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Recreational angling as a vector of freshwater invasions in Central Italy: perceptions and prevalence of illegal fish restocking

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Abstract – Italian freshwater ecosystems were strongly affected by biological invasions during the last few decades. Recreational angling contributed to this, through the widespread use of invasive alien species for fish restocking. To date, no research is available about the psychological and structural determinants of deliberate fish restocking in Italy. This work aims to fill this research gap, through structured questionnaires administered to a sample of recreational anglers ($n = 276$) in the Arno river basin (Central Italy). A predictive model for fish restocking, based on a quasi-binomial logistic regression, was fit and multi-model inference was drawn, to highlight the most significant predictors. Respondents, who expected that most anglers practiced restocking and who believed restocking could create closer fishing spots, were more prone to illegally restock fish. Our findings indicate that expectations about illegal fish restocking might exist among specialized segments of anglers. Targeted communication campaigns must be enforced as soon as possible to change them. Furthermore, fish restocking is supposed to reduce the travel costs for angling: future research about this is needed to model invasion hotspots.

Keywords: Recreational angling / restocking / aquatic invasions / survey / Italy

Résumé – **La pêche à la ligne récréative en tant que vecteur d'invasion des eaux douces en Italie centrale: perception et prévalence de l'empoissonnement illégal.** Les écosystèmes d'eau douce italiens ont été fortement touchés par les invasions biologiques au cours des dernières décennies. La pêche récréative y a contribué, grâce à l'utilisation généralisée d'espèces exotiques envahissantes pour le repeuplement en poissons. A ce jour, aucune recherche n'est disponible sur les déterminants psychologiques et structurels des empoissonnements délibérés en Italie. Ce travail vise à combler cette lacune de la recherche, par le biais de questionnaires structurés envoyés à un échantillon de pêcheurs récréatifs ($n = 276$) dans le bassin de l'Arno (Italie centrale). Un modèle prédictif des empoissonnements, basé sur une régression logistique quasi-binomiale, a été ajusté et une inférence multi-modèle a été tirée, afin de mettre en évidence les prédicteurs les plus significatifs. Les répondants qui s'attendaient à ce que la plupart des pêcheurs à la ligne pratiquent le repeuplement et qui croyaient que le repeuplement pouvait créer des zones de pêche plus proches étaient plus enclins à repeupler illégalement. Nos résultats indiquent que des groupes de pêcheurs à la ligne pourraient avoir des attentes concernant le repeuplement illégal des poissons. Des campagnes de communication ciblées doivent être mises en œuvre dès que possible, afin de les modifier. De plus, la reconstitution des stocks de poissons est censée réduire les frais de déplacement pour la pêche à la ligne: des recherches futures à ce sujet sont nécessaires pour modéliser les points chauds d'invasion.

Mots-clés : Pêche récréative / repeuplement / invasions aquatiques / surveillance / Italie

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1 Introduction

Biological invasions are a major driver of change for freshwater ecosystems and they often interact with other important factors (MacDougall and Turkington, 2005; Rahel and Olden, 2008; Carpenter *et al.*, 2011), reshaping biotic communities (Mollot *et al.*, 2017) and affecting the provisioning of ecosystem services (Catford, 2017), ultimately resulting in substantial social costs (Perrings, 2002; Lovell *et al.*, 2006).

In the last few decades, biological invasions increased both their frequency and their magnitude across a wide range of ecosystems worldwide (Turbelin *et al.*, 2017), including freshwater (Gallardo *et al.*, 2016). Traditionally, commercial boating is deemed to be the main pathway for aquatic invasions, as improper ballast water discharge can dramatically contribute to the accidental introduction of aquatic Invasive Alien Species (IAS) (Costello *et al.*, 2007; Hulme, 2009) and commercial ships can transport propagules across long distances. However, other pathways for the spread of aquatic IAS have been identified as important, since the early 2000s (Zieritz *et al.*, 2017). For example, recreational boating can be a major vector for IAS in freshwater ecosystems (Johnson *et al.*, 2001; Clarke Murray *et al.*, 2011; Anderson *et al.*, 2014) and ornamental aquarium trade enhances the risk of aquatic IAS escaping from captivity, as well as their deliberate release in nature (Padilla and Williams, 2004; Duggan, 2010; Strecker *et al.*, 2011). Recreational angling can be another important vector for invasive alien invertebrates and fish in freshwater, both in terms of accidental and deliberate introductions. Anglers can promote accidental introductions through a poor cleaning of angling equipment (Waterkeyn *et al.*, 2010; Anderson *et al.*, 2014), by improper bait disposal (Keller *et al.*, 2007; Hendrix *et al.*, 2008; DiStefano *et al.*, 2009; Kilian *et al.*, 2012) and by practicing restocking without enforcing biosecurity protocols (Gozlan *et al.*, 2010). Furthermore, anglers can deliberately release invasive species in freshwater to increase their leisure experience: this can lead to the arrival of new fish species and it can seriously undermine eradication efforts (Cambray, 2003; Gozlan *et al.*, 2010; Lorenzen, 2014).

To date, various human dimension studies have explored the role of recreational anglers in biological invasions, as human behaviour is a major source of uncertainty in fisheries and in the management of IAS (Fulton *et al.*, 2011; Hunt *et al.*, 2013). However, most of these works focused on at risk-behaviours which can lead to accidental introduction of aquatic IAS, like improper bait disposal or equipment cleaning (Gates *et al.*, 2009; Seekamp *et al.*, 2016), or on the potential effect of information provisioning and normative change as tools to prevent them (Azevedo-Santos *et al.*, 2015; Howell *et al.*, 2015; Pradhananga *et al.*, 2015; Fujitani *et al.*, 2016). On the other hand, fewer studies addressed drivers of deliberate fish introductions (Drake *et al.*, 2015), especially for Mediterranean Europe (Banha *et al.*, 2017a). This research gap must be addressed, as deliberate angling is responsible for the arrival of many invasive alien fish species in Mediterranean freshwater (Gherardi *et al.*, 2008), including some major ecosystem engineers, like *Silurus glanis* (Carol *et al.*, 2009; Copp *et al.*, 2009), *Cyprinus carpio* (Vilizzi, 2012; Vilizzi *et al.*, 2015), *Micropterus salmoides* (Garcia-Berthou *et al.,* 2000) and *Zander lucioperca* (Lorenzoni *et al.*, 2006; Kopp *et al.*, 2009), that can deeply reshape these ecosystems (Ribeiro and Leunda, 2012; Marr *et al.*, 2013). This study aims to fill such of a gap in IAS management. Notably, we aimed to test the role of various potential drivers of fish restocking, including empirical expectations about angler behaviour, injunctive and descriptive norms, the perceived risk of sanctions and individual beliefs about the potential benefits and the ecological risks of fish restocking. Moreover, following what was suggested by Banha *et al.* (2017a), we tested whether regarding fish restocking as capable of providing closer fishing spots promoted such behaviour.

Fig. 1. Study area: the Arno basin in Tuscany (in red) and the Tuscany region in Italy (blue).

2 Materials and methods

The study area encompasses the proportion of the Arno river basin that lies in Tuscany, Central Italy (Fig. 1). The Arno river originates in Northern Apennines, its basin is 8228 km^2 and it reaches the Tyrrhenian Sea after 214 km. Its basin does not include any significant natural lake, but an unknown number of artificial lakes and ponds are present, as they originated from gravel pits that were subsequently abandoned and submerged. The Arno river has 13 main affluents and an average flow of about 110 m^3/s, which experiences considerable seasonal variations due to the Mediterranean climate of the basin and its morphology. For example, in winter, rainfalls range from over 2000 mm on the mountains in the North-Western portion of the basin, to 700 mm in the lowlands at its Easternmost border, and in the central portion of the Arno river, flows range from 3–4 m^3/s in summer to 2000 m^3/s in late autumn. Biological invasions strongly affected freshwater

Table 1. Questions retained for data analysis: layout, format and summary.

Question (layout)	Format	Summary
Age (years)	Open-ended	Mean ± sd = 40.67 ± 14.18
Gender	Dichotomous	Men = 96.85%, Women = 3.15%
Angling site	Multiple choice	Fishing ponds = 59.89% Freshwater = 67%% Sea = 44.16%
Angling technique	Multiple choice	Coarse fishing = 62.9% Baitcasting = 60.9% Fly fishing = 15.7%
Empirical expectations	10-Points rating scale	Mean ± sd = 3.20 ± 2.84
Beliefs about the level of discomfort	7-Points rating scale	Mean ± sd = 3.87 ± 2.43
Perceived risk of sanctions	7-Points rating scale	Mean ± sd = 3.72 ± 2.29
Awareness about the potential environmental consequences of fish restocking	7-Points rating scale	Mean ± sd = 3.29 ± 2.54
Beliefs about the effectiveness of fish restocking	7-Points rating scale	Mean ± sd = 6.21 ± 1.41
Perceived savings in travel costs	7-Points rating scale	Mean ± sd = 3.26 ± 2.25
Descriptive norms about fish restocking	7-Points rating scale	Mean ± sd = 2.69 ± 1.75
Injunctive norms about fish restocking	7-Points rating scale	Mean ± sd = 4.57 ± 2.24
Fish restocking	Dichotomous	Yes = 7.6% No = 92.4%

ecosystems in the basin, as about 70% of total aquatic animal species are invasive and some major ecosystem engineers are present (Gualtieri and Mecatti, 2005; Mari *et al.*, 2009; Nocita, 2017). A complete list of native and invasive fish species for the Arno river is available in Nocita (2007), with the exclusion of the Albanian roach (*Pachychilon pictum*), which was recorded for the first time after 2007. In the study area a regional law regulates recreational angling (Regione Toscana, law n.7, 12/01/2005), fining rule violations with sanctions from 80 to 480 €. Fish restocking is authorized for salmonids only, in those streams and water bodies that have been classified as suitable for trout fishing.

From November 2016 to January 2017, a total number of 276 anglers were involved in a survey about compliance with existing angling regulations and at-risk behaviours that could trigger aquatic invasions. Trained interviewers invited anglers to fill an anonymous paper-and-pencil questionnaire at fishing shops. As no public list of anglers exists in the study area, random sampling was impossible and purposive sampling was adopted. The questionnaire took approximately 10 min to fill and measured illegal fish restocking across freshwater bodies, altogether with respondents' demographics, information about their recreational angling experience and some antecedents of restocking. These antecedents were measured through single items, and they included empirical expectations about illegal restocking by anglers (Bicchieri and Xiao, 2009), the perceived risk of sanctions connected this practice (Elffers and Ruimschotel, 1997; Arias, 2015), the level of awareness about the potential environmental consequences of fish restocking (Selge *et al.*, 2011; Drake *et al.*, 2015; Banha *et al.*, 2017), respondent's beliefs over the benefits of restocking over fish populations (Arlinghaus *et al.*, 2014), beliefs about the potential capacity of fish restocking to provide closer fishing spots (Hunt *et al.*, 2007; Beardmore *et al.*, 2014; Banha *et al.*, 2017), as well as injunctive and descriptive norms about fish restocking. The questionnaire is available in the Supplementary Materials (S1). Questions retained for data analysis and their proportion of missing answers are reported in Table 1. The effect of the various drivers, demographics and recreational attributes of respondents, over self-reported fish restocking was assessed by fitting a logistic regression with a quasi-binomial distribution of the error to account for the overdispersion of observations caused by self-protecting strategies of some respondents, that were likely to deny any restocking behaviour, therefore increasing the proportion of negative answers in the response variable (Krumpal, 2013). Multimodel inference was adopted to estimate the relative weight of the various predictors over fish restocking by averaging a subset of candidate models. Model averaging was conducted over those candidate models whose quasi-AIC differed from the quasi-AIC of the best candidate model by a value greater than 5. Furthermore, the area under the curve (AUC) and the pseudo-R^2 (Faraway, 2016) were calculated for the best candidate model to have an overall idea about its predictive power. Multicollinearity of predictors was assessed by graphi graphically inspection of the data and through the variance inflation factor (VIF). Statistical analysis was performed with the software R (R Core Team, 2017).

3 Results

Pilot questionnaires were easily completed, and they were retained for data analysis. A total of 197 questionnaires were selected for data analysis, discarding those completed by anglers who practiced sea fishing only. The percentage of unanswered questions was low (mean ± sd = 2.49 ± 1.31%). Our sample was almost entirely composed by male anglers (96.85%) and we recorded an average age of 40.67 ± 14.18 years (mean ± sd). Our sample of respondents encompassed anglers who fished in private fishing ponds (59.89%), freshwater (67%) and sea (44.16%). Coarse fishing was the most common type of fishing (62.9%), followed by bait casting (60.9%) and fly fishing (15.7%). Respondents did not rate fish restocking as a particularly sensitive behaviour

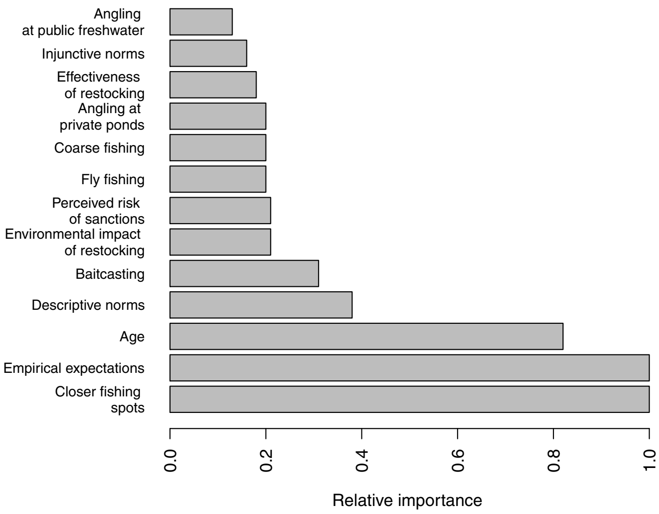

Fig. 2. Relative importance of the various predictors in the averaged models.

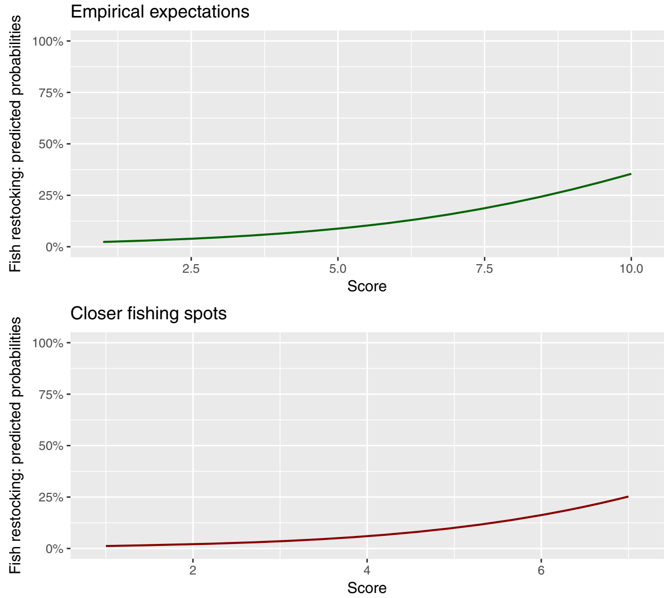

Fig. 3. Effect of empirical expectations and perceived advantages of fish restocking to obtain closer fishing spots: predicted probabilities over the response variable in the best candidate model.

(mean ± sd = 3.87 ± 2.43) and 7.6% of them declared to restock fish across water bodies.

Data exploration did not suggest any pattern between the predictors and VIF values were all below 1.8; therefore, we found no evidence for multicollinearity. The best candidate model predicted 42% of variability in the data and its AUC was 0.90. Model averaging was conducted on a very high number of candidate models (n = 198), as the difference between their quasi-AIC and the quasi-AIC of the best candidate model was smaller than 5. The coefficients and information criteria of the various candidate models are included in the Supplementary Materials (S2).

The relative importance of averaged predictors showed that age, empirical expectations about fish restocking and beliefs about the potential of restocking to create fishing spots nearby anglers' home were the most important predictors, followed by practicing baitcasting (Figs. 2 and 3 and Tab. 2). Moreover, descriptive norms about fish restocking and practicing baitcasting seemed to have some sort of effect over self-reported restocking behaviour. On the other hand, the perceived risk of sanction, individual beliefs about the environmental consequences of restocking, practicing fly fishing or coarse fishing, the dominant site of angling, beliefs about the effectiveness of fish restocking as a practice to restore fish populations and injunctive norms about this practice, did not have any strong effect over the response variable.

4 Discussion

To the best of our knowledge, our research provides various novelties to the science of aquatic invasions. Despite various studies addressed the ecological (Ribeiro and Leunda, 2012; Marr *et al.*, 2013) and genetic (Marzano *et al.*, 2003; Madeira *et al.*, 2005; Gandolfi *et al.*, 2017) consequences of indiscriminate fish introductions, and some researchers monitored the angling community to map aquatic invasions in Mediterranean freshwaters (Gago *et al.*, 2016; Banha *et al.*, 2017b), very few studies actually explored the drivers of illegal fish restocking by means of questionnaires. To the best of our knowledge, the only study doing so was Banha *et al.* (2017a), where web-based questionnaires were administered at two samples of recreational anglers in Portugal and Spain, highlighting some major drivers of illegal fish introductions in Iberian freshwater and underlining some country-specific differences. Indirectly, Rees *et al.* (2017) also explored the socio-economic attributes of specialized European catfish anglers in the UK, and their perception of catfish impacts, discussing some potential implications for deliberate catfish restocking in the UK. Therefore, our study is one of the few of this kind, and arguably the only one for Italy, contributing to extend the application of human dimension research into the field of invasion biology. Our findings denounce a concerning situation in the study area: anglers are far from being adequately informed about the environmental consequences and the potential sanctions connected with unauthorized fish restocking. In fact, respondents generally agreed with the idea that restocking operations do not have any consequence on freshwater ecosystems. This point indicates a lack of information about the potential adverse consequences of indiscriminate restocking, which is a mandatory step to raise stakeholder awareness towards biological invasions (García-Llorente *et al.*, 2008). This finding agrees with what has been noticed by Rees *et al.* (2017) about European catfish anglers in the UK, who had low levels of awareness of the environmental risks connected with catfish restocking and of the environmental impact of the species. However, they contrast with the findings of Banha *et al.* (2017a), who noticed that Spanish and Portuguese anglers were generally aware of the negative ecological impact of introduced species, and that they only ignored the effect of aquatic invasions in terms of reduced provisioning of ecosystem services.

Furthermore, respondents generally disagreed with the idea that police and fisheries officers have a good control over

Table 2. Output of the averaged models.

Term	Estimate	SE	Adj. SE	*Z*-value	*p*-value
Model-averaged coefficients: full average					
Intercept	−5.42300	2.52615	2.54011	2.135	0.0328 (**)
Age	−0.04167	0.04100	0.04120	1.012	0.3118
Perceived savings in travel costs	0.60802	0.26809	0.26977	2.254	0.0242 (**)
Empirical expectations	0.37978	0.16342	0.16444	2.310	0.0209 (**)
Baitcasting	−0.24509	0.62553	0.62817	0.390	0.6964
Descriptive norms	0.08364	0.21828	0.21932	0.381	0.7029
Environmental impact of restocking	0.02141	0.10614	0.10671	0.201	0.8410
Fly fishing	−0.15006	0.78524	0.78948	0.190	0.8493
Coarse fishing	0.09611	0.50547	0.50815	0.189	0.8500
Injunctive norms	−0.01503	0.10299	0.10357	0.145	0.8846
Perceived risk of sanctions	−0.02129	0.11191	0.11251	0.189	0.8499
Effectiveness of restocking	−0.03093	0.20538	0.20654	0.150	0.8809
Angling at ponds	0.09640	0.52039	0.52319	0.184	0.8538
Angling at freshwater bodies	0.03289	0.39233	0.39465	0.083	0.9336
Model-averaged coefficients: conditional average					
Intercept	−5.42300	2.52615	2.54011	2.135	0.0328 (**)
Age	−0.05056	0.03987	0.04012	1.260	0.2076
Perceived savings in travel costs	0.60802	0.26809	0.26977	2.254	0.0242 (**)
Empirical expectations	0.37978	0.16342	0.16444	2.310	0.0209 (**)
Baitcasting	−0.77920	0.90983	0.91560	0.851	0.3948
Descriptive norms	0.22080	0.30903	0.31096	0.710	0.4777
Environmental impact of restocking	0.10216	0.21334	0.21470	0.476	0.6342
Fly fishing	−0.74249	1.61591	1.62609	0.457	0.6479
Coarse fishing	0.48909	1.05262	1.05917	0.462	0.6442
Injunctive norms	−0.09323	0.24186	0.24340	0.383	0.7017
Perceived risk of sanctions	−0.10304	0.22842	0.22984	0.448	0.6539
Effectiveness of restocking	−0.17605	0.46316	0.46608	0.378	0.7056
Angling at ponds	0.49164	1.08943	1.09625	0.448	0.6538
Angling at freshwater bodies	0.25100	1.05823	1.06479	0.236	0.8136

Significance code: * = 0.1, ** = 0.05, *** = 0.01.

angling, and the variable did not have any strong effect in the models. Considered that perceived risk is a crucial factor to prevent noncompliance about natural resources (Elffers and Ruimschotel, 1997; Arias, 2015), this indicates that stricter and more capillary control schemes are needed to enforce existing regulations about angling. Finally, anglers in our sample did not believe in their peers' disapproval towards illegal restocking, deeming that an angler in their area would only feel mildly uncomfortable if he was forced to admit illegal restocking operations to other people. This point seems to be confirmed by the lack of any significant effect of injunctive norms over the response variable, despite social norms traditionally are powerful deterrents for noncompliance in using natural resources (Manfredo *et al.*, 2009; St John *et al.*, 2011; Heberlein, 2012).

Such of an absence of information, police controls and social norms are reflected in the role played by empirical expectations and descriptive norms. Empirical expectations drive rational decision-making, when no information is available about others' behaviour (Bicchieri and Xiao, 2009): as anglers do not possess any information about the consequences of fish restocking, nor about any formal and informal sanction about it, their behaviour is guided by their expectations about other anglers' behaviour. In our case, the more respondents believed that other anglers practiced restocking, the higher the chance they engaged in fish restocking as well. The effect of empirical expectations is confirmed by a moderate effect of descriptive norms, which had a moderate influence over the response variable, in the averaged models. To the best of our knowledge, no information campaign has ever been conducted against illegal restocking, nor about invasive alien fish, in the study area. Provided that these initiatives must be adequately tailored to the various types of anglers (Eisworth *et al.*, 2011; Gozlan *et al.*, 2013), we believe that providing information could lay the foundations for counteracting illegal fish stocking and the introduction of IAS by anglers. Despite information per se is often insufficient to stimulate environmental change (Heberlein, 2012), it is crucial, together with stricter police control and structural changes, to foster good stewardship practices by anglers and to promote large-scale increases in the level of compliance and pro-environmental norms (Bruskotter and Fulton, 2008; Cooke *et al.*, 2013). Disseminating information among anglers will also promote the early detection of new aquatic IAS (Hargrove *et al.*, 2015) and could help managers in developing partnerships with the angling community to map introduction hotspots and to identify non-compliant anglers.

Our research also confirms the importance of another driver of fish introductions: the willingness to obtain closer fishing spots. In our model, the belief that fish restocking would enable anglers to create fishing spots in proximity of their home was one of the strongest predictors of illegal fish stocking. These results are not entirely surprising, as travel costs are one of the main factors explaining the quality of leisure experiences in outdoor recreation (Smith, 1989; Fletcher *et al.*, 1990) and various human dimension studies identified distances as variables that can seriously affect the quality of angling experience (Arlinghaus and Mehner, 2004; Hunt, 2005; Beardmore *et al.*, 2014). Moreover, Banha *et al.* (2017a) obtained similar findings from a survey with recreational anglers in the Iberian peninsula, showing that fish were introduced for the convenience of having closer fishing spots providing anglers with a good angling experience. We believe that this aspect could have various implications for predicting and managing the deliberate spread of invasive fish species, as landscape affects angler's distribution and recruitment (Post *et al.*, 2008; Hunt *et al.*, 2017). Choice experiments or factorial survey could be very useful to characterize those fishing spots which are at risk of invasive fish release, not only in terms of their distance from anglers, but also on the basis of their attributes, like the density of recreational anglers or their natural surroundings (Rees *et al.*, 2017). Moreover, these techniques could also account for angler-specific attributes over the evaluation of a specific angling site, like the preference for invasive or native species (Banha *et al.*, 2017a) or individual awareness about aquatic invasions and the impact of invasive fish (Banha *et al.*, 2017a; Rees *et al.*, 2017), through multi-level modelling. We certainly encourage future studies adopting these quasi-experimental approaches that could contribute to increase our understanding of illegal fish restocking. In fact, our model, despite being acceptable in terms of predictive power, could be certainly improved, as shown by the value of the pseudo-R^2.

The age of respondents had a relatively neutral effect over the probability of deliberately restocking fish; however, it was retained in most candidate models, despite often not significant, and it had quite a high relative importance. Age is a conventional driver of non-compliant behaviour, which is traditionally more common until early adulthood (Steffensmeier *et al.*, 1989), and we encourage future studies disentangling its role in illegal fish restocking. For example, by exploring how fish restocking is age-dependent, future policy interventions aimed at discouraging this practice could be tailored for the various age segments of the angling community, who might have different reasons for non-compliance, as well as different ways to access and integrate information in their decision-making.

From our findings, it must be noticed that, despite practicing baitcasting had a moderate effect over averaged models, the various forms of angling did not have a strong effect over probability to engage in fish restocking. This could sound strange, because some major aquatic invaders in the study area are targeted by specialized anglers through baitcasting (*e.g.* largemouth bass, *M. salmoides*) or coarse fishing (*e.g.* European catfish, *S. glanis*). However, our questionnaire did not collect any information about the frequency of the various angling techniques, nor about their application to the various fish species. This probably led to some confounding effect in the model: for example, most anglers who practice baitcasting could target native salmonids, rather than invasive species. In turn, this confounding effect could result in baitcasting having a relatively low predictive power, and even a negative marginal effect, over restocking behaviour. Future studies should better characterize anglers in terms of their angling techniques and the application of the various techniques to the various fish species.

Moreover, future studies should also understand which species are restocked across water bodies. This research gap is particularly urgent, because anglers do not only restock invasive alien fish, but also native ones, and this practice could lead to disease transmission and the loss of genetic diversity among populations of native fish species.

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