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ORIGINAL RESEARCH

Angler's preferences, perceptions and practices regarding non-native freshwater fish

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Abstract It is globally recognized that freshwater anglers can have a decisive role in promoting fish introductions. The aim of this study was to analyze freshwater anglers' actions and perceptions regarding fish introductions, comparing two distinct situations, one with recently arrived non-natives fishes and another with older fish introductions, using the Iberian Peninsula as a case study. To achieve this goal, a bilingual survey was implemented on-line in Portugal and Spain and in person (direct inquiries) in two Iberian regions: Lower Ebro (older fish introductions) in Spain; and Lower Tagus (recent fish introductions) in Portugal. Results showed spatial differences in perceptions and actions, namely about the target species, awareness of the impact of non-native fishes, fish introductions reported and proportion of anglers that wanted new fish species. In the Ebro river there is a high percentage of foreign anglers, higher awareness of fish introduction impact and lower introduction rates reported than in the Tagus river. However, popularity of non-native species like European catfish, was higher in the Ebro. In general, although risk behaviors such as use of fish as life bait was of low prevalence for both countries (approx. 5%), it corresponds to large numbers of fish being introduced. Our conservative estimates revealed 273,600 events of bait discharge per year. Regarding the intentional introductions, we estimated a total of 140,000 intentional introduction (illegal) events per year. These findings may help to improve monitoring, awareness and fisheries management programs led by governmental agencies.

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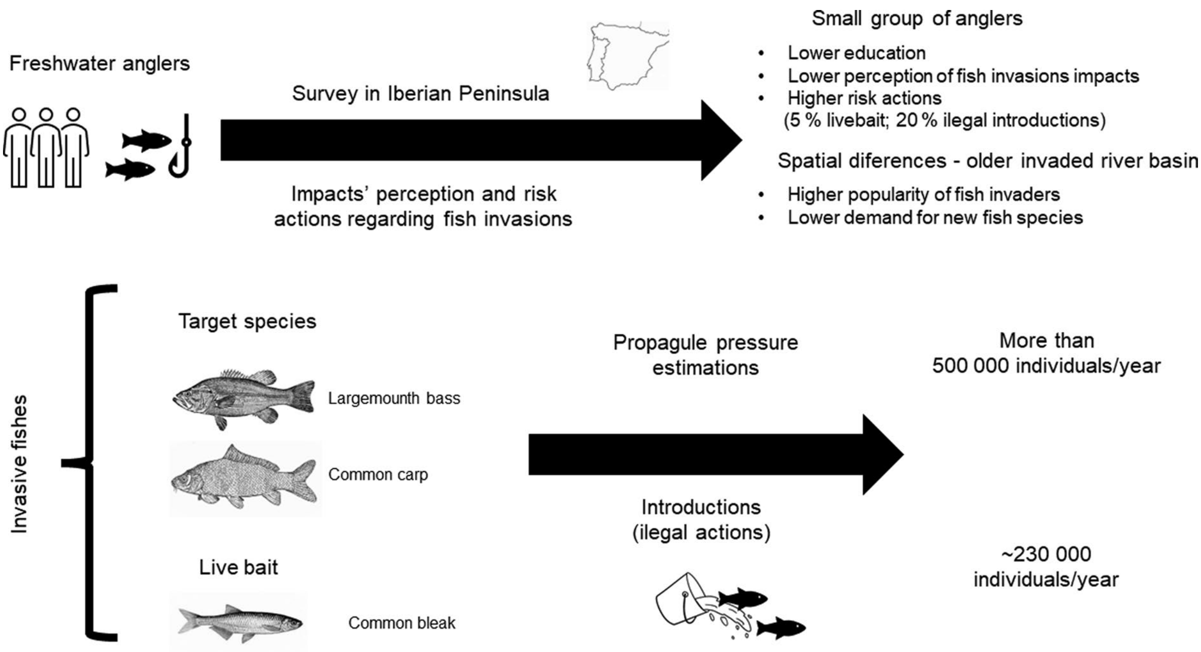
Graphical abstract



Keywords Biological invasions · Freshwaters · Iberian Peninsula · Recreational fisheries · Surveys

Introduction

Biological invasions are one of the main reasons for the loss of biodiversity (Bellard et al. 2016a; b; Ricciardi and MacIsaac 2000; Sala et al. 2000) and the exponential introduction rate of non-native species leads to a growing homogenization of freshwater fauna (Rahel 2007; Villéger et al. 2011). Some non-native species are considered invasive due to their negative impacts on native species, ecosystems and ecosystem services provided to humans, and on human health (EEA 2012). Freshwater fish' invasions are among the most important invasions worldwide, and consequently are one of the most documented invasions among animal taxa. Many aspects have already been studied, namely invasive species' characteristics, origin and invaded regions, invasion pathways, impacts and management. Yet, data gaps and biases remain, and other aspects of freshwater fish invasions need to be clarified to better manage these invasions (Bernery et al. 2022). Recently, the origins and composition of fish introduced worldwide was studied. Two major trends were identified. The first trend occurred before World War II when European and Noth American were the dominant biogeographic regions, in terms of invaders flows, with the major pathways linked with recreational fishing, biocontrol programs and food production. This trend was mainly associated with salmonids and other cold-water fish species. The second trend that has started after this period and goes on until nowadays. The large Sino-Oriental region dominates, being the most important donor and receiver region, with pathways linked to aquaculture and fish keeping. Although the most introduced species are common in all world, each biogeographic region presents nowadays its unique introduced species' composition (Muñoz-Mas et al. 2023). Thus, these findings highlight the necessity to study the fish invasion phenomena at a biogeographic scale to conduct adequate management measures.

Iberian freshwaters are endemic rich ecosystems, hosting unique fish species such as the Lisbon archedmouth nase (*Iberochondrostoma olisiponense*) and nowadays still being discovered new fish species (Doadrio et al. 2024), which are highly vulnerable to invasive species (Cabral et al. 2005). But the Iberian

Peninsula has also numerous established invasive fish species (García-Berthou et al. 2007) which numbers tend to increase (Anastácio et al. 2019; Muñoz-Mas and García-Berthou 2020), with one of the major vectors being recreational fisheries (Banha and Anastácio 2015; Banha et al. 2015, 2016; Bacela-Spychalska 2016).

Intentional fish introductions of game and forage fish species are the main dispersal mechanism related to recreational fisheries, and for Portugal and Spain this is illegal since the last half of the twentieth century (e.g. Banha et al. 2016; Ribeiro et al. 2009a; Elvira and Almodóvar 2001). Game and forage fish species are one of the most representative groups of non-native species introduced in this region (Anastácio et al. 2019; García-Berthou et al. 2007) and are now dominant both in number and biomass in many catchments, representing 30% of the current Iberian freshwater ichthyofauna (García-Berthou et al. 2015; Collares-Pereira et al. 2021). The main routes for these invasions are well identified, especially for central European species, from east to west, with the entryway at the French-Spanish border and the end route in Portugal (e.g. García-Berthou et al. 2005; Ribeiro et al. 2009a). The number of new fish records of non-native fish in Iberia continues to rise at an alarming rate (Anastácio et al. 2019), many due to recreational fisheries (Banha et al. 2016), but with spatial occurrences (new records and species distribution) apparently distinct between Portugal and Spain (Banha et al. 2015; Merciai et al. 2018).

Among Portugal and Spain freshwater anglers are almost one million people, being the largest stakeholder group operating in freshwater ecosystems (Collares-Pereira et al. 2021; MITECO 2021). Surveys have been successfully used to evaluate anglers' perceptions, risk behaviors prevalence and awareness campaigns' effectiveness in the context of biological invasions in freshwaters (e.g. Kilian et al. 2012; Gozlan et al. 2013; Banha et al. 2016; Cerri et al. 2018). Thus, international studies on anglers' role on fish invasions are essential, especially across international rivers and/or fish invasions pathways, as biological invasions do not recognize borders and most countries are not biogeographically isolated. Such information is necessary to apply correct fish invasion management actions, namely when applying measures at a biogeographic scale. There are different anglers' perceptions and risk behaviors across regions or countries (Banha et al. 2022) namely in large Iberian river basins (e.g. Douro, Tagus, Guadiana). In the Iberian Peninsula, policies, laws and management actions are implemented at a national level without significant cooperation between both countries, which have distinct strategies to manage non-native freshwater fauna. Therefore, the adoption of international conventions such as European Union (EU) regulations, needs to be framed within the context of each nation (Anastácio et al. 2019).

The current work aims to clarify anglers' role upon fish invasions in the Iberian Peninsula (IP), exerted by their fishing practices that mediate invasion risk. Anglers' inquiries assessed their practices and evaluated their perceptions regarding fish introductions and their impacts in freshwater ecosystems. Finally, anglers' habits and perceptions were compared among two distinct regions of Iberia, specifically the Lower Tagus (Portugal), with recently arrived non-natives, and the Lower Ebro (Spain), with older fish introductions. These basins often correspond, respectively, to the start and end point of major fish invasions routes in the IP.

Methods

This work was based on a bilingual inquiry survey (in Portuguese and Spanish) following the translation, verification and pilot survey protocol in Banha et al. (2016), for the inquiry content integrity. The survey included 30 questions ("Appendix I"), divided in two sets of questions. An initial set of questions characterized the anglers' group in terms of age, gender, educational and employment levels and residence area and, the second set of questions, evaluated fish invasions awareness and risk behaviors related with angling ("Appendix I"). The same classification as in Banha et al. (2016, 2019) was used for education and employment levels. Three levels were used for the former (Level 1 (basic) $\leq$ 4 years of school; Level 2 (intermediate) 5 to 12 years of school; and Level 3 (superior) > 12 years of school), and also three levels for the later (Level 1 = low (unskilled workers in commerce, services, agriculture, fishing, construction, industry and transport); Level 2 = medium (salespersons, skilled workers in agriculture and fishing, technicians and administrative professionals); Level 3 = high (upper management and specialists in intellectual and scientific professions). A closed binomial response was displayed to choose gender (male/female) and the remaining questions in the first set had open response. In the second section of the survey, a set of questions were displayed with open response regarding: (1) three favorite angling spots; (2) species fished in each location; (3) month of the year with more visits for each location; (4) number of visits. Then, a question regarding the use of fish species as live bait (illegal in both countries) was presented to anglers, to select one option from a 6-point Likert-type scale of frequency: "Never", "Rarely", "Few times", "Sometimes", "Frequently" and "Always". When the option "Never" was not selected, the names of the fish species used were asked (open response), followed by the frequency (same 6-point Likert-type scale as above) of bait release and the frequency (same 6-point Likert-type scale as above) of bait provenance. Finally, the fish bait used and the locations of origin and of use (open response) were asked. Using the same Likert-type scale as above, the frequency of the use of boating devices was asked. When the option "Never" was not the selected one, the respondent was asked about the device used (open response), and how often livewells to hold live fishes were present in the device (same 6-point Likert-type scale above). Next, the 3 most favorite target fish species for angling, ranked, were asked (open response), followed by a binomial (yes/no) question regarding the desire to fish new fish species. To whom answered "yes" the fish species names (open response) was asked. Next, it was asked if the angler knew any case of fish' introduction (binomial response: yes/no). To whom selected "yes" it was asked: (1) the fish species transported and the locations of origin and destination (open response); (2) the method of transport (1 of 6 options: 1) boat livewell; 2) buckets; 3) barrel; 4) cool box; 5) other (open response); 6) do not know); (3) the number of fishes transported (1 of 6 options: 1) < 11; 2) 11–20; 3) 21–30; 4) 31–40; 5) > 40; 6) do not know); (4) the motivation for the transport (1 of 7 options: 1) convenience (fish closer to home); 2) economic motivation (tourism, professional angling); 3) more fish options; 4) forage to other fishes; 5) predate other fishes; 6) do not know; 7) other (open response)). Then, a general question regarding the motivation for fish' introductions was asked to all responders (same 7 options above). Finally, a question regarding the perception about environmental impacts of fish' introduction was presented, asking if the responder considered that those introductions have impacts (binomial: yes/no) and a open response question about the impacts was asked, when the answer was "yes".

The survey was online from March 2017 to May 2018, using Google forms® to be able to reach all the Iberian Peninsula. It was publicized in Portugal and Spain, in six Facebook groups and three forums dedicated to freshwater angling. Additionally, to gather more accurate information about two case-study areas, in person and on-site surveys were conducted for anglers from the Lower Ebro (Spain) and from the Lower Tagus (Portugal) river basins. For the Lower Ebro river, seven field trip visits were done, to 6 locations along a river stretch around 130 km during the period from 9th September 2016 to 25th July 2016. For the Lower Tagus river, twenty-five field trip visits were done, to 19 locations along a river stretch around 100 km and during the period from 17th May 2016 to 9th September 2017.

For both online and face-to-face survey results, a Chi-square on a contingency table was used to test differences between regions and between countries regarding the prevalence of actions/awareness/preferences namely: (1) species popularity; (2) species introduced; (3) number of individuals introduced by event; (4) motivation for the reported introduction; (5) overall perception regarding motivation that drive introductions; (6) proportion of single motivation from particular reported cases face to overall perception; (7) use of live bait; (8) use of boating devices; (9) anglers that desired new angling fish species; (10) awareness about the environmental impacts of introductions; (11) knowing introduction fish events. Due to foreign anglers' prevalence in the Ebro river, for this region, this statistical test was also applied to find differences between Spanish anglers and foreigner anglers regarding fish species popularity.

One-way ANOVA was applied to identify differences between the means of angling activity (days of fishing per year) among locations (regions: Ebro river vs Tagus river; countries: Portugal vs Spain). For the last question in the survey, 'What are the environmental consequences of introductions?' the responses were individually evaluated for the explicit inclusion of three topics: 'Impacts on: native species; ecosystems; ecosystem services provided to humans' in accordance with the EEA (2012) technical report on invasive species.

To evaluate the preference to introduce a particular fish species in relation to angler fishing preferences, the Standardized Forage Ratio (*S*) (Chesson 1983) was applied as in Banha et al. (2019) (Eq. 1). The *S* adapted for fish game species introduction (i) is:

$$S_i = \frac{r_i/P_i}{\sum_{n=1}^{n}(r_n/P_n)} \tag{1}$$

where r_i is the proportion of references of a fish species reported by the responders (i), P_i is the relative proportion of angling popularity among the list of game fish species of the responders, and n is the number of fish species considered. The *S* assumes values between 0 and 1, with $S_i=0$ representing total avoidance of introduction of a fish species (*i*), and $S_i=1$ a fish species (*i*) that is very actively introduced.

To obtain a proxy of propagule pressure for fish invasions for the Iberian Peninsula associated to angling, we estimated the number of fishes introduced per year either as disposal of live bait, or as intentional introduction. In both cases, we considered one million anglers in the Iberian Peninsula (Collares-Pereira et al. 2021; MITECO 2021), and used our online survey information obtained at country-scale. In the first case, the number of introduction events per year (Eq. 2) was obtained using the percentage of anglers associated to this risk activity (i. e. anglers that use live bait captured in one location and used elsewhere, with the discharge of bait in the end of session) multiplied by the mean number of angling sessions per year. This information was obtained from the answers related to live bait use and angling activity. Moreover, considering the frequency of use of each non-native fish species as bait, the number of fish released per year was estimated for each species. We opted for a conservative approach, considering only one individual released per event, since we have no data on the number of fish released (Eq. 3).

$$risk\ bait\ events = risk\ anglers \times frequency \tag{2}$$

Risk bait events - introduction events per year associated to discharges of live bait

Risk anglers - estimated proportion of anglers in the Iberian angler population that use live bait captured and used elsewhere, with the discharge of bait in the end of session - 2% (our online survey) of 1 million people (Collares-Pereira et al. 2021; MITECO 2021).

Frequency - mean number of fishing sessions per year - 36 days (our online survey)

$$p\ bait\ i = fuse\ i \times risk\ bait \tag{3}$$

p bait i - propagule pressure for the fish species i associated to discharges of live bait, expressed as the number of fish discharges per year (considered only one individual per event)

f use i - proportion of use of the fish species i as bait

Risk bait events - introduction events per year associated to discharges of live bait

For the second case (intentional introductions), we used the information from our online survey related to the number of fishes introduced, the species introduced and the percentage of anglers that reported introduction events. Since we do not have information on the regularity of those introductions or when each event occurred, we couldn't accurately calculate the number of fish introduced per year. Yet, based on human memory studies, we know that: unique events are better recalled than routine events, whereas recent events are recalled better than remote events. Autobiographical memories are stored and recalled and can still be remembered after 6 or 7 weeks. Then, information decay starts, but some information can still be stored for 2 decades (Kristo et al. 2009). Therefore, we assumed that the introductions reported with more detail happened within the previous year, while other events without information about the number of fishes introduced probably occurred in a distant past and were excluded from the estimates of propagule pressure. The number of intentional fish introduction events each year was estimated by using the proportion of anglers that reported with detail such introduction events, extrapolated to the overall angler's population in Iberian Peninsula (Eq. 4). Considering the reported number of fish released per introduction and the proportion of each fish species in the reported introduction events, we estimated the propagule pressure for the most frequently introduced species (Eq. 5).

$$introduction\ events = number\ events \times anglers \tag{4}$$

Introduction events - number of events of intentionally introduced fish per year

Number of events - proportion of anglers that reported introduction events with detailed information (assumed to occurred in a period of year)

Anglers - population of angler in Iberian Peninsula

$$p\ introduction\ i = f\ introduction \times number\ introduced \times introduction\ events \quad (5)$$

P introduction I - propagule pressure associated to intentional induction of fish species i

f introduction - reported frequency of introduction of species i

Number introduced - number of reported introduced individuals

Introduction events - per year number of events of intentional introductions of fishes

Non-metric Multidimensional Scaling (nMDS) was applied to identify anglers' features associated with risk behaviors and impacts' awareness, for each case (Portugal, Spain, Ebro river; Tagus river). The variables used were: anglers features, namely gender, age, educational ("Education") and employment ("Employment"); levels and number of days of fishing ("Activity"); anglers' awareness regarding impacts of fish introductions ("Impacts"—binary—yes or no); risk behaviors: fish used as livebait ("Livebait"—binary yes or no); desired new fish species to fish ("New_fish"—binary yes or no) and if they know someone that has translocated fishes ("Know"—binary yes or no). The data were standardized to a 0–1 scale and Euclidean distance was used as a measure of dissimilarity, since it is sensitive to differences in the magnitude or scale of the input variables (Milligan and Cooper 1988). To validate the nMDS and to facilitate its visualization, a hierarchical cluster analysis was performed on the same data (Clarke and Warwick 2001), also using Euclidean distance as a measure of dissimilarity. Clustering was made using Wald's method, since it creates groups without increasing the variance and heterogeneity (Ward 1963) and is considered one of the best cluster methods (Ferreira and Hitchcock 2009), with the highest level of accuracy (Blashfield 1976). Finally, Spearman's rank correlation coefficient was used to quantify the strength of the associations previously identified by nMDS for each of the four cases. All statistical analyses were performed using IBM SPSS Statistics version 24.

Results

In total, 453 responses were collected from both Portugal (online, all country = 156; presential Tagus river = 97) and Spain (online, all country = 119; presential Ebro river = 81) with 61% of responses obtained online and covering the majority of regions in both countries (Appendix—Table S1). Regarding the survey implemented personally in the Tagus river, all anglers were local residents. In the Ebro river, locals correspond to 72% of responders, anglers from other parts from Spain were 2%, and 26% of anglers were from western and central European countries (mainly Germany, France, Czech Republic and Austria) (Table S1).

There are differences between countries and regions regarding fish species popularity (Portugal vs Spain: Pearson Chi-square = 240.938;

Table 1 Fish species popularity (proportion of responses) at local and national levels

Species	Area			
	Tagus	Ebro	Portugal	Spain
Alburnus alburnus	0.057	0.000	0.008	0.000
Ameiurus melas	0.008	0.000	0.000	0.000
Anguilla anguilla	0.064	0.000	0.003	0.000
Argyrosomus regius	0.011	0.000	0.000	0.000
Carassius spp.	0.102	0.000	0.031	0.006
Cyprinus carpio	0.277	0.277	0.202	0.104
Dicentrarchus labrax	0.034	0.000	0.003	0.006
Esox lucius	0.004	0.004	0.031	0.079
Hucho hucho	0.000	0.000	0.000	0.016
Chondrostoma spp.	0.015	0.000	0.031	0.009
Lepomis gibbosus	0.030	0.000	0.000	0.000
Luciobarbus spp.	0.235	0.000	0.185	0.111
Micropterus salmoides	0.083	0.269	0.326	0.089
Mugilidae	0.064	0.000	0.003	0.003
Oncorhynchus mykiss	0.000	0.000	0.000	0.085
Perca fluviatilis	0.000	0.004	0.011	0.016
Rutilus rutilus	0.000	0.000	0.003	0.000
Salmo salar	0.000	0.000	0.003	0.028
Salmo trutta	0.004	0.033	0.056	0.329
Salvelinus fontinalis	0.000	0.000	0.000	0.044
Sander lucioperca	0.011	0.087	0.090	0.022
Silurus glanis	0.000	0.326	0.000	0.038
Squalius spp.	0.000	0.000	0.014	0.003
Thymallus thymallus	0.000	0.000	0.000	0.009

df = 21; $p < 0.001$; Tagus vs Ebro: Pearson Chi-square = 284.035; df = 16; $p < 0.001$). Despite these differences on species popularity, common carp (*Cyprinus carpio*) and largemouth bass (*Micropterus salmoides*) were popular species in both countries and in both regions (Table 1). For Portugal, the most popular angling species were largemouth bass, followed by the common carp and, in third place, the native barbel species (genus *Luciobarbus*). For the Tagus, the common carp was the most popular species, followed by barbel species, the genus *Carassius*, and largemouth bass in fourth place. For Spain, the most important species were the brown trout (*Salmo trutta*) (native), genus *Luciobarbus* (native); common carp in third place and largemouth bass in fourth. In the Ebro, the most desired species were the European catfish (*Silurus glanis*), followed by the common carp and largemouth bass. Also, in the Ebro there were no differences between Spanish and foreign anglers regarding fish preferences (Pearson Chi-square = 8.444; df = 8; $p = 0.391$).

The proportion of anglers that had knowledge of fish introduction events differed between regions (Pearson Chi-square = 11.918; df = 1; $p = 0.001$), with higher values for the Tagus (33%) than for the Ebro (11%) but did not differ between Portugal and Spain (Pearson Chi-square = 1.624; df = 1; $p = 0.203$) with values around 20% in both countries. The responders reported 114 events of fish introductions, mainly in the Tagus river (43 events; 0.44 introductions/responder); followed by Portugal (41 events; 0.26 introductions/responder); Spain (21 events; 0.18 introductions/responder) and finally the Ebro river (9 events; 0.11 introductions/responder). In the Ebro river, foreign anglers did not report introduction events. Excluding foreign responders, the introduction proportion for the Ebro raises to 0.15 introductions/responder. For all surveys, the most introduced species were the common carp and the largemouth bass (Table 2). Yet, there were differences between countries (Pearson Chi-square = 178.399; df = 14; $p < 0.001$) and regions (Pearson Chi-square = 151.967; df = 28; $p < 0.001$) regarding the proportions of each species introduced. In Spain (online) and in the Ebro (presential), there was also an important number of introductions of European catfish being reported (14.3% and 55% of total introductions reported, respectively). In the Tagus, introductions of *Carassius* were also frequently reported.

Table 2 Fish species with introduced events reported

Species introduced	Area			
	Tagus	Ebro	Portugal	Spain
Alburnus alburnus	0.000	0.000	0.098	0.000
Ameiurus melas	0.000	0.000	0.073	0.048
Anguilla anguilla	0.023	0.000	0.000	0.000
Argyrosomus regius	0.000	0.000	0.000	0.000
Carassius spp.	0.279	0.000	0.000	0.000
Cyprinus carpio	0.395	0.444	0.268	0.238
Dicentrarchus labrax	0.000	0.000	0.000	0.000
Esox lucius	0.023	0.000	0.000	0.095
Hucho hucho	0.000	0.000	0.000	0.000
Chondrostoma spp.	0.000	0.000	0.000	0.048
Lepomis gibbosus	0.000	0.000	0.024	0.048
Luciobarbus spp.	0.070	0.000	0.049	0.048
Micropterus salmoides	0.209	0.000	0.366	0.190
Mugilidae	0.000	0.000	0.000	0.000
Oncorhynchus mykiss	0.000	0.000	0.000	0.048
Perca fluviatilis	0.000	0.000	0.000	0.000
Rutilus rutilus	0.000	0.000	0.024	0.000
Salmo salar	0.000	0.000	0.000	0.000
Salmo trutta	0.000	0.000	0.000	0.048
Salvelinus fontinalis	0.000	0.000	0.000	0.048
Sander lucioperca	0.000	0.000	0.073	0.000
Silurus glanis	0.000	0.556	0.024	0.143
Squalius spp.	0.000	0.000	0.000	0.000
Thymallus thymallus	0.000	0.000	0.000	0.000

Finally, in Portugal, introductions of bleak had the third highest frequency (Table 2). The electivity index showed a positive selection of popular angling species for introduction purposes. For example, carp and largemouth bass, the most popular angling species, had a positive electivity for introduction in all four sets of data (Fig. 1). A few species with lower angling popularity presented high levels of electivity for introduction, namely black bullhead (*Ameiurus melas*) and pumpkinseed (*Lepomis gibbosus*), both for Portugal and Spain. The European catfish also presented a high electivity for introduction not only in the Ebro where it is already popular, but also for Portugal and Spain. Additionally, in the Tagus the Northern pike, was the fish species with higher electivity (Fig. 1).

The reported number of individuals introduced was different for each region (Pearson Chi-square = 16.788; df = 5; $p = 0.005$) but not for each country (Pearson Chi-square = 2.850; df = 4;

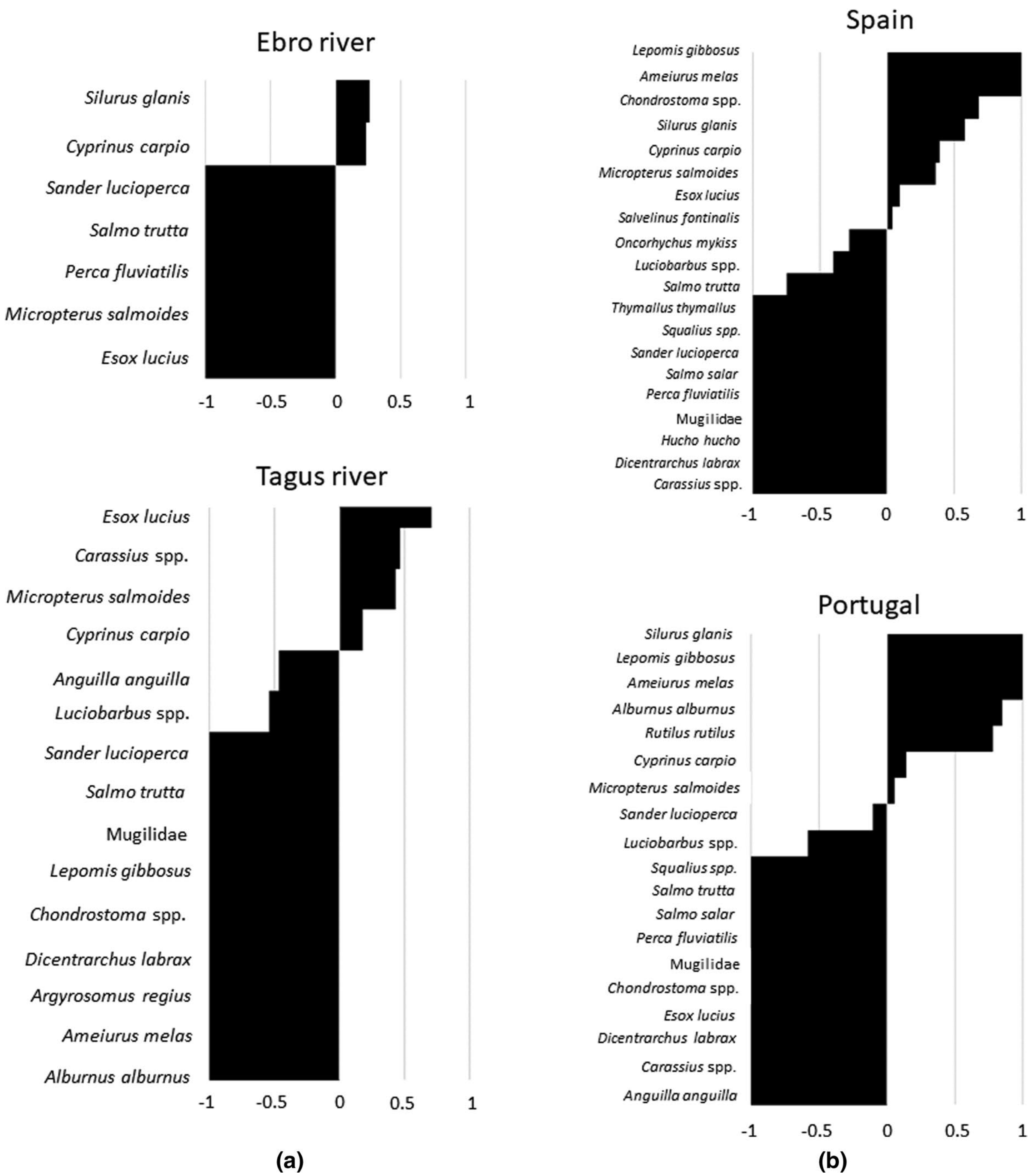


Fig. 1 Electivity for introductions of fish species in relation to their angling popularity

$p = 0.583$). The highest number of individuals transported per introduction event was in the Tagus, since the proportion of events with more than 40 fish introduced was the most chosen answer, while in Ebro no introduction case reports with more than 20 individuals were registered (Fig. 2). Also, methods for fish transport differed between regions (Pearson Chi-square $= 16.001$; df $= 6$; $p = 0.030$) and countries

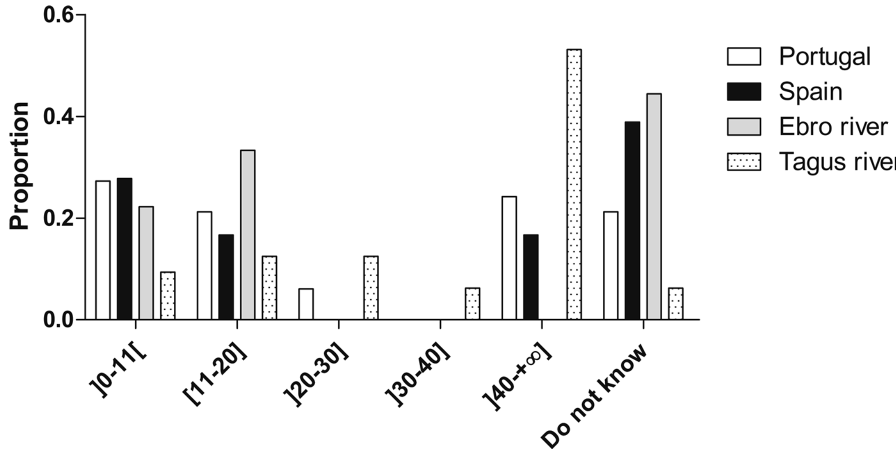


Fig. 2 Relative frequencies, i.e. proportions of the reported number of fish introduced

(Pearson Chi-square = 15.657; df = 6; $p = 0.016$). Overall, the most reported introduction methods were buckets and barrels, with approximately 60% of cases for Portugal and the Tagus river. For Spain all methods reported have similar importance and for the Ebro river the use of coolers was the method more frequently used with more than 50% of the answers (Fig. 3).

The responders attributed introductions to several motivations, with different proportions for each region (Pearson Chi-square = 16.366; df = 6; $p = 0.012$), and country (Pearson Chi-square = 15.5272; df = 7; $p = 0.030$). For instance, for Spain and for the Ebro river there was a higher proportion of responders that "do not know" the motivation, while "Stocking" had a greater proportion for the Tagus river. For Portugal, the "More fish options" had greater representativity compared with Spain. Yet, overall, the most referred motivation was the convenience to fish those species closer to angler's homes (Fig. 4). The perceived motivations driving introductions, also differed among regions (Pearson Chi-square = 87.058; df = 7; $p < 0.001$) and countries (Pearson Chi-square = 52.835; df = 12; $p < 0.001$). Once again, the most referred motivation was the convenience to fish such species closer to their homes, followed by "More fish options" and "economic motivation" associated to tourism and professional angling (Fig. 5). There was no difference for each region/country in the proportion of each motivation for the reported cases of introduction events and the general perception regarding introduction motivations (Portugal: Pearson Chi-square = 10.661; df = 9; $p = 0.300$; Spain: Pearson Chi-square = 8.202; df = 10; $p = 0.609$; Tagus river: Pearson Chi-square = 9.847; df = 7; $p = 0.197$; Ebro river: Pearson Chi-square = 5.237; df = 2; $p = 0.073$).

There were differences between countries (Pearson Chi-square = 16.537, df = 1, $p \leq 0.001$) and regions (Pearson Chi-square = 52.946, df = 1, $p \leq 0.001$) in the proportion of anglers that use boating devices. The Ebro was the region with the most "Boating means" use, corresponding to 72% of the respondents, with 76% of these using boats, followed by kayaks (20%) and only 3% using float tubes. For this region, the use of livewells was not reported. The Tagus presented the lowest percentage of "Boating means" use, with only 18%. Boats were the most commonly used means by most of the fishermen, with 88%, followed by float tubes (12%). Approximately 41% of these devices had livewells. More than half (58%) of the responders in Portugal use some kind of "Boating means", with 54% of these using a boat, followed by float tubes (31%) and kayaks (15%), and the prevalence of livewells on these devices was 52%. A third of the Spanish responders (34%) use "Boating means", and boats are the most used (58%), followed closely by float tubes (35%) and then by kayaks (8%).

There are differences between regions (Pearson Chi-square = 13.378, df = 1, $p < 0.001$) but not between countries (Pearson Chi-square = 2.890, df = 1, $p = 0.089$) in the proportion of anglers that desired new species. Most of the responders (ranging from 52% in Portugal to 62% in Spain) desired new species to be introduced in their country. A comparison between regions showed an inverse pattern, with the Ebro anglers with less demand (28%: 76% for foreigners, 12% for Spanish anglers) while in the Tagus it was the double. Regarding the number of angling

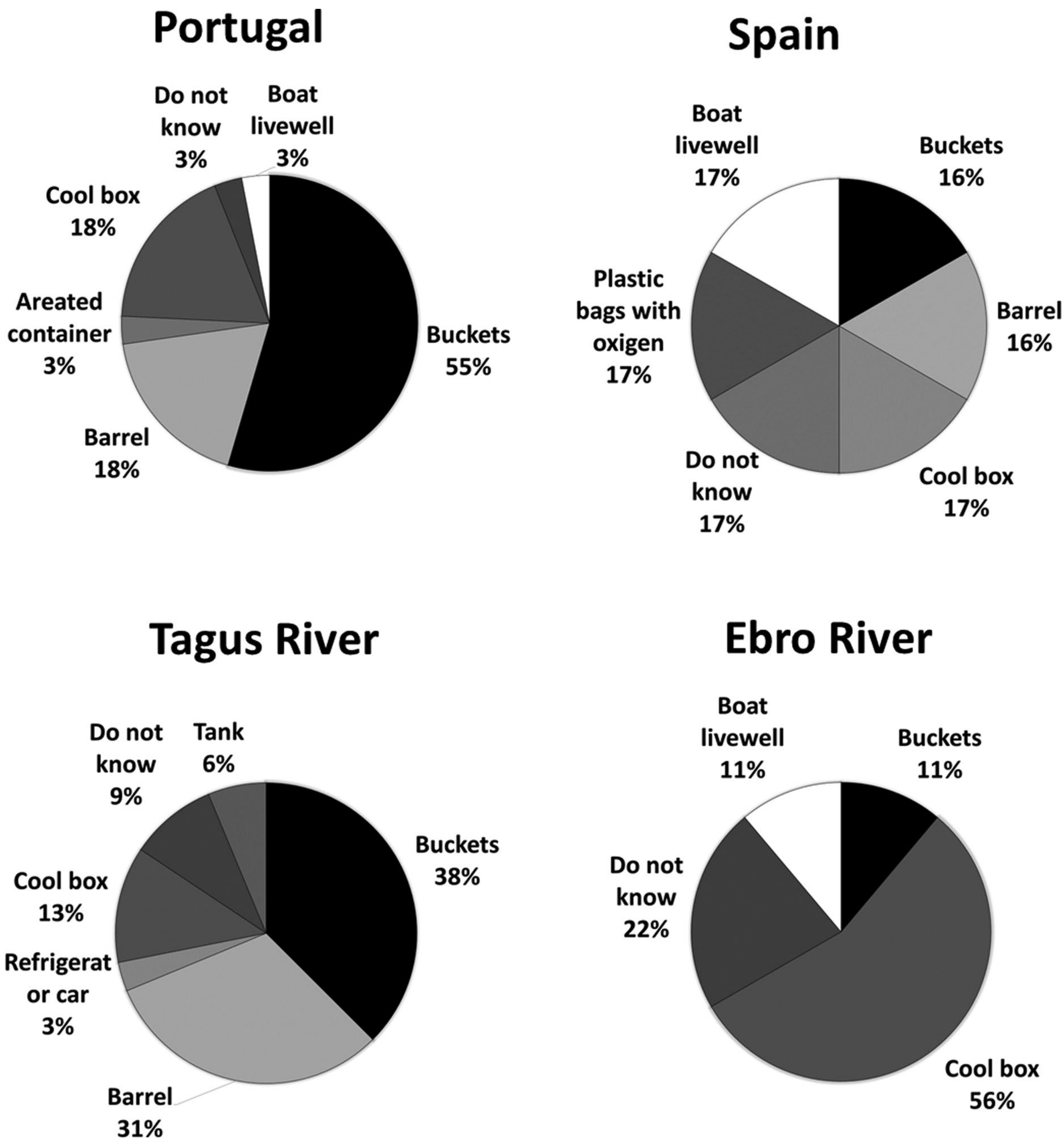


Fig. 3 Percentages of each reported method of fish introductions

species desired, Spain presented 29 species, Portugal 26, the Tagus 15 species and the Ebro four desired new introduced species. The four species referred for the Ebro river (*Silurus glanis*, *Micropterus salmoides*, *Salmo trutta* and *Cyprinus carpio*) were also among the most desired species for Portugal, Spain or the Tagus. Overall, 37 fish species were referred, with only 27% corresponding to native species. From those the most wanted were the threatened Atlantic salmon (*Salmo salar*) and Atlantic sturgeon (*Acipenser sturio*), and the more common genus *Luciobarbus* and the brown trout (*Salmo trutta*). Additionally, we would like to highlight that some desired species are from very distant regions, not yet introduced in

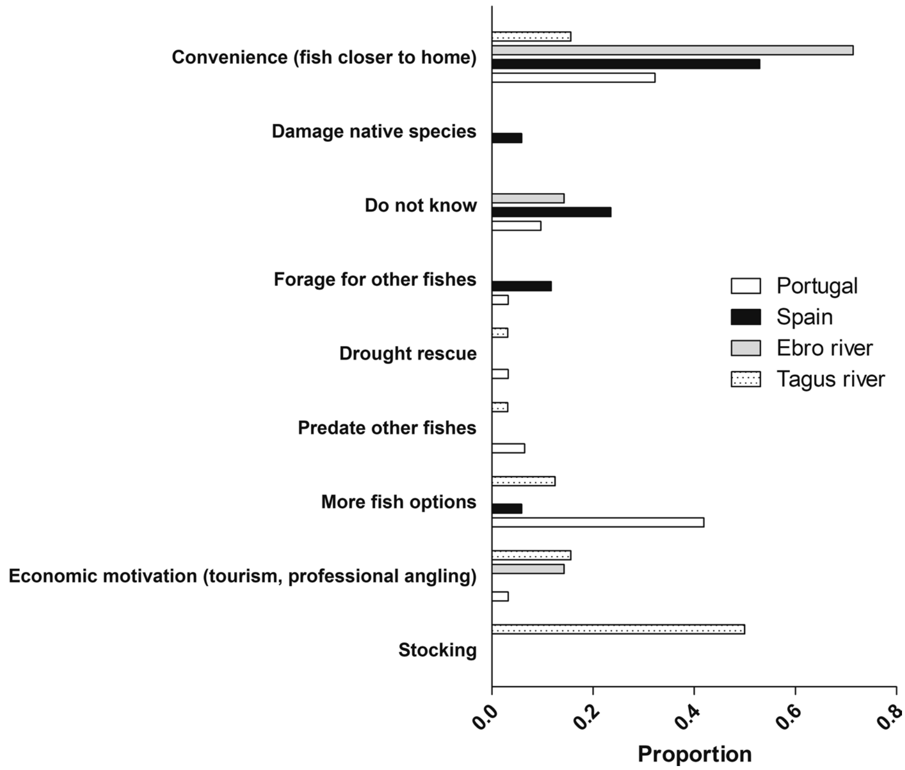


Fig. 4 Motivation (proportion) for the fish introductions reported

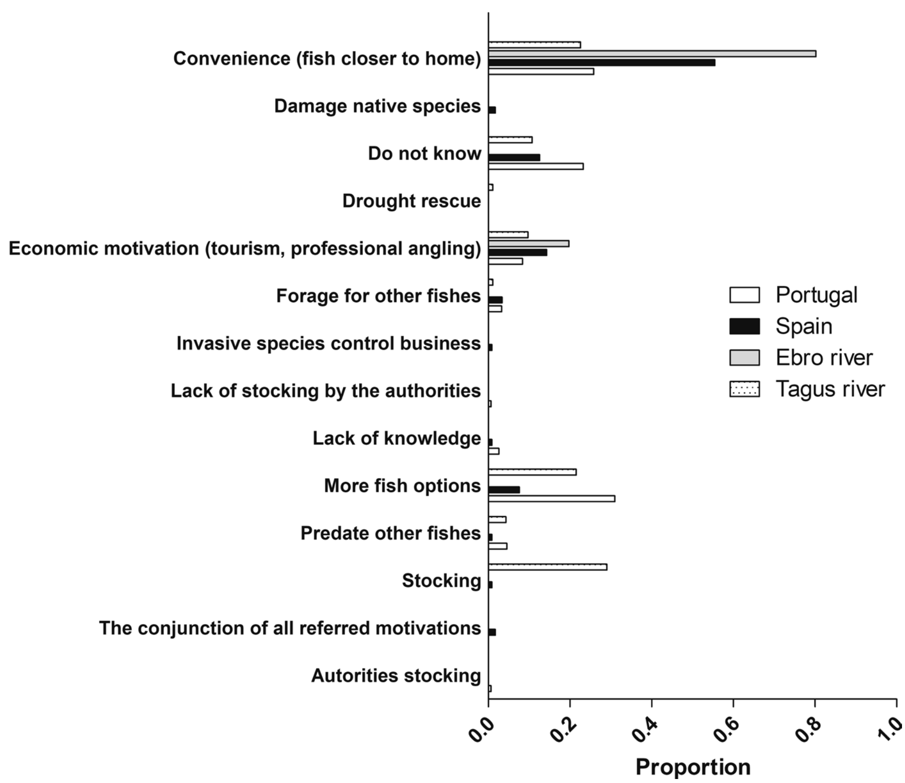


Fig. 5 Overall perception (proportion) about motivations driving fish introductions

Table 3 Proportion of desired species that do not occur in each region

Rk	Spain		Portugal		Tagus river		Ebro river	
	Prop	Species	Prop	Species	Prop	Species	Prop	Species
1	0.195	*Salmo salar*	0.126	*Esox lucius*	0.24	*Esox lucius*	0.520	*Silurus glanis*
2	0.119	*Thymallus thymallus*	0.109	*Salmo trutta*	0.16	*Abramis* spp.	0.200	*Micropterus salmoides*
3	0.093	*Salvelinus fontinalis*	0.092	*Silurus glanis*	0.12	*Micropterus salmoides*	0.160	*Salmo trutta*
4	0.076	*Salmo trutta*	0.084	*Sander lucioperca*	0.12	*Sander lucioperca*	0.120	*Cyprinus carpio*
5	0.076	*Silurus glanis*	0.076	*Cyprinus carpio*	0.08	*Salmo trutta*		
6	0.068	*Esox lucius*	0.059	*Micropterus salmoides*	0.06	*Salmo salar*		
7	0.051	*Luciobarbus* spp.	0.050	*Cichla monoculus*	0.04	*Silurus glanis*		
8	0.034	*Hucho hucho*	0.050	*Luciobarbus* spp.	0.04	*Tinca tinca*		
9	0.034	*Micropterus salmoides*	0.050	*Rutilus rutilus*	0.02	*Carassius* spp.		
10	0.034	*Salmo trutta trutta*	0.050	*Salmo salar*	0.02	*Cichla monoculus*		
11	0.025	*Megalops atlanticus*	0.034	*Abramis* spp.	0.02	*Chondrostoma spp.*		
12	0.017	*Acipenser sturio*	0.034	*Acipenser sturio*	0.02	*Lepomis gibbosus*		
13	0.017	*Arapaima gigas*	0.034	*perca fluviatilis*	0.02	*Luciobarbus* spp.		
14	0.017	*Ctenopharyngodon idella*	0.025	*Chondrostoma spp.*	0.02	*Mugilidae*		
15	0.017	*Oncorhynchus mykiss*	0.025	*Micropterus dolomieu*	0.02	*Rutilus rutilus*		
16	0.017	*Perca fluviatilis*	0.017	*Anguilla anguilla*				
17	0.008	*Abramis* spp.	0.008	*Argyrosomus regius*				
18	0.008	*Albula vulpes*	0.008	*Carassius* spp.				
19	0.008	*Channa micropeltes*	0.008	*Channa micropeltes*				
20	0.008	*Cyprinus carpio*	0.008	*Ctenopharyngodon idella*				
21	0.008	*Hucho taimen*	0.008	*Megalops atlanticus*				
22	0.008	*Chondrostoma spp.*	0.008	*Micropterus salmoides floridanus*				
23	0.008	*Micropterus salmoides floridanus*	0.008	*Oncorhynchus mykiss*				
24	0.008	*Oncorhynchus tshawytscha*	0.008	*Salminus brasiliensis*				
25	0.008	*Osteoglossum bicirrhosum*	0.008	*Scardinius erythrophthalmus*				
26	0.008	*Pangasianodon gigas*	0.008	*Tinca tinca*				
27	0.008	*Salminus brasiliensis*						
28	0.008	*Sander lucioperca*						
29	0.008	*Tinca tinca*						

Prop—Proportion. Rk.—Rank, with the 1st being the most desired species

Europe, but with a high sport value recognized worldwide, as for example the taimen (*Hucho taimen*), the pirarucu (*Arapaima gigas*) and the Mekong giant catfish (*Pangasianodon gigas*) (Table 3).

Regarding the use of fish as live bait, there are no differences between Portugal and Spain (Pearson Chi-square = 0.046; df = 1; $p = 0.830$), with only 5% of anglers using it. Also, between the Ebro and the Tagus no differences were observed (Pearson Chi-square = 3.530; df = 1; $p = 0.060$), with a similar use percentage of less than 10%. Generally, these anglers used live bait in 25% of the fishing sessions, 23% of the time with bait from other locations and in 46% of the occasions the bait was released at the end of the session. Considering the four surveys, the most used fish as live bait was the non-native bleak (*Alburnus*

alburnus) (46%), being the only species reported for the Ebro River. The second most used, but only in Portugal and in the Tagus River, was the native southern Iberian spined-loach (*Cobitis paludica*) (13%). The remaining species, reported for Spain, Portugal and the Tagus river are mainly native and have similar popularity (about 10%) and are represented by the native barbels (*Luciobarbus spp.*), the nase group ("*Chondrostoma"* spp.) and the chubs (*Squalius* spp.). Additionally, and with similar popularity (10%) appears the non-native roach (*Rutilus rutilus*).

The overall mean number of fishing sessions per year was 36 and there was no difference between countries (one-way ANOVA: F = 0.396; df = 1; $p = 0.530$) or regions (one-way ANOVA: F = 0.966; df = 1; $p = 0.327$). This value was used in Eq. 2 (frequency).

Our survey showed that 2% of anglers are associated to the risk of live bait discharge, and this corresponds to anglers that use live fish bait, obtaining it elsewhere and releasing it at the end of fishing sessions. For these 2%, 38% corresponds to discharges of non-native fishes and this corresponds to a real risk of 0.76% of non-native species introduction (risk anglers (component—Eq. 2) = 0.0076 × 1,000,000 anglers = 7600 anglers). Considering Eq. 2, we estimated an impressive total of 273,600 events of bait discharges per year in Iberian Peninsula. Using Eq. 3, we estimated for non-native bleak, the most used species as bait, that corresponds to 82% of these events, the release of 224,352 individuals per year. For the overall other non-native species used as live bait we estimated 49,248 individuals discharged per year.

Regarding the intentional introductions, we verified that from the 20% of anglers of the Iberian Peninsula that reported intentional fish introductions, only 70% gave all the introductions information, being those events considered to have happened in the recent year period. Applying Eq. 4, we estimated a total of 140.000 introduction events per year. Since we do not have a precise number of individuals introduced, taking into consideration the class more frequently reported (~50%) (Fig. 2), we used the mean number of 15 individuals introduced per event. So, using Eq. 5 for the most reported species, the largemouth bass and the common carp (Table 2), considering the mean values of both countries for the proportion of these species (largemouth bass—0.253; common carp—0.278), we estimated a total of 531.300 and 583.800 individuals translocated per year between different freshwater ecosystems, for largemouth bass and common carp, respectively.

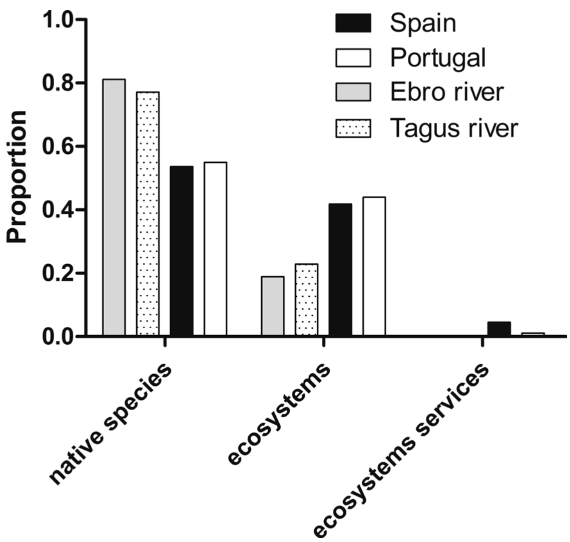


Fig. 6 Proportion of responses mentioning each type of negative impacts of fish introductions

Regarding the level of awareness (i.e. anglers that admit that introductions have impacts), there were differences between countries (Pearson Chi-square = 18.367; df = 1; $p \leq 0.001$) and regions (Pearson Chi-square = 8.431; df = 1; $p = 0.004$). The case with higher awareness was Spain with 84% of responders admitting that fish introductions have impacts, followed by the Ebro with 73%, Portugal with 60% and the Tagus with 51%. Most of the impacts referred were negative impacts on native species (predation, competition, diseases transmission), followed by impacts on ecosystems (destruction, ecosystem disequilibrium). Impacts of invasive species on ecosystem services were mentioned on the online survey: Spain (5% of the responders) and Portugal (15% of the responders), namely impacts on fisheries of native species and on water quality (Fig. 6). The large majority of the anglers referred only one type of impact (Ebro—86%; Tagus—89%; Portugal—96%; Spain—90%), with few responders mentioning two types of impacts, being almost exclusively impacts on native species and ecosystems.

The nMDS analysis showed an association between some angler features and variables related to risk behaviors and awareness regarding fish invasions.

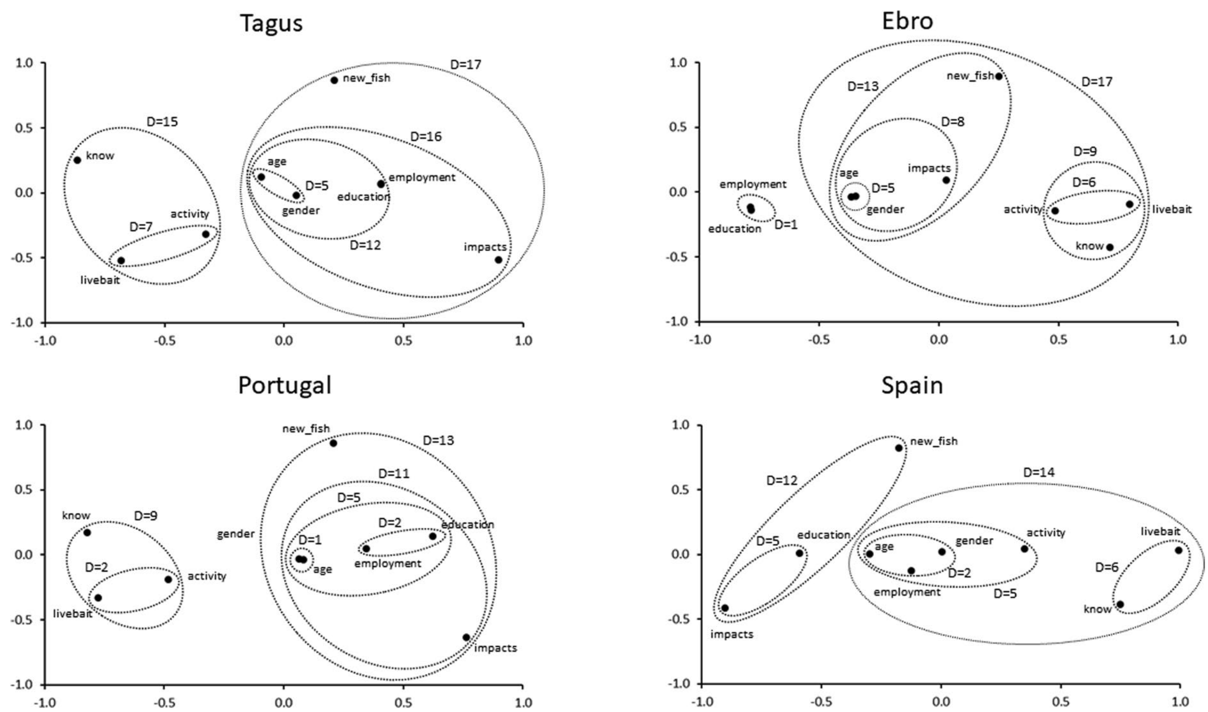


Fig. 7 Association between characteristics, actions and perceptions of anglers related with fish introductions. Dissimilarity between variables were defined by nMDS (non-metric Multidimensional Scaling). A hierarchical clustering analysis was superimposed using Euclidean distances creating groups of related variables represented by a dashed line. nMDS metrics: Tagus—Normalized Raw Stress = 0.0017 (Excellent adjustment Kruskal 1964), Dispersion Accounted For (D.A.F) = 0.9983, Tucker's Coefficient of Congruence = 0.9991. Ebro—Normalized Raw Stress = 0.0008 (Excellent adjustment Kruskal 1964), Dispersion Accounted For (D.A.F) = 0.9992, Tucker's Coefficient of Congruence = 0.9996. Portugal—Normalized Raw Stress = 0.0012 (Excellent adjustment Kruskal 1964), Dispersion Accounted For (D.A.F) = 0.9988, Tucker's Coefficient of Congruence = 0.9994. Spain—Normalized Raw Stress = 0.0025 (Excellent adjustment Kruskal 1964), Dispersion Accounted For (D.A.F) = 0.9974, Tucker's Coefficient of Congruence = 0.9988

Variables such as knowing someone that has introduced fishes ("Know"), use of fish as livebait ("Livebait") and angler's activity ("Activity") are closely associated in Portugal, the Tagus river and the Ebro river. For Spain, angler's activity is less associated to those variables (Fig. 7). Nevertheless, according to a Spearman rank correlation analysis (Appendix—Tables S2–S5) there were significant correlations between "Know" and "Activity" (negative) for the Ebro river; "Livebait" and "Activity" (positive), and "Know" and "Activity" (positive) for the Tagus river. For all 4 cases, the risk behavior of wanting new fish species ("New_fish") was not closely associated to another risk behavior or angler's traits, and those variables that are more associated, do not have significant correlations (Appendix—Tables S2–S5). The awareness of impacts of fish introductions ("Impacts") were associated to anglers' traits "Age", "Gender", "Employment" and "Education" levels, both for Portugal and the Tagus river. For the Ebro river, "Impacts" was associated with "Age" and "Gender". For Spain, the awareness of impacts of fish introductions ("Impacts") is most closely associated to education level ("Education") (Fig. 7). A significant correlation was found between the awareness of impacts of fish introductions ("Impacts") with: "Age" (positive) and with "Employment" (positive) for Portugal; and "Impacts" with "Age" (negative), "Education" (positive), "Employment" (positive) for the Tagus river. For Spain and for the Ebro river, no correlations were found between "Impacts" and its most closely associated variables (Appendix—Tables S2–S5).

Discussion

This work found differences in angling habits and fish introduction impacts awareness across the Iberian Peninsula. Differences were more marked at regional scale, particularly between the Ebro and Tagus stretches, than at large scale, between Portugal and Spain. Yet, for some features there is a common pattern across Iberia, namely regarding fish species popularity for angling and higher anglers' awareness associated to higher levels of education. Overall, our study showed that the proportion of anglers directly related to fish species introductions, both related with live bait discharge or target fish intentional transport, are a minority. Yet, our findings suggested that even a small proportion of anglers involved in such actions represent a great propagule pressure for fish introductions. These findings need be considered carefully due to some bias related to the sample size and its representativity, and also due to the possibility of inaccurate or false answers from some anglers.

We found that the most desired angling species were the non-native common carp (*Cyprinus carpio*) and largemouth bass (*Micropterus salmoides*), as previously found by Banha et al. (2016), which are old introductions with a wide distribution (Clavero and Villero 2014; Godinho et al. 1998). In Spain high levels of popularity were also found for the native brown trout (*Salmo trutta*). Yet, this species only occurs in highlands of Portugal and Spain, (Collares-Pereira et al. 2021; Doadrio 2001) and it is expected that in those areas their popularity would be higher than in the areas where this species is absent. Ebro and Tagus surveys showed different species popularity, although both areas have similar non-native fish assemblages (Banha et al. 2015; Gkenas et al. 2015; Caiola et al. 2014; Ribeiro et al. 2009a). The three most popular species in the Ebro River represented almost 90% of the responses. These were the European catfish (*Silurus glanis*), the common carp (*Cyprinus carpio*) and the largemouth bass (*Micropterus salmoides*). In the Tagus there was a larger number of very popular species, namely the common carp, the native barbels and the gibel carp or goldfish (*Carassius* spp.). Note that, for the Tagus, some marine or diadromous species also have importance, such as the sea bass (*Dicentrarchus labrax*), European eel (*Anguilla anguilla*), mullet (Mugilidae) and the meagre (*Argyrosomus regius*).

Although all popular non-native angling species in the Ebro are also mentioned in the Tagus, in the Ebro most species arrived much earlier, i.e. around the 70's (Leunda 2010), with the exceptions of carp, goldfish and largemouth bass. There was a time lag of about 30 years to the Portuguese Tagus stretch, with European catfish arriving around 2006 (Gkenas et al. 2015), the pikeperch in 2005 (Ribeiro et al. 2009b) and the European perch in 2007 (Banha et al. 2015). Except for the European perch, all these species seem to have dispersed downstream (Banha et al. 2015; Gago et al. 2016; Gkenas et al. 2015; Ribeiro et al. 2009a, b), and Portuguese local anglers do not yet have the habit of targeting for these species. However, in the Ebro, these species are highly desired, and this is demonstrated by the Spanish anglers interviewed in the Ebro river and showing preferences for such species. This is also reinforced by the high percentage (26%) of angler tourists travelling into Spain from countries where those fishes are native.

Regarding the popularity of diadromous species targeted in the Tagus, this may result from the fact that the final stretch of the Tagus is unregulated (I.e. with no barriers) and lies in an area with a very high population density when compared with the upper part of the Tagus which has dams and low population density (INE 2019). Additionally, in the Tagus, fishing for diadromous fishes is part of the local culture (Serrano 2014) and has economic relevance. The lower importance of diadromous fishes for the Ebro river could be explained by the fact that surveys were applied in a river stretch more distant from the sea and located upstream from barriers, namely the Flix dam, 123 km far from the river mouth. In fact, diadromous fishes suffered a severe decline in the Ebro river due to the construction of the Xerta's weir built in the sixteenth century, which is located downstream Flix dam, at 63 km from river mouth (López et al. 2007). Therefore, the differences in popularity between regions could be due to the differences in diadromous species availability in each river basin (Mota et al. 2016).

The use of different survey methodologies usually affects survey results (e.g. Cobanoglu et al. 2001). For instance, the questions connected to illegal actions such as illegal live bait use and fish introductions do not seem to benefit from on-line anonymity. In fact, there was a high number of illegal actions reported in presential surveys, contrary to what was expected (Banha et al. 2016). Yet, the major difference and methodologic gap detected was that the on-line survey, publicized in Portuguese and Spanish social media, did not reach foreign anglers. For the Ebro river, this group may play a major role in international biological invasions due to their travels across biogeographic borders. Bias from the lack or low number of on-line responses from some Portuguese or Spanish regions, as for example the Canary islands and Murcia region in Spain or Algarve region in Portugal, may be low since those regions have few waterbodies and low prevalence of freshwater angling. However, there may be a slight bias towards higher education or income levels, when comparing on-line versus presential surveys, as these tend to have easier access to social media, the web and our survey. This could potentially impact the results regarding prevalence of boating means, which are much higher for Portugal in the on-line survey than in the presential survey in the Tagus river region. However, the situation is inverted in Spain, where in the Ebro river presential survey the prevalence of boating means is higher than for the Spanish on-line survey.

The processes used by anglers to transport fish for introductions were identified and these were usually small to medium size containers transporting usually less than 20 individuals. Banha et al. (2016) reported for the Iberian Peninsula that popular species have higher number of introduction events. In the present study using the electivity index, the common carp and largemouth bass, presented a high level of electivity. Yet, some fish species with low popularity, presented high levels of selection for introduction, namely pumpkinseed sunfish, black bullhead and European catfish. The first two are small fish species that normally attain high densities, are easy to fish (pers. obs.) and are generally very tolerant to transport. Moreover, the black bullhead can survive low oxygen levels and can also survive out of water for long periods, facilitating its transport (Banha et al. 2015). Thus, the easiness to obtain and to transport successfully these two species could explain why so many introductions are reported. The European catfish may however be different since it is more difficult to obtain high numbers of small individuals, and the transport of mature individuals with a very large size, is much more complicated when compared to the two previous species. However, this could be counterbalanced by the important demand for European catfish related to angling interest and tourism (Banha et al. 2016; Gago et al. 2016). Moreover, in regard to fish transport and introduction by anglers, different pathways related to anglers that are also aquarists need to be considered. Recently, it was found that this group could be relevant (22% of anglers in Switzerland), and 53 of 237 non-native fish species in the European Union are used for both angling and aquarium hobbies. Considering the commercial aquarium trade and angling as separate pathways for translocating non-native fish could be an error (Hirsch et al. 2021). Thus, species obtained in pet shops could be released for angling purposes, or fishes captured in fishing sessions could be transported for aquarium use, with the possibility of latter discharge. In the Iberian Peninsula, at least four species were identified with relevance for both activities, angling and aquarium use, namely the common carp, goldfish, pumpkinseed sunfish and chameleon cichlid (Collares-Pereira et al. 2021).

In this work, we found differences in anglers' motivations for fish introductions among areas. Yet, the most referred cause was the convenience of fishing for the species closer to home. In a survey-based study on central Italy, the same main motivation for illegal fish stocking was also found (Cerri et al. 2018). Curiously, we found that few anglers have interest in the introduction of fish species from far away regions, as south America and central Asia, as the cases of *Arapaima* sp. and *Hucho taimen,* respectively. In their natural ranges these large species are popular and are associated with targeted angling tourism (Jensen et al. 2009; Lennox et al. 2018), and this is similar to the most popular game fish species in the Iberian Peninsula (Banha et al. 2016). Such sport species have become part of the global consumer society, reflecting a globalization of alien fish species for sport with the associated expensive angling gear, magazines and accommodation infrastructure (Cambray 2003). Interestingly, the lowest number of new species wanted and the proportion of anglers that want them were found in the Ebro region, which is much sought after by foreign anglers. Thus, this fact could be related to the actual angling sports quality of this region, due to the presence of highly valued game fish targets such as the Wels catfish, the common carp, zander and large largemouth bass (Gómez 2005). As mentioned by Carpio et al. (2019), anglers in the Mediterranean region have been introducing fish with the intention to obtain a diversified spectrum of fishable species. Thus, as the Ebro already has such diversity of valued introduced species, the demand for more was lowered. It is important to highlight that anglers showed some demand for native species, namely barbels, and threatened species such as Atlantic salmon and sturgeons. This may present an opportunity for collaborative work with the angling community, conciliating species conservation with angling. Thereby, examples of those actions are the improvement of "catch & release" practices when native species are involved, promotion of stocking campaigns with these fish species and lowering illegal introductions of non-native species. Moreover, the obligation not to return non-native fishes to water, outside licensed angling grounds, should be reinforced.

Regarding "catch & release" practices, Nolan et al. (2019) reported that anglers release back to water the invasive fishes captured, as a common practice, against the legislation. These authors reported the case of pikeperch in Severn river in England, showing that anglers perceive that the removal of their target fishes will affect their hobby. Both in Spain and Portugal, there was angler' associations pressure when the European Directive n.º 1143/2014, related with invasive species, was applied to national law, with the result of several invasive fish species being excluded or being allowed their release to the environment in particular areas (PCM 2019; Del Estado 2007), and the most recent case was the largemouth bass in Portugal (AR 2023). Additionally, nowadays in some regions of Spain and in Portugal, some invasive species (excluded from this lists) continued to be released against the law, such as the wels catfish in Tagus river, with many videos and photos of such evets being published in social media (pres. obs.). The lobby connected to sport fishes moves large amounts of money and has considerable importance in worldwide economy being capable to overcome biodiversity conservation initiatives (see South et al. 2022). Also, in Spain and Portugal, the tourism was mentioned by anglers as one of the main motivations for the introduction of new fish species (Banha et al. 2016). Thus, a new fish species arrival will have a great demand and economic income associated, and it is expected a great pressure for its exclusion from control or eradication actions.

The use of fish as live bait across the Iberian Peninsula had a low prevalence, ~ 5% of anglers, compared for example with Minnesota state in USA where reaches a prevalence of 72% (McEachran et al. 2022). Yet, this contrasted with the high prevalence of translocation and discharges of fishes used as live bait, as highlighted by our conservative estimations of propagule pressure. This may represent a serious problem since we found that anglers using live fish bait, an illegal practice, are also those who fish more frequently. Moreover, this could explain, why an unpopular species like bleak but frequently used as live bait, had such a fast expansion since the first records in Spain during the 90's (Leunda 2010; Martelo et al. 2021). McEachran et al. (2022) verified in the state of Minesota (USA), that one of the major reasons for livebait discharge relies in the angler's assumption that those fishes will benefit the recipient ecosystem. This practice could also apply to our case, since bleak, which is one of the most introduced fish species in Europe, as forage species for game fishes (Latorre et al. 2023). Its discharge contributes to feed the target fish species, and could explain their rapid spread across watersheds in Iberian Peninsula.

Finally, our estimates also showed that the propagule pressure for fish introductions could be higher for fishes used as bait than for game fish species intentionally introduced. However, the diversity of fish species introduced for bait, namely non-native, and the total amount of individuals translocated could be lower than for angling, considering the cumulative number for all species involved.

This work revealed that anglers which are less aware of fish invasion impacts seem to be the ones knowing someone who introduced fish, the ones with lower educational and employment levels, the ones wanting more fish species, and using live bait and fishing a larger number of days per year. So, it is urgent to raise the environmental awareness levels of this group through educational programs, as proposed by Azevedo-Santos et al. (2015) for Brazil that has a similar reality. These anglers seem to have both an important role in intentional introductions of target fish species and on the introduction of fish used as live bait. Therefore, it is important to educate these anglers about the human activities or ecosystem services impacted by fish introductions and reinforce the knowledge about impact on native species and ecosystems. In this context, an ongoing E.U. project to raise awareness about aquatic invasive species, LIFE Invasaqua, has being implemented since 2018 in the Iberian Peninsula (Banha et al. 2022; Casals and Sánchez-González 2020). Preliminary results from this project show an increasing awareness outcome, namely on invasive species socioeconomic and human health impacts (pres. Obs.). These two main impact domains were previously identified as those with more lack of knowledge (Banha et al. 2022). Another success case occurred in Great Britain, with the awareness campaign "Check, Clean Dry biosecurity", with anglers adopting the biosecurity measures with their equipment, and since the beginning of this campaign the number of anglers that someway handled their equipment raised 15%, reaching 80% in 2020 (Smith et al. 2020). Concluding, we found that anglers less aware about invasion risks presented less educational and employment levels. Anglers that report a greater number of introductions, used live bait more often and presented more fishing activity. These angler groups should be targeted by awareness programs to avoid new fish invasions and minimize its risks. In spite of the low prevalence of risk actions potentially causing fish introductions, our conservative estimates reveal a large propagule pressure associated with intentional introductions and bait discharges. These may be responsible for an annual translocation of around half a million fishes of the most popular non-native and live bait fishes. Additionally, anglers of both countries want some native and some threatened fish species, and this provides an opportunity for environmentally friendly stocking programs, eventually decreasing interest for new non-native fish species.

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Declarations

Conflict of interest Authors declare no conflict of interest.

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