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Recreational fisheries selectively capture and harvest large predators

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Abstract

Size- and species-selective harvest inevitably alters the composition of targeted populations and communities. This can potentially harm fish stocks, ecosystem functionality, and related services, as evidenced in numerous commercial fisheries. The high popularity of rod-and-reel recreational fishing, practiced by hundreds of millions globally, raises concerns about similar deteriorating effects. Despite its prevalence, the species and size selectivity of recreational fisheries remain largely unquantified due to a lack of combined catch data and fisheries-independent surveys. This study addresses this gap by using standardised monitoring data and over 60,000 digital angling catch reports from 62 distinct fisheries. The findings demonstrate a pronounced selectivity in recreational fisheries, targeting top predators and large individuals. Catch-and-release practices reduced the overall harvest by 60% but did not substantially alter this selectivity. The strong species- and size-specific selectivity mirror patterns observed in other fisheries, emphasising the importance of managing the potential adverse effects of recreational fisheries selective mortality and overfishing.

KEYWORDS

angling, catch reports, catch-and-release, fish monitoring, trophic alteration, truncation

1 | INTRODUCTION

By hunting and fishing wild animals, humans shape the terrestrial and aquatic biota of the world. Large species of animals, often apex predators, have historically been, and continue to be, selectively targeted with clear food-web effects (Estes et al., 2011; Lennox,

Brownscombe, et al., 2022; Strong & Frank, 2010). Selectivity-induced changes in relative species abundance can skew the trophic structure and cascade down to impact prey and mesopredator abundance and ultimately shift predator–prey relationships (Barkai & McQuaid, 1988; Duffy, 2002, 2003; Paine, 1980). This may in turn shift animal communities from one stable state to another and, in

worst case, have dramatic consequences for ecosystem functioning (Beisner et al., 2003; Eklöf et al., 2020; Fauchald, 2010; Scheffer et al., 2001; Scheffer & Carpenter, 2003).

Human harvest is also trait selective within species. Hunters and fishers intentionally, or unintentionally, target individuals based on body size, age, sex, morphology, ornaments and behaviours (Allendorf & Hard, 2009). Large individuals are utmost pursued, often resulting in size- and age truncation that weaken population and community resilience (Berkeley et al., 2004; Fenberg & Roy, 2008). Ultimately, the harvested phenotypes might regress, and other traits can proliferate due to phenotypic plasticity or, if heritable, due to human-induced evolution. These changes are likely to decrease the ability of the target population to recover from high exploitation and occur at the cost of adaptation to the natural environment (Allendorf & Hard, 2009; Conover & Munch, 2002; Heino et al., 2015; Kuparinen & Merilä, 2007; Law, 2000; Rhoades et al., 2019; Stokes & Law, 2000).

Mismanaged commercial fisheries represent a prime example of the devastating consequences of intense selective harvest. Repeated overfishing of large long-lived piscivores of high trophic level has caused a global fish crisis with stock collapses (Hilborn et al., 2003; Hutchings, 2000; Jackson et al., 2001; Myers & Worm, 2003; Pauly et al., 1998) and altered community structure through trophic cascades with negative effects on ecosystem functioning and socioeconomical values (Casini et al., 2009; Fauchald, 2010; Frank et al., 2005). Moreover, size-selective harvest of numerous fish stocks, even at moderate levels of exploitation, has decreased the average size and age, leading to reduced yield and population instability (Anderson et al., 2008; Berkeley et al., 2004; Hsieh et al., 2006; Jackson et al., 2001; Svedäng & Hornborg, 2014; Swain et al., 2007).

In addition to commercial fisheries, many fish populations are subjected to intense recreational fisheries with rod-and-reel, i.e. angling (Hyder et al., 2018). With several hundred million practitioners worldwide, recreational fishing now constitutes the dominant use of inland fish stocks (Arlinghaus et al., 2021; Cooke & Cowx, 2004). Logically, there is a growing concern that high and selective mortality from angling has similar deteriorating effects on fish populations and ecosystems as commercial fisheries (Lewin et al., 2006, 2019; Post, 2013; Post et al., 2002). As data on angler catches and associated fisheries-independent (monitoring) surveys of exploited populations are generally lacking, the size and species selectivity of recreational fisheries can be difficult to quantify (Lewin et al., 2006). Consequently, our understanding of the impact of recreational fisheries is limited compared to scientifically assessed commercial fisheries (Arlinghaus et al., 2002; Lewin et al., 2006; Post et al., 2002; Radford et al., 2018; Sutter et al., 2012). Assessing the impact of recreational fisheries is further complicated by the common practice of catch-and-release (hereafter C&R), i.e. when all or some of the captured individuals are released back in the water (Arlinghaus et al., 2007; Bartholomew & Bohnsack, 2005; Cooke & Schramm, 2007). The prevalence of C&R, regardless of whether it is voluntary or mandatory, varies significantly across cultural as well as national boundaries and differ according to target species and traits (Arlinghaus et al., 2007). C&R may refine selectivity and hence depending on when and for what reason applied,

may either aggravate ecological effects, or on the contrary, protect vulnerable species or size classes (Sass & Shaw, 2020).

Increased smartphone and computer usage during the last decades combined with development of software's specifically directed to anglers present a novel opportunity for more comprehensive data collection and understanding of angler behaviour (Gundelund et al., 2020; Lennox, Sbragaglia, et al., 2022; Skov et al., 2021; Venturelli et al., 2017). As a model system to quantify angling selectivity and investigate whether and how this may be modulated by C&R practices, we here take advantage of an extensive database of more than 200,000 angler catch reports from Swedish recreational inland fisheries and relate it to monitoring (fisheries independent) data on the associated fish communities. To this end, we first compared relative species abundance and the trophic level of angling catches to monitoring data across 62 distinct fisheries (lakes) where data overlapped. Next, we assessed size selectivity of these fisheries on European perch (hereafter perch, *Perca fluviatilis*, Percidae) and pikeperch (*Sander lucioperca*, Percidae), two predatory focal species in the fisheries. Finally, we explored the effects of C&R practices on selectivity by disentangling angler harvest from angler catch (including released fish) in all analyses. The results provide quantitative and robust estimates of species and size-selective harvest in recreational fishing with implications for management of stocks targeted by rod-and-reel fisheries.

2 | MATERIALS AND METHODS

2.1 | Angling data

Data on angler species-specific catch (number of individuals and weight of catch in kg), fate of catch (harvested or released), fishery (lake), date and gear use were obtained from catch reports

submitted to the online fishing license sales platform iFiske AB (https://www.ifiske.se/). In Sweden around 2000 local organisations (i.e. fisheries), typically fishing conservation area associations (called fiskevårdsområdesföreningar, FVOF, in Swedish), hold and manage the legal fishing rights to almost all lakes and streams. The platform iFiske administer the sale of fishing licenses for numerous local organisations and is the largest distributor of digital fishing licences in Sweden. They actively encourage their customers to send in digital catch reports and for each sold fishing license an automatic reminder requesting a catch report is sent out to the customer (in 2020 iFiske received an average of 0.25 reports per sold fishing license). The angler decides if reports should be public or not. For this study, we utilised all reports (public and non-public), fully anonymised, available through a collaboration with iFiske. The complete angling dataset from iFiske included 200,684 reports of 408,788 fish caught in Swedish inland waters between 2011 and 2020 distributed over 783 local organisations. Most fish were caught by rod and line (e.g. lure and fly fishing). However, 4% of reported catches (in number of individuals) were fished with passive gears (e.g. gill nets, longlines, and fyke nets), i.e. not angled, and therefore excluded from analyses.

2.2 | Monitoring data

Monitoring data come from the national database for standardised survey fishing with Nordic multi-mesh gillnets (National Register of Survey Test-Fishing – NORS, 2021), a well-established method for estimating species and size composition of northern European fish communities (Appelberg, 2000; Appelberg et al., 1995; Deceliere-Vergès et al., 2009). Data included species-specific catches (number of individuals and individual body lengths) as well as methodological details of the survey fishing and lake metadata for 842 Swedish temperate lakes monitored between 2010 and 2020. Catch data from Nordic multi-mesh gillnets (benthic bottom-set gillnets and pelagic free-floating gillnets) according to the standard Swedish method for freshwater fish (see Appelberg, 2000 for detailed method description; CEN, 2005) were selected for this study and non-standardised data were excluded. The standardised method uses a random sampling regime, performed over the whole lake within fixed depth strata. The number of gillnets is determined according to the size and maximum depth of each lake and gillnets are composed of 12 different mesh-sizes ranging between 5 (6.25 for pelagic gillnets) to 55 mm knot to knot.

2.3 | Selection of fisheries

The software R 4.2.2 (R Core Team, 2022) through RStudio 2022.12.0.353 (RStudio Team, 2022) was used to identify and select lakes that were included in both datasets and for all statistical analyses. Merging and filtering of data were conducted in R using the dplyr package (Wickham et al., 2023). Small Swedish

lakes are typically managed jointly with additional waters by a single local organisation, and consequently, catch reports from such waters cannot be linked to specific lakes. Lakes with an area <15,000 m^2 were therefore excluded from the initial lake selection (number of lakes in the monitoring dataset was reduced from 842 to 128). Remaining lakes were matched to the angling dataset resulting in 113 lakes where both monitoring and angler catch data were available. Among these, 78 were managed by distinct local management organisations, each covering the entire lake (constituting at least 90% of the water area). Therefore, we considered each of these lakes as distinct fisheries. Two adjacent lakes, both having monitoring data from the same years, were managed by a single local organisation and, consequently, we merged monitoring data and treated the two lakes as a single fishery in the analyses. At last, fisheries with fewer than 100 reported angling catches were excluded from the selection to improve the overall quality of catch data, resulting in a total of 62 fisheries included in the analyses (Figure 1). For these fisheries, prior to further data filtering, monitoring data contained 197,002 caught individuals of 25 species and angling data contained 60,451 catches of 29 species (see Table S1 for details about the most common species in angler catches).

2.4 | Data filtering

Only complete reports of angler catches, without missing information, were included in analyses. Angler and monitoring catches were pooled over ten years under the assumption that species composition, relative abundances, and within species size structures did not vary significantly within-fishery among years to bias comparisons between datasets (see Table S2 for fishery specific details on the extent of angling and monitoring data). Similarly, we assumed that no large-scale changes had occurred across fisheries and over the study period in fish communities or in angler behaviour that significantly biased the comparisons. The standardised monitoring method has proven to be robust, consistently producing comparable estimates of community structure and size distributions over at least four years (Holmgren, 1999). However, certain species, such as Northern pike (*Esox lucius*, Esocidae), burbot (*Lota lota*, Lotidae), European eel (*Anguilla anguilla*, Anguillidae) and bullhead (*Cottus* spp., Cottidae), are not caught representatively in gillnets due to their morphology and/or behaviour (Appelberg, 2000; Holmgren, 1999). To avoid potential bias resulting from selectivity in the monitoring data, all catches of these species were removed prior to analyses. Similarly, juvenile fish, owing to their small size (<60 mm), consistently show underrepresentation in gillnet catches (Appelberg, 2000; Holmgren, 1999; Olin & Malinen, 2003; Prchalová et al., 2009). Adopting a conservative approach, individuals measuring <60 mm were excluded from the analyses, accounting for approximately 4% and 1% of the monitoring and angling datasets, respectively. To identify these fish in the angling dataset, we first estimated body
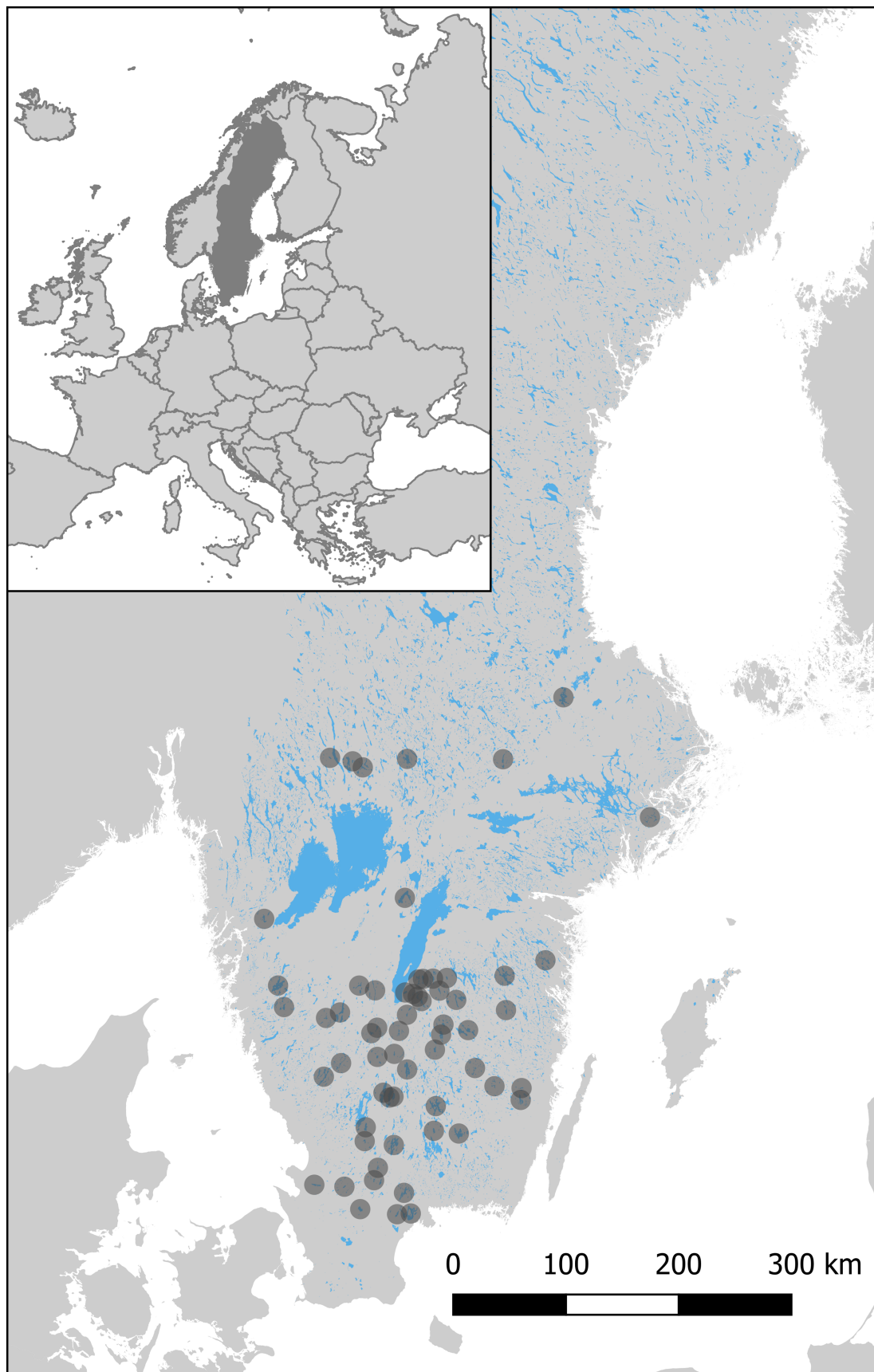
FIGURE 1 Map of the 62 fisheries (lakes) in Sweden, northern Europe (inset), where data from both monitoring (2010–2020) and digital angling catch reports (2011–2020) overlapped and could be included in the study.

length from reported body mass using conversion factors with species-specific constants based on power functions of historical length and mass monitoring data of fish in Swedish waters (see Table S3 for species-specific conversion factors).

Anglers often caught several individuals of the same species and reported the total mass together with the number of caught individuals of the species-specific catch (~50% of reports were of combined body mass after excluding zero catch reports). Smaller individuals and released fish are disproportionately represented in combined catch reports, thus to achieve a representative species and size distribution of angler catch, these reports were included in analyses. Individual body mass from combined reports were calculated as averages and estimated as individual body length according to the power function. Angling selectivity was explored by structuring catch data into a categorical predictor variable with the following levels: monitoring data, angler catch (harvested and released fish) and angler harvest (harvested fish).

2.5 | Data analyses

The overall percentage of released fish was determined for all angled fish included in analyses.

Mean trophic level of captured individuals per fishery were compared between monitoring data, angler catch and angler harvest using the nonparametric Friedman test, followed by Bonferroni's post hoc test (alpha level of .05 was used in all statistical tests). Species-specific trophic levels were obtained from FishBase (Froese & Pauly, 2014; see Table S3) and weighted by the number of individuals per species. The trophic levels in FishBase have been estimated from diet composition data of several studies as the mean trophic level of individual food items, plus one, and corresponds adequately to trophic levels determined from stable isotopes (Carscallen et al., 2012; Mancinelli et al., 2013). Piscivorous fish switch diet during their life cycle and typically begin life feeding on invertebrates (Mittelbach & Persson, 1998). Perch and pikeperch are such species that undergo ontogenetic niche shifts (Ginter et al., 2011; Hjelm et al., 2000; Mittelbach & Persson, 1998; Vašek et al., 2018). Consequently, we assigned different trophic levels for juvenile and adult perch (cut-off value at 20 cm: Hjelm et al., 2000) and pikeperch (cut-off value at 10 cm: Ginter et al., 2011; Vašek et al., 2018) based on diet studies of life stages obtained from FishBase.

Species selectivity was explored by predicting species-specific relative catch proportions per fishery for monitoring data, angler catch and angler harvest. Since not all species were present in all fisheries, we fitted separate generalised linear mixed models (GLMMs) with a binomial distribution and a logit-link function in the lme4 package (Bates et al., 2015) for each species with maximum likelihood as estimation method (Laplace approximation). We restricted analyses of relative catch proportions to species that were present in numerous fisheries (≥20), which resulted in nine species. The response variable was the number of individuals of the focal species out of the total number of individuals in the catch. The

grouping variable, including monitoring data, angler catch, and angler harvest, was treated as an explanatory variable and the fisheries in which focal species were present as random effect (allowing intercepts to vary across fishery). As deviance was high in relation to residual degrees of freedom, we added an observation-level random effect (OLRE) to handle the overdispersion observed in the initial models (Harrison, 2014; Harrison et al., 2018).

The size distribution of perch and pikeperch in the monitoring data, angler catch and angler harvest is descriptively presented as histograms with medians (Figures 4a,b and 5a,b). Please note that the body size of perch and pikeperch in angler data was estimated according to the power function. To increase the explanatory power of the models, we excluded fisheries in which we had <100 angler catches of perch and pikeperch resulting in 50 and 22 fisheries, respectively. Size selectivity was examined by comparing median body size per fishery between monitoring data, angler catch and angler harvest using the nonparametric Friedman test followed by Bonferroni's post hoc tests.

Further, the association between size and C&R practice in perch and pikeperch was analysed with generalised additive mixed models (GAMMs) with a binomial distribution and a logit-link function, fitted with the mgcv package (Wood, 2011) and estimated using restricted maximum likelihood. We fitted the fate of individual fish (a binary factor, harvested or released) as the response variable, fish size (cm) as an explanatory variable with a smooth function (thin plate splines, $k = 5$) and, the fishery, in which focal species were present, as a random effect smooth function.

All GLMMs and GAMMs were checked for overdispersion in simulated residuals using the DHARMa package (Hartig, 2022). Predictions adjusted for non-focal terms (random effect of fisheries) were computed using the ggpredict() function in the ggeffects package (Lüdecke, 2018) and reported in figures using the ggplot2 package (Wickham, 2016).

3 | RESULTS

3.1 | Trophic level and species selectivity

The overall proportion of released fish in angler catches amounted to 60% (25,231 out of 42,105 individuals; 426 fish were excluded due to unreported fate).

Fish of high trophic level were over-represented in the catch (trophic level: 4.16 ± 0.18, mean ± SD) and harvest (4.16 ± 0.20) compared to monitoring data (3.45 ± 0.13; Friedman, $N = 62$, $\chi^2 = 94$, $p < .001$; post hoc Bonferroni adjusted $p < .001$, Figure 2). There was no difference in trophic level of the angler catch and harvest (post hoc Bonferroni adjusted $p = 1$).

Analyses of species selectivity showed that the predatory species perch and pikeperch were over-represented in angler catch and harvest compared to monitoring data (Table 1, Figure 3). Contrary, non-predatory species roach (*Rutilus rutilus*, Cyprinidae), ruffe (*Gymnocephalus cernua*, Percidae), vendace (*Coregonus albula*, Salmonidae), bleak (*Alburnus alburnus*, Cyprinidae), common bream
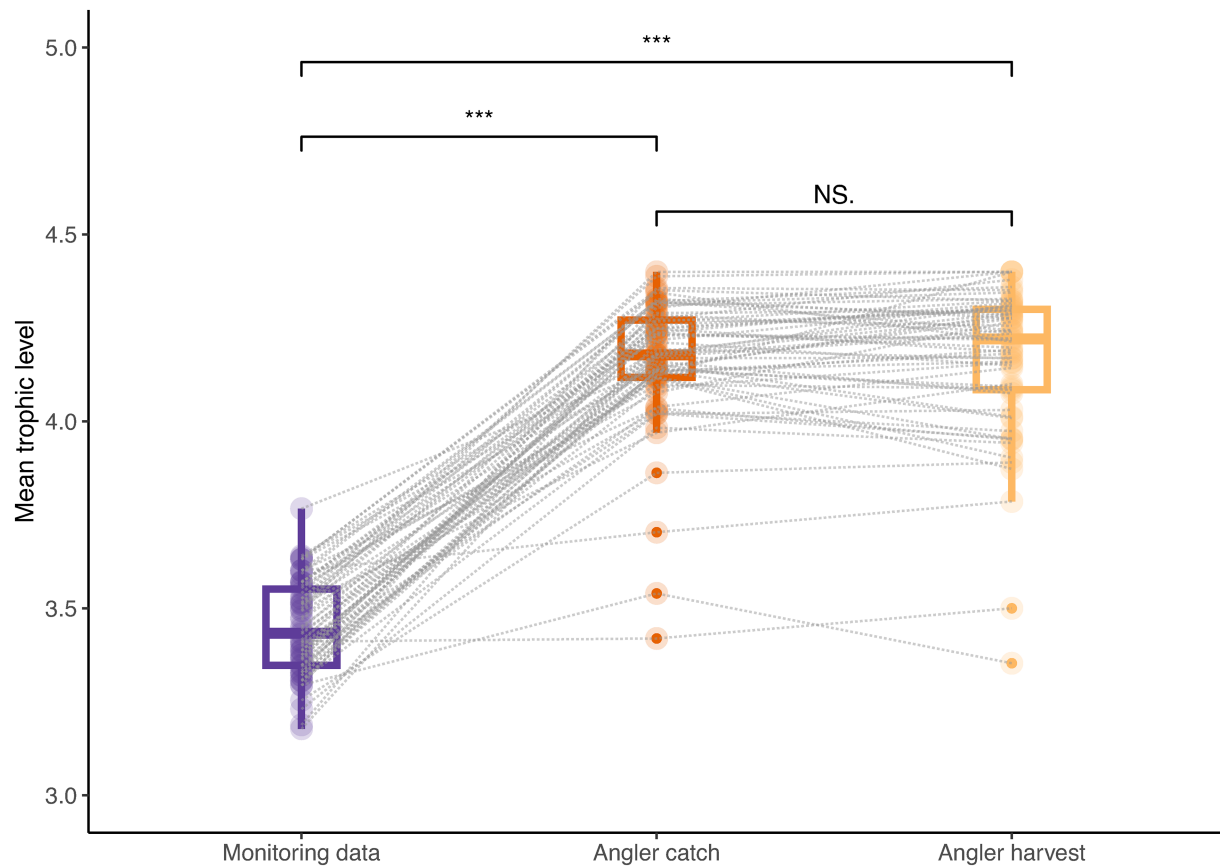
FIGURE 2 Mean trophic level of catch per monitoring data, angler catch, and angler harvest. The solid lines within the boxes indicate medians, the boundaries of the box indicate 25th and 75th percentiles, and whiskers below and above extend from the box to the lowest or largest value no further than 1.5 * the interquartile range, respectively. Data beyond whiskers are outliers. Dashed lines illustrate paired fisheries. Significant difference between groups is indexed according to alpha levels: <.001 = *** and >.05 = NS.

TABLE 1 Summary of species selectivity models comparing selectivity in monitoring data and angler harvest in relation to that in angler catch.

Model (species)	N (fisheries)	Monitoring data (angler catch as intercept)			Angler harvest (angler catch as intercept)		
		Coef.	Std. error	p	Coef.	Std. error	p
European perch	62	**−1.51**	0.19	**<.001**	−.07	0.20	.73
Roach	62	**2.62**	0.18	**<.001**	−.12	0.20	.53
Ruffe	51	**5.69**	0.39	**<.001**	−.07	0.52	.89
Vendace	41	**6.24**	0.64	**<.001**	−.74	1.17	.53
Bleak	43	**4.02**	0.50	**<.001**	.51	0.55	.35
Pikeperch	45	**−2.67**	0.15	**<.001**	.001	0.15	.99
Common bream	52	**1.39**	0.25	**<.001**	−.24	0.29	.41
Rudd	29	**1.19**	0.46	**.009**	−.34	0.61	.57
Tench	22	.55	0.60	.36	−1.41	1.17	.23

Note: Model summary per species with the number of fisheries (*N*) that were included in each model and the statistics (estimated coefficient, its standard error, and *p*-value) for fixed effects (monitoring data and angler harvest) with angler catch as reference category (intercept). Bold values highlight significant results.

(*Abramis brama*, Cyprinidae) and rudd (*Scardinius erythrophthalmus*, Cyprinidae) were under-represented in angler catch and harvest, whereas tench (*Tinca tinca*, Cyprinidae) was captured in similar proportions as observed in monitoring. The relative catch proportions in angler catch, in comparison to angler harvest, were consistent across all species.
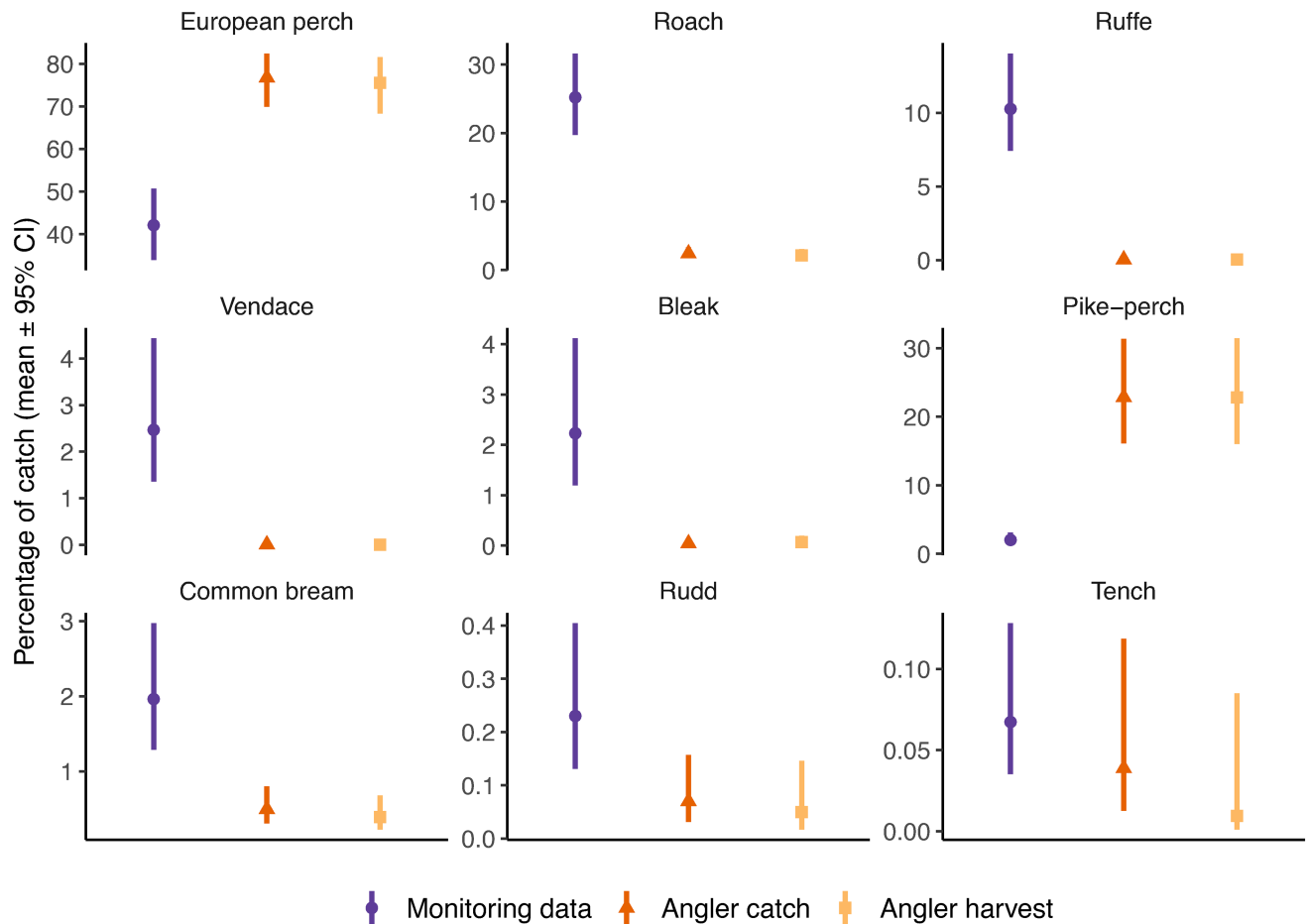
FIGURE 3 Catch proportions (mean and 95% CI) per monitoring data, angler catch, and angler harvest. Predictions from species-specific GLMMs adjusted for random effect of fisheries. Panels are ordered from top left to bottom right according to monitoring catch proportion (note the different scales on the *y*-axis).

3.2 | Size selectivity in perch and pikeperch

Monitoring data exhibited a positively skewed size distribution with more small than large individuals of both perch (Figure 4b) and pikeperch (Figure 5b). However, the size distribution of angler catch and harvest was dome shaped in both species (Figures 4a and 5a). Consequently, median size (cm) per fishery was lowest in monitoring data (perch: 11.0 ± 2.62 mean and 95% SD; pikeperch: 24.8 ± 8.12), considerable higher in angler catch (perch: 23.2 ± 2.82; pikeperch: 47.6 ± 3.72) and highest in angler harvest (perch: 24.4 ± 3.64; pikeperch: 53.7 ± 3.81). Median size per fishery differed significantly in all pairwise comparisons between monitoring data, angler catch, and angler harvest for both perch (Figure 4c; Friedman, $N = 50$, $\chi^2 = 83$, df = 2, $p < .001$; post hoc Bonferroni adjusted $p < .01$) and pikeperch (Figure 5c; Friedman, $N = 22$, $\chi^2 = 44$, df = 2, $p < .001$; post hoc Bonferroni adjusted $p < .001$).

The proportion of perch that were released decreased with size until a threshold of ~35 cm, then the release rate was relatively stable (Figure 4d; GAMM: Edf: 4.48, $\chi^2 = 430$, $p < .001$). The proportion of released pikeperch was high and relatively constant until a threshold of ~45 cm, then the release rate decreased with size until a second

threshold of ~60 cm, then increasing again (Figure 5d; GAMM: Edf: 4.96, $\chi^2 = 1858$, $p < .001$).

4 | DISCUSSION

This study addresses a significant gap in our understanding of the selective nature of recreational fisheries. By utilising over 60,000 digital angling catch reports encompassing 62 distinct fisheries (lakes) coupled with fisheries independent standardised monitoring data of the species and size composition of focal fish communities, we show that recreational fishing exhibits a marked preference for adult top-predatory fish. That recreational fisheries selectively capture and harvest large predators align with the selectivity observed in commercial fisheries (e.g. Myers & Worm, 2003, 2005; Pauly et al., 1998). The practice of C&R did not substantially modify this selectivity. However, the larger size of harvested perch and pikeperch, compared to the total catch, suggests that C&R contributes to a slightly increased selection for larger-sized fish. Despite this nuanced change in selectivity, C&R influence fish population dynamics and demography by reducing overall harvest (Sass & Shaw, 2020).
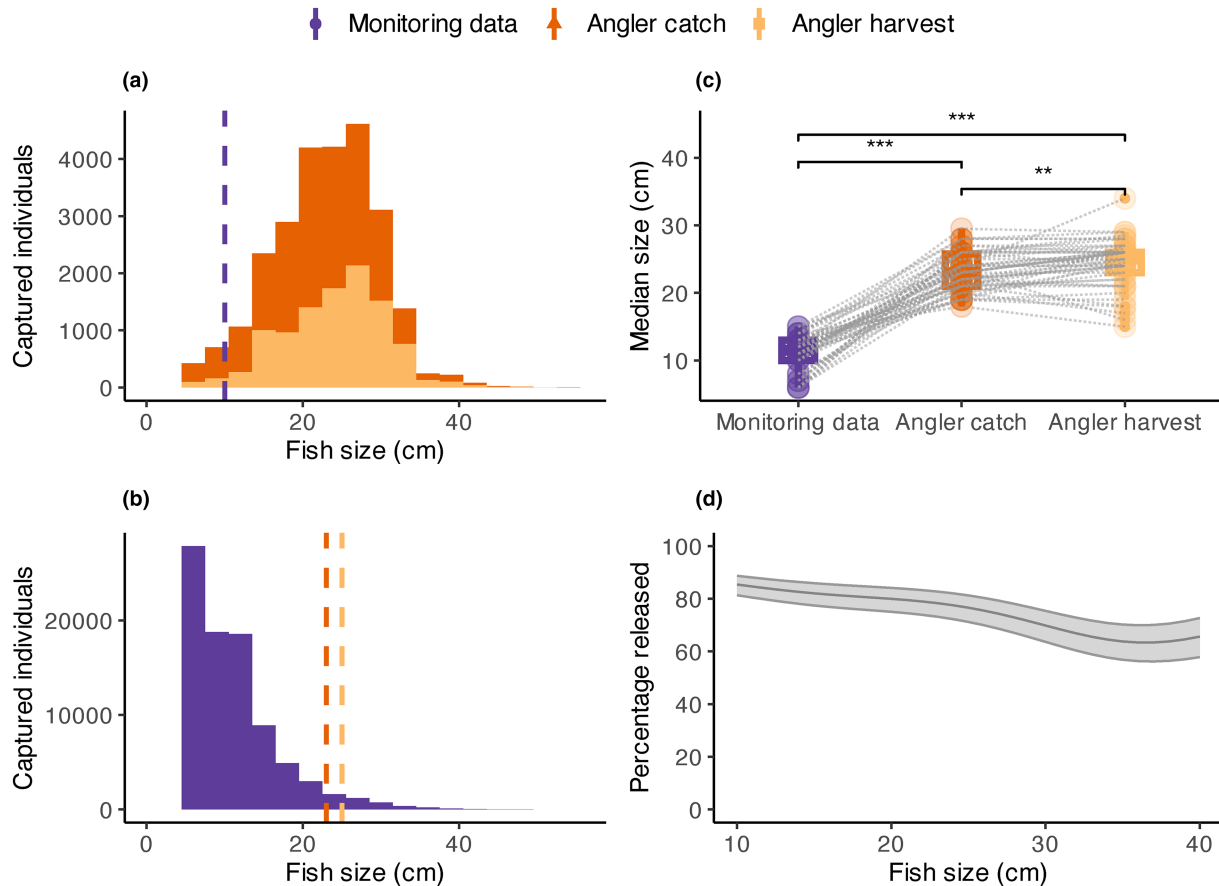
FIGURE 4 Size selectivity within European perch. Left panel shows distributions of caught individuals according to body size as histograms (bin size=3, median values represented by vertical dashed lines) grouped by angler (a) and monitoring data (b). Right panel shows median size per fishery and per monitoring data, angler catch, and angler harvest ((c), see Figure 2 for explanation of the boxplots, significant difference between groups is indexed according to alpha levels: <.01 = ** and <.001 = ***) and the percentage of fish released ((d), mean and 95% CI) in the angler catch according to size as predicted from a GAMM adjusted for random effect of fisheries.

These results underscore the potential local impact of the globally rising popularity of recreational fishing (Arlinghaus et al., 2019). The implications extend beyond individual fish populations, potentially influencing broader ecosystem dynamics and even the long-term demographic trends of various species by exerting a selective pressure capable of altering the evolutionary trajectory of fish populations (Heino et al., 2015). Given these findings, we urge fisheries managers to develop strategies to address the evolving challenges posed by recreational fishing.

Many fish stocks around the globe suffer from overexploitation leading to impaired productivity and altered demography which may ultimately weaken their viability and negatively impact ecosystem functioning and services (Hilborn et al., 2020; Hutchings, 2000; Jackson et al., 2001; Lennox, Brownscombe, et al., 2022; Neubauer et al., 2013). Such effects have typically been attributed to intense and phenotypic-selective harvest by commercial fisheries, but evidence is mounting that similar effects may also arise in stocks exploited by recreational rod-and-reel fishing (Monk et al., 2021; Post et al., 2002; Sutter et al., 2012). A key challenge for advancing our understanding, and aiding successful management, of selectivity in recreational fisheries lies in the scarcity of data linking angling captures

and harvest to the species and size composition of fish communities. In this study, we circumvented this challenge by combining extensive angling capture and harvest data from digital fishing reports with standardised monitoring data. While fisheries-dependent data may suffer from sampling bias due to attitude differences among anglers in sharing captured fish on the internet and the undocumented reliability of reports, our data do not originate from data mining, such as social media mining, but rather from reports (including non-public ones) submitted by anglers who purchased digital fishing licences. Nevertheless, the willingness and knowledge required to report true catches in a precise manner may still be biased; factors such as avidity or recall bias could potentially lead to overestimation of trophy fish or underestimation of smaller individuals (Lennox, Sbragaglia, et al., 2022), thereby possibly influencing our results by overestimating angler selectivity. However, the sheer volume of data, in terms of the number of reports, participating anglers, and distinct fisheries, suggests high reliability and generality of the patterns in angling captures and harvest (Gundelund et al., 2020; Lennox, Sbragaglia, et al., 2022; Skov et al., 2021). This is further supported by the fact that iFiske facilitates user-friendly reporting through digital means such as computer/mobile, automatic reminders following fishing
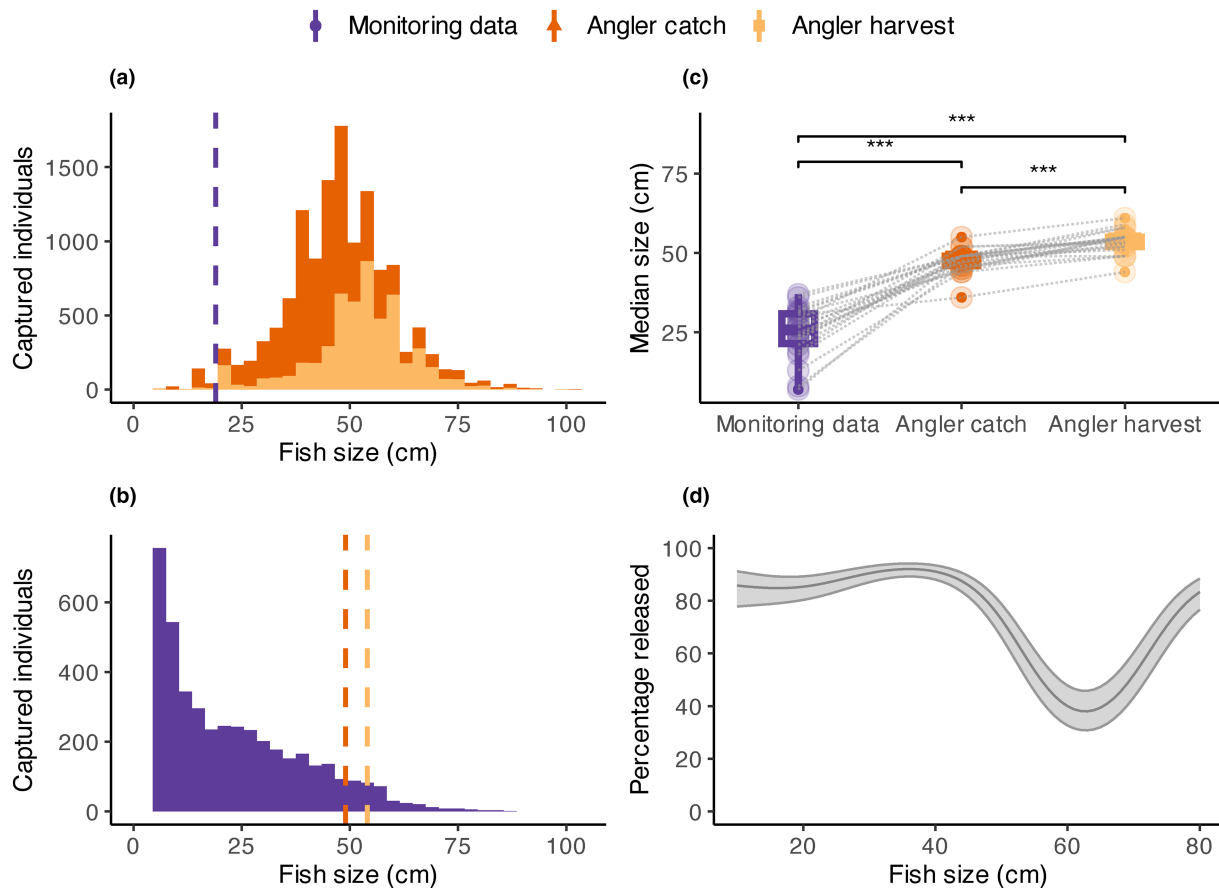
FIGURE 5 Size selectivity within pikeperch. Left panel shows distributions of caught individuals according to body size as histograms (bin size = 3, median values represented by vertical dashed lines) grouped by angler (a) and monitoring data (b). Right panel shows median size per fishery and per monitoring data, angler catch, and angler harvest ((c), see Figure 2 for explanation of the boxplots, significant difference between groups is indexed according to alpha levels: <.001 = ***) and the percentage of fish released ((d), mean and 95% CI) in the angler catch according to size as predicted from a GAMM adjusted for random effect of fisheries.

events, and that a high proportion of reports (~22%) were 0-catches. Ecological monitoring data may also suffer from sampling bias and to this end we relied on the Swedish standardised gill-net surveys. This method generates reliable estimates of the species and size composition of freshwater fish communities, with the exception of only a few species (e.g. pike, see methods), which were excluded from the analyses (Appelberg, 2000; Holmgren, 1999).

Our findings demonstrate that recreational fisheries exhibit strong selectivity, specifically targeting and capturing species positioned high in the food web, essentially top predators, disproportionate to their natural occurrence. Moreover, this selectivity extends to the size of the catches, revealing a distinct preference for larger individuals. While the common practice of targeting large predators by anglers has been observed in numerous fisheries, reflecting either consumption or trophy-seeking behaviour (Beardmore et al., 2011; Cooke et al., 2018), and its implications extensively discussed in the scientific literature (e.g. Coleman et al., 2004; Lewin et al., 2006 and references therein), our study marks the first explicit investigation into angler selectivity, offering quantitative insights by systematically comparing catches against the natural species and size distributions across replicated fisheries.

Top predatory species are inherently low in abundances and biomass compared to lower trophic level species, still they often constitute the prime target within fisheries. This poses a particular challenge due to extended recovery times resulting from their long generation time (Conover et al., 2009) and their frequent role as keystone species that structure aquatic food webs and impact ecosystem functioning (Woodward et al., 2005). While our study highlights strong selectivity in recreational fisheries, the extent to which this affects fish populations and aquatic ecosystems, akin to the effects observed in commercial fisheries, depends on the harvest rate and fishing pressure. Addressing this question urges, in addition to our data on selectivity and fish community composition, estimates of total effort in each fishery to assess the harvested biomass. Unfortunately, due to data limitations, this aspect is beyond the scope of our current study. Nevertheless, the observed selectivity underscores the potential local impact on fish populations and the functioning of aquatic ecosystem. The extent of angler selectivity and its consequential impact also hinge on species- and size-specific fishing regulations, which may either enforce catch-and-release (C&R) policies or restrict fishing activities when certain thresholds are reached. Across the focal fisheries, there were generally limited

regulations, with most exceptions being rules exclusively targeting pikeperch, such as size restrictions and bag limits. Consequently, the relative catch proportions of pikeperch and the rates at which they were released based on size may reflect fishing regulations rather than angler attitudes.

The release of captured fish did not mitigate the selectivity of recreational fisheries. On the contrary, C&R practices tended to accentuate the selection for larger sized fish, primarily due to a higher incidence of smaller individuals being released. It is noteworthy, however, that the largest pikeperch were frequently subjected to release. In fact, pikeperch release rates exhibited characteristics akin to a slot-window, while perch did not, indicating species- and size-specific selectivity patterns in harvest. While the extent of voluntariness remains indeterminate, given that local fishing rules are fishery-specific, we interpret the presence of such a relationship as reflective of a conservative approach – aligning with a generally advocated management strategy (Ahrens et al., 2020). The rising trend of implementing regulations on the maximum size allowed for harvest, including the use of harvest slots, in the management of recreational fisheries suggests a growing recognition of the need for more specific C&R regulations. This may be essential to overcome selective harvest issues in recreational fisheries and prevent adverse impacts on fish stocks. If C&R maintains the fitness of released fish (Arlinghaus et al., 2007; Cooke & Suski, 2005; Flink et al., 2021), it becomes also imperative for reducing the overall harvest, thereby allowing for high fishing effort with a relatively low impact on the fish community. Our findings reveal that C&R practices led to a substantial reduction in harvest, underscoring the importance that best practices for C&R are developed and communicated to the angler community (Björkvik et al., 2023; Brownscombe et al., 2017) in order to reduce mortality and impacts on reproduction and other sublethal fitness consequences (Arlinghaus et al., 2007; Cooke & Suski, 2005).

To conclude, we highlight the potential of digital angling reports in advancing our understanding of recreational fisheries. In particular, the strong species and size selectivity of anglers. The observed pattern resembles the selectivity seen in commercial fisheries, emphasising that intense recreational fisheries risk having similarly adverse impacts on fish populations, ecosystem function and services, as known from mismanaged commercial fisheries. By selectively catching and harvesting top-predators, often keystone species sensitive to harvest due to their long generation time, high angling pressure may contribute to trophic cascades, change demographic parameters and lower age-at-maturity. While the practice of C&R did not mitigate species selectivity, it decreased harvest by 60%, reducing to some extent the overall consequences of recreational fisheries on fish stocks. Given the widespread popularity of angling, the findings of this study support the need to consider recreational fisheries selectivity and the potential negative impacts of high angling pressure in fisheries management.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY STATEMENT

Fully anonymised data and code are publicly available in the Dryad Digital Repository: https://doi.org/10.5061/dryad.m0cfxppbg (Flink et al., 2024).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.