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Carp angling: potential cultural ecosystem services and angler perceptions of a non-native species in Italy

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Freshwater ecosystems face increasing pressures from non-native species, including Common carp (*Cyprinus carpio*), which is considered one of the world's most damaging invasive species. Despite its documented ecological impacts, carp is an important target of recreational fisheries in many regions. Understanding the socio-economic and perceptual dimensions of carp fishing is therefore relevant to freshwater conservation and management. Using Italy as a nationwide case study, we investigated carp angler profiles, fishing behaviour, economic indicators, and perceptions of the ecological role of carp. An anonymous 24-question online survey yielded 911 valid responses from an estimated population of approximately 20,000 carp anglers. Factor Analysis of Mixed Data (FAMD) was used to identify gradients structuring angler profiles. Respondents were predominantly male (96.4% ± 1.2%), aged 25–45 years (60.3% ± 3.2%), with high-school education (60.8% ± 3.2%) and employed (89.7% ± 2.0%). Annual expenditure among weekly anglers averaged €5,085 ± 214. This expenditure may serve as a proxy for the potential economic value associated with the cultural ecosystem service of recreational carp fishing, although it does not constitute a full economic valuation. Most respondents (87.9% ± 2.1%) perceived carp as ecologically beneficial, contrasting with scientific evidence documenting negative effects on water quality, benthic communities, and native biodiversity. FAMD identified two main gradients: one distinguishing high-effort specialists fishing in lentic habitats from more opportunistic anglers in lotic systems, and another reflecting demographic and educational differences. Perceived ecological role showed only weak associations with fishing effort, indicating limited correspondence between species perception and behavioural investment. The results illustrate a socio-ecological paradox in which a non-native species can simultaneously generate cultural ecosystem services while exerting ecological impacts. The expenditure indicator captures a potential component of the cultural ecosystem service associated with carp fishing but does not account for ecosystem disservices linked to carp populations or their spread. These findings highlight the importance of considering recreational benefits and stakeholder perceptions alongside ecological impacts when addressing the management of non-native carp populations.

KEYWORDS
carp angler's dimension, carps, cultural ecosystem services, freshwater management, global invader species, recreational fisheries, socio-ecological indicators

1 Introduction

Freshwater, despite representing only 0.01% of the world's water and approximately 0.8% of the Earth's surface, are pivotal biodiversity hotspots (Dudgeon et al., 2006). These ecosystems are also threatened by multiple stressors, to the point that almost one-quarter of freshwater fauna is at risk of extinction (Sayer et al., 2025). In addition, recreational fishing substantially contributes to the global spread of aquatic non-native species (Yang et al., 2026).

The presence or arrival of a non-native fish species (sensu Soto et al., 2024) in a freshwater habitat is widely recognized by ecologists as detrimental to ecosystem functioning (Vitousek et al., 1996; Tarkan et al., 2015 and references therein). Nevertheless, ecological impact and societal perception do not always align, as these species might also be capable of offering a suite of cultural and provisioning ecosystem services (Arlinghaus et al., 2002; Sax et al., 2022; Costanza, 2024) or be considered naturalized (Clavero, 2022). However, public perceptions of species can potentially lead to misinformed management decisions (McDaniel et al., 1997; Estévez et al., 2015; Pope et al., 2016; Elwell et al., 2018).

Recreational fishing is a leisure activity relying on fish communities, therefore representing a cultural service of economic and socio-ecological importance (Morales-Nin et al., 2025 and references therein; Sbragaglia et al., 2025). On a global scale, recreational angling was estimated nearly 20 years ago to generate expenditures amounting to several billions of dollars, with the number of recreational anglers worldwide ranging from approximately 220–700 million individuals (Arlinghaus et al., 2017, and references therein). Scaling the phenomenon to Europe, Morales-Nin et al. (2025) reported that ~10% of population fish for leisure, highlighting its relevance not only economically (Arlinghaus and Mehner, 2003), but also promoting wellbeing and mental health (Pita et al., 2025).

The occurrence of carps among multiple freshwater habitats contribute to increase their catch rate among anglers, raising the paradox of a non-native species providing valuable ecosystem services. The capture of big carp in Europe gave aid to a complex socio-economic recreational phenomenon, nowadays spreading worldwide, called carp fishing (Arlinghaus and Mehner, 2003; Arlinghaus et al., 2017).

Carp is an umbrella terminology referring to a taxa composed of different breeds of the species *Cyprinus carpio* (Linnaeus, 1758) considered within the 100 world's worst invaders (Lowe et al., 2000). This species, along with the grass carp *Ctenopharyngodon idella* (Valenciennes, 1844), is also increasing in popularity among carp anglers worldwide. Indeed, since the 1950s a group of eclectic anglers in the UK started conceiving a specialized fishing technique, which using specific hardened bait (e.g., boilies) targeted the bigger specimens of this species (Arlinghaus and Mehner, 2003; Milardi et al., 2015; Imbert et al., 2022 and references therein). The capture of big carps, over 20kg, first in UK and over 30 kg few decades later across different lakes in Europe triggered the diffusion and inspired new tackle, giving aid to a complex socio-economic recreational phenomenon, nowadays spreading worldwide, called carp fishing (Arlinghaus and Mehner, 2003; Arlinghaus et al., 2017).

Additionally, carps belong to the top ten reared fish globally, with over 10 million tons produced mainly from inland aquaculture (FAO, 2024). Moreover, in Japan between the end of the 1700s and the 1800s, an additional socio-cultural and economic interest that persists to this day began, obtained via the artificial breeding of carps aimed at selecting specific ornamental traits (e.g., colors, size), named Koi carp farming (De Kock and Gomelsky, 2015). Their contribution to the fish farming sector and as a food source is an undeniable provisioning ecosystem service provided by these species.

However, the review conducted by Weber and Brown (2009), further implemented by the research of Vilizzi et al. (2015), gave a holistic overview of the main effects of the common carp on freshwater ecosystems. More recently, also the ecological role of the grass carp in a channels network has been pointed out (Milardi et al., 2020).

The management of the species has been addressed on a global level. Arlinghaus and Mehner (2003) acknowledged the rising interest in these species among carp anglers. They also suggested the reduction of carp biomass by angling to improve water quality and to maintain and improve aquatic ecosystem status in Germany, coupled with the protection of a smaller number of larger carp (trophy specimens) for the interests of anglers. The same authors also endorsed education programs targeting local fisheries managers and anglers to show the negative impacts of dense carp stocks, reporting how in the Netherlands, education courses succeeded in reducing stocking densities of carp (Walder and van der Spiegel, 1990). In the United States of America, where *C. carpio* is considered as a non-native species that negatively impacts habitat and water quality in lakes, different practical and selective removal strategies for carps have been implemented. Examples were the stocking of lakes with a small native predator of juvenile carps (Poole and Bajer, 2019), through pulsed commercial harvest (Colvin et al., 2012), or via extirpation using oral toxicants into corn-based baits (Poole et al., 2018). Recognizing the similar ecological impacts posed by *C. carpio*, Australia initiated research on a cyprinid herpesvirus as a potential biocontrol agent in 2008. This effort culminated in the National Carp Control Plan (NCCP), completed in 2022. The assessment indicated that viral biocontrol could potentially reduce national carp populations by 40%–80%, but it also highlighted uncertainties regarding the safety of viral release. Consequently, the NCCP recommended that additional research be conducted before any management decisions are made (Fisheries Research and Development Corporation, 2022). Also in Africa, despite being an economically important species through aquaculture farming in many countries such as Egypt (Mohammed et al., 2024), common carp management is primarily focused on controlling invasive populations through removal efforts, and preventing further spread (Ellender and Weyl, 2014).

The presence of carps among Italian freshwater has been described across the entire Peninsula (Volta et al., 2011 and references therein; Vilizzi et al., 2015; Milardi et al., 2022; Gavioli et al., 2023 and references therein). Nevertheless, timing and route of carp introduction is still under debate. Both the Roman and monastic domestication, as well as the Franco-Burgundian pond culture of the 12–13th Centuries were plausible, as outlined by Vilizzi (2015). Regional regulations govern the conditions under which professional inland-water fisheries can operate; however, despite a few remaining local culinary traditions, the commercial

demand for wild (non-farmed) carps remains negligible within the Italian gastronomic sector (Ittico BMTI, 2023). Furthermore, carp production is supported by a limited number of extensive or semi-intensive farms and, lately, carp rearing has been introduced into aquaponics systems (IZSVe and API, 2025). National legislation classified *C. carpio* as a para-autochthonous species, a category that includes taxa introduced and naturalized before 1500 AD and therefore counted among native species (Genovesi, 2007). However, from a biological and ecological perspective, which is the focus of this manuscript, carps are considered non-native, since speciation typically requires approximately 2 million years (Hedges et al., 2015). In addition, carp fishing targeted both *C. carpio* and *C. idella* (a non-native species), further supporting this choice.

It is therefore clear that researchers, stakeholders and politicians involved in effective and adaptive water basin management shared a high level of interest in these species, since the last 90 years, which is still actual (Vilizzi et al., 2015 and references therein; Stuart et al., 2021).

Whereas the negative impacts of non-native species on ecosystem services and human wellbeing have been widely assessed and valued, for example, in the case of carps (Chen et al., 2026; Pejchar and Mooney, 2009; Weber and Brown, 2009; Vilizzi et al., 2015), the role of carp angler and the potential benefits provided by non-native species in the broader context of managing freshwater ecosystems for their ecological functioning remain poorly explored (Sax et al., 2022). Evaluating these social benefits is necessary to prevent public backlash against control measures and ensure long-term policy compliance.

Thus, through a survey targeting Italy as a representative nationwide study case, this manuscript aimed to highlight both (1) the ongoing attractiveness of carp to anglers to the point to adopt a specialized fishing technique, as well as carp anglers' socio-cultural profiles, and (2) the potential positive ecosystem services provided by a cosmopolitan species non-native to Italy. It was therefore explored (3) the carp anglers' perceptions of carp's role in aquatic ecosystems and the appropriate ecological functioning of the latter.

2 Materials and methods

2.1 Study area

Italy (Southern Europe) covers a total area of 301,336 km^2, characterized by a highly heterogeneous climate, ranging from alpine conditions in the north to Mediterranean climates along the coasts and in the southern regions. This climatic variability, together with complex geomorphology, supports a wide diversity of hydrological systems. Across its territory, Italy hosts numerous and heterogeneous water bodies, including small channels, irrigation canals, reservoirs, pit lakes, rivers and lakes of different origins (Benedini and Rossi, 2021; Ghirardi et al., 2023).

The widespread presence and abundance of carps throughout Italy's inland waters coupled with the presence of ~20,000 carp anglers in Italy (L. Montanari, experienced carp angler, brand ambassador and reference contact of the biggest carp trade show in Italy, personal communication, 9 February 2025), determined Italy as a representative nationwide study case aligning with the scope of the manuscript.

2.2 Survey protocol and quantified metrics

After a preliminary bibliographic inspection, questionnaires emerged as an appropriate methodology to answer our research questions (Arlinghaus and Mehner, 2003; van der Hammen and Chen, 2020; Pita et al., 2025). Therefore, an anonymous and voluntary 24 single-answer questionnaire was designed as the means of data collection. The survey structure was arranged on previous examples in the literature (e.g., Morales-Nin et al., 2025). Before submission, questions were discussed and cross-validated by a team of ecologists, ecosystem service and socio-economic experts (M.Gaglio, personal communication). The survey encompassed an exploration of both demographic characteristics and the habitual practices of carp anglers.

In contrast to Arlinghaus and Mehner (2003), no incentives were provided to respondents. Although participation was voluntary and the sampling design was not strictly probabilistic (Vaske, 2019), the event-based approach ensured broad national coverage and substantial representation of the active carp fishing community. However, the explorative nature of the present work justified the approach (Vaske et al., 2025), often generally applied for understanding niche groups dynamics (Howarth et al., 2024). Following the successful administration protocol described by Arlinghaus and Mehner (2003), the distribution of questionnaires occurred in two distinct modalities: (1) during the Italian specialized tradeshow (https://www.carpparma.it/, 8–9 February 2025), which represents a primary gathering event for the Italian carp fishing community (2) through the online Survio platform (https://www.survio.com/it/, last access 30 April 2025). The dissemination of questionnaires was facilitated by the main national carp angling association (https://www.carpfishingitalia.it/) together with tradeshow staff.

To attribute value to a single ecosystem service offered by the suite of habitat considered in the study, i.e., carp fishing - thus indirectly given by carps - we calculated a simple and effective comparable indicator reflecting it. It is worth underlying that this indicator does not account for the ecosystem disserveces generated, which calculations was out of the scope of this manuscript. The calculation of the average annual *per capita* fishing expenses (APE, Euro person^{-1} year^{-1}) was computed by converting the expenditure categories (see Question No. 14 in Supplementary Material: Supplementary Figure S2) into midpoint values (in Euro) per session, whereas fishing frequency was converted to annual sessions (days year^{-1}). Therefore:

$$APE = Annual\ sessions * Euro\ spent\ per\ session$$

The bait cost represented a fraction of APE's indicator and is calculated on the average *per capita* fishing bait expenses afforded by each respondent per fishing session (BC, Euro person^{-1} fishing session^{-1}). Indeed, the average quantities of bait (kg, e.g., boiles, particles, pellets, groundbait) used for baiting in a 24 h fishing session (see Question No. 16 in Supplementary Material: Supplementary Figure S2) were converted to midpoint values (in kg), whereas an average price of 7.00 Euro was set as a reliable price

for 1 kg of bait mix (e.g., boilies, seeds, pellets, ground bait), based on market costs. Therefore:

$$BC = 7.00 * Kg\,of\,bait\,per\,session$$

The investigation further examined the economic implications of this practice and the perceptions of anglers regarding the role of carps in relation to the species of fauna and flora that coexist within aquatic ecosystems (see Supplementary Material: Supplementary Figures S1, S2).

Willingness to pay (WTP) is defined as the maximum amount an individual is prepared to give up in income to secure a good or service or to avoid its loss (Carson, 2012; Hanemann, 1994). WTP is an indicator widely used in ecosystem-service valuation due to its capacity to include aspects such as use, non-use, existence, and inheritance values into total economic value (Gaglio et al., 2024), as well as to provide a monetary metric compatible with cost-benefit analysis and environmental accounting (Costanza et al., 1997; Drupp et al., 2024; Scheufele et al., 2025; Kumar, 2012 and references therein). The approach is distinguished by its flexibility, wide applicability to a wide range of non-market ecosystem services, and grounded in welfare economics, reflecting individual preferences. However, WTP has several limitations. Estimates may suffer from hypothetical bias, scope insensitivity and embedding effects, as well as income constraints that may undervalue benefits for lower-income populations. Survey design choices, including scenario framing and payment vehicles, can systematically bias responses, while certain irreplaceable ecological functions may simply resist meaningful monetary valuation by respondents (Arrow et al., 1993; Carson, 2012; Kumar, 2012).

A deeper conceptual issue is that WTP-based valuation of common goods assumes purely self-interested preferences, which tends to overlook fairness, distributive justice, and social context, with respondents typically assigning higher value to ecosystem services from which they personally benefit (Mossone, 2019).

Nevertheless, we deemed valuable to consider WTP indicators in our research, by asking carp anglers if, and if so, which categories of expenditure they would have been willing to pay -lump-sum payment - for: (a) the conservation of the overall fish community, and specifically of carps in their fishing spot, and (b) the conservation of their fishing site, keeping this last question general to assess if carp anglers care just about carp or also about the site where they fish (see Supplementary Material: Supplementary Figures S1, S2).

2.3 Statistical analysis

When the assumptions were met, including data normality assessed through plotting residuals and homogeneity of variance evaluated using Levene's test, a one-way analysis of variance (ANOVA) was used to examine differences in APE of respondents among reported fishing frequencies. The same statistical test was used for differences in BC among both respondents' educational qualification and habitat type chosen for fishing session respectively. Afterwards, Tukey HSD *post hoc* tests were used to identify statistically significance differences among pairwise comparisons.

Annual Per Capita Expenditure (APE) was calculated yielding a continuous monetary proxy. This continuous variable was used in the Factor Analysis of Mixed Data (FAMD). For chi-square tests of independence involving APE, a categorical version was derived by binning the continuous variable into five ranges (€0–1,000; €1,000–2,000; €2,000–5,000; €5,000–10,000; €10,000–15,600), spanning the observed range of the variable in the dataset. This categorical version of APE was used exclusively for chi-square analyses and does not replace the continuous variable used elsewhere in the manuscript.

To analyze whether there was a significant association between categorical variables, chi-square tests of independence were applied. To identify the cells that contributed most to the chi-square statistics, standardized residuals were examined; values with absolute magnitude greater than 2 were considered to indicate a significant contribution (Agresti, 2007).

Furthermore, mixed data factor analysis (FAMD) enabled the analysis of similarity between mixed types (quantitative and qualitative) of variables. Variables with a variance inflation factor (VIF) < 5 were selected for the analysis, while different combinations were discarded to avoid multicollinearity issues (Menard, 2001; James et al., 2013).

FAMD variable selection was also based on obtaining a cumulative percentage of the proportion of variance retained by the different dimensions of ~20–40%, a commonly accepted threshold when addressing mostly categorical data (Pagès, 2004). These were: age category of respondents (Age), average kg of bait used per session by the carp angler (Aver_bait), carp anglers' perception of the effect of carp in aquatic ecosystems (Carp_role), educational attainment of respondents (Education), APE (Expenditure), habitat preference for fishing (Habitat), and session duration in hours (Session_span). Breakages of "Session_span" were set based on a preliminary pool of 4 expert-based judgements on average fishing session duration. Ordered categorical variables (Age, Aver_bait, Carp_role, Education, and Session_span) were treated as qualitative variables in the FAMD framework, allowing the analysis to respect their ordinal nature without imposing metric assumptions about distances between categories (Pagès, 2004). The categorical variable <Habitat> and continuous variable <APE> completed the seven-variable model.

Quantitative and qualitative variables were normalized during the analysis to balance the influence of each set of variables. All analyses and graphs were performed using R v. 4.4.1 software (R Core Team, 2022).

3 Results

3.1 Survey response rate and characteristics of Italian carp anglers

Data collection in 2025 concluded after three consecutive weeks without additional responses. In total, 911 valid questionnaires were obtained over a period of approximately 3 months. One response provided by a Dutch carp angler during the tradeshow was excluded from analysis. Among respondents, affiliated with a national angling association, 79.1% completed the questionnaire via the online platform, while 20.9% were interviewed during the tradeshow. To

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TABLE 1 Categorization of demographic characteristics and features of respondents.

Demographic characteristic					
Gender	Male	Female	ND[a]		
%[b]	96.4 ± 1.2	3.4 ± 1.2	0.2 ± 0.4		
Age class	5–16	16–25	25–45	45–65	>65
%[b]	1.4 ± 0.8	9.2 ± 1.9	60.3 ± 3.2	27.8 ± 2.9	1.3 ± 0.8
Employment status	Student	Employed	Unemployed	Retired	
%[b]	4.1 ± 1.3	89.7 ± 2.0	3.1 ± 1.1	3.1 ± 1.1	
Education	None	Middle school	High school	Degree or higher	
%[b]	1.1 ± 0.7	24.7 ± 2.8	60.8 ± 3.2	13.5 ± 2.2	
Carp angler features					
Fishing habitat preference	Canal	Dam	Lake	River	Ticket lake
Stationary angler (%[b])	3.8 ± 1.3	0.6 ± 0.5	2.9 ± 1.1	6.2 ± 1.6	1.9 ± 0.9
Traveller angler (%[b])	16.6 ± 2.4	4.1 ± 1.3	31.5 ± 3.0	26.6 ± 2.9	5.8 ± 1.5
Fishing frequency	Weekly	Beweekly	Monthly	Quarterly	Lonthm[c]
%[b]	32.2 ± 3.0	32.7 ± 3.0	30.6 ± 3.0	2.9 ± 1.1	1.6 ± 0.8
Average bait used per fishing session (kg)	*<5*	*5–10*	*10–20*	*>20*	
%[b]	*32.7 ± 3.0*	*47.3 ± 3.2*	*14.6 ± 2.3*	*5.4 ± 1.5*	
Average session span (hours)	<6	6–24	24–72	>72	
%[b]	7.8 ± 1.7	41.9 ± 3.2	41.8 ± 3.2	8.5 ± 1.8	
Carp role perception	Very negative	Negative	Neutral	Positive	Very positive
%[b]	0.1 ± 0.3	1.4 ± 0.8	11.6 ± 2.1	33.4 ± 3.1	54.5 ± 3.2

[a]ND = Prefer not to declare.

[b]Percentages are calculated relative to the total number of respondents (n = 911). For each reported proportion, the 95% confidence interval (CI) was calculated using the Wilson score method for binomial proportions. Results are reported as percentages ± the half-width of the 95% CI, calculated as (upper CI - lower CI)/2. The intervals quantify sampling uncertainty associated with the 911 respondents and do not account for potential selection or non-response bias.

[3]Lonthm = Less than once every 3 months.

reduce the risk of duplicate submissions, the final dataset was screened, and no entries required removal. Given the reported number of carp anglers in the study area, the broad spatial coverage, represented by at least one respondent in 16 of the 20 Italian regions, enabled a data-driven characterization of the socio-economic dynamics associated with recreational carp fishing. Respondents' demographic characteristics and main angling habits are presented in Table 1.

The majority of respondents were male (96.4% ± 1.2%) aged between 25–45 years old (60.3% ± 3.2%), most of whom has obtained a high school diploma (60.8% ± 3.2%), employed (89.7% ± 2.0%). 93.2% ± 1.6% of anglers' community affirmed to prefer *ad hoc* fishing tackles catching carps (gears and baits, summarized as carp fishing technique), whereas the remaining 6.8% ± 1.6% adopted more generalist approaches. 84.5% ± 2.3% of carp anglers reported habitual travel to reach their customary fishing locations, predominantly a lake (31.5% ± 3.0%) or a river (26.6% ± 2.9%). The majority of carp anglers declared to go carp fishing at least once per month (95.5% ± 1.4%), reporting fishing sessions ranging from less than 18 h (41.9% ± 3.2), up to 72 h (41.8% ± 3.2%).

The results clearly demonstrate that carp fishing valued the target species above accessory features: 92.7% ± 1.7% of respondents would relocate if carp were absent from their usual fishing spot (Question 8), and 98% ± 0.9% practiced catch-and-release (Question 9), enabling recapture by other anglers. Auxiliary amenities held minimal importance: 70.3% ± 3.0% and 78.6% ± 2.7% considered nearby facilities or alternative activities not or slightly important, respectively (Questions 17–18, see Supplementary Material: Supplementary Figures S1, S2).

When asked to identify primary threats to fishing site conservation and fish fauna, respondents perceived poaching as the greatest threat (34.5% ± 3.1%), followed by lack of local and national interest (28.9% ± 2.9%), while remarkably, non-native species ranked lowest (3.9% ± 1.3%).

3.2 Economic quantification and perceptions of carp fishing goods

APE was calculated on a per-respondent basis. Annual expenditure decreased as fishing frequency decreased, with APE's values decreasing from up to 5,085 ± 214.3 to 250 ± 47.3 Euro

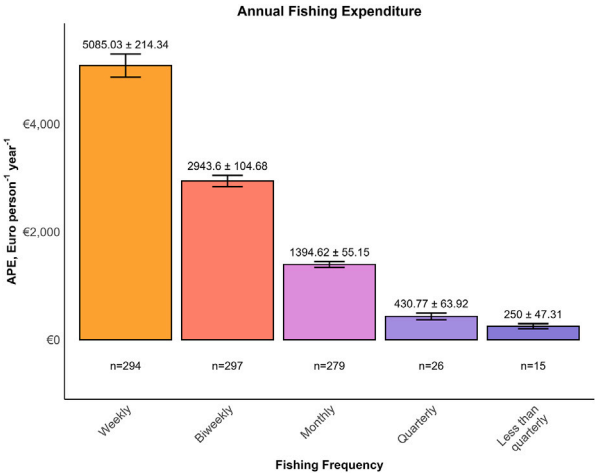

FIGURE 1
Bar plot of average annual *per capita* fishing expenses (APE) in Euro calculated per each of the fishing frequency categories to which respondents reported to belong (N = 911). Averages ± standard errors are reported.

person^{-1} year^{-1}, for anglers who go fishing weekly rather than less frequently than once every 3 months, respectively (Figure 1). Consequently, differences in APE and fishing frequencies were inspected, highlighting statistical differences ($p < 0.001$, $F_{4,906} = 100.1$). Additionally, Tukey HSD *post hoc* tests revealed statistically significant differences. With p-value <0.001 among the following pairwise comparisons: "Biweekly-Weekly", "Monthly-Weekly", "Quarterly-Weekly", "Less than quarterly-Weekly", "Monthly-Biweekly", "Quarterly-Biweekly", and "Less than quarterly-Biweekly".

A series of Chi-square tests of independence provided no evidence of a significant association between APE and habitat choice, APE and educational qualification, and between APE and age of respondents (Supplementary Table S1).

Besides, no statistical differences also emerged in BC (Euro person^{-1} fishing session^{-1}) based on the different educational qualifications of respondents ($p = 0.76$, $F_{3,907} = 0.39$), reflecting a shared pattern of monetary investment for angling bait among carp anglers. Conversely, statistical differences emerged in BC based on the different habitat chosen for fishing session by respondents ($p < 0.001$, $F_{4,906} = 5.25$), with lakes showing significantly higher mean values (see Supplementary Material: Supplementary Figures S3, S4 respectively).

3.3 Perceived ecological role of carp among anglers

Overall, a strong agreement emerged among carp anglers about the positive role of carp on the aquatic ecosystem and/or other species (fauna/flora) present in it (87.9% ± 2.1%).

Chi-square tests were used to examine associations between variables describing angling preferences. A significant association was found only between the perceived ecological carp's role and educational qualification of respondents (Supplementary Table S3). Standardized residuals suggested that respondents who have a degree or higher educational qualification perceived ecological carp's role as neutral more frequently than expected, or as very negative more frequently than expected (Supplementary Table S4).

No significant associations between the perceived ecological carp's role and respondents' age, or habitat type chosen for the fishing session emerged (Supplementary Table S3).

3.4 Drivers of angling preferences

A series of Chi-square tests of independence were performed to investigate the association among drivers of angling preferences.

A significant association between educational qualification and habitat choice for carp fishing session emerged (Supplementary Table S5). These results suggest that respondents with lower educational levels tend to prefer rivers more frequently than expected, whereas respondents with higher education favor other habitats. Indeed, rivers were preferred less frequently than expected. Moreover, respondents who have a high school qualification preferred ticket_lake less frequently than expected (Supplementary Table S6). Instead, no association between educational qualification and Aver_bait used by respondents for baiting during carp fishing session emerged (Supplementary Table S5).

Furthermore, respondents revealed a proactive WTP to preserve both the overall fish community and the fishing site where they are used to fish for carps. WTP levels were comparable for the two conservation targets, with 89.9% ± 2.1% (N = 819) of respondents willing to contribute for fish community conservation and 88.3% ± 2.2% (N = 804) for fishing site protection. The most frequently selected lump-sum payment among respondents willing to preserve both fish stocks and their fishing sites was €50–100, selected by 68.2% ± 3.0% and 65.2% ± 3.1% of respondents, respectively. The latter values were adjusted by excluding those who indicated they were not willing to pay but nonetheless answered the subsequent question - likely due to a misunderstanding - which accounted for only 1.54% and 1.98% of respondents, respectively. No significant associations between WTP for fish conservation and educational qualification or age emerged (Supplementary Table S7). The same trend was observed between WTP for the protection of the fishing site and educational qualification or age, (Supplementary Table S8).

Additionally, FAMD analysis allowed further highlighting of socio-economic and ecological association among respondents' preferences. From the output of the dataset analyzed (n = 911), the first five dimensions, which together explained 32.2% of the variance (Figure 2A), were maintained.

Dimension 1 explained 8.6% of total variance, and Session_span, Aver_bait and APE contributed most to it (Figure 2B). Dimension 2 instead explained 6.4% of total variance, and Age, Education and Habitat contributed most to it (Figure 2C). The quality of representation of the categorical levels on the first two FAMD axes was evaluated using the sum of squared cosines (cos^2) and varied substantially across categories (Figure 3). Across the 27 categorical levels, cos^2 values for dimensions 1 and 2 ranged from 0 to 0.59. Five levels were strongly associated with these dimensions ($cos^2 > 0.40$). Eight levels showed moderate representation ($0.20 < cos^2 < 0.40$). The remaining 14 levels had low cos^2 values (<0.10), indicating their variance is largely captured by higher-order dimensions (Supplementary Table S9).

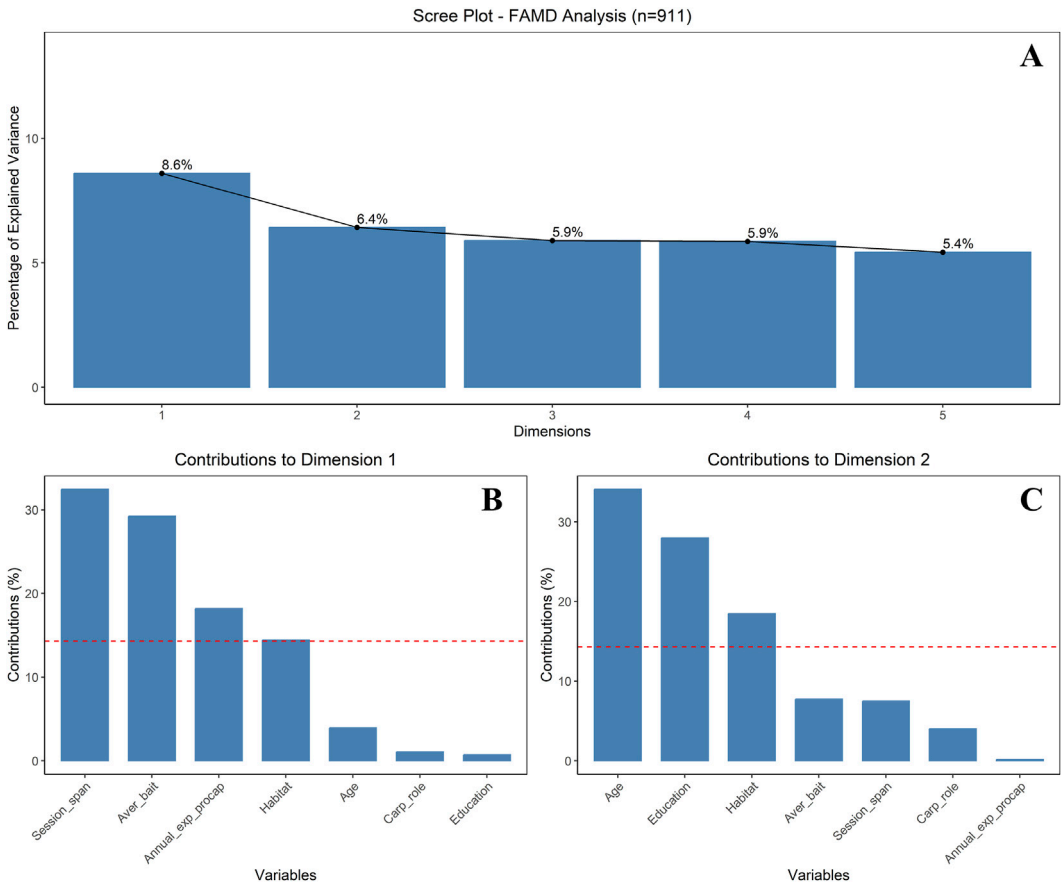

FIGURE 2
Multipanel plot representing the scree plot **(A)** of the FAMD analysis (see Statistical analysis paragraph within the Methods section for further explanations), and histograms showing the contribution of the selected variables to the principal dimensions (1 and 2), **(B,C)**, respectively.

4 Discussion

Even with an open questionnaire period of about 3 months, the high response rate to the survey indicates a clear and growing interest in carps among Italian specialized recreational carp anglers. Moreover, despite the non-probabilistic nature of the survey and potential self-selection biases, the results show a broad socio-demographic coverage (Table 1). We thus acknowledge the limitations of the survey and the potential bias affecting it. However, considering the response rate higher than previous research (Arlinghaus and Mehner, 2003; Morales-Nin et al., 2025), and the rigorous statistics applied, the following discussions are supported by a reliable and robust dataset.

4.1 Carp fishing as a cultural ecosystem service

Fishing is among the oldest activities that connect aquatic ecosystems with human societies (Pope et al., 2016, and references therein). While this practice has been and still is in use for millennia by people to ensure a food supply, from the last decades of the 20th Century onwards, industrialized and recreational fishing have increased in popularity (Pope et al., 2016). Narrowing the focus, people involved in recreational fishing are rising steeply, as are the suite of co-occurring potential cultural and provisioning ecosystem services (Arlinghaus et al., 2002, Agresti, 2007; Vilizzi et al., 2015; Pope et al., 2016; Sax et al., 2022).

The occurrence of carps among multiple freshwater habitats (e.g., lakes, rivers, channels, ponds, *etc.*) contribute to increase their catch rate among anglers, raising the paradox of a non-native species providing valuable ecosystem services.

4.2 Socio-economic indicators of recreational use

The survey results described the occurrence of this tendency also in Italy. Carp fishing involved citizens, mainly males, as previously reported for recreational fisheries in Spain (Morales-Nin et al., 2025), of different ages, ranging from 5 to over 65 years old, but also characterized by varying monthly incomes (data not shown). Van der Hammen and Chen (2020) reported young people belonging to the age group 5_16 as the most abundant fishing age class in freshwater. Despite direct comparisons not being possible, since the results presented here investigated a specialized anglers group, the most abundant age class resulted in 25_45 years old (60.3% ± 3.2% of respondents, see Table 1). The explanation lies in the fact that carp fishing requires both an

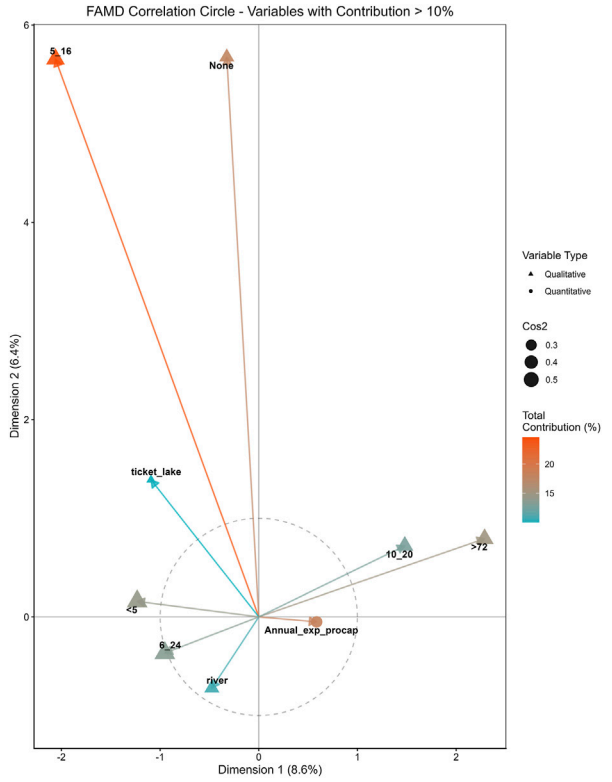

FIGURE 3
Correlation circle representing the loading of both qualitative (triangles) and quantitative (circle) variables on the first and second dimensions obtained via the FAMD analysis. The unit circle indicates maximum representation quality for quantitative variables (arrow length = $\sqrt{\cos^2}$); coordinates for qualitative category levels are not bounded by the unit circle, as these represent scaled centroid positions rather than correlation coefficients. Details of the acronyms are provided in Supplementary Table S2 of the Supplementary Material.

important investment of time, almost 94% ± 8.1% of respondents declared that their fishing session lasts from 6 to 72h, in the range of what was previously found by Arlinghaus and Mehner (2003) in Germany, and money, which is thus possible mainly for workers. However, workers could experience a lack of free time, which can be accounted as a limited factor in recreational fishing (Fedler and Ditton, 2001).

Being counted among cultural ecosystem services provided by freshwater ecosystems, carp fishing contributes to human wellbeing (Arlinghaus et al., 2017 and references therein; Pita et al., 2025). At present, this specific recreational fishing technique is rarely practiced with the primary aim of consuming the captured fish (Sbragaglia et al., 2025). That said, anglers's behaviors could lead to the collapse of the targeted fish populations (Dao et al., 2025). However, regardless of few exceptions or national rules (Arlinghaus and Mehner, 2003), one of the most satisfactory features triggering the willingness to pursue another fishing session in the same fishing spot is the success of the trip in terms of catches, making the release of the captured fish (catch-and-release practice; C&R), a dogma in most cases (Birdsong et al., 2025). Nevertheless, if the latter mentioned practice is not applied, carp fishing can also be valued as a provisioning ecosystem service derived from aquatic ecosystems (Sax et al., 2022).

Besides, carp fishing may contribute to local and national economies (Arlinghaus and Mehner, 2003). Despite this not being the focus of the research, calculated APE attributed a value to a single ecosystem service offered by the suite of habitat considered in the present study, as it is carp fishing - thus indirectly given by carp. It is crucial to remark that such a metric does not reflect either the environmental value, or the value of carp.

The economic relevance of carp fishing is reflected in the frequency of fishing sessions. APE's values of up to 5,085 ± 214.3 Euro person^{-1} year^{-1} (see Figure 1) resulted for anglers who go fishing weekly. This amount is aligned with the average reported value of 5,490 Euro per person^{-1} year^{-1} by Arlinghaus and Mehner (2003). Even if corrected for the current value of the Euro compared to 2003 (conversion factor = 1.457, https://rivaluta.istat.it/Rivaluta/, last accessed 27/11/2025), the potential economic relevance of carp fishing is undeniable in both Germany and Italy, and potentially wherever a high rate of carp anglers willing to invest in it is present.

However, a full economic evaluation of carp fishing is lacking in the literature, and many previously reported estimates are therefore non-exhaustive (Haubrock et al., 2022; Scheufele et al., 2021). To credibly state that carp fishing contributes to regional or national economies requires broader assessment of parameters often omitted from simple valuations. For example, costs associated with non-native species damages or control, ecosystem-service losses, sectoral shifts in growing industries, and economy-wide effects that may reduce production elsewhere, which calls for modelling approaches beyond single-site valuations, such as input–output (IO) or computable general equilibrium (CGE) analyses (Akbari et al., 2023; Cuthbert et al., 2021; Warziniack et al., 2021).

Moreover, the higher participation in carp fishing *per se* also poses caveats to ecological sustainability of the practice, since it translates into more access to the inland water banks, often via roads or vehicles, thus potentially damaging banks, increasing pollution (e.g., through soil compaction, litter, hydrocarbons, tire wear particles, runoff), and altering riparian and littoral habitat (O'Toole et al., 2009; Schafft et al., 2021; Song et al., 2025). Furthermore, the willingness to reach a specific habitat, as outlined in the survey's results (see Table 1), highlighting the preference of most Italian carp anglers for river and lakes, may further contribute to habitat fragmentation, degradation of aquatic vegetation, increased erosion or sedimentation, and thereby to the alteration of ecosystem functioning in these crucial but delicate habitats (Burgin and Hardiman, 2017; Ottburg and Blank, 2015). Further research into addressing these aspects is thus advisable.

4.3 The social-ecological paradox of non-native species providing ecosystem services, possible implications of shifting baselines

The FAMD correlation circle (Figure 3) revealed two orthogonal gradients among the variables contributing most strongly to the ordination. The modest variance explained (15%) reflects appropriate preservation of categorical complexity rather than analytical limitation; forcing ordinal variables into metric assumptions would artificially inflate explained variance while

distorting ecological relationships (Pagès, 2004). This level of variance is consistent with previous studies applying FAMD to similarly complex, mixed socio-ecological datasets (Vasquez et al., 2024).

Dimension 1 separated high-effort anglers (longer sessions, greater bait provisioning) from low-effort, younger anglers fishing river habitats with brief sessions and minimal bait - consistent with a recreational specialization gradient characteristic of heterogeneous angler populations (Bryan, 1977; Ditton et al., 1992). Dimension 2 was structured primarily by age and education rather than effort: the youngest age class and respondents with no formal education loaded strongly and positively, alongside ticket-lake fishing, largely independent of Dimension 1 ($r \approx 0$). This orthogonality suggests demographic and educational background shape angler profiles along an axis distinct from effort intensity, and that catch-oriented specialization (Dim1) does not map onto a single underlying respondent "type" together with age or education (Dim2). Broader patterns involving habitat type, additional age classes, and species-perception categories are detailed in the full variable summary (Supplementary Table S9), where several of these - including "lake," "dam," and mid-range age and education categories - showed moderate representation ($0.20 < \cos^2 < 0.40$) but did not meet the >10% contribution threshold used for Figure 3.

These results indicate that demographic structuring of angler subgroups (Dim2) is largely decoupled from effort-based specialization (Dim1), meaning interventions targeting one dimension - e.g., effort regulation for high-investment anglers - cannot be assumed to generalize across the age/education gradient captured by the other. Effective management is therefore likely to require distinct approaches tuned to each axis rather than a single behavioral or demographic lever.

Critically, 87.9% ± 2.1% of respondents perceived carp as having positive ecological roles, a perception contrasting with extensive scientific evidence documenting carp's detrimental impacts on freshwater ecosystems (Weber and Brown, 2009; Vilizzi et al., 2015; Stuart et al., 2021). This discordance between angler perceptions and ecological reality underscores the risks of incorporating stakeholder opinions into management decisions without scientific validation (Estévez et al., 2015). However, it is worth noting that when discussing introduced species that have established viable populations for over 100 years, a phenomenon of cultural naturalization emerges, linked to ecological amnesia or a shifting baseline syndrome. This can, in fact, lead to the opposite paradox, where an introduced species becomes a protected species outside its original range (Clavero, 2014; 2022).

While respondents demonstrated WTP for fish community conservation and habitat protection, primarily selecting €50–100 lump-sum payments, such economic valuation does not address, and may inadvertently legitimize, the ecological damage caused by established non-native populations.

The habitat segregation observed along Dimension 1 - with river fishing associated with lower-effort, shorter-session profiles (Figure 3), and lake/dam habitats linked to higher-effort profiles in the broader ordination (Supplementary Table S9) - coupled with high mobility patterns (84.5% ± 2.3% traveling to fishing locations), raises concerns about anthropogenic pressures on freshwater ecosystems. Increased access to riparian zones elevates risks of bank degradation, soil compaction, pollution from vehicles and equipment, and habitat alteration, consequences documented for water-based recreation globally (Burgin, 2017; Schafft et al., 2021). These impacts compound the ecological disruptions attributable to carp themselves, creating synergistic degradation pathways that threaten native biodiversity and ecosystem functioning (Pejchar and Mooney, 2009).

4.4 Suggested recommendation for reconciling stakeholder perceptions with conservation priorities through adaptive management

Among the primary threats to fishing site conservation and fish fauna, respondents perceived poaching as the greatest, followed by lack of local and national interest while remarkably, non-native species ranked lowest (3.9% ± 1.3%). This threat-hierarchy further illustrates the perception-reality disconnect: anglers prioritize illegal harvest over the documented ecological impacts of established non-native species like carp themselves (Cooke and Cowx, 2004). The emphasis on poaching, a legitimate conservation concern in many freshwater systems, suggests anglers frame threats through resource depletion rather than ecosystem functioning, reinforcing the necessity for education initiatives that bridge experiential knowledge with scientific understanding of non-native species impacts.

From a conservation perspective, effective freshwater management requires integrating diverse stakeholder perspectives, including recreational anglers, commercial fishers, indigenous communities, conservation organizations, and scientific experts, within participatory governance frameworks that prioritize data-driven decision-making over subjective perceptions (Arlinghaus et al., 2017; Pope et al., 2016; Scheufele and Pascoe, 2022). While carp fishing demonstrably provides cultural ecosystem services (e.g., recreational opportunities, wellbeing enhancement, economic contributions), these benefits must be evaluated against the disservices imposed by non-native species on native biodiversity, water quality, and ecosystem functioning (Chen et al., 2026; Hegedűs et al., 2026; Rabaey et al., 2026; Sax et al., 2022; Yang et al., 2026).

Practical eradication of established carp populations across large spatial scales remains unrealistic given their fecundity, dispersal capacity, and population resilience (Stuart et al., 2021). Localized removals may succeed in small, isolated water bodies where ecological restoration holds priority, as demonstrated through selective harvesting, biocontrol research, and targeted removal strategies implemented internationally (Colvin et al., 2012; Poole and Bajer, 2019; Fisheries Research and Development Corporation, 2022). However, broad-scale management necessitates pragmatic approaches balancing ecological integrity with socioeconomic realities.

We therefore advocate for adaptive co-management strategies that: (1) implement population control measures in ecologically sensitive areas prioritizing native species. These areas will be defined as AZN - Allocated Zone for Natives *"A freshwater area designated for native species conservation priority, maintained not through physical isolation but through a recurring, risk-calibrated non-native control regime (e.g., harvest quotas, concentrated removal*

efforts), such that non-native suppression effort is sustained at a rate exceeding the reinvasion/recolonization pressure from the surrounding connected network."; (2) designate zones where recreational carp fishing continues under regulated access to minimize habitat degradation; (3) develop transparent communication campaigns educating the population about carp's ecological impacts while acknowledging legitimate recreational values, following successful European precedents (Arlinghaus and Mehner, 2003); (4) invest in long-term monitoring quantifying both ecosystem-service provisioning and disservice costs to inform evidence-based policy.

Ultimately, sustainable freshwater management demands honest acknowledgment that recreational preferences for non-native species exist within complex socio-ecological systems where human wellbeing and ecological integrity intersect imperfectly. Public participation in environmental decision-making remains essential for democratic legitimacy and social acceptance of conservation policies (Elwell et al., 2018). However, cautiousness and data-driven approaches must be preferred over perception alone when managing freshwater ecosystems for long-term ecological status improvement. Carps represent a non-native species complex that provides measurable ecosystem services yet simultaneously degrades freshwater habitats and threatens native biodiversity, a paradox requiring scientifically informed, adaptive management rather than stakeholder-driven perpetuation of ecologically harmful status quos. Proactive, evidence-based interventions guided by restoration ecology principles offer the most viable pathway toward reconciling human use with ecosystem functioning in freshwater systems increasingly stressed by multiple anthropogenic pressures.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, upon reasonable request.

Ethics statement

The requirement of ethical approval was waived by at the time of study design and data collection, there was no institutional research ethics committee requirement applicable to anonymous questionnaire-based social research of this type; therefore, no formal ethics approval was sought or required. Participants were informed about the aims of the research, the voluntary nature of their participation, the anonymity of their responses, and data storage and protection procedures. Informed consent was obtained from all participants prior to their participation, and consent was implied by their voluntary completion of the questionnaire. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was not obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article because Participation in this survey is anonymous and voluntier. This survey has no commercial or advertising purposes but is purely scientific.

Author contributions

SP: Conceptualization, Data curation, Investigation, Methodology, Visualization, Writing – original draft, Writing – review and editing. MG: Methodology, Validation, Writing – original draft. PM: Methodology, Validation, Writing – review and editing. GC: Conceptualization, Resources, Supervision, Writing – review and editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

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References

Agresti, A. (2007). *An Introduction to Categorical Data Analysis*, 2nd Edition, New York: John Wiley and Sons. doi: 10.1002/bimj.4710290113

Akbari, N., Failler, P., Pan, H., Drakeford, B., and Forse, A. (2023). The impact of fisheries on the economy: a systematic review on the application of general equilibrium and input–output methods. *Sustainability* 15 (7), 6089. doi: 10.3390/su15076089

Arlinghaus, R., and Mehner, T. (2003). Socio-economic characterisation of specialised common carp (*Cyprinus carpio* L.) anglers in Germany, and implications for inland fisheries management and eutrophication control. *Fish. Res.* 61 (1–3), 19–33. doi: 10.1016/s0165-7836(02)00243-6

Arlinghaus, R., Mehner, T., and Cowx, I. G. (2002). Reconciling traditional inland fisheries management and sustainability in industrialized countries, with emphasis on Europe. *Fish Fish.* 3 (4), 261–316. doi: 10.1046/j.1467-2979.2002.00102.x

Arlinghaus, R., Alós, J., Beardmore, B., Daedlow, K., Dorow, M., Fujitani, M., et al. (2017). Understanding and managing freshwater recreational fisheries as complex adaptive social-ecological systems. *Rev. Fish. Sci. and Aquac.* 25 (1), 1–41. doi: 10.1080/23308249.2016.1209160

Arrow, K., Solow, R., Portney, P. R., Leamer, E. E., Radner, R., and Schuman, H. (1993). Report of the NOAA panel on contingent valuation. *Fed. Register* 58 (10), 4601–4614. doi: 10.1108/s0573-8555(1993)0000220017

Benedini, M., and Rossi, G. (2021). "Water resources of Italy," in *Water Law, Policy and Economics in Italy: Between National Autonomy and EU Law Constraints* (Cham: Springer International Publishing), 3–31. doi: 10.1007/978-3-030-69075-5_1

Birdsong, M., Beardmore, B., Dorow, M., Pagel, T., and Arlinghaus, R. (2025). Culture, context, and fish length drives voluntary catch-and-release behaviour of recreational anglers. *Rev. Fish Biol. Fish.* 35, 1–28. doi: 10.1007/s11160-025-09971-6

Bryan, H. (1977). Leisure value systems and recreational specialization: the case of trout fishermen. *J. Leisure Research* 9 (3), 174–187. doi: 10.1080/00222216.1977.11970328

Burgin, S. (2017). Indirect consequences of recreational fishing in freshwater ecosystems: an exploration from an Australian perspective. *Sustainability* 9 (2), 280. doi: 10.3390/su9020280

Carson, R. T. (2012). Contingent valuation: a practical alternative when prices aren't available. *J. Economic Perspectives* 26 (4), 27–42. doi: 10.1257/jep.26.4.27

Chen, X., Evans, T. G., Jeschke, J. M., Griffith, P., Jähnig, S. C., and He, F. (2026). Global assessment of alien freshwater megafauna reveals complex socio-economic impacts. *One Earth* 9, 101623. doi: 10.1016/j.oneear.2026.101623

Clavero, M. (2014). Shifting baselines and the conservation of non-native species. *Conserv. Biol.* 28 (5), 1434–1436. doi: 10.1111/cobi.12266

Clavero, M. (2022). The King's aquatic desires: 16Th-Century fish and crayfish introductions into Spain. *Fish Fish.* 23 (6), 1251–1263. doi: 10.1111/faf.12680

Colvin, M. E., Pierce, C. L., Stewart, T. W., and Grummer, S. E. (2012). Strategies to control a common carp population by pulsed commercial harvest. *North Am. J. Fish. Manag.* 32 (6), 1251–1264. doi: 10.1080/02755947.2012.728175

Cooke, S. J., and I. Cowx, G. (2004). The role of recreational fishing in global fish crises. *BioScience* 54 (9), 857–859. doi: 10.1641/0006-3568(2004)054[0857:trorfi]2.0.co;2

Costanza, R. (2024). Misconceptions about the valuation of ecosystem services. *Ecosyst. Serv.* 70, 101667. doi: 10.1016/j.ecoser.2024.101667

Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., et al. (1997). The value of the world's ecosystem services and natural capital. *Nature* 387 (6630), 253–260. doi: 10.1038/387253a0

Cuthbert, R. N., Pattison, Z., Taylor, N. G., Verbrugge, L., Diagne, C., Ahmed, D. A. L., et al. (2021). Global economic costs of aquatic invasive alien species. *Sci. Total Environment*, 775: 145238. doi: 10.1016/j.scitotenv.2021.145238

Dao, T., Arlinghaus, R., Ehrlich, E., and Quaas, M. (2025). Adaptive fisher behavior alone can induce tipping points and stock collapse: a synthesis of bioeconomic theory that applies to all capture fisheries under open access. *Rev. Fish. Sci. and Aquac.* 34, 1–40. doi: 10.1080/23308249.2025.2549054

De Kock, S., and Gomelsky, B. (2015). "Japanese ornamental koi carp: origin, variation and genetics," in *Biology and Ecology of Carp*. Editors C. Pietsch and P. Hirsch (CRC Press), 27–53.

Ditton, R. B., Loomis, D. K., and Choi, S. (1992). Recreation specialization: re-Conceptualization from a social worlds perspective. *J. Leis. Res.* 24 (1), 33–51. doi: 10.1080/00222216.1992.11969870

Drupp, M. A., Hänsel, M. C., Fenichel, E. P., Freeman, M., Gollier, C., Groom, B., et al. (2024). Accounting for the increasing benefits from scarce ecosystems. *Science* 383 (6687), 1062–1064. doi: 10.1126/science.adk2086

Dudgeon, D., Arthington, A. H., Gessner, M. O., Kawabata, Z. I., Knowler, D. J., Lévêque, C., et al. (2006). Freshwater biodiversity: importance, threats, status and conservation challenges. *Biol. Rev.* 81 (2), 163–182. doi: 10.1017/s1464793105006950

Ellender, B. R., and Weyl, O. L. F. (2014). A review of current knowledge, risk and ecological impacts associated with non-native freshwater fishes in South Africa. *Aquat. Invasions* 9 (2), 117–132. doi: 10.3391/ai.2014.9.2.01

Elwell, T. L., Gelcich, S., Gaines, S. D., and Lopez-Carr, D. (2018). Using people's perceptions of ecosystem services to guide modeling and management efforts. *Sci. Total Environ.* 637, 1014–1025. doi: 10.1016/j.scitotenv.2018.04.052

Estévez, R. A., Anderson, C. B., Pizarro, J. C., and Burgman, M. A. (2015). Clarifying values, risk perceptions, and attitudes to resolve or avoid social conflicts in invasive species management. *Conserv. Biol.* 29 (1), 19–30. doi: 10.1111/cobi.12359

FAO (2024). *The State of World Fisheries and Aquaculture 2024: Blue Transformation in Action*. Rome: FAO. doi: 10.4060/cd0683en

Fedler, A. J., and Ditton, R. B. (2001). Dropping out and dropping in: a study of factors for changing recreational fishing participation. *North Am. J. Fish. Manag.* 21 (2), 283–292.

Fisheries Research and Development Corporation (2022). The National Carp Control Plan (NCCP). *Deakin West, ACT*. Canberra, ACT, Australia: National Carp Control Plan. Available online at: https://www.agriculture.gov.au/biosecurity-trade/pests-diseases-weeds/pest-animals-and-weeds/carp-biological-control-program (Accessed January 10, 2026).

Gaglio, M., Lanzoni, M., Muresan, A. N., Schirpke, U., and Castaldelli, G. (2024). Quantifying intangible values of wetlands as instrument for conservation in the Po Delta park (italy). *J. Environ. Manag.* 360, 121227. doi: 10.1016/j.jenvman.2024.121227

Gavioli, A., Filipe, A. F., Patonai, K., Milardi, M., and Castaldelli, G. (2023). Effectiveness of the natura 2000 network for freshwater fish conservation in a mediterranean region. *Front. Environ. Sci.* 11, 1122464. doi: 10.3389/fenvs.2023.1122464

Genovesi, P. (2007). Linee guida per la reintroduzione e il ripopolamento di specie faunistiche di interesse comunitario [Guide to reintroduction of species important from faunistic point of view]. *Quad. Conserv. Nat.* 27, 1–51. (*in Italian*).

Ghirardi, N., Bresciani, M., Pinardi, M., Nizzoli, D., and Viaroli, P. (2023). Pit Lakes from gravel and sand quarrying in the po river basin: an opportunity for riverscape rehabilitation and ecosystem services improvement. *Ecol. Eng.* 196, 107103. doi: 10.1016/j.ecoleng.2023.107103

Hanemann, W. M. (1994). Valuing the environment through contingent valuation. *J. Economic Perspectives* 8 (4), 19–43. doi: 10.1257/jep.8.4.19

Haubrock, P. J., Bernery, C., Cuthbert, R. N., Liu, C., Kourantidou, M., Leroy, B., et al. (2022). Knowledge gaps in economic costs of invasive alien fish worldwide. *Sci. Total Environ.* 803, 149875. doi: 10.1016/j.scitotenv.2021.149875

Hedges, S. B., Marin, J., Suleski, M., Paymer, M., and Kumar, S. (2015). Tree of life reveals clock-like speciation and diversification. *Mol. Biol. Evol.* 32 (4), 835–845. doi: 10.1093/molbev/msv037

Hegedűs, A., Staszny, Á., Weiperth, A., Bányai, Z., Lente, V., Urbányi, B., et al. (2026). Characterization of management practices and ecological challenges of sustainable recreational fishery management in Hungary (central Europe). *Rev. Fish Biol. Fish.* 36 (1), 2. doi: 10.1007/s11160-025-10004-5

Howarth, A., Cooke, S. J., Nguyen, V. M., and Hunt, L. M. (2024). Non-probabilistic surveys and sampling in the human dimensions of fisheries. *Rev. Fish Biol. Fish.* 34 (2), 597–622. doi: 10.1007/s11160-023-09831-1

Imbert, A., Cucherousset, J., Parthuisot, N., and Boulêtreau, S. (2022). Elemental composition and microbial decomposition of different angling baits. *Fish. Manag. Ecolology* 29 (5), 552–559. doi: 10.1111/fme.12537

Istituto Zooprofilattico Sperimentale delle Venezie (IZSVe), e Associazione Piscicoltori Italiani (API) (2025). Manuale sul benessere per le specie ittiche allevate. Guida per l'operatore. Legnaro (PD): IZSVe. Available online at: https://www.izsvenezie.it/manuale-benessere-specie-ittiche/ (Accessed January 10, 2026).

Ittico, BMTI (2023). *CARPA - ANALISI ECONOMICA E PROSPETTIVE DI CONSUMO*. Available online at: https://ittico.bmti.it/CaricaPdfRegolamenti.do?doc=11 (Accessed January 10, 2026).

James, G., Witten, D., Hastie, T., and Tibshirani, R. (2013). *An Introduction to Statistical Learning: With Applications in R*, 103. New York: Springer. doi: 10.1007/978-1-4614-7138-7_2

Kumar, P. (2012). *The economics of ecosystems and biodiversity: ecological and economic foundations*. Abingdon, United Kingdom: Routledge. doi: 10.4324/9781849775489

Lowe, S., Browne, M., Boudjelas, S., and De Poorter, M. (2000). *100 of the World's Worst Invasive Alien Species: A Selection from the Global Invasive Species Database*. Auckland: Invasive Species Specialist Group.

McDaniels, T. L., Axelrod, L. J., Cavanagh, N. S., and Slovic, P. (1997). Perception of ecological risk to water environments. *Risk Anal.* 17 (3), 341–352. doi: 10.1111/j.1539-6924.1997.tb00872.x

Menard, S. (2001). *Applied Logistic Regression Analysis*. 2nd ed. Thousand Oaks, CA: SAGE publications. doi: 10.4135/9781412983433

Milardi, M., Lanzoni, M., Kiljunen, M., Torniainen, J., and Castaldelli, G. (2015). Natural recruitment contributes to high densities of grass carp *Ctenopharyngodon idella* (valenciennes, 1844) in Western Europe. *Aquat. Invasions* 10 (4), 439–448. doi: 10.3391/ai.2015.10.4.07

Milardi, M., Soana, E., Chapman, D., Fano, E. A., and Castaldelli, G. (2020). Could a freshwater fish be at the root of dystrophic crises in a coastal lagoon? *Sci. Total Environ.* 711, 135093. doi: 10.1016/j.scitotenv.2019.135093

Milardi, M., Iemma, A., Waite, I. R., Gavioli, A., Soana, E., and Castaldelli, G. (2022). Natural and anthropogenic factors drive large-scale freshwater fish invasions. *Sci. Rep.* 12 (1), 10465. doi: 10.1038/s41598-022-14556-5

Mohammed, H. H., Ebrahim, M., Youssef, M. I., Saleem, A. S. Y., and Abdelkhalek, A. (2024). Behavior and management of carp fish: a review. *Open Veterinary J.* 14 (1), 1. doi: 10.5455/ovj.2024.v14.i1.1

Morales-Nin, B., Arlinghaus, R., and Alós, J. (2025). Gender differences in participation rate, socioeconomic profile, recreational motivation, and wildlife-related value orientation among recreational Fishers in Spain. *Fish. Res.* 285, 107363. doi: 10.1016/j.fishres.2025.107363

Mossone, P. (2019). Can the economic valuation of the environment be considered a problem of individual choice. *J. Aquatic Res. Mar. Sci.*, 2019, 121–124. doi: 10.29199/arms.103028

Ottburg, F., and Blank, M. (2015). "Solutions to the impacts of roads and other barriers on fish and fish habitat," in *Handbook of Road Ecology*. Editors R. van der Ree, D. J. Smith, and C. Grilo (Wiley) 364–372. doi: 10.1002/9781118568170.ch45

O'Toole, A. C., Hanson, K. C., and Cooke, S. J. (2009). The effect of shoreline recreational angling activities on aquatic and riparian habitat within an urban environment: implications for conservation and management. *Environ. Management* 44 (2), 324–334. doi: 10.1007/s00267-009-9299-3

Pagès, J. (2004). Analyse factorielle de données mixtes. *Rev. Stat. appliquée* 52 (4), 93–111.

Pejchar, L., and Mooney, H. A. (2009). Invasive species, ecosystem services and human well-being. *Trends Ecol. Evol.* 24 (9), 497–504. doi: 10.1016/j.tree.2009.03.016

Pita, P., Tracey, S., Arlinghaus, R., Bachiller, E., Pinho-Duarte, F., Ferter, K., et al. (2025). Staying hooked: effective science engagement and communication in recreational fisheries. *Front. Mar. Sci.* 12, 1589544. doi: 10.3389/fmars.2025.1589544

Poole, J. R., and Bajer, P. G. (2019). A small native predator reduces reproductive success of a large invasive fish as revealed by whole-lake experiments. *PloS One* 14 (4), e0214009. doi: 10.1371/journal.pone.0214009

Poole, J. R., Sauey, B. W., Amberg, J. J., and Bajer, P. G. (2018). Assessing the efficacy of corn-based bait containing antimycin-a to control common carp populations using laboratory and pond experiments. *Biol. Invasions* 20 (7), 1809–1820. doi: 10.1007/s10530-018-1662-y

Pope, K. L., Pegg, M. A., Cole, N. W., Siddons, S. F., Fedele, A. D., Harmon, B. S., et al. (2016). Fishing for ecosystem services. *J. Environ. Manag.* 183, 408–417. doi: 10.1016/j.jenvman.2016.04.024

R Core Team (2022). *R:* A Language and Environment for Statistical Computing. Vienna: R Foundation for Statistical Computing. Available online at: https://www.R-project.org/ (Accessed June 30, 2026).

Rabaey, J. S., Huser, B. J., and Downing, J. A. (2026). Invasion of common carp (*Cyprinus carpio*) reduces the quality of bottom sediments in shallow Lakes. *Water Res.* 292, 125316. doi: 10.1016/j.watres.2025.125316

Sax, D. F., Schlaepfer, M. A., and Olden, J. D. (2022). Valuing the contributions of non-native species to people and nature. *Trends Ecol. Evol.* 37 (12), 1058–1066. doi: 10.1016/j.tree.2022.08.005

Sayer, C. A., Fernando, E., Jimenez, R. R., Macfarlane, N. B., Rapacciuolo, G., Böhm, M., et al. (2025). One-quarter of freshwater fauna threatened with extinction. *Nature* 638 (8049), 138–145. doi: 10.1038/s41586-024-08375-z

Sbragaglia, V., Arlinghaus, R., Ochwada-Doyle, F., Embke, H. S., Griffin, L. P., and Hunt, T. L. (2025). Three decades of world recreational fishing conferences: what have we learned about the dynamics of recreational fisheries? *Fish. Manag. Ecol.* 32, e12815–10. doi: 10.1111/fme.12815

Schafft, M., Wegner, B., Meyer, N., Wolter, C., and Arlinghaus, R. (2021). Ecological impacts of water-based recreational activities on freshwater ecosystems: a global meta-analysis. *Proc. R. Soc. B Biol. Sci.* 288 (1959), 20211623. doi: 10.1098/rspb.2021.1623

Scheufele, G., and Pascoe, S. (2022). Estimation and use of recreational fishing values in management decisions. *Ambio* 51 (5), 1275–1286. doi: 10.1007/s13280-021-01634-7

Scheufele, G., Burton, M., and Pandit, R. (2025). On the importance of discrete choice experiment framings to derive accounting values for ecosystem and species appreciation services. *Ecosyst. Serv.* 74, 101745. doi: 10.1016/j.ecoser.2025.101745

Song, W., Lin, L., Oh, S., Grossart, H. P., and Yang, Y. (2025). Tire wear particles in aquatic environments: from biota to ecosystem impacts. *J. Environ. Manag.* 388, 126059. doi: 10.1016/j.jenvman.2025.126059

Soto, I., Balzani, P., Carneiro, L., Cuthbert, R. N., Macêdo, R., Tarkan, A. S., et al. (2024). Taming the terminological tempest in invasion science. *Biol. Rev.* 99, 1357–1390. doi: 10.1111/brv.13071

Stuart, I. G., Fanson, B. G., Lyon, J. P., Stocks, J., Brooks, S., Norris, A., et al. (2021). Continental threat: how many common carp (*Cyprinus carpio*) are there in Australia? *Biol. Conserv.* 254, 108942. doi: 10.1016/j.biocon.2020.108942

Tarkan, A. S., Marr, S. M., and Ekmekçi, F. G. (2015). Non-native and translocated freshwater fish. *FiSHMED Fishes Mediterr. Environ.* 3, 1–28. doi: 10.29094/FiSHMED.2015.003

van der Hammen, T., and Chen, C. (2020). Participation rate and demographic profile in recreational angling in the Netherlands between 2009 and 2017. *Fish. Res.* 229, 105592. doi: 10.1016/j.fishres.2020.105592

Vaske, J. J. (2019). *Survey Research and Analysis*, 2nd edn. Sagamore-Venture Publishing LLC, Urbana.

Vaske, J. J., Needham, M. D., and Miller, C. A. (2025). "Fundamentals of sampling and implementing human dimensions of fishing surveys," in *Understanding Recreational Fishers: Disciplinary and Interdisciplinary Approaches for Fisheries Management* (Cham: Springer Nature Switzerland), 327–353. doi: 10.1007/978-3-031-99739-6_11

Vazquez, K., Johnson, J. C., Griffith, D., and Muneepeerakul, R. (2024). Exploration of underlying patterns among conflict, socioeconomic and political factors. *Plos One* 19 (5), e0304580. doi: 10.1371/journal.pone.0304580

Vilizzi, L., Tarkan, A. S., and Copp, G. H. (2015). Experimental evidence from causal criteria analysis for the effects of common carp *Cyprinus carpio* on freshwater ecosystems: a global perspective. *Rev. Fish. Sci. and Aquac.* 23 (3), 253–290. doi: 10.1080/23308249.2015.1051214

Vitousek, P. M., d'Antonio, C. M., Loope, L. L., and Westbrooks, R. (1996). Biological invasions as global environmental change. *Am. Scientist* 84 (5), 468–478.

Volta, P., Oggioni, A., Bettinetti, R., and Jeppesen, E. (2011). Assessing Lake typologies and indicator fish species for Italian natural Lakes using past fish richness and assemblages. *Hydrobiologia* 671 (1), 227–240. doi: 10.1007/s10750-011-0720-6

Walder, J., and van der Spiegel, A. (1990). Education for fisheries managers in the Netherlands. In: *Proceedings of the Symposium on Management of Freshwater Fisheries, European Inland Fisheries Advisory Commission, Göteborg, Schweden, May 31–June 3, 1988*. Pudoc, Wageningen, pp. 372–381.

Warziniack, T., Haight, R. G., Yemshanov, D., Apriesnig, J. L., Holmes, T. P., Countryman, A. M., et al. (2021). "Economics of invasive species," in *Invasive Species in Forests and Rangelands of the United States: A Comprehensive Science Synthesis for the United States Forest Sector* (Cham: Springer International Publishing), 305–320.

Weber, M. J., and Brown, M. L. (2009). Effects of common carp on aquatic ecosystems 80 years after "carp as a dominant": ecological insights for fisheries management. *Rev. Fish. Sci. and Aquac.* 17 (4), 524–537. doi: 10.1080/10641260903189243

Yang, H., Haubrock, P. J., Britton, J. R., Tarkan, A. S., Jeppesen, E., Galib, S. M., et al. (2026). Recreational fishing drives the global spread of aquatic non-native species. doi: 10.32942/x25d6k