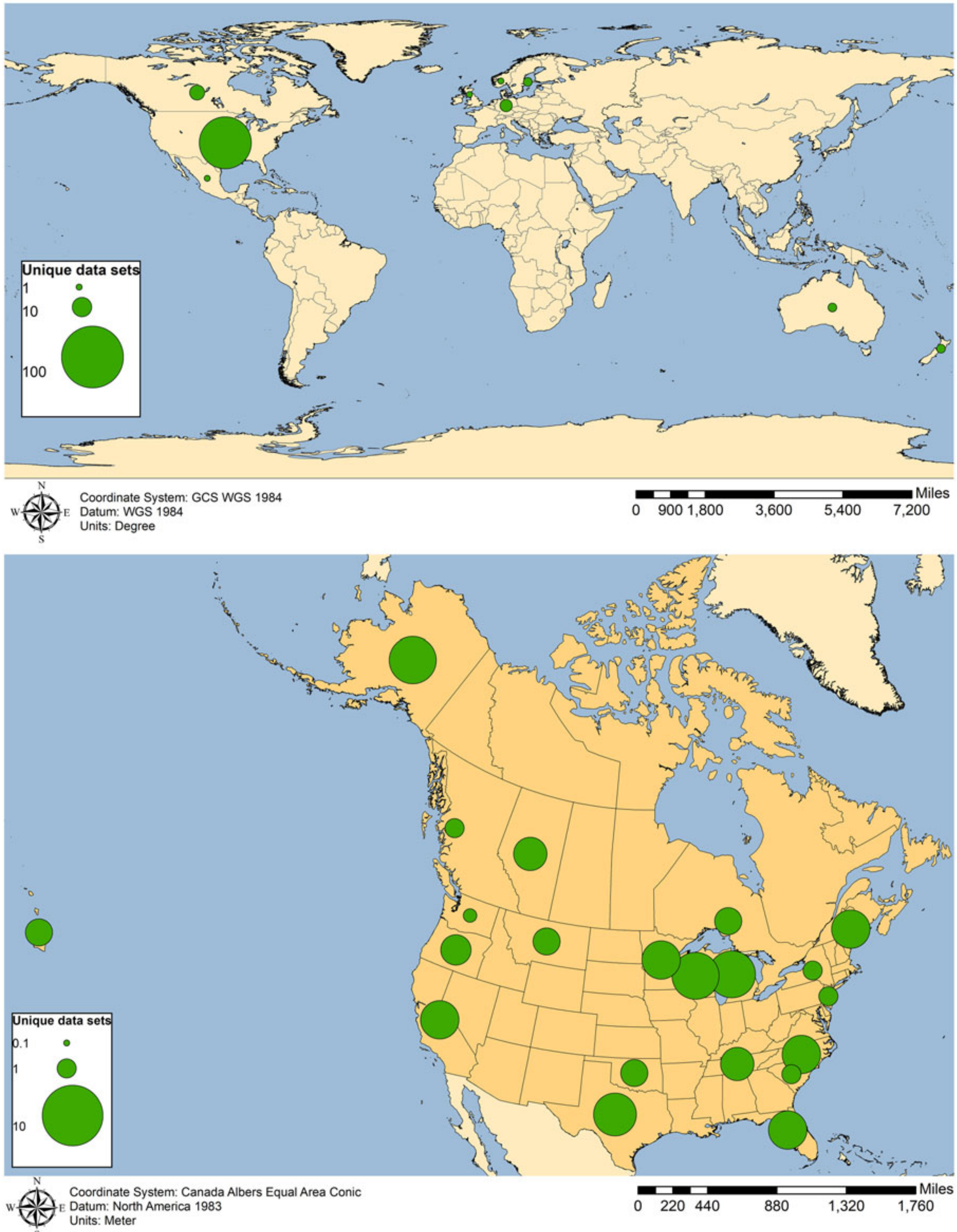

Figure 2. Locations of data sets from reviewed studies. (top panel – global distribution; bottom panel – detailed distribution within the United States and Canada).

had a negative significance score. Regulations had a larger significance score for marine than freshwater fisheries ($Z = 2.25$, $p = 0.03$).

Most studies (85%) measured the cost attribute with monetary cost (Figure 5a). Distance was used in about 16% of the data sets while time, which was included often with monetary cost, was estimated as a separate effect in 11% of the data sets. Each measure of cost almost always resulted in a significant and negative effect on fishing site choices by anglers (Figure 5b).

Of the 82 data sets that used monetary costs to measure cost, 72% of the data sets used a travel cost,

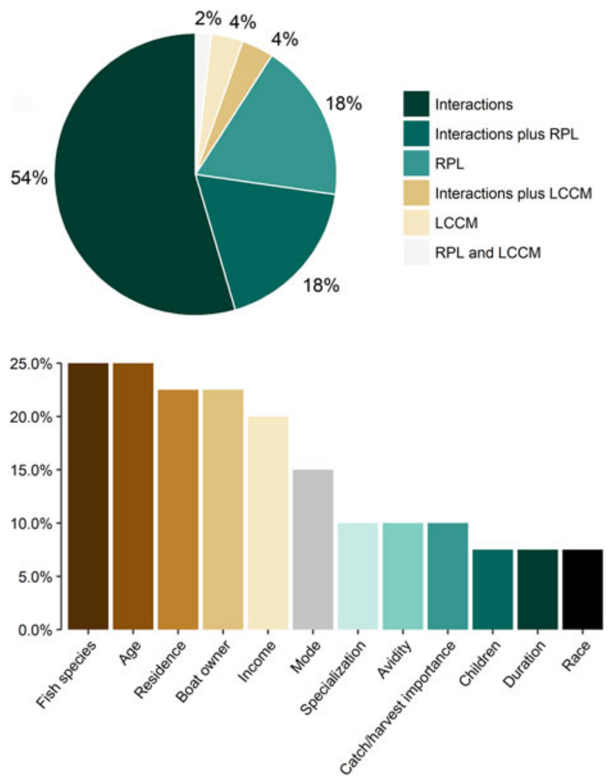

Figure 3. Approaches to account for preference heterogeneity in studies of where anglers fish. (top panel – general ways that researchers have studied heterogeneity (Interactions – interactions with observable characteristics, LCCM – latent class choice model, RPL – random parameters logit); bottom panel – distribution of characteristics used in studies accounting for heterogeneity through interactions).

13% a fee, 6% other, and 9% lacked information about the cost. Within the data sets using travel costs, 59% used vehicle expenses and the opportunity cost of time (e.g., value of travel time to site), 31% only used vehicle operating expenses, 8% used a combination of vehicle operating expenses, opportunity cost of time, and on-site costs. Vehicle operating costs were typically based on Automobile Association mileage rates although this information was not always explicitly provided. Little information was provided about ride sharing and associated adjustments to the per person vehicle operating costs. Travel times were often based on estimated wage rates, a fraction of the wage rate (usually 1/3), and a travel speed for vehicles (often 64 to 80 km per hour).

Within the catch-related attribute, researchers employed several different measures ranging from catch rates and average fish size to presence of species, abundance, and stocking as a proxy for expected abundance (Figure 6a). Basing statistical analyses on the three attributes with greater than 10% use in models, catch rates were used more often than fish size ($Z = 2.69$, $p < 0.01$) and harvest rate ($Z = 8.66$, $p < 0.01$). Fish size was more often employed than harvest rate ($Z = 7.29$, $p < 0.01$). Fish size was more often used in stated than revealed preference data sets ($Z = -4.75$, $p < 0.01$). Harvest rate was more commonly used in studies of marine than freshwater fisheries context ($Z = 2.89$, $p < 0.01$), while abundance was more often used in freshwater contexts ($Z = -2.03$, $p = 0.05$).

Harvest rates were the most consistently, significantly positive measure of catch-related fishing quality having a positive effect in almost every study where it was tested (Figure 6b) and a ratio statistically significantly greater than either fish size or catch rates ($Z = 3.04$, $p < 0.01$ and $Z = 2.65$, $p < 0.01$, respectively). Catch rates and fish size had similar levels of positive effect to each other ($Z = 0.94$, $p = 0.35$), but were not as consistently positively significant when compared to harvest rate.

Environmental quality was most often measured (Figure 7a) as water quality (i.e. water chemistry, area of concern, water clarity, flow, or general quality) when compared to fish health in relation to consumption security of the harvested fish ($Z = 4.18$, $p < 0.01$) or aesthetics ($Z = 3.64$, $p < 0.01$). Of the environmental quality proxies, water quality and aesthetics were most positively related to where anglers fish ($Z = 2.09$, $p = 0.04$ and $Z = 3.07$, $p < 0.01$) when compared to improved fish health (Figure 7b).

Researchers evaluated the effect of regulations on angler behaviors by using several different measures including daily bag limits, size limits (primarily minimum size), other input-related regulations such as season length, and gear and equipment regulations (Figure 8a). Bag limits were used more often than were size-based limits ($Z = 4.56$, $p < 0.01$), other input-related regulations ($Z = 8.96$, $p < 0.01$), and gear/equipment regulations ($Z = 8.96$, $p < 0.01$). Size limits were used more often than other input-related ($Z = 5.10$, $p < 0.01$) and gear/equipment regulations ($Z = 5.10$, $p < 0.01$). Stated preference studies were more likely to have employed daily bag limits ($Z = -2.37$, $p = 0.02$) than did revealed preference studies.

Bag and size limits were used in >10% of the data sets and thus, were eligible for statistical analysis of effect size (Figure 8a). Reductions to bag limits were more likely to affect negatively angler behaviors than did increases in size limits (Figure 8b, $Z = 5.75$, $p < 0.01$).

The general attributes identified by Hunt (2005) used to predict where anglers fish were revisited considering the literature surveyed here. Based on this review, the general attribute of destination size was

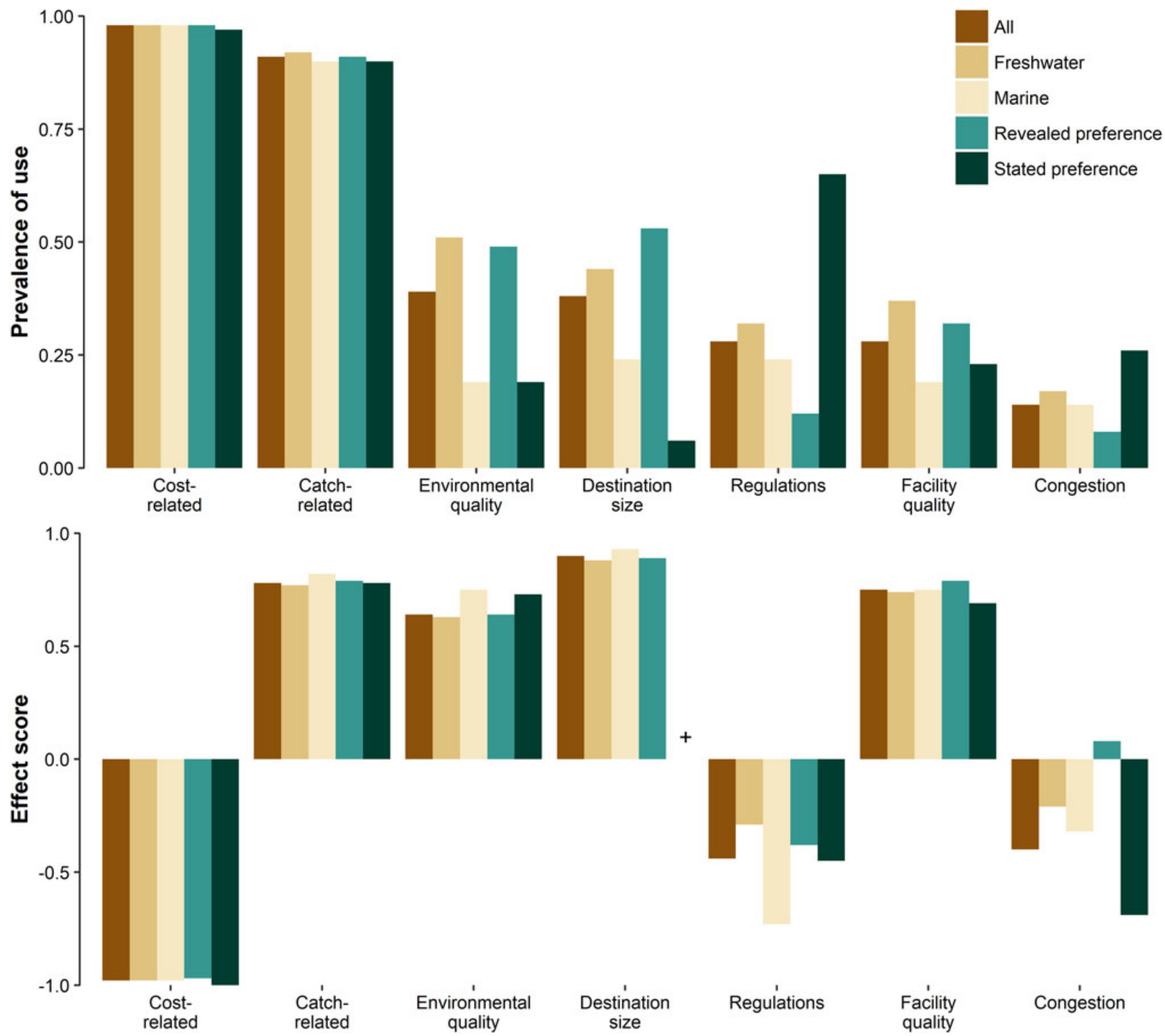

Figure 4. Prevalence of use and significance (effect) of general attributes from review of studies (96 unique data sets) where people fish. (top panel – percentage of data sets analyzed with the attribute; bottom panel – significance score based on statistical significance of parameter estimates ($p < 0.05$) with coding of -1, 0, and 1 for negative, nonsignificant, and positive relationship, respectively; bottom panel based on data sets that researchers used to examine the attribute in question; + number of data sets was <5).

Table 3. Z values based on pairwise comparisons of the prevalence of attribute used in data sets to explain where anglers fish.

Attribute	Cost-related	Catch-related	Environmental quality	Destination size	Regulations	Facility quality
Catch-related	2.17					
Environmental quality	8.84*	7.54*				
Destination size	8.95*	7.67*	0.15			
Regulations	10.02*	8.82*	1.53	1.38		
Facility quality	10.02*	8.82*	1.53	1.38	0.00	
Congestion	11.77*	10.69*	3.95*	3.95*	2.25	2.49

$n = 92$, df = 182, * - denotes statistically significant differences based on Holm-Bonferroni-corrected probabilities with $p < 0.05$.

appended to the list of general attributes that influence where anglers fish (Table 5). This review also revealed that researchers employed a diversity of measures for attributes such as catch, cost, regulations, and environmental quality.

We further examined studies that provided parameter estimates for monetary cost or distance that was converted to cost, which represented 75% of the data sets. From these studies, the marginal rate of substitution (MRS) between a change to an attribute level

Table 4. *Z*-values based on pairwise comparisons of the significance (statistical significance) of attributes used in data sets to explain where anglers fish.

Attribute	Cost-related	Catch-related	Environmental quality	Destination size	Regulations	Facility quality
Catch-related	4.15*					
Environmental quality	5.40*	1.60				
Destination size	2.18	−1.40	2.47			
Regulations	7.06*	3.36*	1.60	3.82*		
Facility quality	4.02*	0.30	0.93	1.43	2.23	
Congestion	6.81*	2.92	1.55	3.56*	0.34	2.19

Z-values; * - denotes statistically significant differences based on Holm-Bonferroni-corrected probabilities with $p < 0.05$.

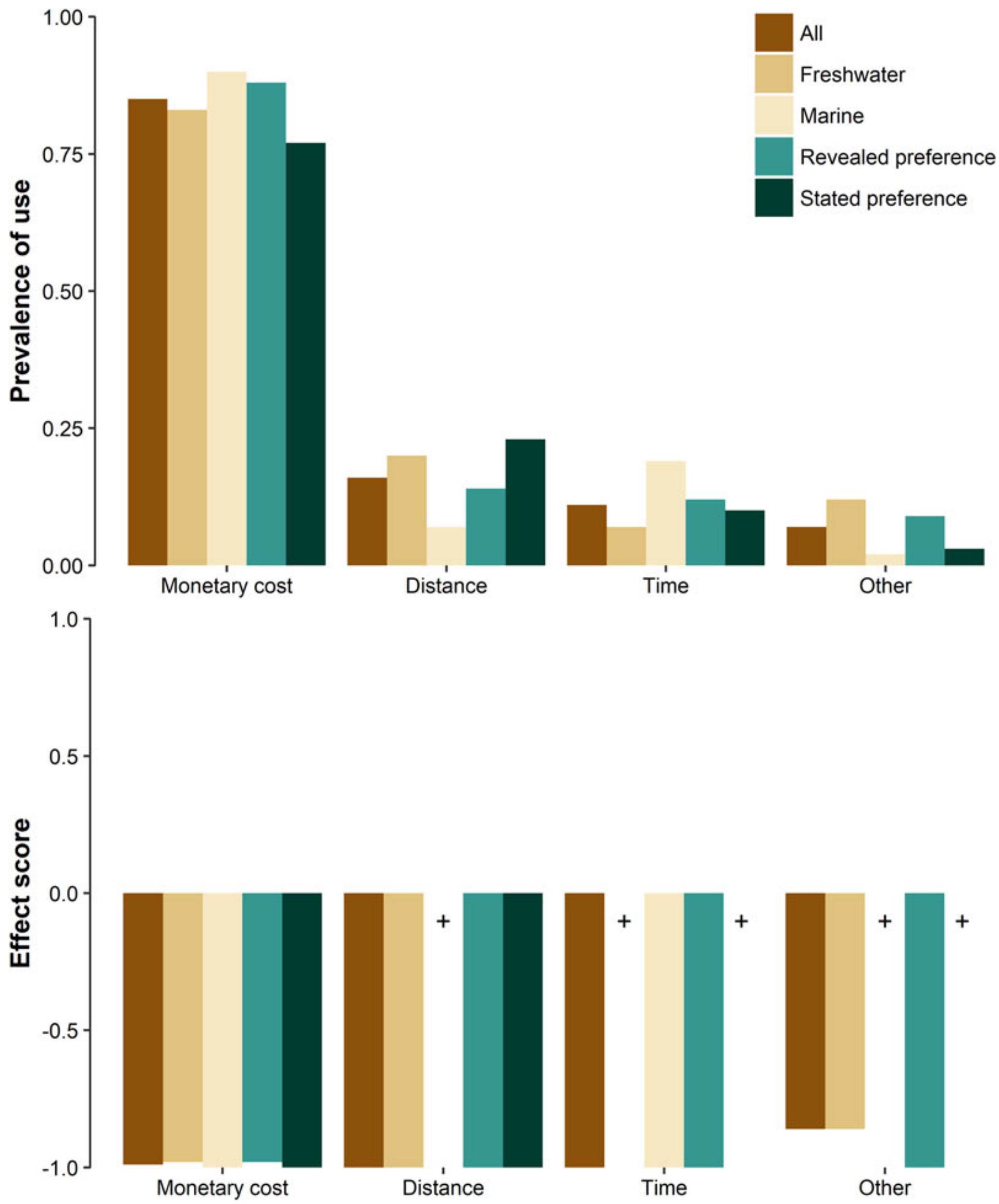

Figure 5. Prevalence of use and significance (effect) of different measures of the cost attribute from review of studies where people fish. (top panel – proportion of data sets analyzed with the attribute; bottom panel – significance score based on statistical significance of parameter estimates ($p < 0.05$) with coding of −1, 0, and 1 for negative, non-significant, and positive relationship, respectively; bottom panel based on data sets that researchers used to examine the attribute in question; + number of data sets was <5).

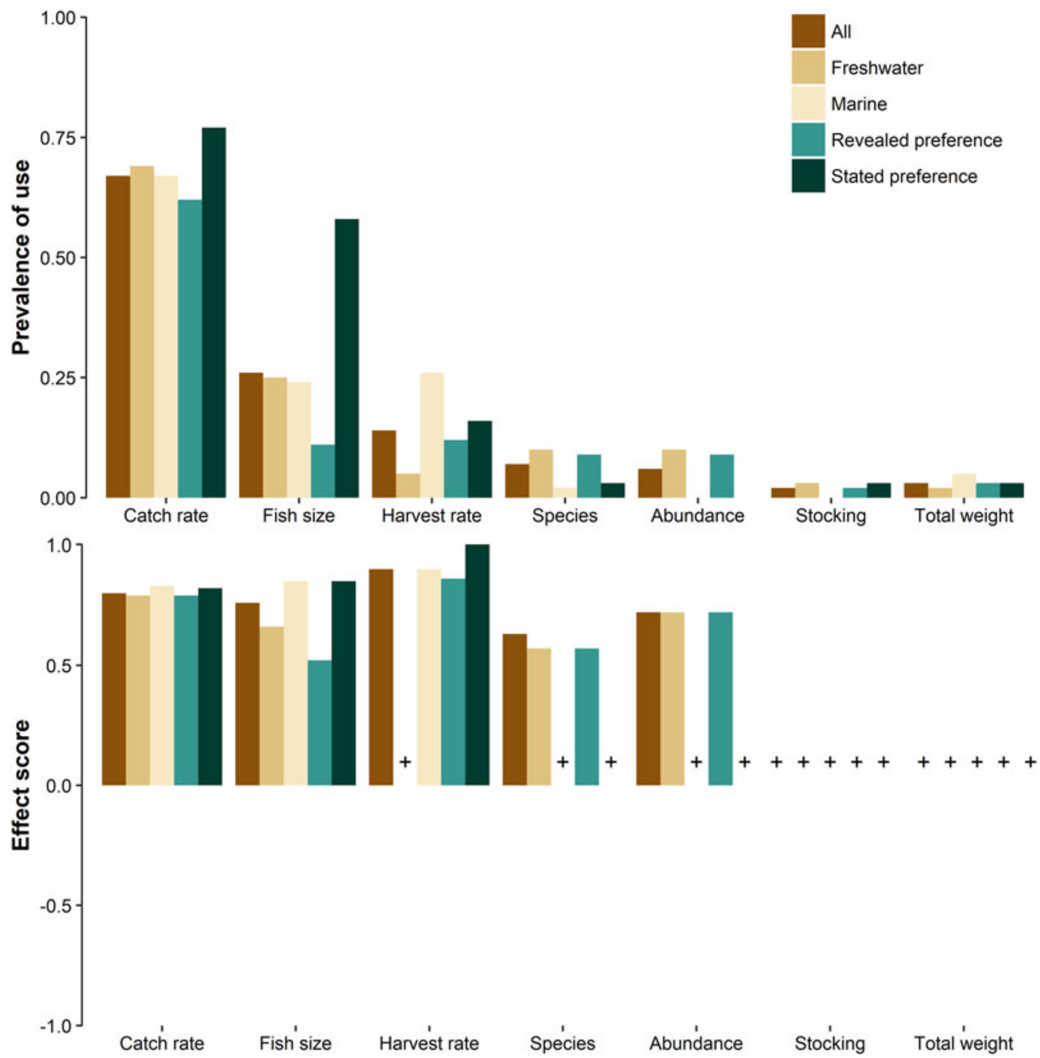

Figure 6. Prevalence of use and significance (effect) of different measures of catch-related attributes from review of studies where people fish. (top panel – proportion of data sets analyzed with the attribute; bottom panel – significance score based on statistical significance of parameter estimates ($p < 0.05$) with coding of −1, 0, and 1 for negative, nonsignificant, and positive relationship, respectively; bottom panel based on data sets that researchers used to examine the attribute in question; + number of data sets was <5).

(see Table 1 for details) and 2017 US$ was reported. The MRS estimates are provided for five non-catch related attributes that were based on a minimum of three data sets. The presence of a fish consumption advisory had a strong effect on fishing site choice (Table 6). The median MRS estimate suggested that anglers would pay about $25 (in 2017 US$) to avoid fishing at a site with a consumption advisory or concern for fish health, such as avoiding fishing in an area of concern. The presence of a boat launch was also associated with a high MRS (ca. $22). Improvements to water clarity through increased Secchi depth (1 to 2 m) also had strong positive effects on anglers with a median willingness to pay (WTP) of over $8 (in 2017 US$). A bag limit increase from 2 to 3 fish had the next highest median WTP (ca. $7), although considerable variation around this median existed due to one data set reporting a very high and negative MRS. Increases to water area (500 to 600 ha) was valued at about $4.

We combined measures of catch and harvest to estimate the MRS of an increase in catch from 2 to 3 fish per trip for select groups of species. This analysis provided a fair comparison of the value of catching an additional fish, although the values are likely higher for low-catch than high-catch rate species. Key marine fisheries groups, including salmon (in the ocean phase), big game pelagic, snapper, flatfish, and mackerel, had amongst the highest median MRS values ranging from $45 to $137 US2017 (Table 7). In fact, the top four most valuable fish species were marine species with a median MRS for marine salmon being

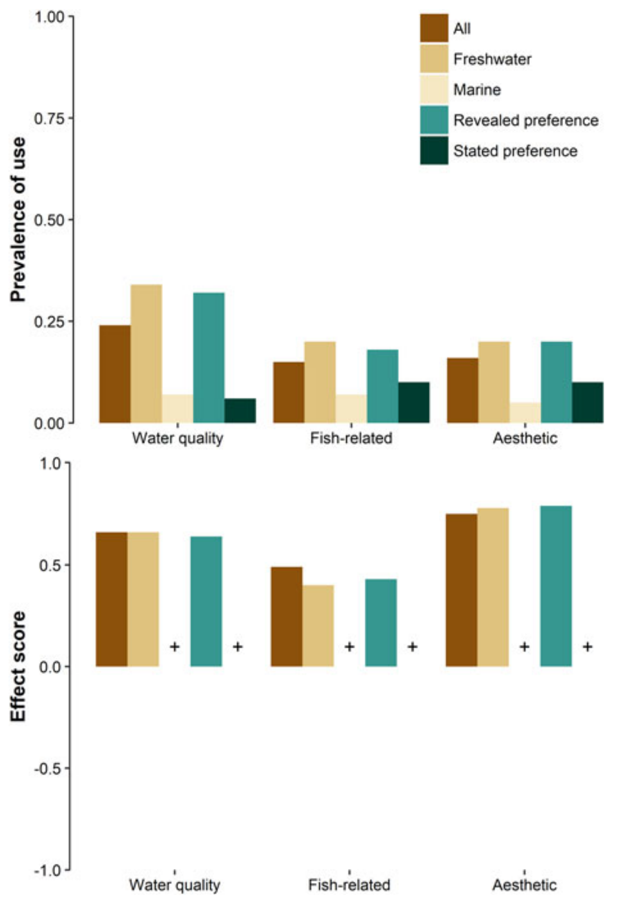

Figure 7. Prevalence of use and significance (effect) of different measures of the environmental quality attribute from review of studies where people fish. (top panel – proportion of data sets analyzed with the attribute; bottom panel – significance score based on statistical significance of parameter estimates ($p < 0.05$) with coding of -1, 0, and 1 for negative, non-significant, and positive relationship, respectively; bottom panel based on data sets that researchers used to examine the attribute in question; + number of data sets was <5).

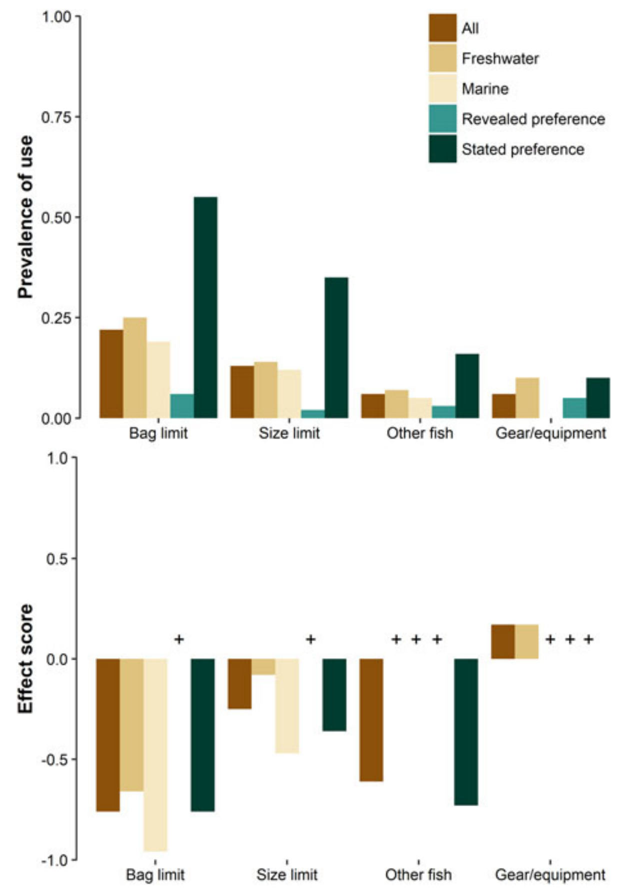

Figure 8. Prevalence of use and significance (effect) of different measures of the regulation attribute from review of studies where people fish. (top panel – proportion of data sets analyzed with the attribute; bottom panel – significance score based on statistical significance of parameter estimates ($p < 0.05$) with coding of -1, 0, and 1 for negative, non-significant, and positive relationship, respectively; bottom panel based on data sets that researchers used to examine the attribute in question; + number of data sets was <5).

over three times greater than the median MRS for salmon in freshwater fisheries. Within the freshwater fish species community, the order by MRS was salmon (in the freshwater stage), trout, sander, bass, pike, and panfish with the median MRS estimates ranging from $41 to $2 US2017. Finally, increasing the catch of other marine species was more valuable than the catch of other freshwater species, but the "other freshwater species" had a median MRS greater than most of the median MRS for named freshwater fish species.

Question 3. How do researchers link attributes and preferences among attributes to develop predictive models of where anglers fish?

The algebraic forms (e.g., linear, non-linear) by which attributes are represented in the utility function have important implications for how anglers consider tradeoffs when making site choices. For two of the most often used attribute measures, cost and catch rate, evidence for alternative relationships was examined between an attribute and utility, including additive (linear in the parameters), nonlinear (e.g., logarithm), tested (e.g., linear and quadratic), and freely-estimated forms (e.g., no relationship is assumed for the attribute) (Figure 9). Except for catch rates for stated preference data sets, over 80% of studies assumed that catch and cost had a linear effect on utility. For stated preference data sets and catch rate measures, most data sets were still used to develop models assuming a linear relationship. Very few researchers tested the functional relationship between utility and catch and especially between utility and cost. Of the six studies that tested the functional form of catch, five (Shaw and Ozog, 1999; Anderson and

Table 5. Summary of general and specific attributes used to predict where anglers fish.

General attribute	Specific attributes			
Catch-related fishing quality[a]	Catch rate	Harvest rate	Fish size	Fish abundance
Cost-related	Cost (travel or fees)	Distance	Travel time	Other
Environmental quality	Water quality	Fish quality	Aesthetics	
Facility quality				
Regulations	Bag limits	Size limits	Other fish limits	Gear and equipment
Congestion				
Destination size				

[a]Other specific attributes include fish species presence and stocking.

Table 6. Marginal rate of substitution (US $2017) for selected attributes related to where anglers fish.

Measure	Median	Mean	Standard deviation	Minimum	Maximum	Data sets
Boat Launch presence	$21.86	24.41	$29.73	−$7.86	$87.95	13
Water clarity (1 to 2m Secchi)	$8.41	$6.59	$11.25	$2.33	$29.09	5
Bag Limit (2 to 3 fish)	$7.10	−$22.63	$166.64	−$487.27	$93.05	10
Destination size (500 to 600 ha)	$4.09	$5.34	$4.71	$1.72	$18.05	13
Fish advisory presence	−$24.79	−$30.83	$23.34	−$85.57	−$0.46	9

Table 7. Marginal rate of substitution (US $2017) for catching a third fish from a fish species group from models of where anglers fish.

Group	Median	Mean	Std. Dev	Minimum	Maximum	Data sets
Salmon (marine)	$136.66	$174.77	$173.95	$7.49	$461.00	6
Big game (pelagic)	$107.33	$316.58	$480.91	$5.18	$1,344.62	7
Snapper	$57.24	$63.25	$43.45	$23.13	$109.39	3
Flatfish	$44.96	$99.03	$178.71	-$46.33	$487.01	7
Salmon (freshwater)	$41.17	$67.01	$86.14	$0.35	$311.30	11
Mackerel	$26.92	$29.68	$34.94	-$5.67	$70.53	4
Trout (freshwater)	$18.03	$39.12	$50.31	$2.13	$194.16	18
Sander	$15.38	$15.44	$12.58	-$0.71	$32.45	7
Bass	$10.69	$11.38	$12.63	-$1.01	$33.10	7
Panfish	$2.01	$3.63	$3.49	$0.28	$9.44	7
Pike	$6.95	$8.52	$7.92	$1.72	$18.45	4
Other (marine)	$15.84	$33.67	$66.34	-$2.59	$307.51	24
Other (freshwater)	$11.35	$19.58	$22.18	-$0.08	$80.93	15

Lee, 2013; Carter and Liese, 2012; Hindsley et al., 2011; Lawrence, 2005) supported a positive yet diminishing effect of catch (i.e., non-linearity) on utility, while only Latila and Paulrud (2006) did not.

Discussion

Synthesis of angler site choice research

The first goal for this study was to summarize the extant literature on anglers' fishing site choices into a digestible form for fisheries researchers and managers. Seven general attributes were identified that influence where anglers fish. Six of these attributes were previously identified by Hunt (2005): catch-related fishing quality, costs, environmental quality, facility quality, regulations, and congestion. The seventh attribute was the destination size, which appears to measure anglers' preference for maintaining the free choice of where and when to fish, independently of how many people are encountered or how many fish are caught. When this destination size attribute was included in fishing site choice models, it was very often (>80%) associated with a positive and significant effect on fishing site choice. This finding is consistent with empirical models of boating activity that have found positive relationships between total fishing activity and lake size (e.g., Bossenbroek et al., 2007; Muirhead and MacIsaac, 2011). The results here indicate that destination size is a critical and often-overlooked non-catch related site attribute for fishing site choice.

Cost had almost a universal negative effect at influencing where anglers fished. Clearly, anglers are constrained by time and financial resources and thus, pursue fishing in a limited spatial arena. This limited arena for fishing activity has important implications for assessing impacts of angling as locations near urban centers are especially vulnerable to effects of overfishing (Carpenter and Brock, 2004; Post et al., 2008).

Catch-related fishing quality emerged as a critical and common attribute that also strongly affected where anglers fished, although it did not have as consistently a significant effect as did cost. Harvest rate, which

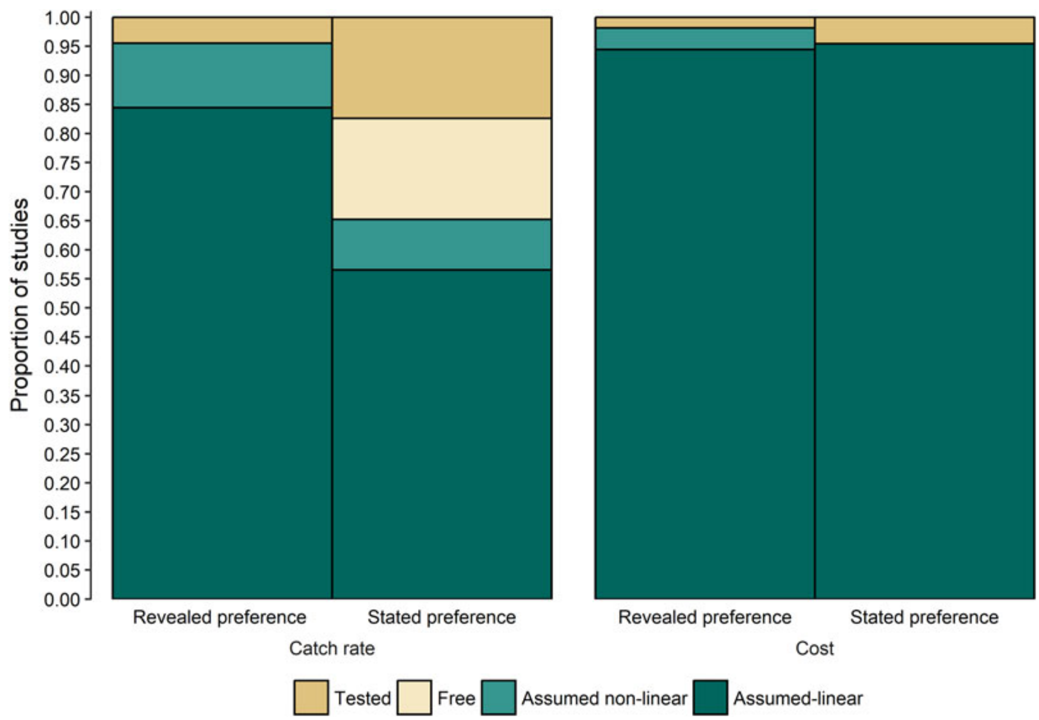

Figure 9. Relationships used to link catch rates and costs to angler utility by type of data set. (RP – revealed preference data set; SP – stated preference data set $n = 45$, 23, 54, and 22 for the revealed and stated preference bars for catch rate and cost, respectively).

depends upon the catch rate, regulations, and voluntary release rates, had the greatest significance score for explaining fishing choices when compared to catch rate or expected fish size measures of catch-related fishing quality, particularly in marine fisheries. This result is supported by research in marine fisheries that harvested fish are more economically valuable to anglers than are released fish (Carter and Liese, 2012; Lew and Larson, 2014; Lee et al., 2017). The conclusion is also consistent with research in freshwater fisheries that released fish are less significant contributors to the quality of fishing than are harvested fish (Askey et al., 2013; Wilson et al., 2015). The significance of harvest to anglers is also reinforced by the conclusions from this review that many anglers are discouraged from fishing at sites with decreased bag limits or the presence of fish consumption advisories.

The significance of harvest to anglers is, of course, not universal and exceptions exist. For examples, largemouth bass (*Micropterus salmoides*) fisheries in the US where anglers have developed a strong, voluntary catch-and-release ethic (Myers et al., 2008) or bonefish (*Albula vulpes*), a marine species commonly targeted in the Caribbean by anglers practicing voluntary catch and release (Danylchuk et al., 2007).

The difference in effect of harvest between freshwater and marine environments may be a function of species richness being greater in marine waters, reflect culinary and cultural preferences for marine over freshwater fish, be due to a higher proportion of fisheries with harvest restrictions in freshwater fisheries that are the norm for these anglers, or may reflect the higher likelihood of barotrauma in marine environments making harvest almost a foregone conclusion. Independent of the exact mechanism, these findings on the significance of harvest provides insights into why bans or severe constraints on harvest can and most likely will result in strongly reduced fishing pressure in many fisheries and for consumptive anglers despite high remaining catch rates (Beard et al., 2003; Johnston et al., 2011; Haglund et al., 2016) and in increased conflict among anglers and between anglers and managers (Matlock et al., 1988; Matlock, 1991). The median MRS estimates for catch and other attributes also suggest that catch of most fish species are more valuable to anglers than were the albeit arbitrary identified changes in destination size (500 to 600 ha), water clarity (1 to 2 m), and bag limits (2 to 3 fish), in turn suggesting that catch-related factors are essential for angler well-being.

The results related to catch and harvest are notable as human dimensions researchers studying fishing motives have generally (but not always, Beardmore et al., 2011) concluded that many non-catch dimensions of fishing such as relaxation, enjoyment of scenic beauty, and social reasons are more important motives than are catch-related aspects of a fishing experience (e.g., Fedler and Ditton, 1994; Ditton, 2004). The contrasting result about catch and harvest can be explained by the fact that motivations are a different concept than utility. Motivations are the expected psychological benefits of engaging in an activity and the fact that recreational fishing is conducted as a leisure activity helps to explain why certain non-catch dimensions of the fishing experience (e.g., relaxation outcomes, nature experience) are often rated as highly important in motivational studies. This result, however, does not mean that catch is irrelevant to people (Arlinghaus, 2006) and researchers have concluded that non-catch related motives are more easily satisfied than catch expectations, meaning that it is ultimately constrained catch that limits angler satisfaction or realized utility (Arlinghaus, 2006; Beardmore et al., 2015). This result from satisfaction research is fully consistent with the review here on catch-related fishing quality as a key determinant of where anglers fish. This finding on the significance of catch to anglers is also consistent with evidence from studies on aggregated angling effort dynamics in response to changes in fish abundance (e.g., Post et al., 2008; Mee et al., 2016, but see Camp et al. (2016) for a different conclusion). Overall, this choice model review indicates that while a range of non-catch related factors unrelated to cost influence where anglers fish, it is catch along with non-catch related attributes of cost and destination size that are generally and consistently the most common factors associated with an angler's choice of a fishing site.

Fish species vary in their value to anglers (Johnston et al., 2006; Melstrom and Lupi, 2013) due to reasons of culinary value, ease of catching, or culture. Four key groups of marine fish species (big game pelagic, salmon (marine stage), snappers, and flatfish) were identified as being in the top four most valuable groups of fish species. It appears that increased catch rates for marine fish species are more valuable to anglers than are increases of the same degree to freshwater fish species. Among the freshwater species groups, salmon was the most valuable followed by trout, sander, bass, pike, and panfish groups. While considerable variability surrounds the MRS estimates, this order is generally consistent with results from Melstrom and Lupi (2013) for the Great Lakes and reflects availability, access opportunities, expected catch rates, and tradition. Obviously, the conclusions here are conditioned by the types of fisheries that researchers have studied, and more research is needed.

The influence of non-catch-related attributes on fishing site choices is much broader than simply acknowledging that the costs of accessing fishing sites (almost) always constrain where anglers fish. Instead, many instances where other non-catch related attributes influenced where anglers fish. The finding that preferences for regulations including minimum size-limits were less consistent among anglers also parallels other research and likely relates to strong heterogeneity in anglers' preferences for size limits (Dorow et al., 2010). While most anglers agree that high levels of crowding or low catch rates are not desirable and lead to low satisfaction (Beardmore et al., 2015), the evaluation of size-limits is affected by an angler's fishing style, the size of fish captured, and the degree to which desired outcomes of the experiences such as harvest are affected. A voluntary catch-and-release angler will likely value high minimum-size limits, while a consumptive angler will not (Johnston et al., 2010). This heterogeneity will be reflected in a large error term and will result in non-significant effects at the population-level unless the sample size is excessively large. By contrast, decreases to daily bag limits were more consistently and negatively related to fishing site choice by anglers. While managers can design size limits to function as a catch-and-release fishery, in the reviewed studies, the range of size limits tested appeared less influential on angler site choice than were bag limits, possibly because bag limits have a stronger psychological effect of reducing the likelihood of benefiting from an exceptional catch. This agrees with suggestions that bag limits may act more strongly to affect angler expectations and site choice than directly limiting harvest (Cook et al., 2001; Radomski et al., 2001; Beard et al., 2003). The result that bag limits are more important in stated than revealed preference contexts also warrants further investigation to ensure that the hypothetical context does not result in an overstatement of effect. Bag limits and other regulations, however, may not vary strongly in space and the preference for them may then not be estimable from revealed preference studies. These facts help to explain why regulations are more often studied in stated than revealed preference studies.

Facility quality is an important and often overlooked attribute that influences where anglers fish. This significance, however, likely relates to specific fisheries where facilities and services matter such as for urban and charter boat fisheries that were well represented in this review. When facility quality was included, it was often a significant and positive attribute in the reviewed studies, in recreational fisheries models developed by fisheries scientists (Post et al., 2008), and in models of angler satisfaction with fishing (Arlinghaus, 2006; Hunt et al., 2012).

The quality of the environment was positively associated with angling site choices, reflecting that the natural environment is a key component of angler utility similar to findings from motivation research (e.g., high importance of the motive to go fishing "to experience nature", Fedler and Ditton, 1994). Importantly, aesthetics and water quality were more often positively-related to fishing site choice than was the health of fish, including the presence of fish consumption advisories. This result seems counter to the tenet that harvest is a key attribute that drives anglers' choices of fishing sites. Site choice models based on the three data sets that both employed stated preference data and that examined fish health, however, all produced positive and significant results between fish health and site choice (Banzhaf et al., 2001; MacNair and Desvousges, 2007; Morey and Breffle, 2006; Breffle et al., 2011). This result suggests that challenges exist in measuring fish health in revealed preference studies, anglers are not always aware of fish health concerns at specific fishing sites, or that anglers overstate the importance of fish health in driving their fishing site choices in hypothetical contexts. Future research should be directed to this issue to provide more clarity on the importance of fish health to anglers [see Burger (2000) for insights about a tendency for anglers to de-amplify risks of fish consumption].

The final attribute of congestion provided mixed support about its role in influencing where anglers fish. The influence became clearer when the effect was separated by the type of data set with a strong negative effect of congestion on site choices in stated preference while no effect of congestion in revealed preference studies. This difference again raises concerns about hypothetical bias affecting the conclusions of important attributes in stated preference studies. Increasing crowding, however, has reduced angler satisfaction in multiple studies (e.g., Herrmann et al., 2002; Kainzinger et al., 2015; Beardmore et al., 2015), and congestion is difficult to measure in revealed preference contexts (Schuhmann and Schwabe, 2004) and extreme congestion may in fact be unobservable due to dynamic angler behavior *in situ*. The fact that instances of extreme congestion do occur in some fisheries, however, also suggests that for some species and some anglers, congestion is less influential to anglers than is the expected catch rate (e.g., in a heavily-stocked put-and-take fishery). For some social anglers, congestion may even increase satisfaction (e.g., coarse anglers in the study of Beardmore et al., 2015), indicating heterogeneity in preferences on this attribute. In the absence of any other information, however, it is safe to assume that most anglers prefer less congested conditions, which agrees with the positive utility expressed towards large areas of the fishing sites as discussed above.

Most publications of choice models based on revealed preference data sets do not consider the full range of attributes that were presented. This fact largely reflects the difficulty that researchers experience in trying to identify suitable measures for attributes such as aesthetics quality in empirical contexts. The consequences of omitting these attributes, however, can affect the estimated parameters for other attributes such as congestion that tend to include both a repelling effect of too many anglers being present with the unobserved reasons why there are so many anglers fishing at a site (Schuhmann and Schwabe, 2004). Therefore, researchers should find effective ways to control for omitted attributes (e.g., Murdock, 2006).

Suggestions for future research

The second goal here was to help guide future research on fishing site choices by anglers. Drawing from answers to the three research questions, researchers are challenged to: (i) clearly communicate their methods and results; (ii) enhance comparability among published studies; (iii) challenge implicit assumptions when estimating models; and (iv) conduct research in different contexts and novel environments.

The suggestion that future site-choice researchers clearly communicate all details from their study seems both trite and unnecessary; this review demonstrates that it is neither. An unexpected finding from the review was that many research publications lacked sufficient information to help describe the study's context. For example, 18% and 42% of the data sets did not explicitly mention the number of sampled anglers and number of observations upon which models were estimated. Some studies also did not adequately define cost (9%), let alone provide explicit information about how costs were specifically measured (e.g., mileage cost, speed of travel, wage rates, and percentage of wage rate assigned as opportunity cost rate). The variability in providing this basic information greatly reduces the ability of researchers to conduct meta-analyses, especially when combined with the previously discussed issue that the usual practice of weighting parameters by their standard errors is not appropriate for choice models.

Researchers and editors of journals should ensure that all future publications contain basic information that: describes the sample including the timing and location of data collection, the number of anglers sampled, and the number of observations upon which models are estimated; explicitly defines attributes and their measurement and how, if at all, preference heterogeneity was assessed; and publishes parameter estimates and *t* values/standard errors at sufficient resolution to permit use by others. Armed with this information, future researchers will be better able to quantify relationships about the relative importance of attributes at affecting fishing site choices by anglers.

Like the review of commercial fishers by Girardin et al. (2016), comparability issues associated with the reviewed studies created challenges. Arguably, comparability issues are greater for the recreational than for commercial fishing context given that recreational fisheries lack a unifying metric like value of catch that links studies of commercial fisheries and permits comparable MRS estimates. While anglers are clearly influenced by costs, researchers measured cost with both non-monetary (e.g., distance) and monetary forms. Even for monetary costs, some researchers used fees (13%) while most used travel-based costs, which themselves were estimated with different components (e.g., vehicle operation, opportunity cost of travel time, on site costs) and values related to these components (e.g., mileage rates, calculation of opportunity cost, speed to calculate travel costs, ride sharing). These differences affect the denominator of the MRS estimates and consequently, can reduce the direct comparability of estimates.

Enhancing the comparability among studies could be greatly improved by adopting standardized methods to measure fishing site attributes and to account for preference heterogeneity among anglers. Developing standards are clearly challenging. Researchers have many good reasons for estimating models with different measures of attributes because: (i) revealed preference applications often lack the data necessary for standardization (e.g., an expected catch rate for a range of sites); (ii) researchers often need to tailor attributes and their measures to the specific fisheries context (e.g., planning novel fishing regulations); and (iii) empirical testing is required to evaluate innovative methods and alternate measures for attributes. The goal here is not to encourage researchers to use approaches that limit the usefulness of results for local fisheries and method development. Rather, researchers are asked to consider providing supplementary information that will facilitate future meta-analyses of angler behaviors.

One obvious candidate for a supplement is the actual data set upon which a model was estimated. By publishing these data sets, other researchers can re-estimate models to predict not only MRS estimated for attributes but to enhance the comparability of estimated models and results. For example, other researchers can estimate travel cost models using only distance to measure cost or can specify monetary costs in similar terms such as travel costs and travel time.

Researchers should work to standardize attributes that are measured in rates of time. Catch, harvest, and possibly congestion (encounters) all should be expressed as rates in a time unit that are scalable among hour, day, and trip scales. The separation of catch-related fishing quality into harvested and released catch rates is also likely important given the different values for harvested and released fish (e.g., Carter and Liese, 2012; Wilson et al., 2015).

Destination size could also be standardized into measures of lake size (ha) and river length (km) for freshwater fisheries. Destination size is challenging to standardize for marine fisheries. Past attempts to measure size have included proxies of number of interview sites in an aggregate (e.g., McConnell and Tseng, 1999), size of grid cells (e.g., Haab et al., 2008), and coastal length (e.g., Raguragavan et al., 2013). Except for coastal length, these measures are largely arbitrary. Clearly, more work is needed to identify a standard approach to measure the size of marine-based fishing sites.

Researchers have used two general approaches to test for heterogeneity in preferences for fishing site attributes among anglers: observable (classic) and unobservable (random parameters, latent class) characteristics of anglers. Researchers adopting the classic approach have employed a variety of socio-demographic, context (residence, species preference, mode), and centrality characteristics, many of which appear ad hoc and not supported by an underlying framework to measure angler heterogeneity. Many of the used characteristics typically lack careful measurement and a strong motivation for their inclusion. These facts have led to a paucity of generalizable insights about preference heterogeneity as a function of an angler characteristic of interest (e.g., commitment to fishing) despite the significant percentage of studies that have examined this issue in recent years. Researchers should spend greater efforts on identifying characteristics that can provide important insights to fisheries managers and that are ideally informed by human dimensions theory (e.g., the recreational specialization framework, Bryan, 1977; Scott and Shafer, 2001). Context-related factors such as target species (e.g., Haab et al, 2012; Arlinghaus et al., 2014), residence (e.g., Morey et al., 2002; Lew and Larson, 2014), and fishing mode such as boat versus shore (e.g., Anderson and Lee, 2013; Melstrom and Jayasekera, 2017) all have been successfully applied to study preference heterogeneity and it should be possible to develop hypotheses based on these characteristics, but it would be preferable to zoom into a common "currency" to describe angler heterogeneity.

An obvious characteristic to include in future studies is a measure of the psychological connection of the angler to the activity of fishing. Connection could be assessed by the multidimensional concept of recreation specialization (Bryan, 1977), which provides a theoretically-grounded characteristic based on anglers' commitment or connection to fishing as revealed by behaviors such as avidity, cognition such as skill, and affect such as centrality of fishing to lifestyle (Scott and Shafer, 2001). Past research has helped to develop (Ditton et al., 1992) and to test (e.g., Oh and Ditton, 2006; Dorow et al, 2010) hypotheses using specialization (for applications in a bio-economic framework, see Johnston et al., 2010; Carruthers et al., 2018). By using specialization and consistently measuring it with the Sutton (2007) modified centrality to lifestyle scale (Kim et al., 1997) or a modified involvement scale (Kyle et al. 2007), results across studies would be directly comparable.

Common assumptions within most of the reviewed studies were to specify utility as additive and to specify the effect of attributes as linear. These assumptions imply that attributes are both compensatory (e.g., reduced catch rates could be offset by improving non-catch related attributes) and invariant to the base level of an attribute (e.g., anglers would pay the same amount for an increase in catch rates regardless of whether the increase was from zero to one or 20 to 21 fish per day of fishing). Researchers should challenge these assumptions by testing whether other relationships result in better predictions of where anglers fish.

Very few researchers tested alternate relationships between key drivers of fishing site choice (catch and cost) and utility to the common linearity assumption. When these tests were undertaken, some support exists for a positive yet diminishing effect of catch rate on fishing site choices with five studies supporting this assertion (Shaw and Ozog, 1999; Anderson and Lee, 2013; Carter and Liese, 2012; Hindsley et al., 2011; Lawrence, 2005) and one not (Latila and Paulrud, 2006). This tenuous conclusion of a diminishing yet positive relationship between catch and site choice is supported by research examining anglers' satisfaction (Beardmore et al, 2015). By contrast, no evidence exists that the chances of catching increasingly large "trophy-sized" fish has a diminishing effect on utility (Arlinghaus et al., 2014; Beardmore et al., 2015). Based on these studies and economic arguments, catch rate and other absolute catch-related metrics (e.g., harvest rate) are assumed to generally scale non-linearly to utility, and researchers are encouraged to test such relationships in future studies. Models linking angler behaviors to outcomes are sensitive to the way that catch scales to utility (Camp et al., 2015), and thus, it is critical to provide accurate relationships when the angler behavioral models are linked with fish population models to examine policy choices (Johnston, Arlinghaus and Dieckmann, 2010).

Evidence for nonlinear relationships between cost and utility also exists from other sources including models of angler and boater demand primarily developed by ecologists. Gravity models are frequently used to predict propagule pressure for aquatic invasive species as delivered through boating pathways (Leung and Mandrak, 2007). These gravity models are based on potentially non-linear relationships between distance (cost) separating origins and destinations (fishing sites) and the attractiveness of these destinations. Researchers consistently find that distance has a negative yet diminishing effect on trip taking by boaters (e.g., Bossenbroek et al., 2007; Drake and Mandrak, 2014; Gertzen and Leung, 2011; Chivers and Leung, 2012). In fact, Chivers and Leung (2012) concluded that a production-constrained gravity model better predicted trips by Ontario boaters than did a revealed preference choice model. While this conclusion is misguided because one can use the same function of attraction and cost in gravity or choice models, this work nevertheless, suggests that the predictive validity of a non-linear utility function outperformed that for a linear in the parameters form. Obviously, these results do not warrant broad generalizations of how cost influences angler site choices, but rather they should signal the need to test assumed functional relationships in future work.

Our review clearly showed a spatial bias in study areas towards a few key areas within the United States. While some studies were conducted in other countries, these locations were focused on western European countries and in countries where English is the dominant language. This selection bias makes it reasonable to question the generality of conclusions from these studies to all recreational fisheries. Researchers are encouraged to examine novel recreational fisheries in other continents and countries to start to address this selection bias. While it is likely difficult to identify suitable sampling frames of anglers for some fisheries, it is important to test the robustness of conclusions here to these different contexts.

Even within the countries studied to date, more research is needed to understand contextual differences among anglers. There is a clear tendency to focus on a few species and areas. Comparatively fewer studies have focused on freshwater species such as bass or panfish that reside in warm waters when compared to trout and salmon (Table 7). This deficiency is especially curious given that bass anglers appear to release fish voluntarily at very high rates (Myers et al., 2008), tournament-based bass angling is growing in popularity (Oh et al., 2007), and that climate change can result in transition from walleye to bass fisheries in southern limits of walleye range (Carpenter et al., 2017). Urban fisheries have also received little attention by researchers who study where anglers fish (see Bingham et al., 2011 for an exception). It is likely that fisheries managers will increasingly need information about urban anglers and fisheries given that more people will be concentrated in urban areas (The World Bank, 2018) and that urban anglers might differ from their rural counterparts (e.g., Arlinghaus and Mehner, 2004; Dabrowksa et al., 2017). There has also been a tendency for researchers to focus on day and exclude multiple day fishing trips from studies. For some fisheries, multiple day trips represent important sources of fishing effort (Hunt et al., 2007). Multiple day trippers are likely less influenced by travel distance and cost than are other anglers and therefore, might be more capable of selecting fishing sites with better catch-related fishing quality (e.g., Lupi et al., 2003; Dabrowksa et al., 2017). Such a tendency would imply that past studies of day trip anglers might underestimate the significance of catch to the anglers in their choices of fishing sites. In summary, even within the United States and other developed countries, a pressing need exists to better understand how anglers in different fisheries make decisions about where (and how often) to fish.

Conclusion

Thirty years of studying where people fish has provided important insights about the primary drivers (i.e. cost, catch-related quality, facility quality, environmental quality, destination size, regulations and congestion) that influence fishing site choice. Among these drivers cost, catch, and destination size appear to be more influential than facility quality, environmental quality, regulations, and congestion. Conclusions of influence, however, depend upon the units of comparison and context (marine or freshwater fisheries), angler type, and data type (stated or revealed preference model).

While novel insights were provided within the review, the conclusions were limited by the design, implementation, and publication of past studies on fishing site choice. Consequently, researchers are encouraged to: (i) clearly communicate all results from their studies; (ii) to enhance comparability among studies; (iii) to challenge implicit assumptions; and (iv) to conduct research in novel environments.

By addressing these points, future research can increase not only the quantity and diversity of studies to review but the quality of information. Increased comparability and even standardization of key attributes among studies would facilitate more formal analyses of effects and the robustness of these effects given different contexts, data sets, and even methods. Consequently, it is sincerely hoped that researchers follow the suggestions here to permit greater insights about angler behaviors.

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Appendix 1. Literature Included in Review of Recreational Fishing Site Choices by Anglers

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