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RESEARCH

Culture, context, and fish length drives voluntary catch-and-release behaviour of recreational anglers

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Abstract Recreational anglers' decisions to harvest or release fish have significant implications for fisheries mortality and therefore fisheries management. In this study, we explore the psychological and contextual factors influencing voluntary catch-and-release (vCandR) of harvestable fish in northern Germany–a culture with a strong tradition in keeping fish for personal consumption. We compiled and analyzed 19,558 trip-level catch and harvest records from two contrasting fisheries: a small club-based fishery in Lower Saxony (LS) in West Germany and a largely open-access fishery in Mecklenburg-Western Pomerania (MWP) in East Germany. Due to differing cultural and socio-economic histories before and after German reunification, we hypothesized lower voluntary release rates in MWP, driven by stronger utilitarian values common to Eastern Germany. In support, MWP anglers harvested a greater proportion of their catch. Saltwater species, migratory species and salmonids were retained to a greater degree than freshwater species. Voluntary CandR behaviour varied by target species, other trip context, angler specialization as represented by the subdimensions psychological commitment, behavioural commitment and skill, catch and consumptive orientation and fish length. The influence of angler characteristics on retention probability of fish often varied by target species, and retention probability was found to be largest in intermediately sized fish in most species. Satisfaction with previous trips increased the likelihood of releasing fish, suggesting a feedback process where past psychological outcomes affected future harvest decisions independent of angler personality. Our findings underscore the importance of culture, individual angler characteristics, and situational factors, highlighting the crucial interaction of target species, fish length, angler psychological predisposition and past fishing success in determining whether an angler keeps or voluntary releases its catch. That said, our work in German angling culture does not support the

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proposition that more specialized anglers generally release more fish.

Keywords Social-ecological context · Harvest behaviour · Angler specialization · Satisfaction · Fish size · Human dimensions · Catch & Release · Recreational angling · Harvest · Specialization

Introduction

Whether recreational anglers' harvest or release fish can have important implications for fisheries management and conservation as well as angler well-being (Arlinghaus et al. 2007; Coggins et al. 2007; Johnston et al. 2015). Harvest regulations attempt to control exploitation levels to reach biological or social goals (Beard et al. 2003; Johnston et al. 2010; Noble and Jones 1999; Radomski et al. 2001). Common to most recreational fisheries are some form of size-based harvest regulations, such as minimum-size or slot-type length limits that require anglers to release undersized or otherwise protected fish (Noble and Jones 1999; Arlinghaus et al. 2016). Anglers also practice voluntary CandR (vCandR) (Arlinghaus 2007; Myers et al. 2008), where they make the decision to keep or release a fish that could be legally retained. Voluntary behaviours of anglers, including rule compliance and engaging in best-practice release behaviours, are key for fishery sustainability (Cooke et al. 2013, 2025; Johnston et al. 2015; Brownscombe et al. 2017). Psychologically, regulatory CandR and vCandR represent distinct decision-making processes for anglers. While regulatory CandR is driven by rule compliance, in vCandR, anglers release fish that could be harvested, thereby forgoing yield. Here, the motivations are diverse, ranging from lack of interest in fish consumption (Hunt et al. 2002; Sutton 2003; Anderson et al. 2007) to personal conservation ethic (Arlinghaus et al. 2007), including desires to comply with social norms and to release only fish that have a high survival probability (Stensland et al. 2013; Stensland and Aas 2014; Blyth and Rönnbäck 2022). Both rule compliance (Arlidge et al. 2023) and voluntary conservation action (Cooke et al. 2013) are highly relevant to recreational-fisheries management, but we will focus on vCandR behaviour and the factors contributing to it.

The voluntary harvest or release decision is a psychological process moderated by situational (alternatively termed contextual) variables (Sutton and Ditton 2001; Hunt et al. 2002; Sutton 2003; Arlinghaus et al. 2007; Stensland et al. 2013; Kaemingk et al. 2020; Blyth and Rönnbäck 2022). Past human dimensions research has shown that anglers vary in both their commitment to fishing and their consumptive orientation and that both aspects contribute to voluntary CandR behaviour (Bryan 1977; Sutton 2003; Oh and Ditton 2006; Oh and Sutton 2017). Bryan (1977) introduced the multidimensional concept of angler specialization as a spectrum of behaviour from the "general to the particular", hypothesizing, based on observation in freshwater trout anglers in the USA, that as the angler gets more involved and specialized the tendency to engage in vCandR fishing increases. A wealth of follow-up studies largely supported this notion (e.g., Chipman and Helfrich 1988; Sutton and Ditton 2001; Oh and Ditton 2006; Hutt and Bettoli 2007; reviewed in Arlinghaus et al. 2007), but exceptions were also noted (e.g., no relationship of centrality of fishing in the lifestyle of an angler as measure of psychological commitment and vCandR behaviour, Sutton 2003). Moreover, in consumptive fisheries where the local culture prescribes a norm of retaining rather than releasing fish, and for species with high culinary value, or in cases where the post-release mortality is high (Stensland et al. 2013; Blyth and Rönnbäck 2022), specialized anglers may actually release fewer fish. This has for example been documented in German eel (*Anguilla anguilla*) (Dorow et al. 2010) and several cod (*Gadus morhua*) angler populations (Andrews et al. 2021, Bronnmann et al. 2023) as well as in other marine fisheries (Oh and Sutton 2017). Also, whether the caught species is a primary target or bycatch as well as the amount of fish captured relative to formal (e.g., daily bag limit) or personal upper limits on how many fish to take moderates whether angler keeps or releases a fish (Hunt et al 2002; Sutton 2003). The culinary value of a species varies among cultures and anglers, therefore decisions to harvest vs. release must be analysed in light of local norms and in relation to angler characteristics (e.g., degree of specialization, consumptive orientation). In Germany, the key social reason to engage in recreational fishing is to catch fish for dinner (Arlinghaus 2007). This, however, does not mean that all fish are harvested, as anglers will still voluntarily release harvestable fish (e.g., trophy fish; Arlinghaus 2007; Beardmore et al. 2011; Arlinghaus et al. 2007, 2023). The German angling context therefore provides a compelling case to study the situational impact on vCandR behaviours as moderated by angler characteristics, specifically angler specialization or attitudes towards various catch aspects of fishing (e.g., orientation to keep fish, importance attached to catch many or fish of certain sizes, compare Sutton 2003).

Globally roughly 60% of the catch is released by recreational anglers either due to regulations or via voluntary behaviour (vCandR) (Cooke and Cowx 2004; Bartholomew and Bohnsack 2005; Ferter et al. 2013). However, vCandR is not easily generalizable across fisheries and cultures, as vCandR practices might differ across social-ecological contexts due to diverse history, laws, cultures, and economic environments, and be further influenced by target species choices and other situational contexts (Hunt et al. 2002; Sutton 2003; Oh and Sutton 2017). Past research has identified several extreme vCandR fisheries where nearly all fish are voluntarily released. Examples include coarse fishing, which targets non-salmonid freshwater species like common bream (*Abramis brama*), tench (*Tinca tinca*) or carp (*Cyprinus carpio*) in the UK (North 2002) or big game angling, which involves pursuing large predatory species in offshore marine environments (e.g., Atlantic white marlin, *Tetrapturus albidus)* (Cramer 2004). Other examples include largemouth bass (*Micropterus nigricans*) fishing in North America (Myers et al. 2008), fly-fishing for bonefish (*Albula vulpes*) in the Caribbean (Policansky 2002), muskellunge (*Esox masquinongy*) (Fayram 2003) and some steelhead (*Oncorhynchus mykiss*) fisheries in North America (Policansky 2002), and trophy carp fishing in much of Europe (Arlinghaus 2007). There are also fisheries with limited vCandR, for example, recreational fisheries for Atlantic cod or herring (*Clupea harengus*) in Europe (Bronnmann et al. 2023). Also, marine and salmonid fish in parts of northern Europe, are sought after for retention by many anglers under certain conditions (Aas et al. 2002; Olaussen 2016; Blyth and Rönnbäck 2022). Some fisheries have very little legal release rates of fish due to animal welfare concerns. For example, in Germany, the Animal Protection Act (Tierschutzgesetz [Animal Welfare Act; TierSchG] 2006) has led to a social norm, sometimes enforced through court cases or binding fishery-specific fishing regulation, of harvesting every legally sized fish that is caught outside protected seasons for personal consumption (Arlinghaus 2007). However, despite the common notion that CandR is "banned" in Germany (e.g., Eckhardt 2024), it legally speaking is not prohibited in many states and therefore continues to be prominent among some angler groups and in certain fisheries, regularly creating conflicts in Germany (Arlinghaus et al. 2012; Eckhardt 2024). For example, species unprotected by size limits but considered of poor nutritional quality or too small and otherwise undesirable are commonly voluntarily released in Germany, even if legally retainable (Arlinghaus 2007; Beardmore et al. 2011).

Not only does vCandR behaviour vary across social-ecological contexts and target species, but as already alluded to briefly above differences in the tendency to release fish also exists among anglers of the same angler population. Recreational specialization (Bryan 1977; Ditton et al. 1992; Fisher 1997; Arlinghaus et al. 2007) has been the primary framework for understanding this diversity within angler populations. Bryan observed a "continuum of behaviour from the general to the particular, reflected by equipment and skills used in the sport and activity setting preferences" (p. 175) in freshwater salmonid anglers in North America. The concept has since evolved to differentiate three sub-dimensions of specialization (Scott and Shafer 2001): cognitive and skill development (Salz and Loomis 2005), psychological commitment (e.g., centrality of fishing in the lifestyle of an angler, Kim et al. 1997; Sutton 2003), and behavioural commitment (Ditton et al. 1992). While Bryan's (1977) qualitative study suggested that increasing specialization always leads to greater vCandR behaviour, more recent work has shown that this relationship depends on cultural context and target species (Wilde and Ditton 1994; Hunt et al. 2002; Dorow et al. 2010; Oh and Sutton 2017) as well as the sub-dimension of specialization (Sutton 2003; Slaton et al. 2023). Few studies systematically link angler specialization sub-dimensions to release behaviour across various species and conditions (Sutton 2003; Oh and Sutton 2017).

Another means of understanding variation in an angling population is by measuring attitudes related to the catch aspects of fishing (e.g., Lupi et al. 2003; Sutton 2003; Schuhmann and Schwabe

2004), including the tendency of keeping vs. releasing fish (Sutton 2003; Haab et al. 2012; Lew and Larson 2015). The catch orientation construct includes four sub-dimensions and is defined as "the attitudes anglers hold towards catching something, retaining fish (as opposed to releasing fish), catching large fish (size), and catching large amounts of fish (numbers)" (Anderson et al. 2007, p 181–182). Previous work has shown that, not unexpectedly, less consumptive anglers release more fish (Ditton et al. 1992; Aas and Kaltenborn 1995; Sutton and Ditton 2001; Sutton 2003; Wallmo and Gentner 2008; Kagervall et al. 2014) but it is less clear how other sub-dimensions of the catch orientation construct relate to release behaviour of anglers. For example, Sutton (2003) found no relationship of the importance attached to catching many fish and the tendency to release fish in a study in the USA, and importance attached to the trophy aspects of fishing interacted with target species in determining release behaviour. Sutton's (2003) study relied on hypothetical release behavioural decisions in a survey, and although stated and revealed behaviours can show consistency (Wallmo and Gentner 2008), revealed behaviours have greater ecological realism. Slaton et al. (2023) reported that the predictive power of sub-dimensions of the catch orientation construct varied with the management action that anglers evaluated, indicating that more studies on the relationship of specialization, catch orientation and release orientation in real data set is warranted.

Most recreational-fisheries research has assumed that an angler's degree of specialization, as well as their traits expressed in a certain context (e.g., target species choice, consumptive orientation) are stable within a person in a given moment in time. A recent conceptualization of angler heterogeneity proposed by Hunt et al. (2023), however, assumes that angler traits (e.g., consumptive orientation) are expressed only in a given context (e.g., target species, social group one fishes with) and thus the association of angler traits and behaviours (e.g., release tendency) might change as the context changes (e.g., after prolonged periods of lack of fishing success, different target species, different social groups while fishing). Moreover, angler traits such as catch and consumption orientation may or may not be positively correlated with more enduring angler characteristics (e.g., degree of specialization) or correlations might change in direction depending on target species and other trip contexts. For example, a consumptive angler might take most of the fish in one context, but release fish in another. Indeed, situational variables have repeatedly been found to affect vCandR decisions (Hunt et al. 2002; Sutton 2003; Arlinghaus et al. 2007; Wallmo and Gentner 2008; Stensland and Aas 2014; Oh and Sutton 2017), similar to other angler behaviours or psychological evaluation of fishing outcomes (Lupi et al. 2003; Haab et al. 2012; Whitehead et al. 2013; Beardmore et al. 2015; Dabrowska et al. 2017; Hunt et al. 2023; Birdsong et al. 2022). Key contextual conditions are the fish species targeted and the size of the fish captured (e.g., Hunt et al. 2002; Sutton 2003; Siepker et al. 2007; Haab et al. 2012; Arlinghaus et al. 2014), the duration of a trip (e.g., Lupi et al. 2003; Hunt et al. 2007; Kaemingk et al. 2020), the composition of the social group (Hunt et al. 2002), the type of fishing method used (Grilli et al., 2020) and the purpose of the trip (e.g., whether it is single day or multiple-day, resident vs. touristic outing, Whitehead et al. 2013; Dabrowska et al. 2017). Fully understanding the vCandR behaviour demands a thorough look at both angler characteristics and context, as well as the interactions among the two (Hunt et al. 2002; Sutton 2003).

Angler behaviour within a fishery is a dynamic process, with antecedents to behaviour (i.e., norms, attitudes, motivations, specialization levels) influencing behaviours, behaviours leading to outcomes (physical, cognitive or psychological), and these outcomes influencing post-behaviour evaluations (Beardmore 2013). A key measure of post-behaviour evaluations in recreational fisheries is angler satisfaction (Birdsong et al. 2021). The concept of satisfaction has its roots in expectancy theory and is determined by the differences between expectations and the actual experience (Schreyer and Roggenbuck 1978). Post-behaviour evaluations made by an angler can alter expectations for future angling experiences (Schramm et al. 1998), thereby influencing future behaviour and evaluations of future outcomes (Gale 1987; Spencer and Spangler 1992). Research is needed to understand better the conceptual link between angler satisfaction and angler behaviour (Birdsong et al. 2021, 2022), and specifically the decision to harvest or release a fish and how this is moderated by context and variation in specialization and catch orientation of anglers. Thereby, social dimensions (angler characteristics, satisfaction levels) become linked to ecological outcomes (e.g., to harvest or release a fish)—an aspect that has received limited attention so far (but see Stensland et al. 2013; Oh and Sutton 2017).

We used comprehensive trip-level data collected via analogous angler diaries that tracked the catch, harvest, and satisfaction with catch of anglers in two different social-ecological contexts within the same general consumptive angling culture of Germany. While angling in Germany is generally harvest-oriented (Arlinghaus 2007), we also expect to find differences across German fisheries in different states (Birdsong et al. 2022). Our study involves two different fisheries, one located in the Western German state of Lower Saxony (LS) and the other located in the Eastern German state of Mecklenburg Western Pomerania (MWP). We expect that the history of economic hardship and legacy of utilitarian thinking in East Germany during its socialist regime after World War II (Mollenkopf and Kaspar 2005; Brosig-Koch et al. 2011; Riepe and Arlinghaus 2021) led to more utilitarian views towards fishing (for which there is empirical support, Riepe and Arlinghaus 2021). In East Germany, where economic constraints and state-controlled systems emphasized practical, survival-oriented values, there was less emphasis on individual social behaviour and more on the immediate, tangible benefits of personal actions (Brosig-Koch et al. 2011). Even almost 30 years after reunification, stronger utilitarian values related to wildlife and fish were reported for people living in East compared to West Germany (Riepe and Arlinghaus 2021), and participation rates in recreational fishing are substantially larger in East compared to West Germany (Arlinghaus 2006b). Given these and other (e.g., Alesina and Fuchs Schündeln 2007) persistent differences in cultural and historical experiences and preferences between East and West Germany, we hypothesized that Eastern German anglers, shaped by their more utilitarian mindset and greater reliance on fish for subsistence in the past, may generally exhibit a higher tendency to harvest more fish, all else being equal, compared to Western German anglers.

The objective of our study was to improve the understanding of the decision to harvest or voluntarily release a fish in different social-ecological contexts, trip contexts, and for different angler types using revealed preference data based on actual behaviours. The following five hypotheses were tested:

H1: Target species, especially its assigned culinary value, influences release probability

H2: More specialized anglers release more fish of a given species, except for species of high culinary value

H3: The higher the consumptive orientation of an angler, the less fish are released

H4: Anglers who are less satisfied with catch will compensate by harvesting more on a future trip

H5: Anglers in eastern Germany are more consumptive than in western Germany and therefore release less fish

Methods

Our study draws on data collected during a 1-year diary program in the German state of Mecklenburg Western Pomerania (MWP) and a subsequent 1-year diary program in the German state of Lower Saxony (LS). Both states are located in northern Germany, with LS being in the west and MWP in the east (former German Democratic Republic). Details of the survey methods are described in detail in Birdsong et al. (2022). A brief summary follows.

To examine angler characteristics and behaviour in MWP, trip-level data were collected through a one-year diary program from September 2006 to August 2007 (see Dorow and Arlinghaus 2011 for details on recruitment procedure, incentives etc.). A total of 1121 anglers were recruited using random digit dialling over the phone. Those who agreed to participate recorded details of each fishing trip in a printed diary. Anglers documented trip timing, location, effort, social group composition, target species, number of fish caught, the largest fish's length for retained fish, the number of fish harvested, and the number of fish released over the course of one fishing year. To minimize recall bias, participants received quarterly follow-up calls (Anderson and Thompson 1991; Tarrant et al. 1993; Connelly et al. 1996; Bray and Schramm 2001). In these calls, angler characteristics such as fishing preferences, commitment to fishing, consumptive orientation and demographics were measured. To minimize burden on the respondent, individual fish length of fish captured or retained were not recorded in the diary. To reduce measurement error of fish length data, anglers were asked to record the length of only the largest retained fish per species rather than estimating an average. Catch satisfaction for each trip was rated on a ten-point satisfaction scale (Matlock et al. 1991). In total, 648 anglers (58%) returned diaries after one year, reporting 12,937 trips targeting 56 different freshwater and marine fish species.

In LS, anglers were recruited from 17 angling clubs across the state (Arlinghaus et al. 2014). Larger clubs (> 400 members) provided a random sample of participants, while in smaller clubs (< 400 members), all members were invited to participate in a baseline postal survey (conducted between May 2011 and February 2012) with three reminders. The survey gathered demographics, attitudes toward fish and fisheries, angling habits, and specialization levels. A subset of five clubs participated in a one-year diary program, where all members received an invitation to document their fishing activity in the diary similar to the case in MVP. Participants recorded trip timing, location, effort, target species, total catch, individual fish lengths, harvest decisions for each fish, and catch satisfaction, using the same ten-point scale as in MWP. Although participation was limited to angling club members, recreational fishing in LS largely requires club membership. As a result, the sample is considered representative of anglers in the state. In total, 855 anglers contributed 11,248 trip records, targeting 63 different freshwater and marine species.

Unlike in MWP; in LS, the length and harvest decision were recorded for each individual fish that was caught. By contrast, in MWP, for each species caught, the angler was only asked to record the size of the largest fish retained, the number of fish caught, and the number of fish harvested. Due to this difference, we first performed an analysis of the datasets combined with the dependent variable being the proportion of the catch harvested (at the species-level), and then separately analyzed the LS dataset at the individual fish level (whether it was harvested or released). To control for the differences in fish sizes across species, a normalized value (z-score) was computed using the means and standard deviations of fish sizes across species. Only fish of legal size (Table 1) were considered as we are interested in the vCandR behaviour of anglers. Species without state-level size limits were all considered voluntarily released. However, it is important to note that there is some uncertainty regarding the size limits employed across different fishing clubs/associations as private fishing rights holders, which could be strengthened beyond the state-level minimum standard prescribed by law. It was not feasible to research the multitude of different local regulations. Therefore, we assumed the state-level minimum size limits applied in each case. In addition to minimum-size limits, anglers in Lower Saxony are subject to daily catch limits. These catch limits may also influence voluntary release behaviour by capping retention opportunities once daily quotas are reached.

Table 1 Minimum legal-size limits for fish species in Lower Saxony following the Nds. FischG (Lower Saxonian Fisheries Act) of February, 1, 1978 (last updated October, 13, 2011)

Fish species	Minimum-size limit (cm)
Perch (*Perca fluviatilis*)	20
Brown trout (*Salmo trutta*)	25
Eel (*Anguilla anguilla*)	35
Carp (*Cyprinus carpio*)	40
Zander (*Sander lucioperca*)	40
Pike (*Esox lucius*)	45

Measuring trip contexts

We incorporated several trip-context variables to account for their possible influence on harvest decisions. First, we included target species, as some species are more likely to be harvested than others (Colvin 1991; Hunt et al. 2002; Siepker et al. 2007). Second, we measured species diversity by counting the number of species an angler targeted per trip, reflecting a measure of trip specificity (Beardmore et al. 2015). Third, we distinguished between targeted vs. incidental catch, as anglers may be less likely to harvest fish they did not intentionally pursue (Hunt et al. 2002). Fourth, we included trip duration (hours), which has been linked to harvest behaviour of anglers (Kaemingk et al. 2020). Fifth, we accounted for catch satisfaction (scale rating from 1 to 10) from the angler`s most recent prior trip as a potential driver of harvest decisions. Finally, in the LS model, because we limited our analysis to six focal species/species groups (Table 1 and further below) and lacked observations on all others, we added two binary indicators: one denoting whether an angler had already kept another individual of the same focal species during the trip, and the other denoting whether they had harvested a different species during that trip.

Operationalizing angler specialization

In both MWP and LS, centrality to lifestyle (CTL) was used as a measure of psychological commitment–a key subdimension of angler specialization (Scott and Shafer 2001). CTL was assessed using a six-item, five-point agreement scale adapted from Kim et al. (1997) (see Beardmore et al. 2013 for details). To ensure that these six items reliably captured a single underlying construct, we first conducted an exploratory factor analysis with varimax rotation, a statistical technique used to identify underlying patterns in correlated variables. This was conducted separately for MWP and LS, each yielding a single reliable factor. A combined analysis across both datasets confirmed a single factor explaining 47% of the variance, and subsequent reliability analysis indicated a Cronbach's alpha of 0.84 (see Table 1 in Birdsong et al. 2022), indicating high internal consistency among the six survey items. Cronbach's alpha values above 0.7 generally indicate strong reliability, meaning the items measured a cohesive construct. The mean of the six items (or the available subset in cases of item non-response) was used as a centrality index. These analyses were conducted in R (R Core Team 2020).

Beyond CTL, we included self-perceived skill as the cognitive dimension of angler specialization (Scott and Shafer 2001), which has been found to relate to catch success (Monk and Arlinghaus 2018). Self-perceived skill was measured by asking anglers to rate their own skill level compared to other anglers they know using a five-point Likert-type scale in both MWP and LS (similar to Ditton and Sutton 2004). The behavioural commitment of anglers, the third and last sub dimension of specialization (Scott and Shafer 2001), was measured as the total number of trips recorded in the angler's diary (Scott and Shafer 2001).

To capture angler attitudes toward fishing experiences, we examined catch orientation, which reflects individual preferences for catching and consuming fish (Ditton and Fedler 2004; Aas and Kaltenborn 1995; Arlinghaus 2006a). Catch orientation was assessed using a four-item, five-point agreement scale measuring the following statements: (1) "I go fishing to catch fish to eat." (2) "The bigger the fish caught, the better the fishing day." (3) "The greater the number of fish I catch, the happier I am." (4) "I release most of the fish I catch back into the water." These four items were selected as they capture the primary dimensions of catch orientation while reducing survey length and respondent burden. Since this is a reduced version of the original sixteen-item catch orientation scale (Anderson et al. 2007), we conducted an exploratory factor analysis with varimax rotation to assess dimensionality and ensure internal consistency. The analysis indicated that attitudes toward fish size and fish number loaded on the same factor, whereas consumption orientation ("I go fishing to catch fish to eat") and release orientation ("I release most of the fish I catch back into the water") formed distinct factors. However, release orientation was excluded from further analysis due to the low social acceptance of voluntary catch-and-release angling in Germany (Arlinghaus 2007), which raised concerns about the validity of this item in our survey context. Consequently, in our models we averaged the size and number items (items 2and3) to create a "catch importance" index, while consumption orientation (item 1) was retained as a single-item predictor.

Statistical model building

First, we modelled the influence of various factors on the proportion of catch harvested in a dataset combining the diary data from MWP and LS using a mixed-effects linear model (lme4 package in R, Bates et al. 2015; R Core Team 2020), with a nested structure to account for the hierarchical nature of the data with random effects at the angler and trip-level. The dependent variable was proportion of catch harvested, and the analysis was done at a species or species-group level. Species were grouped into eel, perch (*Perca fluviatilis*), cod, trout *(Oncorhynchus mykiss and Salmo trutta)*, pike (*Esox lucius*), carp, zander (*Sander lucioperca*), smaller bodies cyprinids such as roach (*Rutilus rutilus*) or bream (*Abramis brama*) grouped, other freshwater species such as ruffe (*Gymnocephalus cernua)*, other migrating salmonids such as sea trout (*Salmo trutta trutta)* and salmon (*Salmo salar*), and other saltwater species like Atlantic herring (*Clupea harengus*). The independent variables used were grouped into six categories. First, we included trip and species-level catch per unit (hour) effort (CPUE), standardized across species. Second, we accounted for social-ecological context by including fishery (LS and MWP) as a binary variable. Third, we included measures of inter-angler heterogeneity, such as CTL, self-perceived skill, behavioural commitment, age, consumptive orientation, and importance attached to catch. Fourth, we included variables accounting for trip context, such as previous satisfaction with the trip, total trip time (in hours), whether the catch/species was incidental or targeted, the number of species targeted, and the target species. Fifth, we included interactions between species and CTL, skill, behavioural commitment, consumptive orientation, and fishery to test if the moderating influence of these variables was species dependent. Last, we included interaction effects between fishery and variables such as CTL, skill, previous satisfaction, and consumptive orientation to check if these indicators worked similarly in both German states.

Second, we modelled the influence of various factors on the decision to harvest or release an individual fish (of legal size) using the diary data from LS only. As before, we used a mixed-effects logistic regression model (Bates et al. 2015; RStudio Team 2020), with a nested structure to account for the hierarchical nature of the data with random effects at the angler and trip level. The second model was limited to the six most popular species (i.e., eel, perch, cod, trout, pike, carp, and zander), to keep the model simple as mixed-effects logistic regression models regularly fail to converge due to over-parameterization (Bates et al. 2015). The independent variables were grouped similarly to the first model, with a few differences. First, we included the size of each fish, standardized across species. Second, we included a quadratic term for size of fish, as we expected anglers to behave differently with trophy fish and release them more likely than smaller fish. The final difference was that in this model we did not differentiate between targeted or incidental, because a large majority of the observations in this dataset were targeted and there was not enough variation to include it as a variable.

To test the robustness of our findings, we conducted a sensitivity analysis in which the state-level minimum size limits for all species were increased by 20%. This analysis aimed to explore whether changes in regulatory thresholds by local fishing club could have influenced harvest behaviour and the significance of predictors in the model. The same mixed-effects logistic regression framework was applied to this adjusted dataset, allowing for direct comparisons between the original and adjusted scenarios. We evaluated differences in model parameters and significance levels to identify predictors of harvest probability that remained stable and those that were affected by the increased size limits. This approach provided insight into the consistency of key factors driving harvest decisions under different regulatory conditions.

In the model-building process, we utilized likelihood ratio tests to systematically assess and compare the fit of different models. Specifically, we tested and compared models by sequentially adding or removing groups of parameter estimates and their interactions. These groups, or "baskets" included (1) the main effects for species and trip-level variables, (2) the interactions between species and angler characteristics (e.g., CTL, skill, consumptive orientation), (3) the interactions between fishery and angler traits, and (4) the trip context variables (e.g., previous satisfaction, trip time, species targeted) (Table 2). This approach allowed us to evaluate how each set of parameters influenced model fit and determine which factors contributed most to explaining the variance in the proportion of catch harvested and the likelihood of release.

Results

Descriptive and contextual conditions

The retention rates varied substantially among the different target species (Fig. 1). Harvest rates were greater for saltwater than for freshwater species. Among species or species groups harvest rates were highest (often > 75% retention rates of all individuals captured) for salmonids (e.g., trout), cod, and eel and carp in MWP and lowest (often < 55% retention rates) in perch, pike, carp in LS and other cyprinids in both states. For most species, anglers in MWP exhibited higher catch rates (CPUE) (see Table 2, Birdsong et al. 2022) and harvested a greater proportion of their catch compared to anglers in LS (Fig. 1). LS anglers only experienced higher CPUE than MWP anglers for other salmonids and other cyprinids but did not harvest a greater proportion of their catch compared to MWP anglers for any fish species. In both fisheries,

Table 2 Combined fishery mixed-effects linear model, with random effects at the angler and trip-level, predicting the proportion of catch harvested by anglers (at the species-level) in Mecklenburg-Western Pomerania (MWP) and Lower Saxony (LS), Germany, in 2006–2007 and 2011–2012, respectively

Parameter	Beta	SE	P − value
Normalized CPUE	− 0.216	0.019	< 0.001*
Social–ecological context			
Fishery (ref = LS)	0.918	0.238	< 0.001*
Specialization			
Centrality to Lifestyle	0.275	0.138	0.045*
Skill	− 0.384	0.134	0.004*
Behavioural Commitment	− 0.203	0.117	0.083
Age	0.347	0.054	< 0.001*
Other Personality			
Consumption Orientation	0.468	0.137	< 0.001*
Catch Orientation	0.067	0.109	0.539
Trip Context			
Previous Satisfaction	0.038	0.022	0.091
Total Trip Time	− 0.062	0.024	0.008*
Incidental	− 0.607	0.061	< 0.001*
Number of Species Targeted	− 0.196	0.025	< 0.001*
Species (ref = eel)			
Perch	− 0.747	0.412	0.070
Cod	1.732	0.628	0.006*
Trout	2.194	0.685	0.001*
Pike	− 1.625	0.343	< 0.001*
Carp	− 0.675	0.377	0.073
Zander	− 0.117	0.461	0.799
Other freshwater	− 1.044	0.670	0.119
Other salmonids	2.750	2.655	0.300
Other saltwater	0.718	1.309	0.583
Other cyprinids	− 1.309	0.336	< 0.001*
*Species*Consumption Orientation*			
Perch	− 0.059	0.113	0.601
Cod	0.004	0.157	0.979
Trout	− 0.078	0.219	0.722
Pike	0.138	0.115	0.229
Carp	− 0.033	0.124	0.792
Zander	0.106	0.166	0.523
Other freshwater	0.292	0.146	0.046*
Other salmonids	− 1.468	0.680	0.031*
Other saltwater	− 0.205	0.171	0.231
Other cyprinids	0.232	0.109	0.034*
*Species*Centrality to Lifestyle*			
Perch	0.022	0.015	0.121
Cod	− 0.048	0.021	0.024*
Trout	0.007	0.032	0.824
Pike	0.014	0.014	0.302
Carp	− 0.017	0.016	0.308
Zander	0.008	0.019	0.681
Other freshwater	0.014	0.018	0.435
Other salmonids	0.030	0.082	0.718
Other saltwater	− 0.014	0.021	0.525
Other cyprinids	0.001	0.014	0.974
*Species*Behavioural commitment*			
Perch	− 0.181	0.117	0.122
Cod	− 0.100	0.292	0.732
Trout	0.159	0.183	0.387
Pike	− 0.193	0.096	0.043*
Carp	0.125	0.110	0.255
Zander	0.054	0.146	0.711
Other freshwater	− 0.478	0.163	0.003*
Other salmonids	0.454	1.197	0.704
Other saltwater	− 0.070	0.304	0.819
Other cyprinids	− 0.313	0.010	0.002*
*Species*Skill*			
Perch	0.520	0.115	< 0.001*
Cod	0.511	0.160	0.001
Trout	− 0.619	0.229	0.006*
Pike	0.174	0.112	0.121
Carp	− 0.099	0.135	0.458
Zander	0.303	0.151	0.044*
Other freshwater	0.303	0.157	0.053
Other salmonids	− 1.220	0.699	0.081
Other saltwater	0.044	0.178	0.013*
Other cyprinids	0.235	0.107	0.029*
*Species*Fishery (ref = LS)*			
Perch	− 0.967	0.344	0.005*
Cod	− 1.081	0.510	0.034*
Trout	− 0.534	0.567	0.347
Pike	0.061	0.253	0.811
Carp	0.640	0.275	0.020*
Zander	− 1.116	0.344	0.001*
Other freshwater	0.234	0.605	0.698
Other salmonids	− 1.325	2.296	0.563
Other saltwater	0.015	1.267	0.990
Other cyprinids	0.334	0.251	0.182
*Fishery*Consumption Orientation*	− 0.227	0.124	0.066
*Fishery*CTL (ref = LS)*	− 0.338	0.131	0.009*
*Fishery*Skill*	− 0.053	0.019	0.683

The species estimates in the table are all in reference to eel, which serves as the reference species

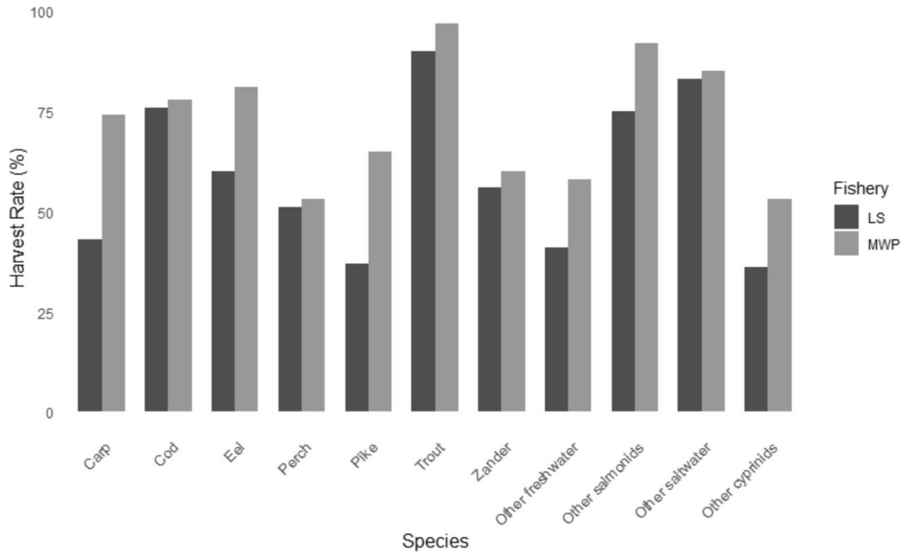

Fig. 1 Mean proportion of total catch harvested (harvest rate; %) for the most commonly caught species in each fishery (MWP—Mecklenburg–Western Pomerania; LS—Lower Saxony). Species are eel (*Anguilla anguilla*), perch (*Perca fluviatilis*), cod (*Gadus morhua*), rainbow trout and brown trout (*Oncorhynchus mykiss* and resident *Salmo trutta*), pike (*Esox lucius*), carp (*Cyprinus carpio*), zander (*Sander lucioperca*), other freshwater species (*Gymnocephalus cernua*), other salmonids (seatrout *Salmo trutta* and *Salmo salar*), other saltwater species (*Clupea harengus*), and other cyprinids (*Rutilus rutilus* and *Abramis brama*). Data are derived from the same sampling frame as Birdsong et al. (2022) and are presented here to provide necessary context for the fisheries analysed in this study

trout (97% in MWP and 90% in LS) and other salmonids (92% in MWP and 75% in LS) had the highest retention rates and "other cyprinids" the lowest (53% MWP and 36% LS).

Understanding proportion of catch harvested by fishery and angler characteristics (combined fishery model)

Table 2 presents the results of the combined fishery model, which investigated the factors related to the proportion of catch harvested by anglers in two different fisheries. We found that CPUE, standardized across species, had a negative effect on the proportion of catch harvested by anglers, meaning that angler kept a greater portion of the catch when catch rates were low (Fig. 2). We revealed a significant difference between the proportion of catch harvested by LS and MWP anglers, after controlling for a set of covariates, with MWP anglers in East Germany harvesting a greater proportion of their catch compared to LS anglers in West Germany. However, we found numerous significant interactions between fishery and species, suggesting there are differences in species-related harvest preferences across fisheries. Specifically, MWP anglers harvested lower proportions of zander, cod and perch than LS anglers, while harvesting greater proportions of carp (Fig. 2).

Among the measures of inter-angler heterogeneity (e.g., specialization, catch orientation measures, demography) we found fishing centrality-to-lifestyle (CTL), age, and consumptive orientation to have a positive main effect on the proportion of catch harvested, all else being equal. Furthermore, we found an interaction between CTL and fishery, showing that the positive relationship between CTL and the proportion of catch harvested was stronger in LS than MWP (Fig. 3). With increasing levels of self-perceived skill, anglers harvested a lower proportion of their catch (Fig. 3). Behavioural commitment had a negative effect on the proportion of catch harvested, but only for pike, other cyprinids, and other freshwater fish. Catch orientation did not have any significant effect on the proportion of catch harvested by anglers. The species caught also had an effect, independent of other variables, on the proportion of catch harvested by anglers. In ranked order of effect size magnitude, with all else being equal, anglers were most likely to

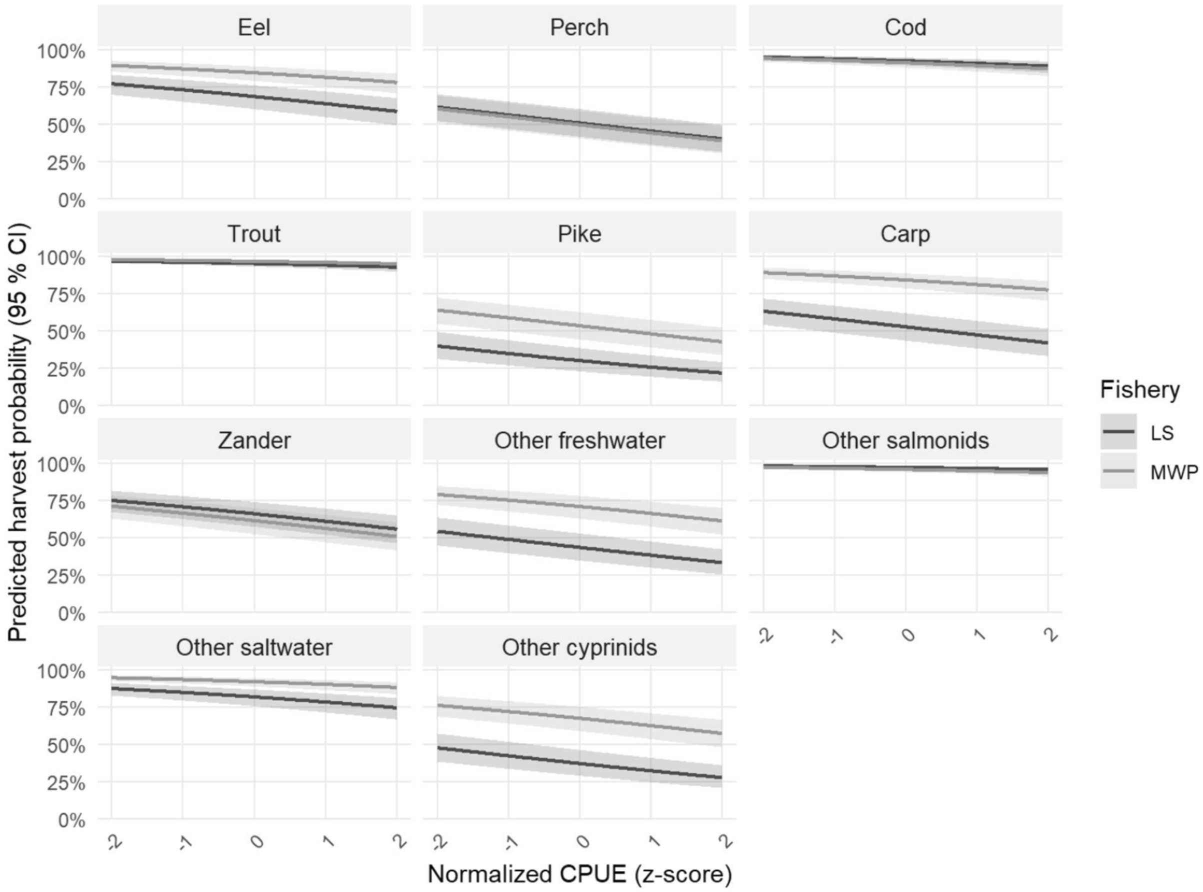

Fig. 2 Predicted angler harvest probability (%) as a function of normalized CPUE (z-score) for each species. Dark lines (and ribbons) represent estimates for Lower Saxony (LS), light grey for Mecklenburg–Western Pomerania (MWP). Shaded bands show 95% confidence intervals from the logistic mixed-effects model (Table 2), with all other covariates held at their reference values

harvest trout, other salmonids, cod, other saltwater fish, followed by eel, zander, carp, perch, other freshwater fish, other cyprinids, and lastly pike, which was the least consumptive species of all.

Regarding trip context, we found that previous satisfaction with the trip did not have a significant effect on the proportion of catch harvested ($p = 0.091$). However, total trip time had a negative effect, indicating that anglers were less likely to harvest fish as the duration of the trip increased. The variable for incidental catch also had a negative relationship with harvest, meaning that anglers were more likely to release incidental catches compared to targeted species. Lastly, the number of species targeted was negatively associated with the proportion of catch harvested, suggesting that anglers targeting a greater number of species tended to harvest a smaller proportion of their total catch.

Influence of angler characteristics and fish length on retention rates (single fishery model)

Table 3 presents the results of the single-fishery model, which investigated the factors related to the probability of harvesting an individual fish using data from LS. The size of the fish, standardized across species, was an important predictor of the likelihood of harvest, with a positive linear effect and a negative quadratic effect (Fig. 4). The negative quadratic effect indicated that the largest fish were less likely retained than the intermediately sized fish. To assess the robustness of these findings, especially the role of fish

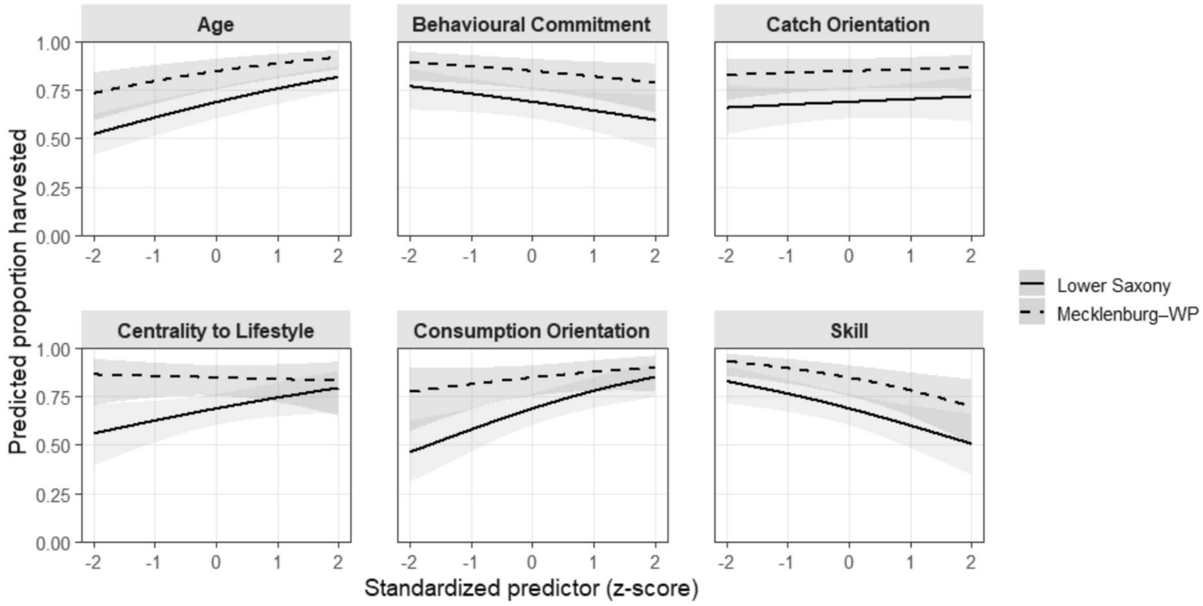

Fig. 3 Predicted proportion of catch harvested as a function of six standardized angler attributes—centrality to lifestyle (CTL), skill, age, behavioural commitment, catch orientation, and consumption orientation—based on logistic regression results from the combined Lower Saxony (LS) and Mecklenburg–Western Pomerania (MWP) diary datasets (Table 2). All predictors are z-scored; in each panel, the focal predictor varies from − 2 to + 2 SD while all other covariates are held at their mean (0). Solid lines denote LS, dashed lines denote MWP, and shaded ribbons show approximate 95% confidence intervals

size in determining harvest likelihood, we conducted a sensitivity analysis by increasing all the species-specific minimum size limits in LS by 20% (Table 3). This analysis confirmed that our most significant findings, particularly the influence of fish size, remained present.

The LS model again demonstrated significant inter-angler heterogeneity affecting harvest decisions. While CTL generally did not affect the likelihood of harvesting an individual fish across all species pooled, there was some evidence that anglers with higher CTL were more likely to harvest pike (Table 3). However, this effect was not significant when assumed size limits were increased by 20%, suggesting that the relationship may be influenced by local regulatory constraints as confounders rather than reflect an inherent tendency of more specialized anglers to harvest pike. Increasing skill consistently correlated with a lower likelihood of harvest across all species. The impact of behavioural commitment on harvest likelihood varied by species, with trout, pike, and carp anglers less likely to harvest as their commitment increased. Although neither consumption orientation nor age had a significant overall effect on harvest probability, both influenced decisions for specific species: stronger consumption orientation increased the likelihood of retaining pike and carp (and to a lesser extent perch) but not trout or zander, while older age raised the likelihood of harvesting trout (and modestly carp) but had no clear impact on perch, pike, or zander. Catch orientation significantly increased harvest likelihood in LS (Table 3). The species caught continued to play a crucial role in determining harvest likelihood also in LS, with anglers more inclined to harvest fish in the following order: zander, trout, perch, pike, carp, and finally, eel.

Increasing minimum size limits by 20% resulted in several changes to the specialization and attitudes-related predictors of harvest probability (Table 3). For species-specific predictors, the effect of carp as a harvest species was no longer significant in the adjusted model. Additionally, the interaction between trout and CTL changed in both direction and significance, while the interaction between trout and behavioural commitment approached non-significance. The interaction between carp and catch orientation became

Table 3 Single-fishery model from Lower Saxony, Germany (LS), with individual fish size (n = 3812) and a scenario with a 20% increase in size limit (n = 2916)

Parameter	Beta	SE	P-Value	Beta (20%)	SE (20%)	P-value (20%)
Standardized Size	12.424	1.278	< 0.001*	10.412	1.321	< 0.001*
Quadratic Size	– 2.677	0.686	< 0.001*	– 2.436	0.710	< 0.001*
Specialization						
Centrality to Lifestyle	0.093	0.396	0.814	0.542	0.485	0.264
Skill	– 0.979	0.368	0.008*	– 0.852	0.421	0.043*
Behavioural Commitment	– 0.332	0.433	0.443	– 0.458	0.487	0.347
Age	0.046	0.402	0.909	– 0.159	0.480	0.740
Other Personality						
Consumption Orientation	0.325	0.409	0.427	0.039	0.459	0.931
Catch Orientation	0.848	0.355	0.017*	1.103	0.396	0.005*
Trip Context						
Previous Satisfaction	– 0.175	0.089	0.048*	**– 0.063**	**0.094**	**0.503**
Total Trip Time	– 0.391	0.131	0.003*	**– 0.457**	**0.487**	**0.347**
Harvest Other (same species)	0.466	0.201	0.020*	**0.537**	**0.359**	**0.135**
Harvest Other (different species)	– 0.148	0.302	0.626	**0.849**	**0.201**	**< 0.001***
Species (ref = eel)						
Perch	5.219	0.745	< 0.001*	2.863	0.662	< 0.001*
Trout	10.371	0.952	< 0.001*	6.898	0.872	< 0.001*
Pike	3.500	0.569	< 0.001*	1.635	0.474	< 0.001*
Carp	3.260	0.630	< 0.001*	**0.261**	**0.572**	**0.647**
Zander	22.824	3.307	< 0.001*	12.162	3.023	< 0.001*
*Species*Standardized size*						
Perch	– 6.435	0.920	< 0.001*	– 5.626	1.016	< 0.001*
Trout	– 8.857	0.921	< 0.001*	– 7.805	1.014	< 0.001*
Pike	– 5.987	0.831	< 0.001*	– 5.297	0.961	< 0.001*
Carp	– 10.284	0.959	< 0.001*	– 9.055	1.072	< 0.001*
Zander	– 3.719	1.664	0.025*	– 6.124	1.616	< 0.001*
*Species*Centrality to lifestyle*						
Perch	0.157	0.573	0.784	– 0.616	0.648	0.342
Trout	– 0.817	0.546	0.134	**– 1.610**	**0.646**	**0.012***
Pike	0.931	0.400	0.019*	**0.578**	**0.485**	**0.233**
Carp	0.314	0.402	0.434	– 0.369	0.531	0.485
Zander	0.701	0.614	0.254	0.695	0.709	0.327
*Species*Skill*						
Perch	– 0.334	0.550	0.543	– 0.686	0.611	0.261
Trout	0.136	0.431	0.752	0.075	0.494	0.879
Pike	0.633	0.354	0.073	0.228	0.397	0.567
Carp	0.446	0.368	0.225	0.438	0.451	0.331
Zander	– 0.076	0.539	0.887	– 1.323	0.806	0.101
*Species*Behavioural commitment*						
Perch	– 0.681	0.473	0.149	– 0.624	0.519	0.229
Trout	– 1.046	0.512	0.041*	**– 1.025**	**0.560**	**0.067**
Pike	– 1.099	0.309	0.001*	– 0.912	0.349	0.009*
Carp	– 0.705	0.350	0.044*	– 0.983	0.472	0.037*
Zander	– 0.518	0.643	0.420	– 0.933	0.782	0.232

Table 3 (continued)

Parameter	Beta	SE	P-Value	Beta (20%)	SE (20%)	P-value (20%)
*Species*Consumptive orientation*						
Perch	0.971	0.560	0.082	1.489	0.653	0.022*
Trout	0.191	0.476	0.688	0.354	0.556	0.524
Pike	1.577	0.439	< 0.001*	1.644	0.482	< 0.001*
Carp	1.039	0.411	0.011*	1.702	0.505	< 0.001*
Zander	– 1.067	0.599	0.075	– 0.537	0.684	0.433
*Species*Catch orientation*						
Perch	– 0.101	0.494	0.837	– 0.449	0.504	0.372
Trout	0.445	0.481	0.355	– 0.144	0.540	0.789
Pike	– 0.351	0.344	0.308	– 0.601	0.382	0.116
Carp	– 0.587	0.355	0.098	**– 1.057**	**0.429**	**0.013***
Zander	0.620	0.616	0.314	0.556	0.687	0.418
*Species*Age*						
Perch	0.578	0.522	0.268	0.487	0.604	0.420
Trout	1.990	0.549	< 0.001*	2.330	0.670	< 0.001*
Pike	0.077	0.409	0.849	0.364	0.478	0.445
Carp	0.694	0.402	0.084	**1.036**	**0.527**	**0.049***
Zander	0.946	0.633	0.135	0.288	0.797	0.718

Mixed-effects logistic regression model, with random effects at the angler and trip level, predicting the likelihood of harvesting an individual fish by anglers in Lower Saxony (LS), Germany, in 2011–2012. The model examines the impact of standardized fish size, angler specialization, trip context, and species-specific effects on harvest probability, adjusted for variations in legal size limits. Differences in the direction of effects or significance levels between the original and 20% increased size limit scenarios are bolded. The species estimates in the table are all in reference to eel, which serves as the reference species

significant with a stronger negative effect. These findings suggest that increasing minimum-size limits altered the role of species-specific interactions in influencing harvest decisions. However, key predictors, especially, fish size (both linear and quadratic effects) and species-specific effects for perch, trout, pike, and zander remained robust to changes in the minimum-size limit threshold.

In terms of trip contexts, our initial findings with the state-level minimum size standards (Table 3) showed that when an angler had already harvested a particular species during the same trip, the likelihood of retaining additional fish of that species decreased. While satisfaction from the previous trip and the total time spent fishing were initially found to negatively affect the likelihood of harvest, these effects became non-significant in the sensitivity analysis where the minimum size limits were increased by 20% (Table 3). This suggests that the relationship between past satisfaction and harvest behaviour, as well as the influence of trip duration, may be influenced by regulatory thresholds, and that their impact could diminish under different regulatory conditions. Additionally, the analysis revealed that the number of species harvested during the same trip, which initially did not show a significant effect (Table 3), became a positive predictor of harvest probability when the minimum size threshold was elevated. This shift indicates that altering the voluntary release size threshold can modify how trip context variables, like the number of species targeted, influence anglers' harvest decisions. In contrast, more consistent predictors, such as fish size, remained stable and significant, suggesting that while trip context variables may fluctuate based on regulatory changes, certain factors like fish size have a more stable and direct influence on harvest behaviour.

Model fit

The likelihood ratio tests indicated a decisive enhancement in model fit with the sequential inclusion of parameters such as species, specialization

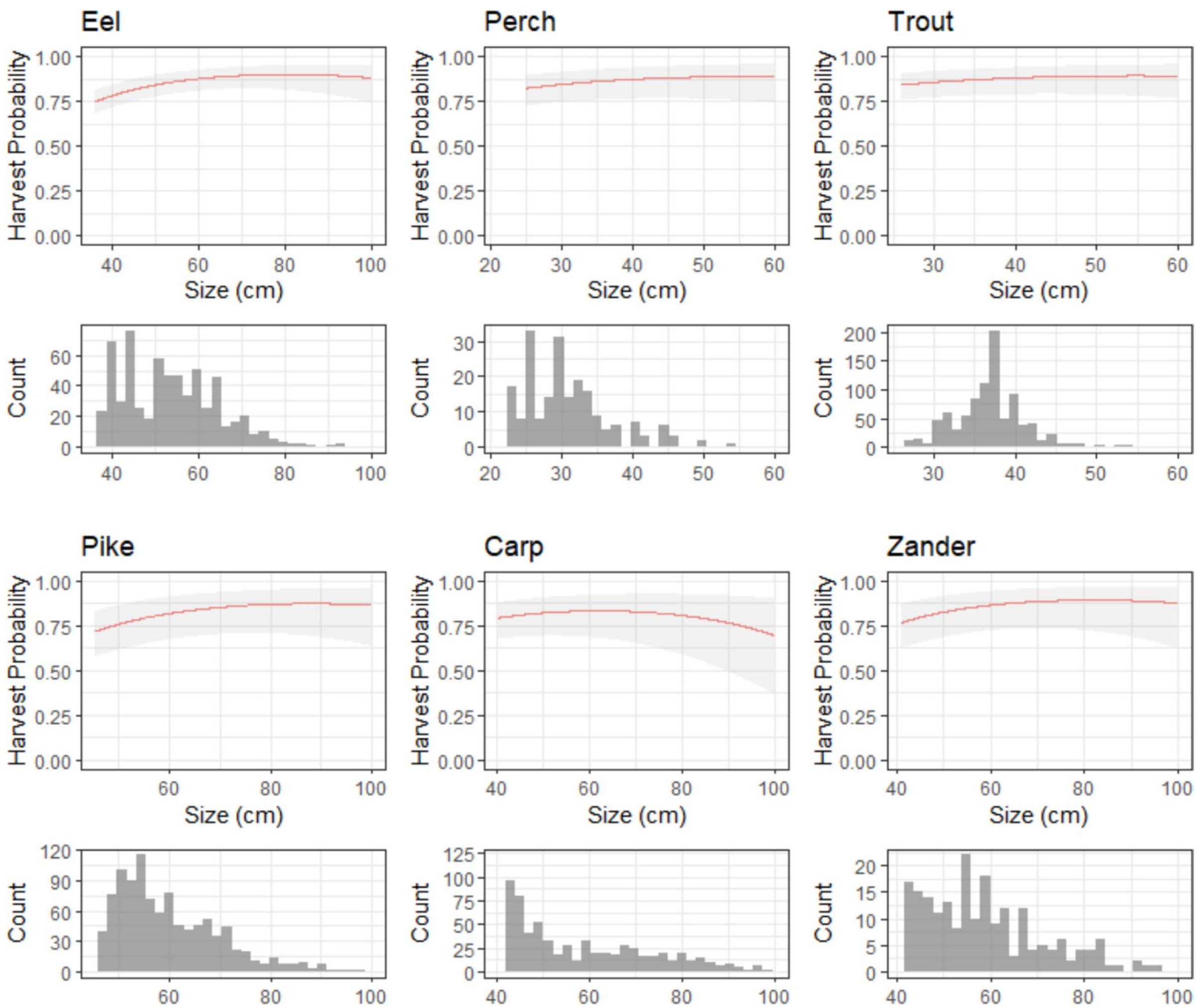

Fig. 4 Predicted harvest probability for individual, legally sized fish of six species from the Lower Saxony (LS) diary dataset. Top panels show species-specific logistic regression curves (red lines) of harvest probability versus fish length (cm), with 95% confidence intervals (grey shading) and dashed vertical lines marking state-mandated minimum-size limits. Bottom panels present histograms of the length distributions of all LS observations for each species

sub-dimensions, catch orientations, trip contexts (encompassing previous satisfaction, total trip time, incidental catch, and number of targeted species), and the interaction between species and specialization sub-dimensions, supporting their incorporation into the final combined fisheries model (Table 4). Similarly, the optimal LS model (Table 5) warranted the inclusion of analogous parameters, with the addition of size and its interaction with species, corroborating the significance of these variables in refining the model.

Discussion

As hypothesized (H1), we found that target species influenced the decision to harvest or release a fish, as it was a significant variable in both models and moderated many other relationships. Overall, German anglers tended to keep marine and diadromous fish species to a greater degree than obligate freshwater species, a finding previously implied for the USA (Salz et al. 2001; Salz and Loomis 2005) and strongly indicating that marine fishes tend to have greater culinary value than obligate freshwater

Table 4 Selected likelihood ratio tests estimated to choose the final dual-fishery model

	LL	Df	−2(LL1-LL2)	Df1-df2	*p*
+ species	− 10,333.3	19,052			
+ specialization/orient	− 9870.1	18,366	926.4	686	< 0.001*
+ contexts	− 9121.7	17,308	1496.8	1058	< 0.001*
+ species*specialization	− 8969.0	17,245	305.4	63	< 0.001*

Baskets of parameter estimates (e.g., related groups of interactions) were sequentially tested and retained if they improved model fit. Each row indicates the addition of one basket of parameters and tests this specification against the nearest preceding model. The final selected model is presented in bold. LL = log-likelihood; df = degrees of freedom

Table 5 Selected likelihood ratio tests estimated to choose the final single-fishery model

	LL	Df	−2(LL1-LL2)	Df1-df2	*p*
size	− 1873.9	3819			
+ species	− 1490.2	3814	767.4	5	< 0.001*
+ specialization/orient	− 1421.0	3734	138.4	80	< 0.001*
+ contexts	− 1412.3	3730	17.4	4	< 0.001*
+ species*specialization	− 1307.0	3700	210.6	30	< 0.001*
+ size*species	− 1083.3	3695	447.4	5	< 0.001*

Baskets of parameter estimates (e.g., related groups of interactions) were sequentially tested and retained if they improved model fit. Each row indicates the addition of one basket of parameters and tests this specification against the nearest preceding model. The final selected model is presented in bold. LL = log-likelihood; df = degrees of freedom

fishes. Furthermore, we found support for H2, with the three sub-dimensions of specialization playing varying roles in moderating the decision to harvest a release a fish, but the relationships often differed from the standard assumption initially expressed by Bryan (1977) and reported in other studies from the USA where more specialized anglers tended to release more fish than less specialized anglers (Sutton and Ditton 2001; Sutton 2003; Oh and Ditton 2006; reviewed in Arlinghaus et al. 2007). The three specialization subdimensions also exerted different relationships, with retention rates increasing with fishing centrality, and harvest rates decreasing with skill and behavioural commitment, depending on species. A large discrepancy to the literature was for the fishing centrality-to-lifestyle (CTL) index, which was found in previous studies to increase the odds of voluntary release (Chipman and Helfrich 1988; Sutton and Ditton 2001). By contrast, the combined fishery model indicated that increasing CTL was related to an increased proportion of catch harvested rather than an increased propensity to release as reported before from the USA (e.g., Sutton and Ditton 2001). Note, however, that Sutton (2003) failed to find a relationship of CTL and hypothetical catch-and-release behaviour in a study from the USA, similar to what we reported in the single fishery LS model, implying that the relationship of CTL and vCandR behaviour is species (and study) specific. Indeed, in the combined fishery model the effect of CTL on harvest probability was dependent upon the target species, with it having the strongest effect on pike anglers and weakest effect on trout anglers. As hypothesized, we found that as anglers' skill levels increased, they were less likely to harvest fish in both models, likely due to their greater ability to catch fish. Further, in both models, we found that with increasing behavioural commitment anglers were less likely to harvest fish, however, this finding was species-specific in both models and likely related to anglers with greater behavioural commitment being able to reap harvest benefits through repeat angling trips. In broad support of H3, we found that consumptive orientation was, as expected, a significantly positive predictor of harvest behaviour, in line with previous studies in the USA (e.g., Sutton and Ditton 2001; Sutton 2003). There was a general association between consumptive orientation and the proportion of catch harvested in the combined fishery model, and a species-specific association in the single fishery model, for carp and pike anglers only.

We also found some evidence in support of H4, with increasing satisfaction with catch on a previous trip decreasing the likelihood of harvest in our single fishery model. As satisfaction broadly relates to satisfying catch expectations (Arlinghaus 2006a; Birdsong et al. 2021), this finding implies that past catch successes will affect future vCandR behaviour. Finally, in broad support of H5, we found anglers in MWP to harvest more fish than anglers in LS, suggesting that people in Eastern Germany have a stronger retention orientation than anglers from Western Germany. A final key finding of work was a dome-shaped relationship among the size of fish and the retention probability, with both small and large fish being more likely released, especially for Pike and Carp.

Specialization

Although recreational specialization is a popular construct in the social science of recreational fisheries, there is little consensus over how it should be measured (Scott and Shafer 2001; Hunt et al. 2023). We found diverse effects of the three sub-dimensions of specialization on vCandR behaviour, which underscores the proposition that all three sub-dimensions should be used by recreational fisheries researchers and managers and empirical support be gathered to better learn which sub-dimension relates to the construct of interest (Scott and Schafer 2001; Slaton et al. 2023). For example, if we had used CTL as the only proxy for specialization we might have wrongly concluded that highly specialized pike anglers are consumptive (in line with earlier studies in selected species, Dorow et al. 2010; Oh and Sutton 2017), but this is not necessarily the case if you consider and control the independent effects of the other subdimensions, such as skill and behavioural commitment on vCandR behaviour. Especially skill often had a negative association with harvest rates in our study, the opposite of what we found for CTL or behavioural commitment. Importantly, only by jointly including all three subdimensions alongside other key predictors of vCandR behaviour we were able to isolate the influence of each specialization variable on vCandR release behaviour, thereby avoiding spurious results. Most of the published studies only used selected subdimensions or only very rough measures of specialization (e.g., Ditton et al. 1992 who used avidity to index specialization). It is therefore important to interpret relationships of specialization indicators and dependent variables of interest in light of possible confounders and considering the set of predictor variables before wrongly concluding about the generality of the direction of a relationship of specialization and vCandR behaviour. Relatedly, Slaton et al. (2023) in a sample of German pike anglers found the three sub-dimensions'relationships to attitudes about diverse management actions varied and were thus not consistent in terms of direction. In a series of multiple linear regression models predicting attitudes to management, Slaton et al. (2023) found either CTL or behavioural commitment to be the significant metric, but not both. This pattern of selective significance aligns with our findings, further highlighting the complex and nuanced ways in which different aspects of angler specialization influence vCandR behaviour depending on context (e.g., target species). It is by know well established that the early hypothesis by Bryan (1977) that more specialized (trout) anglers have a greater tendency to release fish voluntarily does not generally hold and strongly varies with context and culture (e.g., Dorow et al. 2010; Oh and Sutton 2017). Our research adds to this literature by showing that also the significant and direction of relationship can vary by subdimension of specialization (e.g., negative effect of skill and behavioural commitment on harvest propensity and positive effect of CTL depending on target species). The value of our study may lie in the large sample size and the multitude of predictor variables, which allowed isolating the influence of each predictor. But even with this strength, variables such as CTL varied in their influence in the two models that we estimated (significant in the combined fishery model and not significant as main effect in the single fishery model).

CTL

We found that CTL influenced the decision of anglers to harvest or release a fish, but the effect was strongly dependent upon the model and the release context. First, in our combined-fishery model, we found that higher CTL to lifestyle was associated with an increased proportion of catch harvested for LS anglers, but not for MWP anglers. This finding supports recent research showing the relationship between CTL and harvest behaviour to be context specific, with higher-CTL anglers sometimes being more consumptive in consumptive-culture fisheries or when targeting species that have high culinary value (e.g., Dorow et al. 2010; Dorow and Arlinghaus 2012; Oh and Sutton 2017). Our finding seemingly contradicted results from another study utilizing part of the dataset we used, showing that higher CTL anglers received less satisfaction from harvest (Birdsong et al. 2022). Note that the dependent variable is different, as we modelled the release decision itself, while Birdsong et al. (2022) modelled catch satisfaction. This suggests that the higher proportion of catch harvested by high-CTL anglers in our study among LS anglers may not be due to an increased desire to harvest fish, but may result from an increased desire to conform to social norms of the consumptive German angling culture. Research has shown that awareness of consequences strongly influences the harvest decision of anglers (Stensland et al. 2013), and therefore, the positive association between CTL and harvest behaviour in our study could be attributed to the anti-voluntary vCandR norms prevalent in the consumptive fishing context of Germany. Another explanation may simply be that increasing proportions of catch harvested may not necessarily increase satisfaction levels in highly central anglers.

Additionally, differences in the management structures of LS and MWP might explain why higher CTL anglers of LS harvested more fish compared to higher CTL anglers of MWP who did not show such behaviour. In LS, fisheries management is decentralized, with individual angling clubs overseeing small water bodies, whereas in MWP, larger water areas are managed by regional angling associations. These regional angling associations set broad management policies, issue licenses, and regulate fishing practices across expansive territories, rather than managing discrete, club-controlled local waters in isolation from other clubs. In club-controlled fisheries like LS, it is easier to control angling effort and monitor rule compliance, foster traditional ecological knowledge, develop an emotional attachment to fisheries, foster communication between managers and anglers, and enforce rule compliance (Daedlow et al. 2011). Varying resource governance structures, such as private, common, or public fishing rights regimes, have been implemented in many countries worldwide, and these governance structures influence how fishing practices and management are approached (Young 1999; Hilborn et al. 2005; Hoel and Kvalvik 2006). The decentralized management structure in LS likely facilitates greater involvement of anglers in decision-making, promoting stronger self-commitment to local fishing norms (Pomeroy and Berkes 1997; Berkes 2003; Daedlow et al. 2011; Guckian et al. 2018). In contrast, the centralized structure in MWP, with larger regions controlled by broader angling associations, may dilute the sense of individual involvement or community-driven norms. In such a system, anglers may have to navigate through multiple layers of internal structure to influence decision-making, making it more difficult for them to engage in cooperative management (Daedlow et al. 2011). This added complexity could hinder direct communication and a sense of ownership over fishing practices, leading to a less pronounced influence of CTL on harvest behaviour.

In the single-fishery model (LS), we observed that the influence of CTL was species-specific, with the strongest influence on pike anglers and the weakest influence on trout anglers. One potential explanation could be the emerging release norms for pike, as alluded to in recent literature (Koemle et al. 2022; Arlinghaus et al. 2023). Furthermore, the existence of species-specific angling communities, each with potentially distinct norms and practices, might contribute to these observed differences. Given that pike is among the premier target species in Germany (Ensinger et al. 2016), one could speculate that its angling community might have evolving philosophies and practices that reduce reliance on harvest pike in favour of vCandR. In contrast, trout in Germany is highly valued for consumption, as indicated by exceedingly low release rates. This maybe particularly expressed in the lowlands of northern Germany where our study was conducted and where many trout fisheries are based on repeated put-and-take type of stocking practices. In such scenario, there is limited value in vCandR of trout, which could have diluted the influence of CTL and angling behaviours related to when trout is targeted, captured and subsequently largely retained.

Skill

We found that self-perceived skill was negatively associated with the proportion of catch harvested in our combined-fishery model, and negatively associated with likelihood of harvest in our LS model. One possible interpretation of this finding is that more skilled anglers have more confidence in their ability to catch fish (for which there is empirical support, Monk and Arlinghaus 2018), and therefore can afford to be more selective in harvesting the fish that they do catch. If you assume that angling skill is correlated with release skill (i.e., ability to release a fish without mortality), this finding is consistent with past research showing that anglers with higher release-skill are more comfortable releasing fish (Stensland et al. 2013; Brownscombe et al. 2017; Blyth and Rönnbäck 2022). This increased release-skill is likely more important in consumptive fisheries with norms condemning the unlawful release of fish, and for fish perceived as more difficult to release safely (Cooke and Suski 2005). In our case, we found that with increasing skill anglers were more likely to release trout, eel, and other salmonids, in support of Bryan (1977) early work in US American trout anglers. It is also worth noting that in much of Germany, anglers must pass an examination before receiving their permits, demonstrating knowledge in ichthyology, aquatic ecology, legislation, and fish handling, in line with fish welfare principles (von Lukowicz 1998). This certification likely enhances release skills and self-confidence, especially for species requiring careful handling, which may further encourage selective harvest behaviour among skilled anglers in selected species.

Behavioural commitment

The effects of increased behavioural commitment (i.e., increased avidity) on harvest behaviour was also species dependent. In our combined-fishery model, increased behavioural commitment was associated with lower proportion of catch harvested for pike, other freshwater species, and other cyprinids. The expected mechanism is that with increased behavioural commitment, these anglers will be more selective with the fish that they harvest, because they have more catch opportunities, similar to higher-skilled anglers. In the LS model, increased behavioural commitment was associated with decreased likelihood of harvesting pike, carp and trout. This could be explained by anglers setting personal limits on how often they harvest certain species within a season, effectively creating self-imposed harvest caps (Chizinski et al. 2014), known in Germany as selective harvest. This explanation especially would apply to carp and pike, as anglers will be concerned that harvesting too many fish will damage the probability of catching large fish in the future (Arlinghaus 2007; Arlinghaus et al. 2014, 2020, 2021, 2023; Koemle et al. 2022, 2024; Slaton et al. 2023), a form of delayed gratification (Kirby and Marakovic 1996). Regular anglers could come to see themselves as stewards of the fish populations they engage with (Shephard et al. 2023). This could manifest as a tendency to release more of their catch, in an effort to ensure the health and sustainability of the population and mitigate the risks of stock depletion (Bryan 1977; Oh and Ditton 2006).

Angler age

In our combined-fishery model we found that increasing age was associated with a higher proportion of catch harvested, for all species, which might suggest generation shifts in release orientation or represent an aging effect. We are unable to differentiate among the two hypotheses. In our single-fishery model (LS), we found age to only influence the likelihood of harvest for trout anglers, increasing the likelihood of harvest. If utilitarian values affect harvest behaviour, then it follows that age is a factor, because values change inter-generationally (Manfredo et al. 2017), and therefore one would expect older anglers to have increased adherence to these values and traditional utilitarian norms of keeping rather than releasing fish. Release rates have been increasing lately in Germany for selected species such as pike (Arlinghaus et al. 2023), which might indicate that the younger generation may engage in more voluntary release behaviour for certain species. At the same time, conflicts are escalating around vCandR in Germany (Arlinghaus 2007; Eckhardt 2024; Fromherz et al. 2024), anecdotally often involving young vs. older generations, but more research is needed to substantiate this speculation. It is also possible that what we observe reflects a cohort effect—that is, enduring social norms of older generations who grew up before catch-and-release ethics became widespread in Germany—rather than a pure life-cycle aging process. Disentangling true age effects (changes within individuals over time) from cohort effects (differences between birth-year groups) will require longitudinal studies or cross-cohort comparisons that follow anglers over time or compare anglers of different birth cohorts with similar experience levels.

Consumptive orientation

In support of H3, we found consumptive orientation—a single-item indicator measuring angler attitudes towards retaining fish—to be a significant predictor of harvest behaviour. As hypothesized, our results displayed a positive correlation between consumptive orientation and harvest. This aligns with past studies suggesting a relationship between harvest orientation and actual harvest behaviours (e.g., Sutton and Ditton 2001; Hunt et al. 2002; Sutton 2003; Wallmo and Gentner 2008; Carlin et al. 2012; Johnston et al. 2010, 2013; Schroeder and Fulton 2013). Our combined-fishery model particularly showed that heightened consumption orientation, as expected, led to an increase in the proportion of catch harvested. Within our single-fishery model (LS), the effects of consumptive orientation on harvest decisions were notably species-specific, with consumptive orientation being a significant predictor of harvest for perch, pike and carp anglers only. What stands out is that both carp and pike, despite typically being species with a high release propensity, were still strongly influenced by consumptive orientation in the single-fishery model. This highlights a critical behavioural consideration: in scenarios where a species has a prevailing trend of release, other factors like the overarching norms or generalized perceptions about the species might overshadow individual variables such as consumptive orientation. In simple terms, if a broad segment of anglers predominantly releases a specific species, the role of an individual's inclination towards consumption could be diminished or relegated to the background in statistical models. This observation is congruent with earlier findings (Oh and Sutton 2017), which suggest that entrenched norms or species-specific perceptions can sometimes attenuate the influence of individual attitudes on decision-making processes (Kagervall et al. 2014). However, for species without a dominant release norm, individual consumptive orientation is likely to have a stronger influence on the harvest decision, as it is less constrained by prevailing social or cultural expectations, such as is likely the case with carp and pike who are regularly released voluntarily in Germany (Arlinghaus 2007; Arlinghaus et al. 2023).

The relationship between catch orientation (i.e., an angler's attitude toward catching fish in large quantities and sizes) and harvest outcomes presented a more mixed picture, similar to earlier work on this topic (Sutton and Ditton 2001; Sutton 2003). In our dual fishery model, catch orientation bore no significant correlation with the proportion of catch harvested, similar to Sutton and Ditton (2001) and Sutton (2003). However, in the single-fishery model, a positive correlation was observed between catch orientation and the likelihood of harvest. It is important to note that the differences in results could stem from methodological disparities between the two models. In the single-fishery model (LS), the study was narrowed down to six target species and individual fish sizes were accounted for, potentially leading to amplified effects of consumptive and catch orientations. In contrast, the combined-fishery model incorporated a wider array of species without individual size data, possibly diluting these effects. We included a broad set of angler characteristics as simultaneous predictors, whereas previous studies typically examined only a few variables at a time. With fewer predictors, any one factor is more likely to appear significant simply because it's capturing the effect of unmeasured, strongly related variables (Babyak 2004). In our full model, 'catch orientation' alone added little explanatory power once we accounted for other contextual and angler-specific predictors.

Satisfaction

Our initial findings suggested a possible relationship between increased satisfaction from previous catches and a decreased likelihood of harvest in future trips, aligning with literature that links angler satisfaction to the consumptive value of catches (Beardmore et al. 2015; Birdsong et al. 2021, 2022). This indicates that anglers might alter their harvest behaviour based on previous trip satisfaction, potentially harvesting more when dissatisfied to compensate for less rewarding experiences. Although we found some support for our assumption that lower satisfaction on past trips increased harvest propensity in future trips, a sensitivity analysis involving a 20% increase in the minimum-size threshold applied to the LS data set weakened this relationship, rendering it statistically insignificant. This outcome suggests the initial observation might be contingent on specific regulatory contexts and sample sizes and that in the initial single fishery model where past satisfaction was a significant predictor both voluntary and some regulatory CandR were confounded. We interpret the 20% increased model as a cleaner measure of vCandR behaviour, which showed that previous satisfaction did not affect the propensity to keep fish voluntarily on a future trip. The nuanced findings caution against drawing firm conclusions from the initial hypothesis 4, highlighting the need for further research to explore the complex dynamic among past outcomes and future release behaviours. We did not model the time interval since the last trip here, but future work could examine how spacing between trips moderates the carry-over effect of past satisfaction on harvest decisions.

Trip contexts

Trip context plays a significant role in shaping voluntary catch-and-release (vCandR) behaviour, as it introduces additional factors that influence anglers' decisions beyond individual and species-specific characteristics. In line with previous studies (e.g., Hunt et al. 2002; Sutton 2003; Lupi et al. 2003; Kaemingk et al. 2020), we found that certain trip-specific variables, such as trip duration and the number of species targeted, were associated with lower harvest probabilities. Specifically, anglers who fished for longer periods were less likely to retain fish, suggesting that longer trips may lead to diminishing returns, making anglers more selective in their harvest decisions. Additionally, targeting a higher number of species was also negatively associated with harvest, supporting the idea that diversifying catch targets may result in a more cautious approach to retention. The finding that anglers were more likely to release incidental catches compared to targeted species further underscores this selective behaviour. These results align with the notion that incidental catches—those not actively targeted—are less likely to be kept, as they may not align with anglers' intended catch objectives (Hunt et al. 2002).

Interestingly, our sensitivity analysis, which examined the effects of increasing the minimum size limits by 20%, revealed that some of these initial trip context effects, such as previous satisfaction and trip time, became non-significant. However, an important shift occurred in the analysis of multiple species harvested on the same trip: under the adjusted regulatory conditions, this variable emerged as a significant predictor of harvest. This suggests that as regulations evolve, trip context variables such as the number of species caught may interact differently with harvest decisions. For instance, the increased minimum size limit could heighten anglers' awareness of fish sizes, making them more selective and less inclined to harvest additional species within a trip. In contrast, more stable predictors, like fish size, maintained their influence throughout the analysis. These findings emphasize the complex interplay between trip context, regulatory changes, and anglers' decisions regarding voluntary release and harvest, highlighting that regulatory frameworks can significantly modify how context influences behaviour.

Fishery effects

We found that anglers in MWP harvested higher proportions of their catch, which supported our fifth and final hypothesis that MWP anglers would harvest higher proportions of their catch due to the utilitarian background and possibly history of economic hardship in East Germany compared to the West (Molenkopf and Kaspar 2005; Brosig-Koch et al. 2011; Riepe and Arlinghaus 2021). This finding joins other recent research showing that vCandR behaviour can be highly culture dependent (Oh and Sutton 2017). While a legacy of economic hardship and utilitarian values were the basis for our hypothesis, there are other social-ecological characteristics that might explain why MWP anglers harvest higher proportions of their catch. First, MWP anglers enjoy better catch outcomes (Birdsong et al. 2022), relatively large amounts of natural fishing areas, and lower levels of congestion. It is possible that for these reasons, MWP anglers are less motivated to release fish because they have better stocks than in LS, just as Oh and Sutton (2017) speculated that Australian anglers were less motivated to release fish than Texas anglers for similar reasons. Second, MWP angling is managed at the regional level, while LS angling is managed by smaller clubs. Daedlow et al. (2011) show that in small member-managed fisheries in Germany and in similar U.S. clubs, managers can use membership rules, peer monitoring and localized sanctions to influence angler behaviour. In such closed-membership settings, requiring catch and release for the collective benefit of stock protection is therefore more practicable than in larger open-access public fisheries. Relatedly, as the local club context means substitute sites are rare, this might instil a greater tendency to keep local stocks through vCandR. However, we cannot rule out temporal effects as the LS and MWP surveys were done about 10 years apart and release rates are rising in some fisheries in Germany (Arlinghaus et al. 2023). The difference in harvest between MWP and LS demonstrates that vCandR behaviour, to some degree, is influenced by social-ecological forces and culture. Rather than applying one-size-fits all policies, managers may want to tailor decisions to the specific social, regulatory, and ecological conditions that influence angler behaviour within a given system.

Size of fish

In the single fishery model of LS, we found that increasing size (standardized by species) was associated with an increased likelihood of harvesting a fish, due to a positive linear effect, although a negative quadratic effect indicated that this relationship reverses for the largest individuals (Fig. 4). Thus, even for comparing fish that are already large enough to be legally harvesting, size is an important factor in the harvest decision, and large trophy fish are more likely to be released, particularly in pike and carp. This finding is supported by past research showing that anglers can be motivated to release both smaller fish and trophy-sized fish (Blyth and Rönnbäck 2022) for various reasons. Smaller fish maybe less desirable to anglers because they do not provide enough food to be worth the effort or they are perceived as too young to be harvested, while anglers may be less likely to harvest trophy sized fish for multiple reasons, such as leaving them for future catch, for conservation reasons, safety concerns of eating larger fish (Tollefson and Cordle 1986), or concerns about their palatability. However, a dome-shaped relationship of fish size and release propensity did not apply to all species (e.g., in German eel anglers this is not found, Dorow et al. 2010) and is particularly pronounced in pike and carp, which are species which have lower retention rates compared to other species. Our findings underscore the potential (intended or unintended) conservation benefits that can be realized when anglers adopt vCandR practices, especially for trophy-sized specimens, possibly contributing to sustainable fish populations and enhanced angling experiences (Ahrens et al. 2020; Marshall et al. 2021; Birdsong et al. 2022).

Limitations

While our study offers several valuable new and nuanced insights into the angler decision-making process in relation to fish harvested and release, it is important to acknowledge certain limitations that might influence the interpretation of our findings. Our two diary programs used different recruitment methods—random-digit dialing of licensed anglers in MWP versus club-based invitations in LS—which could introduce systematic differences in who chose to participate. We partially adjust for this by including angler-type covariates (e.g. specialization, catch orientation) in all models, but some residual bias from non-response and outreach mode cannot be fully excluded. A significant limitation emerges from the confounding nature of the timing of the survey and cultural differences. As documented by Arlinghaus et al. (2023), there has been a noticeable increase in vCandR rates in some species in Germany over time, particularly in East Germany, where rates of release of northern pike in coastal sites have risen from 30% in 2006 to 75% in 2023. Consequently, the observed differences between the two regions that we report may not be solely attributed to cultural variations but could also be a reflection of temporal changes in angler behaviour. Specifically, the LS survey being of more recent origin recorded higher vCandR rates, indicating a potential shift in angler attitudes and practices over time. Furthermore, both of our attitude surveys were conducted over a decade ago, and thus shifts in the demographic profile of today's anglers could influence the generalizability of our findings. Another key limitation is that we interpreted the CandR behaviour shown by the anglers as vCandR behaviour. However, it is possible that in our standard model some of the fish released were released to comply with regulations as local angling club rules might deviate from the state-wide standard in terms of minimum-length limits. We cannot be certain that the altered model where we raised the threshold to define a vCandR event to 20% larger than the statewide standard captured only voluntary release context. Some local angling clubs might have local rules that even go beyond this threshold, but we consider this probability to not strongly affect our results. Finally, our study depends on self-reports and is correlative not causative. We cannot be sure that all types of voluntary release behaviours were recorded as anglers might have provided social desirable answers and indicate having kept fish when they released them. We speculate, however, that our data are not strongly polluted as the diary was completed by an independent research institute and not by a governmental agency, which should reduce social desirability in the answer patterns.

Conclusions and implications

Our work contributes several new insights to the understanding of the decision to harvest or voluntarily release a fish, with implications for fisheries management. First, our findings substantiate previous research indicating the important role of social-ecological context and culture in the behaviour of anglers (e.g., Oh and Sutton 2017; Birdsong et al. 2022). Collectively, our results, in combination with previous studies, imply that angler behaviour might, to some degree, be outside of the direct control of fishery management. Moreover, our findings suggest that governance structures and more broadly cultural embedding may play an important role in shaping harvest decisions. The contrast between decentralized (LS) and centralized (MWP) management systems as well as the exposure to different political climates in East and West Germany suggests that regulatory frameworks as well as the different political regimes can shape angler behaviour, potentially affecting both sustainability and stakeholder satisfaction (Birdsong et al. 2022). Second, our findings show that different species show different propensity for being released, largely reflecting a marine to freshwater gradient where retention rates are larger for marine species or diadromous species than for obligate freshwater species, especially cyprinids and pike. Third, our results provide support for the use of three specialization sub-dimensions by researchers and managers and raise the notion that each indicator carries a specific information value for predicting angler behaviour in terms of CandR. Fourth, the general picture emerging from this study is that managers and researchers must account for wide-ranging diversity across anglers, situations, and social-ecological contexts when investigating angler behaviour. It is not easily possible to provide general conclusions about the vCandR behaviour of anglers with single-species studies or the predictors of CandR, because vCandR behaviour is moderated by culture, context and angler characteristics, in intimate interactions with the target species, previous catch outcomes on past trips and current catch outcomes (e.g., whether primary or secondary species are captured, Hunt et al. 2002). Fifth, we documented a demographic age effect in that the younger generation is more readily engaging in vCandR, which may suggest an inter-generationally shift in vCandR behaviour in German anglers. Finally, our work showed that specific species attract greater voluntary release rates than others, e.g., pike and carp, and that generally German anglers are voluntarily releasing the largest fish they catch within each species. Voluntary behaviours of anglers can have unintended consequences, either undermining well-intended harvest regulations (e.g., when harvest is incentivized but anglers do not take fish, Gigliotti and Taylor 1990; Myers et al. 2008) or they can help in conservation, such as the voluntary protection of the largest fish in exploited populations (Ahrens et al. 2020).

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Author contribution M.B. conceptualized the study, conducted analyses, and led the manuscript writing. B.B. assisted with data interpretation, collected data, and provided feedback on the manuscript. M.D. and T.P. collected data and provided feedback on the manuscript. R.A. supervised the study, contributed to conceptualization, and provided critical revisions to the manuscript.

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Data availability The original data sets are available from RA based on reasonable request.

Declarations

Conflict of interest The authors declare no conflict of interest.

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References

Aas Ø, Kaltenborn BP (1995) Consumptive orientation of anglers in Engerdal, Norway. Environ Manag 19(5):751

Aas Ø, Thailing CE, Ditton RB (2002) Controversy over catch-and-release recreational fishing in Europe. Recreat Fish Ecol Econ Soc Eval 95–106. https://doi.org/10.1002/9780470995402.ch7

Ahrens RNM, Allen MS, Walters C, Arlinghaus R (2020) Saving large fish through harvest slots outperforms the classical minimum-length limit when the aim is to achieve multiple harvest and catch-related fisheries objectives. Fish Fish 21(3):483–510. https://doi.org/10.1111/faf.12442

Alesina A, Fuchs-Schündeln N (2007) Good-bye Lenin (or not?): the effect of communism on people's preferences. Am Econ Rev 97(4):1507–1528. https://doi.org/10.1257/aer.97.4.1507

Anderson L, Thompson P (1991) Development and implementation of the angler diary monitoring program for Great Bear Lake, Northwest Territories. Am Fish Soc Symp 12:457–475

Anderson DK, Ditton RB, Hunt KM (2007) Measuring angler attitudes toward catch-related aspects of fishing. Hum Dimens Wildl 12(3):181–191. https://doi.org/10.1080/10871200701323066

Andrews B, Ferrini S, Muench A, Brown A, Hyder K (2021) Assessing the impact of management on sea anglers in the UK using choice experiments. J Environ Manag 293:112831. https://doi.org/10.1016/j.jenvman.2021.112831

Arlidge WNS, Arlinghaus R, Kurvers RHJM, Nassauer A, Oyanedel R, Krause J (2023) Situational social influence leading to non-compliance with conservation rules. Trends Ecol Evol. https://doi.org/10.1016/j.tree.2023.08.003

Arlinghaus R (2006a) On the apparently striking disconnect between motivation and satisfaction in recreational fishing: The case of catch orientation of German anglers. North Am J Fish Manag 26(3):592–605. https://doi.org/10.1577/M04-220.1

Arlinghaus R (2006b) Understanding recreational angling participation in Germany: preparing for demographic change. Hum Dimens Wildl 11(4):229–240. https://doi.org/10.1080/10871200600802889

Arlinghaus R, Cooke SJ, Lyman J, Policansky D, Schwab A, Suski C, Sutton SG, Thorstad EB (2007) Understanding the complexity of catch-and-release in recreational fishing: an integrative synthesis of global knowledge from historical, ethical, social, and biological perspectives. Rev Fish Sci 15(1–2):75–167. https://doi.org/10.1080/10641260601149432

Arlinghaus R, Schwab A, Riepe C, Teel T (2012) A primer on anti-angling philosophy and its relevance for recreational fisheries in urbanized societies. Fisheries 37(4):153–164. https://doi.org/10.1080/03632415.2012.666472

Arlinghaus R, Beardmore B, Riepe C, Meyerhoff J, Pagel T (2014) Species-specific preferences of German recreational anglers for freshwater fishing experiences, with emphasis on the intrinsic utilities of fish stocking and wild fishes. J Fish Biol 85(6):1843–1867. https://doi.org/10.1111/jfb.12546

Arlinghaus R, Lorenzen K, Johnson BM, Cooke SJ, Cowx IG (2016) Management of freshwater fisheries: Addressing habitat, people and fishes. In: Craig J (ed) Freshwater Fisheries Ecology. Blackwell Science, pp 557–579

Arlinghaus R, Beardmore B, Riepe C, Pagel T (2020) Species-specific preference heterogeneity in German freshwater anglers, with implications for management. J Outdoor Recreat Tour 32:100216

Arlinghaus R, Braun M, Dhellemmes F, Ehrlich E, Feldhege FH, Koemle D, Niessner D, Palder J, Radinger J, Riepe C, Rittweg T, Roser P, Winkler H (2023) BODDENHECHT: Ökologie, Nutzung und Schutz von Hechten in den Küstengewässern Mecklenburg-Vorpommerns. Berichte des IGB, Band 33

Arlinghaus R, Lucas J, Weltersbach MS, Kömle D, Winkler HM, Riepe C, Kühn C, Strehlow HV (2021) Niche overlap among anglers, fishers and cormorants and their removals of fish biomass: a case from brackish lagoon ecosystems in the southern Baltic Sea. Fish Res 238:105894. https://doi.org/10.1016/j.fishres.2021.105894

Babyak MA (2004) What you see may not be what you get: a brief, nontechnical introduction to overfitting in regression-type models. Psychosom Med 66(3):411–421

Bartholomew A, Bohnsack JA (2005) A review of catch-and-release angling mortality with implications for no-take reserves. Rev Fish Biol Fisheries 15(1):129–154. https://doi.org/10.1007/s11160-005-2175-1

Bates D, Mächler M, Bolker B, Walker S (2015) Fitting linear mixed-effects models using lme4. J Stat Softw 67(1):1–48. https://doi.org/10.18637/jss.v067.i01

Beard TD, Cox SP, Carpenter SR (2003) Impacts of daily bag limit reductions on angler effort in Wisconsin walleye lakes. North Am J Fish Manag 23(4):1283–1293. https://doi.org/10.1577/M01-227AM
Beardmore B, Dorow M, Haider W, Arlinghaus R (2011) The elasticity of fishing effort response and harvest outcomes to altered regulatory policies in eel (Anguilla anguilla) recreational angling. Fish Res 110(1):136–148. https://doi.org/10.1016/j.fishres.2011.03.023
Beardmore B, Haider W, Hunt LM, Arlinghaus R (2013) Evaluating the ability of specialization indicators to explain fishing preferences. Leis Sci 35(3):273–292. https://doi.org/10.1080/01490400.2013.780539
Beardmore B, Hunt LM, Haider W, Dorow M, Arlinghaus R (2015) Effectively managing angler satisfaction in recreational fisheries requires understanding the fish species and the anglers. Can J Fish Aquat Sci 72(4):500–513. https://doi.org/10.1139/cjfas-2014-0177
Berkes F (2003) Alternatives to conventional management: Lessons from small-scale fisheries. Environments 31(1):5–20
Birdsong M, Hunt LM, Arlinghaus R (2021) Recreational angler satisfaction: what drives it? Fish Fish 22(4):682–706. https://doi.org/10.1111/faf.12545
Birdsong M, Hunt LM, Beardmore B, Dorow M, Pagel T, Arlinghaus R (2022) Does the relevance of catch for angler satisfaction vary with social-ecological context? A study involving angler cultures from West and East Germany. Fish Res 254:106414. https://doi.org/10.1016/j.fishres.2022.106414
Blyth S, Rönnbäck P (2022) To eat or not to eat, coastal sea trout anglers' motivations and perceptions of best practices for catch and release. Fish Res 254:106412. https://doi.org/10.1016/j.fishres.2022.106412
Bray GS, Schramm Jr HL (2001) Evaluation of a statewide volunteer angler diary program for use as a fishery assessment tool. North Am J Fish Manag 21(3):606–615. https://doi.org/10.1577/1548-8675(2001)021%3c0606:EOASVA%3e2.0.CO;2
Bronnmann J, Koemle D, Meyerhoff J, Weltersbach MS, Strehlow HV, Arlinghaus R (2023) Willingness to pay for harvest regulations and catch outcomes in recreational fisheries: a stated preference study of German cod anglers. Fish Res 259:106536. https://doi.org/10.1016/j.fishres.2022.106536
Brosig-Koch J, Helbach C, Ockenfels A, Weimann J (2011) Still different after all these years: solidarity behavior in East and West Germany. J Public Econ 95(11–12):1373–1376. https://doi.org/10.1016/j.jpubeco.2011.06.002
Brownscombe JW, Danylchuk AJ, Chapman JM, Gutowsky LF, Cooke SJ (2017) Best practices for catch-and-release recreational fisheries–angling tools and tactics. Fish Res 186:693–705
Bryan H (1977) Leisure value systems and recreational specialization: the case of trout fishermen. J Leis Res 9(3):174–187. https://doi.org/10.1080/00222216.1977.11970328
Carlin C, Schroeder SA, Fulton DC (2012) Site choice among Minnesota walleye anglers: the influence of resource conditions, regulations and catch orientation on lake preference. North Am J Fish Manag 32(2):299–312
Chipman BD, Helfrich LA (1988) Recreational specializations and motivations of Virginia river anglers. North Am J Fish Manag 8(4):390–398. https://doi.org/10.1577/1548-8675(1988)008%3c0390:RSAMOV%3e2.3.CO;2
Chizinski CJ, Martin DR, Hurley KL, Pope KL (2014) Self-imposed length limits in recreational fisheries. Fish Res 155:83–89. https://doi.org/10.1016/j.fishres.2014.02.022
Coggins LG Jr, Catalano MJ, Allen MS, Pine WE III, Walters CJ (2007) Effects of cryptic mortality and the hidden costs of using length limits in fishery management. Fish Fish 8:196–210. https://doi.org/10.1111/j.1467-2679.2007.00247.x
Colvin MA (1991) Population characteristics and angler harvest of white crappies in four large Missouri reservoirs. North Am J Fish Manag 11(4):572–584
Connelly NA, Knuth BA, Brown TL (1996) Sportfish consumption patterns of Lake Ontario anglers and the relationship to health advisories. North Am J Fish Manag 16(1):90–101. https://doi.org/10.1577/1548-8675(1996)016%3c0090:SCPOLO%3e2.3.CO;2
Cooke SJ, Cowx IG (2004) The role of recreational fishing in global fish crises. Bioscience 54(9):857–859. https://doi.org/10.1641/0006-3568(2004)054[0857:TRORFI]2.0.CO;2
Cooke SJ, Suski CD (2005) Do we need species-specific guidelines for catch-and-release recreational angling to effectively conserve diverse fishery resources? Biodivers Conserv 14(5):1195–1209. https://doi.org/10.1007/s10531-004-7845-0
Cooke SJ, Suski CD, Arlinghaus R, Danylchuk AJ (2013) Voluntary institutions and behaviours as alternatives to formal regulations in recreational fisheries management. Fish Fish 14(4):439–457. https://doi.org/10.1111/j.1467-2979.2012.00477.x
Cooke SJ, Danylchuk SC, Tracey SR, Arlinghaus R, Lennox RJ, Brownscombe JW, Weir A, Hinch SG, Patterson DA, Guckian ML, Danylchuk AJ (2025) Individual outcomes matter in the context of responsible and sustainable catch-and-release practices in recreational fisheries and their management. Fisheries 50(4):172–181. https://doi.org/10.1093/fshmag/vuae023
Cramer J (2004) Life after catch and release. https://aquadocs.org/handle/1834/26342
Dabrowksa K, Hunt LM, Haider W (2017) Understanding how angler characteristics and context influence angler preferences for fishing sites. North Am J Fish Manag 37(6):1350–1361. https://doi.org/10.1080/02755947.2017.1383325
Daedlow K, Beard TD, Arlinghaus R (2011) A property rights-based view on the management of inland fisheries. Am Fish Soc Symp 75:13–38
Ditton RB, Sutton SG (2004) Substitutability in recreational fishing. Hum Dimens Wildl 9(2):87–102
Ditton RB, Loomis DK, Choi S (1992) Recreation specialization: re-conceptualization from a social worlds perspective. J Leis Res 24(1):33–51. https://doi.org/10.1080/00222216.1992.11969870
Dorow M, Arlinghaus R (2011) A telephone-diary-mail approach to survey recreational fisheries on large geographic scales, with a note on annual landings estimates

by anglers in northern Germany. Am Fish Soc Symp 75(1):319–344
Dorow M, Arlinghaus R (2012) The relationship between personal commitment to angling and the opinions and attitudes of German anglers towards the conservation and management of the European eel *Anguilla anguilla*. North Am J Fish Manag 32(3):466–479. https://doi.org/10.1080/02755947.2012.680006
Dorow M, Beardmore B, Haider W, Arlinghaus R (2010) Winners and losers of conservation policies for European eel, *Anguilla anguilla*: an economic welfare analysis for differently specialised eel anglers. Fish Manage Ecol 17(2):106–125. https://doi.org/10.1111/j.1365-2400.2009.00674.x
Eckhardt Y (2024) Fishing for compliments: legitimate illegality and institutional signaling in the case of recreational fishing in Germany. Geoforum 155:104082. https://doi.org/10.1016/j.geoforum.2024.104082
Ensinger J, Brämick U, Fladung E, Dorow M, Arlinghaus R (2016) Characterization and perspectives of angling in northeastern Germany, Publications of the Institute for Inland Fisheries, vol 44. Published by the Institute for Inland Fisheries, Potsdam–Sacrow
Fayram AH (2003) A comparison of regulatory and voluntary release of muskellunge and walleyes in northern Wisconsin. North Am J Fish Manag 23(2):619–624. https://doi.org/10.1577/1548-8675(2003)023%3c0619:ACORAV%3e2.0.CO;2
Ferter K, Weltersbach MS, Strehlow HV, Vølstad JH, Alós J, Arlinghaus R, Armstrong M, Dorow M, de Graaf M, van der Hammen T, Hyder K (2013) Unexpectedly high catch-and-release rates in European marine recreational fisheries: implications for science and management. ICES J Mar Sci 70(7):1319–1329
Fisher MR (1997) Segmentation of the angler population by catch preference, participation, and experience: a management-oriented application of recreation specialization. North Am J Fish Manag 17(1):1–10. https://doi.org/10.1577/1548-8675(1997)017%3c0001:SOTAPB%3e2.3.CO;2
Fromherz M, Baer J, Roch S, Geist J, Brinker A (2024) Characterization of specialist European catfish anglers in southern Germany: Implications for future management. Fish Res 279:107144. https://doi.org/10.1016/j.fishres.2024.107144
Gale RP (1987) Resource miracles and rising expectations: a challenge to fishery managers. Fisheries 12(5):8–13. https://doi.org/10.1577/1548-8446(1987)0120008:RMAREA2.0.CO;2
Gigliotti LM, Taylor WW (1990) The effect of illegal harvest on recreational fisheries. North Am J Fish Manag 10(1):106–110
Guckian ML, Danylchuk AJ, Cooke SJ, Markowitz EM (2018) Peer pressure on the riverbank: assessing catch-and-release anglers' willingness to sanction others' (bad) behavior. J Environ Manage 219:252–259. https://doi.org/10.1016/j.jenvman.2018.04.117
Haab T, Hicks R, Schnier K, Whitehead JC (2012) Angler heterogeneity and the species-specific demand for marine recreational fishing. Mar Resour Econ 27(3):229–251. https://doi.org/10.5950/0738-1360-27.3.229
Hilborn R, Orensanz JM, Parma AM (2005) Institutions, incentives and the future of fisheries. Philos Trans R Soc b Biol Sci 360(1453):47–57. https://doi.org/10.1098/rstb.2004.1569
Hoel AH, Kvalvik I (2006) The allocation of scarce natural resources: The case of fisheries. Mar Policy 30(4):347–356. https://doi.org/10.1016/j.marpol.2005.07.001
Hunt L, Haider W, Armstrong K (2002) Understanding the fish harvesting decisions by anglers. Hum Dimens Wildl 7(2):75–89. https://doi.org/10.1080/10871200290089355
Hunt LM, Boxall PC, Boots B (2007) Accommodating complex substitution patterns in a random utility model of recreational fishing. Mar Resour Econ 22(2):155–172. https://doi.org/10.1086/mre.22.2.42629550
Hunt LM, Arlinghaus R, Scott D, Kyle G (2023) Diversity of anglers: drivers and implications for fisheries management. In: Neal JW, Lang TJ, Krogman RM, Kurzawski KF, Hunt KM, Taylor JB (eds) Angler recruitment, retention, and reactivation: The future of fisheries and aquatic conservation summary and synthesis (Chapter 5, pp. 1–28). American Fisheries Society
Hutt CP, Bettoli PW (2007) Preferences, specialization, and management attitudes of trout anglers fishing in Tennessee tailwaters. North Am J Fish Manag 27(4):1257–1267. https://doi.org/10.1577/M05-215.1
Johnston FD, Arlinghaus R, Dieckmann U (2010) Diversity and complexity of angler behaviour drive socially optimal input and output regulations in a bioeconomic recreational-fisheries model. Can J Fish Aquat Sci 67(9):1507–1531. https://doi.org/10.1139/F10-046
Johnston FD, Arlinghaus R, Dieckmann U (2013) Fish life history, angler behaviour and optimal management of recreational fisheries. Fish Fish 14(4):554–579. https://doi.org/10.1111/j.1467-2979.2012.00487.x
Johnston FD, Beardmore B, Arlinghaus R (2015) Optimal management of recreational fisheries in the presence of hooking mortality and noncompliance—predictions from a bioeconomic model incorporating a mechanistic model of angler behavior. Can J Fish Aquat Sci 72(1):37–53
Kaemingk MA, Hurley KL, Chizinski CJ, Pope KL (2020) Harvest–release decisions in recreational fisheries. Can J Fish Aquat Sci 77(1):194–201. https://doi.org/10.1139/cjfas-2019-0119
Kagervall A, Heberlein TA, Hellström G, Ericsson G (2014) Conceptualization and measurement of catch-and-release norms. Hum Dimens Wildl 19(2):139–153. https://doi.org/10.1080/10871209.2014.843221
Kim SS, Scott D, Crompton JL (1997) An exploration of the relationships among social psychological involvement, behavioral involvement, commitment, and future intentions in the context of birdwatching. J Leis Res 29(3):320–341. https://doi.org/10.1080/00222216.1997.11949799
Kirby KN, MarakoviĆ NN (1996) Delay-discounting probabilistic rewards: rates decrease as amounts increase. Psychon Bull Rev 3(1):100–104. https://doi.org/10.3758/BF03210748
Koemle D, Meyerhoff J, Arlinghaus R (2022) How catch uncertainty and harvest regulations drive anglers' choice for pike (Esox lucius) fishing in the Baltic Sea. Fish

Res 256:106480. https://doi.org/10.1016/j.fishres.2022.106480

Koemle D, Gassler B, Kyle G, Meyerhoff J, Arlinghaus R (2024) How involvement drives decision rules behind stated preferences for recreational-fisheries management. J Environ Manage 349:119604. https://doi.org/10.1016/j.jenvman.2023.119604

Lew DK, Larson DM (2015) Stated preferences for size and bag limits of Alaska charter boat anglers. Mar Policy 61:66–76. https://doi.org/10.1016/j.marpol.2015.07.007

Lupi F, Hoehn JP, Christie GC (2003) Using an economic model of recreational fishing to evaluate the benefits of sea lamprey (*Petromyzon marinus*) control on the St. Marys river. J Great Lakes Res 29:742–754. https://doi.org/10.1016/S0380-1330(03)70528-0

Manfredo MJ, Bruskotter JT, Teel TL, Fulton D, Schwartz SH, Arlinghaus R, Oishi S, Uskul AK, Redford K, Kitayama S, Sullivan L (2017) Why social values cannot be changed for the sake of conservation. Conserv Biol 31:772–780. https://doi.org/10.1111/cobi.12855

Marshall DJ, Bode M, Mangel M, Arlinghaus R, Dick EJ (2021) Reproductive hyperallometry and managing the world's fisheries. Proc Natl Acad Sci 118(34):e2100695118. https://doi.org/10.1073/pnas.2100695118

Matlock GC, Osburn HR, Riechers RK, Ditton RB (1991) Comparison of response scales for measuring angler satisfaction. Am Fish Soc Symp 12(1–4):413–422

Mollenkopf H, Kaspar R (2005) Ageing in rural areas of East and West Germany: increasing similarities and remaining differences. Eur J Ageing 2(2):120–130. https://doi.org/10.1007/s10433-005-0029-2

Monk CT, Arlinghaus R (2018) Eurasian perch, *Perca fluviatilis*, spatial behaviour determines vulnerability independent of angler skill in a whole-lake reality mining experiment. Can J Fish Aquat Sci. https://doi.org/10.1139/cjfas-2017-0029

Myers R, Taylor J, Allen M, Bonvechio TF (2008) Temporal trends in voluntary release of largemouth bass. North Am J Fish Manag 28(2):428–433. https://doi.org/10.1577/M06-265.1

Noble RL, Jones TW (1999) Managing fisheries with regulations. In: Kohler CC, Hubert WA (eds) Inland fisheries management (2nd ed., pp. 455–480). American Fisheries Society, Bethesda, Maryland

North R (2002) Factors affecting the performance of stillwater coarse fisheries in England and Wales. Manag Ecol Lake Reservoir Fish, 284–298

Oh CO, Ditton RB (2006) Using recreation specialization to understand multi-attribute management preferences. Leis Sci 28(4):369–384. https://doi.org/10.1080/01490400600745886

Oh CO, Sutton SG (2017) Comparing the developmental process of consumptive orientation across different population groups. Leis Sci 41(3):167–185. https://doi.org/10.1080/01490400.2017.1325795

Olaussen JO (2016) Catch-and-release and angler utility: evidence from an Atlantic salmon recreational fishery. Fish Manag Ecol 23(3–4):253–263. https://doi.org/10.1111/fme.12167

Policansky D (2002) Catch-and-release recreational fishing: a historical perspective. In: Pitcher TJ, Hollingworth CE (eds) Recreational fisheries: Ecological, economic, and social evaluation (pp. 74–94). Blackwell Publishing. https://doi.org/10.1002/9780470995402.ch6

Pomeroy RS, Berkes F (1997) Two to tango: the role of government in fisheries co-management. Mar Policy 21(5):465–480. https://doi.org/10.1016/S0308-597X(97)00017-1

R Core Team (2020) R: *A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. URL: https://www.R-project.org/

Radomski PJ, Grant GC, Jacobson PC, Cook MF (2001) Visions for recreational fishing regulations. Fisheries 26(5):7–18. https://doi.org/10.1577/1548-8446(2001)026%3c0007:VFRFR%3e2.0.CO;2

Riepe C, Arlinghaus R (2021) Angeln in der Mitte der Gesellschaft: Die öffentliche Wahrnehmung der Freizeitfischerei mit der Angel in den alten und neuen Bundesländern. Zeitschrift für Fischerei 1 (Artikel 7): 1-18. https://doi.org/10.35006/fischzeit.2021.14

Salz RJ, Loomis DK (2005) Recreation specialization and anglers' attitudes towards restricted fishing areas. Hum Dimens Wildl 10(3):187–199. https://doi.org/10.1080/10871200591003436

Salz RJ, Loomis DK, Finn KL (2001) Development and validation of a specialization index and testing of specialization theory. Hum Dimens Wildl 6(3):239–258

Schramm HL, Arey SD, Miko DA, Gerard PD (1998) Angler perceptions of fishing success and the effect of on-site catch rate information. Hum Dimens Wildl 3(3):1–10. https://doi.org/10.1080/10871209809359128

Schreyer R, Roggenbuck JW (1978) The influence of experience expectations on crowding perceptions and social-psychological carrying capacities. Leis Sci 1(4):373–394

Schroeder SA, Fulton DC (2013) Comparing catch orientation among Minnesota walleye, northern pike, and bass anglers. Hum Dimens Wildl 18(5):355–372

Schuhmann PW, Schwabe KA (2004) An analysis of congestion measures and heterogeneous angler preferences in a random utility model of recreational fishing. Environ Resource Econ 27(4):429–450

Scott D, Shafer CS (2001) Recreational specialization: a critical look at the construct. J Leis Res 33(3):319–343. https://doi.org/10.1080/00222216.2001.11949944

Shephard S, List CJ, Arlinghaus R (2023) Reviving the unique potential of recreational fishers as environmental stewards of aquatic ecosystems. Fish Fish 24(2):339–351. https://doi.org/10.1111/faf.12723

Siepker MJ, Ostrand KG, Cooke SJ, Philipp DP, Wahl DH (2007) A review of the effects of catch-and-release angling on black bass, Micropterus spp.: implications for conservation and management of populations. Fish Manag Ecol 14(2):91–101. https://doi.org/10.1111/j.1365-2400.2007.00529.x

Spencer PD, Spangler GR (1992) Effect that providing fishing information has on angler expectations and satisfaction. North Am J Fish Manag 12(2):379–385. https://doi.org/10.1577/1548-8675(1992)0120379:ETPFIH2.3.CO;2

Slaton C, Koemle D, Birdsong M, Arlinghaus R (2023) Explaining attitudes to management actions and beliefs about other user groups and conservation with angler

characteristics: A case study in a coastal pike (*Esox lucius*) fishery in the southern Baltic Sea, Germany. Fisheries Res 263:106669. https://doi.org/10.1016/j.fishres.2023.106669
Stensland S, Aas Ø (2014) The role of social norms and informal sanctions in catch-and-release angling. Fish Manag Ecol 21(4):288–298. https://doi.org/10.1111/fme.12078
Stensland S, Aas Ø, Mehmetoglu M (2013) The influence of norms and consequences on voluntary catch and release angling behavior. Hum Dimens Wildl 18(5):373–385. https://doi.org/10.1080/10871209.2013.811617
Sutton S (2003) Personal and situational determinants of catch-and-release choice of freshwater anglers. Hum Dimens Wildl 8(2):109–126. https://doi.org/10.1080/10871200304300
Sutton SG, Ditton RB (2001) Understanding catch-and-release behavior among U.S. Atlantic bluefin tuna anglers. Hum Dimen Wildlife 6(1):49–66. https://doi.org/10.1080/10871200152668698
Tarrant MA, Manfredo MJ, Bayley PB, Hess R (1993) Effects of recall bias and nonresponse bias on self-report estimates of angling participation. North Am J Fish Manag 13(2):217–222. https://doi.org/10.1577/1548-8675(1993)013%3c0217:EORBAN%3e2.3.CO;2
Tierschutzgesetz [Animal Welfare Act; TierSchG]. (2006). *Bundesgesetzblatt Teil I*, 25, 1525.
Tollefson L, Cordle F (1986) Methylmercury in fish: a review of residue levels, fish consumption and regulatory action in the United States. Environ Health Perspect 68:203–208
von Lukowicz M (1998) Education and training in recreational fishery in Germany. In: Hickley P, Tompkins H (eds) Recreational fisheries: Social, economic, and management aspects. Blackwell Scientific Publications, pp 287–293
Wallmo K, Gentner B (2008) Catch-and-release fishing: a comparison of intended and actual behavior of marine anglers. North Am J Fish Manag 28(5):1459–1471. https://doi.org/10.1577/M07-062.1
Whitehead JC, Dumas CF, Landry CE, Herstine J (2013) A recreation demand model of the North Carolina for-hire fishery: a comparison of primary and secondary purpose anglers. Appl Econ Lett 20(16):1481–1484. https://doi.org/10.1080/13504851.2013.826864
Wilde GR, Ditton RB (1994) A management-oriented approach to understanding diversity among largemouth bass anglers. North Am J Fish Manag 14(1):34–40. https://doi.org/10.1577/1548-8675(1994)014%3c0034:AMOATU%3e2.3.CO;2
Young MD (1999) The design of fishing-right systems: the NSW experience. Ecol Econ 31:305–316. https://doi.org/10.1016/S0921-8009(99)00086-5

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