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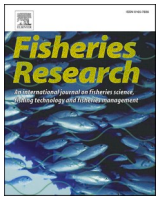

Characterization of specialist European catfish anglers in southern Germany: Implications for future management

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ABSTRACT

The European catfish (*Silurus glanis*) is a large apex predator native to Eastern Europe. Increasing populations within and outside the species' native range in recent years, and its popularity with recreational anglers are fueling discussions about appropriate management. To understand the motivations of anglers and their views on different management strategies, an internet survey was conducted in southern Germany. The results showed that catfish anglers differ in several aspects from those targeting other species. For specialists, catfish fishing is a central part of life, and they invest significant time and money to catch trophy sized fish. Most catfish anglers think that their targeted species has no negative effect on the local fish community and practice catch and release, despite this practice being illegal in Germany. Large catfish are often released under the misapprehension that they are inedible. The findings of this study suggest that new fishery management approaches are needed in order to mitigate the impact of European catfish in southern Germany. A co-production approach actively incorporating anglers' perspectives will be essential in implementing education and incentives for catfish consumption alongside other aspects of fisheries management.

1. Introduction

Though large predators are rare in nature, anthropogenic impacts can cause changes in their distribution and abundance that result in significant and relatively sudden direct and indirect effects on ecosystem functioning and food web structure (Hammerschlag et al., 2019; Ripple et al., 2014; Rooney et al., 2006). While many populations of various large apex predator fish species are in decline (He et al., 2019), stocks of the European catfish *Silurus glanis* (hereafter, catfish) are increasing. This species can grow to over 2.7 m and more than 130 kg (Boulêtreau and Santoul, 2016), making it one of the 20 largest freshwater fishes in the world (Stone, 2007). According to Kottelat and Freyhof (2007), the native range of catfish includes the Baltic, Black, Caspian, and Aral Sea basins of Eastern Europe, with its most westerly extent in the southern part of River Rhine drainage in Germany. Due to various introduction outside the native range, the species is now also found across many different freshwater systems in western and southern Europe (Boulêtreau et al., 2021; Carol et al., 2007), and also outside Eurasia (Claudia and Doina, 2013; Cunico and Vitule, 2014; Schlumberger et al., 2001). In several of areas, the species continues expanding both its distribution range and abundance (Copp et al., 2009; Vejřík et al., 2019).

The two most likely factors for the increasing density and the expansion of the distribution range of *S. glanis* in Europe are artificial stocking (Cucherousset et al., 2018) and climate change (Basen et al., 2022). One of the major stakeholder groups in catfish management are recreational fishers (Cucherousset et al., 2021). Fish size is a key determinant of angler motivation (Arlinghaus et al., 2014) and so the large size of catfish often drives legal and illegal introductions outside their native range (Cucherousset et al., 2018; Hutt et al., 2013). Stocking has been undertaken by fisheries managers and sometimes by individual anglers, to enhance the attractiveness of certain inland waters for recreational fisheries. Rees et al. (2017) report that in England and Wales, *S. glanis* were often released even at trophy weights above 27 kg (usually imported from mainland Europe) in order to bring attention to certain waters and boost sales of angling licenses. In Italy, *S. glanis* was imported for aquaculture purposes in the early 20th century, but was also introduced to the ponds of private fishing reserves, and from the 1930s onwards began to be reported in rivers (Boldrin and Rallo, 1980; Copp et al., 2009; Gandolfi and Gianni, 1979). Furthermore, emerging evidence suggests that as a generalist and tolerant fish species (Basen et al.,

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2022; Buisson et al., 2008; Markovic et al., 2012), the catfish is probably benefitting from climate change impacts on aquatic ecosystems (Basen et al., 2022; Buisson et al., 2008; Markovic et al., 2012) such as increasing water temperatures (Desgué-Itier et al., 2023), seasonal changes in precipitation patterns (Madsen et al., 2014), and increasing habitat availability (Schneider et al., 2013). With its ability to benefit from warmer water temperatures and to tolerate low oxygen levels, the catfish is apparently more resilient and adaptive than many other fish species (Copp et al., 2009).

Apex predators can provide important ecosystem services (Matich et al., 2011; Rooney et al., 2006; Vejřík et al., 2017), however their introduction can also cause unexpected effects. Impacts on native local fish communities can be dramatic. Undesired effects of predation by catfish are well documented in Spain and other countries in Southern Europe, where high rates of endemism and an absence of native piscivorous fishes make small-bodied fish species especially vulnerable to the sudden appearance of a new predator (Copp et al., 2009). Furthermore, the dietary plasticity of catfish (Vejřík et al., 2017b) also results in predation impacts on other vertebrates, including waterfowl (Carol et al., 2009). Even in their native home range, high densities of *S. glanis* can negatively affect local food webs, especially those subject to additional anthropogenic stressors (Wysujack and Mehner, 2005). While many studies focus on ecological effects caused by the introduction of catfish (Carol et al., 2009; Ferreira et al., 2019; Milardi et al., 2022; Vagnon et al., 2022; Vejřík et al., 2019), there is also a need for specific socio-economic studies to facilitate an evidence-based catfish management (Arterburn et al., 2002).

The present study was conducted in the federal state of Baden-Württemberg, southern Germany. Before the end of the 13th century, *S. glanis* was a very rare endemic species in the region, found only occasionally in the Rivers Danube and Rhine, and in Lake Constance (Dußling et al., 2018). In the 20th century however, most likely as a result of stocking events, *S. glanis* began to appear elsewhere and is now present in nearly every larger stream as well as in many lakes and gravel pits. Furthermore, the abundance of this species is increasing state-wide. The impact on the local fish community is unknown, but given the recent rise and potential ecological consequences, an informed discussion of potential management actions in light of existing perceptions among important stakeholder groups is needed. In most freshwater ecosystems in Baden-Württemberg, responsibility for fisheries management rests with anglers, and they are required by law to keep any catfish caught. However, despite these strict regulations, catch and release (C&R) is suspected to be common practice across Baden-Württemberg (personal observation, J. Baer & M. Fromherz).

Recreational specialization is an important framework for understanding diversity in behavior of anglers (Beardmore et al., 2013; Bryan, 1977; Oh and Ditton, 2006). However, it is unknown if anglers targeting specifically catfish could be seen as a specialized angler group. An answer to this question is of high interest, as more specialised anglers exhibit a distinctly different preference structure for catch and harvest variables, typically favoring the release of fish over retention of fish for consumption (Arlinghaus, 2007; Bryan, 1977). Furthermore, specialised anglers were found to be more receptive to stricter regulations than less specialised anglers, in part due to their supposedly higher concern for preservation of fish stocks and trophy fish that facilitate high quality fishing experiences (Arterburn et al., 2002; Ditton et al., 1992; Salz and Loomis, 2005). Therefore, understanding the perceptions, requests, and intentions of specialized catfish anglers, especially regarding C&R, is relevant for the development of effective conservation and sustainable fishery management including its communication (Drymon and Scyphers, 2017; García et al., 2022; van den Heuvel and Rönnbäck, 2023).

The objectives of this study are to a) identify to what extent catfish anglers are a specialized group, distinct from non-catfish anglers, and to investigate motivations in fishing for this apex species; b) evaluate the socio-demographic and economic aspects of catfish fishing; and c) identify what catfish anglers think about the potential impact of their

Table 1
Socio-demographic characterization of non-catfish and catfish anglers; their investment in angling and views on what to do with captured catfish and fisheries management. Significant differences between both groups are shown in bold. *P*-values marked with asterisks (*) were determined using a Mann-Whitney-U-Test.

Item	non-catfish anglers (n=81)	catfish anglers (n=233)	X^2	df	*P*-value
Section 1: Socio-demographic description					
Q1: Age?			-	-	0.58 *
Mean age (years) ± standard deviation	42.8 ± 14.6	41.9 ± 11.7			
Q2: Where do you live?			4.53	3	0.21
North-West	19.7 %	28.8 %			
North-East	35.8 %	38.6 %			
South-West	24.7 %	16.7 %			
South-East	19.8 %	15.9 %			
Q3: Membership in a fishing club?			0.55	1	0.46
Yes	78.1 %	80.6 %			
No	21.9 %	19.4 %			
Q4: Your monthly income?			2.98	1	0.56
> 4.000 Euro	13.1 %	14.3 %			
2.600–4.000 Euro	35.6 %	41.7 %			
1.500–2.600 Euro	21.9 %	25.2 %			
900–1.500 Euro	0.6 %	1.1 %			
< 900 Euro	0.6 %	0.8 %			
Dont want to declare income	28.2 %	16.9 %			
Q5: Your degree of education?			10.93	9	0.28
Doctorate	4.5 %	2.6 %			
University degree	25.7 %	14.0 %			
High school diploma	8.4 %	9.0 %			
Master craftsman	22.6 %	23.0 %			
Apprenticeship	24.5 %	30.0 %			
Secondary school diploma	5.2 %	12.7 %			
Secondary school certificate	7.1 %	6.0 %			
Without graduation	0 %	0.8 %			
Pupil/ Student	0.7 %	0.4 %			
Other	1.3 %	1.5 %			
Q6: Your actual status of employment?			9.27	6	0.16
Full-time employment	81.3 %	85.7 %			
Part-time eployment	3.9 %	4.1 %			
Marginal employment	0 %	0 %			
Parental leave	0 %	0 %			
Trainee	0.7 %	0.4 %			
Pupil. Student	3.2 %	0.4 %			
Social volunteer	0 %	0 %			
Unemployed	0.7 %	0.4 %			
Housekeeper	0.7 %	0.4 %			
Pension	7.1 %	3.7 %			
Other	2.4 %	4.9 %			
Section 2: Investment in angling					
Q1: How much money do you invest yearly in angling?			**5.43**	**5**	**0.034**
>2000 Euro	3.7 %	15.9 %			
1500–2000 Euro	14.8 %	9.9 %			
1000 – 1499 Euro	11.1 %	13.8 %			
500–999 Euro	21.0 %	22.7 %			
250–499 Euro	32.1 %	24.0 %			
< 250 Euro	17.3 %	13.7 %			
Q2: How many days did you fish in 2022?			-	-	**0.001** *
Fishing time (days) ± standard deviation	55.1 ± 56.8	72.1 ± 61.6			

(*continued on next page*)

Table 1 (*continued*)

Item	non-catfish anglers (n=81)	catfish anglers (n=233)	X^2	df	*P*-value
Section 3: Catch related aspects					
Q1: What statement is correct (select one)?			**15**	**3**	**0.002**
I take every catfish	45.0 %	27.3 %			
I take no catfish at all	17.8 %	16.6 %			
I just take trophy catfish	5.4 %	6.3 %			
I just take small catfish	31.8 %	49.8 %			
Q2: Do you prefer C & R?			**13.12**	**1**	**0.0003**
Yes	49.4 %	71.5 %			
No	50.6 %	28.5 %			
Q 3: Why do you take no catfish?			**7.95**	**3**	**0.047**
Fish will grow larger and get older	17.2 %	29.8 %			
Large catfish cannot be consumed	55.7 %	52.0 %			
I cant do anything with small catfish	5.7 %	2.7 %			
other	21.4 %	15.5 %			
Q4: What is the best daytime to catch catfish?			6.41	3	0.093
Morning	35.8 %	31.8 %			
Noon	1.2 %	5.6 %			
Evening	9.9 %	4.3 %			
Night	53.1 %	58.3 %			
Q5: What is the best season to catch catfish?			4.878	3	0.181
Spring	16.1 %	27.6 %			
Summer	19.7 %	18.1 %			
Autumn	63.0 %	52.2 %			
Winter	1.2 %	2.1 %			
Section 4: Fisheries management					
Q1: What is the impact of catfish on the waterbodies?			**33.25**	**2**	**< 0.0001**
Catfish is harmful	54.3 %	24.5 %			
Catfish is positive	11.1 %	41.6 %			
Catfish has no influence	34.6 %	33.9 %			
Q2: At your fishing water, are there some management restrictions to protect the catfish?			**7.96**	**2**	**0.019**
I dont know	14.6 %	5.1 %			
Yes	6.8 %	7.6 %			
No	78.6 %	87.3 %			
Q3: How happy are you with the existing management regulations?			4.07	4	0.397
Very unhappy	39.8 %	46.2 %			
Unhappy	5.8 %	6.6 %			
adequate	30.1 %	20.3 %			
Happy	9.7 %	8.6 %			
Very happy	14.6 %	18.3 %			
Q4: Which of the following management actions are the best to manage catfish under the actual expansion trend?			**38.18**	**3**	**< 0.0001**
Fishing of hotspots	11.1 %	5.9 %			
Prohibition of stocking	19.3 %	32.9 %			
Obligation to take every catfish	58.5 %	26.3 %			
other	11.1 %	34.9 %			

preferred species and ascertain their knowledge and views of existing management regulations. Therefore, a questionnaire was designed to characterize specialized catfish anglers. The findings should inform novel and effective fishery management approaches that may help reduce negative impacts of European catfish in southern Germany.

2. Data and methods

2.1. Data: survey of anglers in Baden-Württemberg, Germany

The questionnaire was designed in collaboration with the "survey-LAB" of the University of Konstanz. The questionnaire was conducted online, using a secure survey platform. Participants accessed the questionnaire through a web link and completed it at their convenience. The survey remained open for eleven weeks to ensure a high response rate. Participants were actively recruited via online platforms and fishing-related networks, including fishing forums, the homepages of fishing associations, and fishing clubs. Additional 'snowball sampling' techniques (Johnson, 2014) were employed, where participants were encouraged to share the survey link with other anglers. Participation was voluntary, and no incentives were provided. This study adhered to ethical guidelines, ensuring the privacy and confidentiality of respondents. All collected data were anonymized and analyzed in an aggregated form. Informed consent was obtained at the beginning of the survey, outlining the purpose of the study and the voluntary nature of participation.

To classify respondents as catfish or non-catfish anglers, respondents were asked whether they (a) never caught catfish, (b) caught catfish just as bycatch, or (c) fished actively for catfish. If the participants selected a) or b), they were counted as non-catfish anglers; if they picked c), they were counted as anglers specializing in catfish fishing. Afterwards, participants were asked to answer various questions which were presented in two chapters (Table 1 & 2). The first chapter, divided into four sections, contained socio-economic and management related questions. The second chapter, divided into seven sections, asked questions regarding angler motivations for and attitudes towards recreational fishing. In chapter one, we aimed to identify differences between catfish and non-catfish anglers; in chapter two, we aimed to determine the extent to which personal attributes increased the likelihood of specialization in catfish fishing.

The first chapter started with section one (six questions). Here we asked anglers about their age, their residency background (north-western, north eastern, south-western, or south eastern part of Baden-Württemberg), their membership in a fishing club (yes, no), their income, their education level, and their employment status. In section 2 (two questions), we asked about financial investment in angling equipment per year and the number of days spent fishing in 2022. In section 3 (five questions), we asked participants if they keep every caught catfish, only small or only trophy-sized catfish, or if they generally release them. In addition, anglers were asked for the reasons why they preferred to keep or C&R catfish, and we asked their opinion on the best time and season for catfish fishing. In section 4 (four questions), we asked about their perceptions of the role of European catfish for the local fish community (harmful, positive, no impact). We asked if they knew of existing fisheries regulations for the management of catfish stocks (Yes, No, I dont know). They were then asked to rate their opinion on existing fisheries regulations from 1 (very unsatisfied) to 5 (very satisfied) and to choose the most useful fisheries management options (*e.g.* fishing hotspots, prohibition of stocking, obligation to remove catfish and other). For every question in the sections 1–4, they were required to select one single answer (Table 1).

The second chapter started with section 5. Here we wanted to figure out the degree of specialization. One metric of specialization is centrality-to-lifestyle (Kim et al., 1997). Different studies showed that centrality-to-lifestyle was the best predictor of intended behavior of German anglers (Beardmore et al., 2013) and it was thus chosen as the

Table 2
Factor loadings and standard errors from the seven-factors model.

Latent factors (sections) and variables (questions)	Loading estimates	Standard error	*P*-value
Section 5: Centrality of lifestyle			
Q1: If I stopped fishing, I would probably lose touch with a lot of my friends	2.99	0.06	<0.0001
Q2: If I could not go fishing, I am not sure what I would do	3.10	0.07	<0.0001
Q3: Because of fishing, I do not have time to spend participating in other leisure activities	2.83	0.06	<0.0001
Q4: I know most of my friends due to fishing	3.01	0.06	<0.0001
Q5: I find that a lot of my life is organized around fishing	3.48	0.06	<0.0001
Q6: Others would probably say I spend too much time fishing	3.47	0.06	<0.0001
Q7: I would rather go fishing than do most anything else	3.98	0.05	<0.0001
Q8: Other leisure activities don't interest me as much as fishing	3.68	0.06	<0.0001
Section 6: Overall catch interest			
Q1: A fishing trip can be successful even if no fish are caught	4.20	0.04	<0.0001
Q2: When I go fishing, I am just as happy if I don't catch any fish	3.99	0.05	<0.0001
Q3: When I go fishing, I am not satisfied unless I catch at least something	2.51	0.06	<0.0001
Section 7: Nature experience			
Q1: I fish to find inner peace	4.08	0.04	<0.0001
Q2: I fish to enjoy beautiful surroundings	4.03	0.04	<0.0001
Q3: I fish to relax	4.12	0.04	<0.0001
Q5: I fish to be in nature	4.03	0.04	<0.0001
Q6: I fish to forget workaday life	4.02	0.04	<0.0001
Section 8:Catching trophy fish			
Q1: I would rather catch 1 or 2 big fish than 10 smaller	3.25	0.06	<0.0001
Q2: I fish to make a photo of my catch	1.95	0.05	<0.0001
Q3: I fish to catch trophy fish	2.45	0.06	<0.0001
Q4: As bigger the catch, as better the fishing trip	2.91	0.07	<0.0001
Q5: I'm happiest with the fishing trip if I catch a trophy fish	3.19	0.06	<0.0001
Q6: I fish in areas with a high probability to catch a trophy fish	3.17	0.06	<0.0001
Section 9: Catch expectations			
Q1: I fish because of the fight with the fish	2.79	0.06	<0.0001
Q2: I fish to catch one fish	3.02	0.06	<0.0001
Q3: I fish to catch several fish	2.38	0.05	<0.0001
Section 10: Angling skills			
Q1: I fish to test new angling techniques	3.16	0.05	<0.0001
Q2: I fish to gain new experience	3.60	0.05	<0.0001
Q3: I fish to test angling equipment	2.68	0.06	<0.0001
Q4: I fish to increase my fishing knowledge and skills	3.61	0.0	<0.0001
Section 11: Specialization for catfish fishing			
Q1: I only fish for European catfish	1.83	0.05	<0.0001
Q2: Fishing days for European catfish	1.56	0.06	<0.0001
Q3: Portion of specialized catfish angling on angling activity	3.17	0.07	<0.0001

primary indicator of specialization here. Therefore, we asked participants to rate 8 statements about the importance of fishing (for example "If I could not go fishing, I am not sure what I would do", see Table 2) according to the scale developed by Kim et al. (1997), using a 5 point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Besides centrality-to-lifestyle as an index of personal commitment, we also included the cognitive dimension of angler specialization (*i.e.*, skill, knowledge, and expertise) in the survey (section 6–11), as it was expected to most directly relate to differentiate catfish from non-catfish anglers (as Dorow et al., 2010 did to detect the heterogeneity in eel anglers). In the sections 6–10, we used the method developed by Graefe (1980) as modified in subsequent studies (Anderson et al., 2007; Fedler and Ditton, 1994; Fisher, 1997). In these sections, the anglers rated their level of agreement with 22 different statements relating to catch-related aspects of fishing (Table 2). Each question was measured on a 5-point Likert-type scale (Sutton, 2003) with response categories ranging from 1 (strongly disagree) to 5 (strongly agree). In section 11, we used the same scale as in sections 6–10 for the first question (Q1, Table 2). For question 2 of section 11, we asked for the number of days anglers spent fishing for European catfish in 2022 and allocated those into 5 categories ($\leq$ 5 days = 1; $\leq$ 50 days = 2; $\leq$ 100 days = 3; $\leq$ 150 days = 4; $\geq$ 151 days = 5). For question 3 of section 11, based on the answers for question 2 of this section and of section 2 ("How many days did you fish in 2022?", Table 1), we calculated the proportion total angling activity focused on catfish and grouped those results into 5 categories ($\leq$ 5 % = 1; $\leq$ 15 % = 2; $\leq$ 40 % = 3; $\leq$ 75 % = 4; > 75 % = 5).

2.2. Data analysis

Only fully completed questionnaires were considered for final inference analysis. For the sections 1-4, the answers of non-catfish and catfish anglers were counted and percentages calculated for each group (Table 1). Differences between groups were calculated using Chi-square tests on frequency of selected answers. Due to *a priori* knowledge, we expected that specialized catfish anglers invested more money in angling equipment than a random group of anglers (here: non-catfish anglers, with most likely a certain amount of generalist anglers, who in general invest less money) (Bryan, 1977; Hutt and Bettoli, 2007), and one-tailed Chi-square tests was used for question 1 in section 2. Differences in age and angling days in 2022 were calculated using Mann-Whitney-U tests.

For section 5 to 11, we calculated Cronbach's α values for each question and for all questions of one section, to provide measures of internal consistency for the questionnaire (Tab. S1) and the interrelatedness of questions (Cortina, 1993; Cronbach, 1951; Tavakol and Dennick, 2011) expressed as a number between 0 and 1 with an index $\geq$ 0.6 being considered acceptable (Taber, 2018) (Tab. S1).

To examine the linkage between latent factors (section 5 to 11) and their corresponding manifest variables (questions, Table 2), and therefore the factors explaining the individual degree of specialization in catfish angling among anglers in Baden-Württemberg, we performed an orderly simplification of interrelated measures using Confirmatory Factor Analysis (CFA, Anderson et al., 2007). To do so, we first took the latent factors (Table 2) and checked the eight identification rules implemented by JMP Pro ®, assuming a positively defined covariance matrix. Bartlett's test of sphericity was applied to evaluate data suitability and whether the correlation matrix was an identity matrix based on uncorrelated variables. A p value of less than 0.05 indicated correlation and suitability for an explanatory factor analysis (EFA). Furthermore, the Keiser-Meyer-Olkin test was used to measure sampling adequacy for single manifest variables. Following elimination, all remaining variables led to a value < 0.5. Furthermore, following CFA, the indicator reliability plot on squared standardized loadings of the latent factors, and the construct validity matrix report were inspected for suggested minimum thresholds of acceptable reliability (0.25). Finally, we tested different meaningful functional models and an unrestricted model and chose the best based on a chi-square difference test. Goodness of fit of the final model was assessed using Root Mean Squared Error Approximation (RMSEA) and the Comparative Fit Index (CFI). RMSEA values are considered "excellent" if <0.06 and acceptable at RMSEA < 0.08. CFI values $\geq$ 0.95 indicate excellent fit and values between 0.90 and 0.94 indicate acceptable fit (Little, 2024).

All statistics were performed in JMP Pro 17.2.0 (64 bit, SAS Institute).

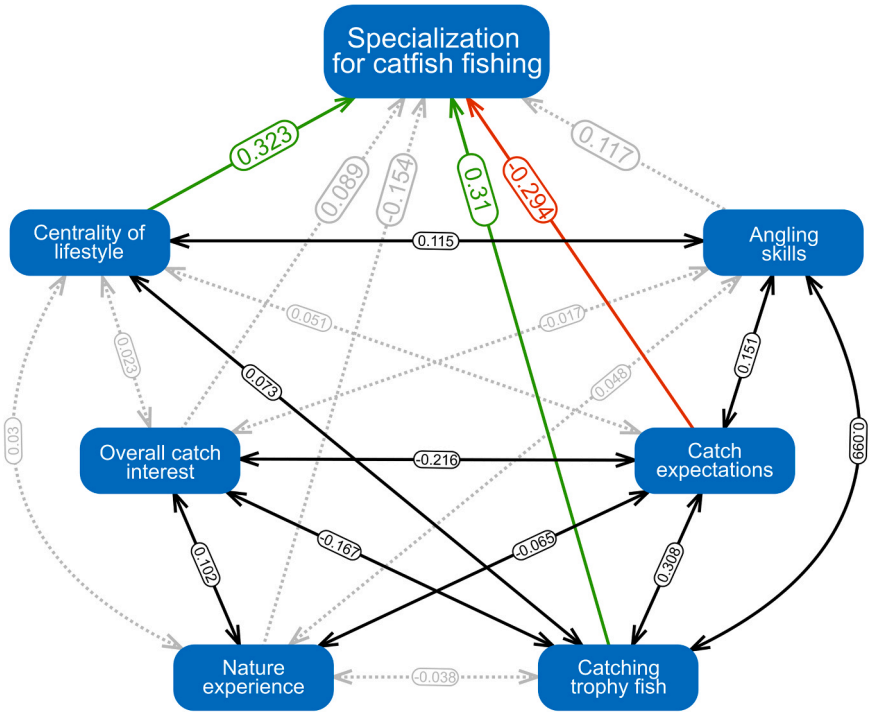

Fig. 1. Path diagram of the CFA model addressing catfish fishing specialization. The lines between the seven latent factors showing significant (bold lines) and non-significant (dashed lines) loadings. Factors showing positive loadings with "Specialization for catfish fishing" are represented by green lines, the significant negative loading is represented by a red line. Variables loading the different latent factors can be seen in Table 2.

3. Results

A total of 769 recreational anglers participated in the survey. Of these, 314 (40.8 %) provided complete responses and were included in the inference analysis. From those 314 responses, 74.2 % (n = 233) answered that they fished actively for *S. glanis* while 25.8 % (n = 81), responded that they never fished actively for catfish or caught them only as bycatch.

3.1. Comparison of catfish and non-catfish anglers: socio-demographic characteristics, fishing behavior, and management attitudes

Both groups were similar in age with an average of 42.8 years in non-catfish anglers and 41.7 years in catfish anglers (Table 1). Most non-catfish anglers (78.1 %) and most catfish anglers (80.6 %) were members of a fishing club and both groups were evenly distributed over the study region (Table 1). No statistically significant differences between both groups were observed in terms of income (Chi-square test, $p = 0.56$), educational background (Chi-square test, $p = 0.28$) or employment status (Chi-square test, $p = 0.16$) (Table 1). A significant difference was observed between both groups in their investment in fishing equipment (Chi-square test, $p < 0.05$), with catfish anglers spending more than non-catfish anglers: 15.9 % of catfish-specialists invested more than 2000 Euros per year in fishing equipment, while only 3.7 % of non-catfish anglers spent this amount (Table 1). Catfish anglers also reported significantly more fishing days in 2022 (Mann-Whitney-U-Test, $p = 0.001$), averaging 72.1 days, compared to non-catfish anglers, who on average invested 55.1 days for fishing (Table 1). Further significant differences between groups were observed in the practice of C&R (Chi-square test, $p = 0.002$), with 45.0 % of non-catfish anglers stating that they kept every catfish they caught, compared to only 27.3 % of catfish-anglers. However the majority of both groups practise C&R to some extent, taking no catfish, only trophy catfish or only small catfish (55.0 % of non-catfish anglers and 72.7 % of catfish-anglers) (Table 1). Furthermore, significantly (Chi-square test, $p = 0.0003$) more catfish anglers (71.5 %) stated a preference for C&R in comparison to non-catfish anglers (49.4 %). Reasons for practising C&R varied between groups (Chi-square test, $p = 0.047$) with more catfish anglers than non-catfish anglers selecting the reason that released catfish will grow larger and get older (29.8 % *vs.* 17.2 %) indicative of a trophy fishery. However the majority of both groups (55.7 % of non-catfish anglers and 52.0 % of catfish anglers) cited the challenge of processing and consuming large catfish as their primary reason for practising C&R (Table 1). In terms of preferred time of day for fishing, no significant differences were observed between groups (Chi-square test, $p = 0.181$) and the majority of both groups opted for spring and summer as the best season for catfish fishing (Table 1).

The assessment of the different groups regarding the impact of catfish on the aquatic ecosystem varied significantly (Chi-square test, $p < 0.0001$), with the majority of non-catfish anglers (54.3 %) perceiving the species as harmful to the ecosystem while only 24.5 % of catfish anglers shared this opinion. Furthermore, 41.6 % of catfish anglers perceived catfish as positive, while only 11.1 % of non-catfish anglers believed in a positive impact of catfish on the waterbodies (Table 1). Knowledge of existing management regulations concerning catfish also differed between groups (Chi-square test, $p < 0.05$), with a higher proportion of non-catfish anglers admitting they did not know about regulations (14.6 % of non-catfish anglers *vs.* 5.1 % of catfish anglers). A large proportion of both groups reported no knowledge about management regulations concerning catfish at their preferred fishing spots (78.6 % of non-catfish anglers, 87.3 % of catfish anglers) (Table 1). Satisfaction with existing management regulations did not differ significantly between both groups (Chi-square test, $p > 0.05$). 39.8 % of non-catfish anglers and 46.2 % of catfish anglers were very unhappy with management regulations (Table 1). When asked about different regulations proposed to manage increasing catfish populations, the answers differed significantly between groups (Chi-square test, $p < 0.0001$): most non-catfish anglers (58.5 %) favoured an obligation to take every caught catfish while only 26.3 % of the catfish anglers agreed with this proposal (Table 1).

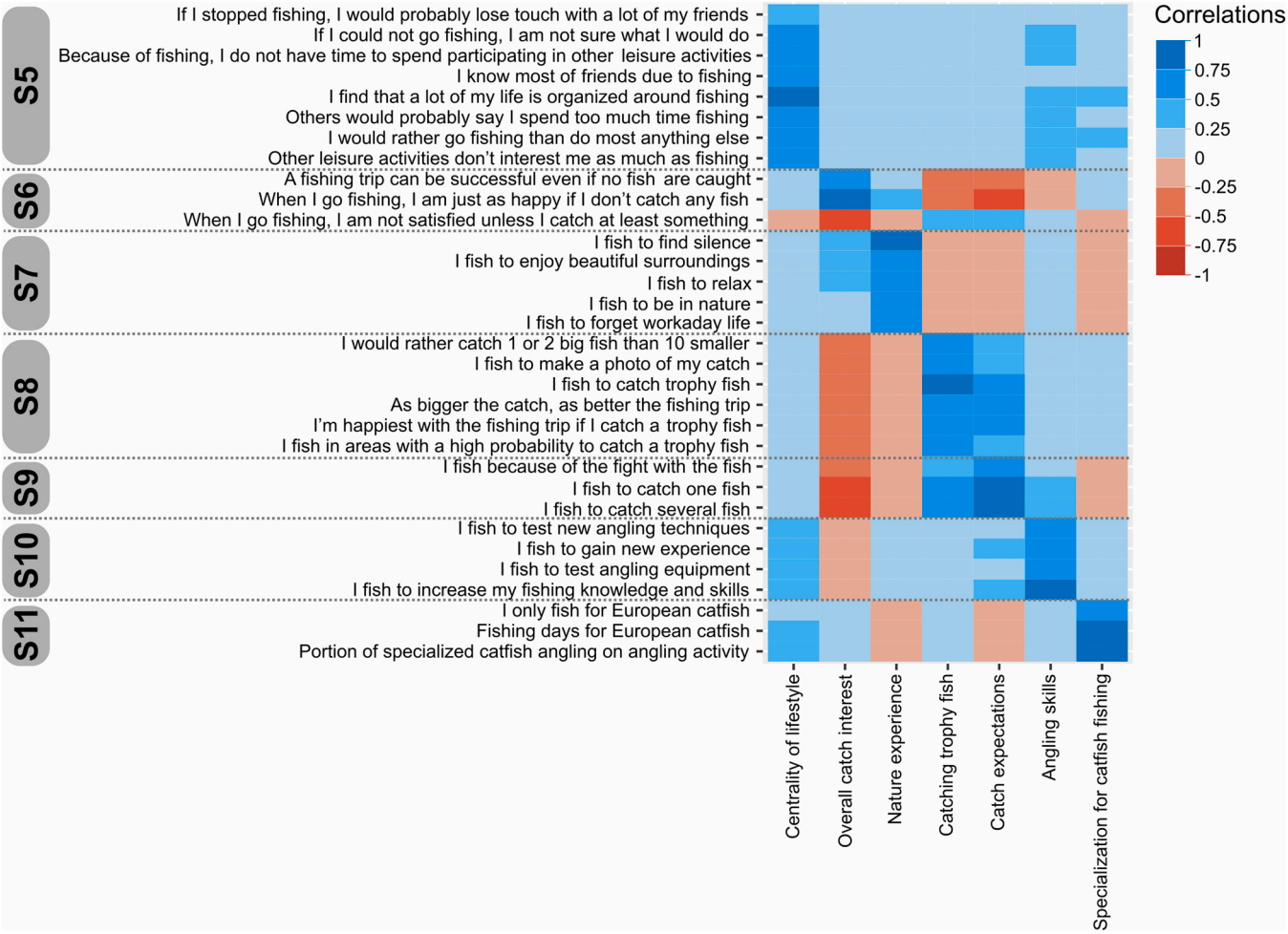

Fig. 2. Heatmap showing the correlations between individual statements in section 5-11 (S5: centrality of lifestyle; S6: overall catch interest; S7: nature experience; S8: catching trophy fish; S9: catch expectations; S10: angling skills; S11: specialization for catfish fishing) to the seven latent factors.

3.2. Reliability of the model and factors explaining the individual degree of specialization in catfish angling

The overall reliability of chapter 2 of the questionnaire (section 5-11) was high, given a Cronbachś α value of 0.75 – 0.87, dependent on section (Tab. S1). Every question yielded at least an acceptable Cronbachś α value ≥ 0.6 (Tab. S1). The deletion of any one question would still result in a Cronbachś α value in the range of 0.57–0.86 (Tab. S1), further underlining the reliability of this part of the questionnaire.

The best performing model for our CFA (Fig. 1) revealed a RMSEA value of 0.06 and a CFI value of 0.9, indicating an excellent to appropriate model (Little, 2024). The variety of other tested models, including an unrestricted one (data not shown) explain significantly less of the observed variation in data. Factor loadings and standard errors for the used seven-factor model are shown in Table 2.

The results of the CFA suggest that the sections "overall catch interest", "nature experience", and "angling skills" do not significantly ($P > 0.05$) explain catfish fishing preferences (Fig. 1). The significant drivers ($P < 0.05$) of angler preference for catfish fishing are "centrality of lifestyle", "catching trophy fish", and "catch expectations" (Fig. 1). The two sections "centrality of lifestyle" and "catching trophy fish" show comparably high estimated effect strengths at 0.32 and 0.31 respectively and they correlate positively with "specialization for catfish fishing", whereas "catch expectations" correlate negatively (estimates −0.29) with "specialization for catfish fishing" (Fig. 1). The CFA also reflected the high importance of "catching trophy fish" in explaining angling behaviour in general, with significant interactions with all other sections except "nature experience" ($P > 0.05$) (Fig. 1). "Catch expectations" also carried significant implications for nearly all other sections, excluding "centrality of lifestyle" (Fig. 1) including negative correlations ($P < 0.05$) with "nature experience" and "overall catch interest" (Fig. 1).

Positive correlations with "specialisation for catfish fishing" were found for every single aspect of "centrality of lifestyle", "catching trophy fish" and "angling skills" (Fig. 2). Statements 6 "I find a lot of my life is organized around fishing" and 8 "I would rather go fishing than do anything else" in section 5 found highest positive correlations scores (> 0.25) with specialized catfish anglers (Fig. 2). In contrast, every aspect of "nature experience" and "catch expectations" was correlated negatively with specialization for catfish fishing (Fig. 2).

Every aspect of "centrality of lifestyle" showed a positive correlation to all other sections, whereas all other questions yielded at least one negative correlation (Fig. 2). The section with the highest numbers of negative correlations was section 6 (overall catch interest), as here every statement correlated negatively at least once with the other sections (Fig. 2).

4. Discussion

The results of the present study underline that catfish anglers in the study area exhibit distinct preferences, motivations and a higher degree of technical specialization than those who do not target this species or only catch it incidentally. The first objective of the study was thus reached and we can now classify catfish anglers in south-western Germany as a specialized group. However, with the data at hand we could

not describe the common angler in southern Germany or other specialized angler groups, *e.g.* trout or carp anglers. If that would have been our goal, the sample size and the design of the questionnaire had to be different and more extended (Arlinghaus et al., 2008; Birdsong et al., 2021). Nevertheless, a random sample of more than 80 non-catfish anglers is sufficient to describe a subgroup of non-catfish anglers and compare them to specialized catfish anglers.

Within the recreational specialization theory three subdimensions are regularly used to describe the heterogeneity within the targeted group: psychological commitment, cognitive development, and behavioural involvement (Ditton et al., 1992; Kim et al., 1997; Scott and Shafer, 2001). All three can be addressed by the data now at hand. Psychological commitment was clearly exhibited by respondents, with our CFA showing a positive correlation between specialization for catfish fishing and centrality of lifestyle. This is most apparent in the link between lifestyle and time invested in fishing for catfish, as anglers fishing with high intensity for catfish agreed that much their life is organized around fishing and that they would rather go fishing than do anything else.

The second dimension, cognitive development, includes acquisition of special skills and knowledge (Salz and Loomis, 2005), and is visible in the time invested by catfish anglers in their hobby: they fish roughly 35 % more days than non-catfish anglers. They also invest more money in fishing than non-catfish anglers, most likely in trialling new methods or baits (Hutt and Bettoli, 2007). Interestingly, our CFA reveals that while the section "angling skills" had no significant influence on specialization for catfish fishing, every question in the section "angling skills" showed positive correlations with the specialization for catfish angling. While it remains uncertain why this relationship is not evident from the CFA, one explanation may be that the overall effect is masked by other participants specialized for other fish species (*e.g.*, carp, trout) who thereby possess similar or even stronger skill enhancements (Connelly et al., 2001). In order to disentangle this, the questionnaire could have been worded in a more specific way (such as "I fish to test new angling techniques especially for catfish") or by the inclusion of additional constrained questions regarding the preference and degree of specialization for other fish species.

The third descriptive dimension, behavioural involvement, is clearly evident among catfish anglers, as our CFA showed a high positive loading between specialisation for catfish fishing and intention to catch trophy fish. Furthermore, a positive loading is apparent between single aspects within the section "catching trophy fish" and the section "specialization for catfish fishing". The CFA also showed a high degree of connection between specializations for catfish fishing and catch expectation. This relationship is negative and every aspect of the section "catch expectations" was correlated negatively to specialization for catfish fishing. Therefore, the capture of trophy fish or testing of new angling techniques seem to be more important to catfish anglers than either the capture of one or more fish or the fight with the fish. Furthermore, it has to be noted that motivation to catch trophy fish plays a major role in explaining overall angling behaviour, as our CFA reveals that this topic is impacted by all other factors except experience of nature. This is in line with results from other studies showing that the capture of trophy fish is highly important for both catfish anglers (Arterburn et al., 2002) and other groups of anglers, too (Hampton and Lackey, 1976; Hutt and Bettoli, 2007; Stensland and Aas, 2014). However, catch quality and quantity are not the only drivers of angler motivation. According to the respondents of this questionnaire, catch expectation is of minor importance. Today's consensus is that multi-attribute models are required to accurately describe angler behaviour (Birdsong et al., 2021; Matsumura et al., 2019). This is because anglers can be continually attracted to fisheries for other reasons than high catch rates or the presence of trophy fish (Johnston et al., 2011). We found support for this in our data, too, as the section "nature experience" was a significant factor in our model explaining motivation for non-catfish anglers. The statements dealing with nature experience and escape from urban areas found particularly high levels of agreement. In contrast, for specialized catfish anglers, nature experience seems to be of minor importance, as every aspect of this section related negatively with specialization for catfish fishing.

The second goal of the study was to gain insight into socio-demographic and economic aspects of catfish fishing. Interestingly, our data do not reveal any difference between catfish and non-catfish anglers in terms of age, education, residence, and income. This outcome is in strong contrast to other studies which found large differences in these broad demographic characteristics between specialized groups (Hutt and Bettoli, 2007; Warren Schlechte et al., 2021; Wright and Sanyal, 1998). However, this pattern is not consistent. For example, the age and income did not vary between specialized and non-specialised anglers in Alabama, US (Maceina et al., 2019). Probably the limited sample size of non-catfish anglers is not sufficient to prove the observed differences in demographic trends that other studies identified (*c.f.* specialised eel angler; Dorow et al., 2010, 2009, Dorow and Arlinghuas, 2012). Furthermore, catfish fishing in southern Germany *per se* does not require specific and partly exclusive waters or gear. This gives nearly every local angler an opportunity to fish for catfish, setting the threshold for this species much lower than, for example for salmon or trout fishing, which requires access to restricted location and payment of high fees (Baer and Brinker, 2010). In this respect, and in line with other authors (Beardmore et al., 2013), we find that general specialization constructs such as centrality to lifestyle seem to be better predictors of general fishing preferences than socio-demographic and economic factors, at least where other barriers to catching a certain species, *e.g.* catfish, are low.

The third goal of the present study was to assess how anglers rate the potential impacts of catfish and their perceptions of existing management regulations. In this respect, catfish anglers see European catfish in a more positive light than non-catfish anglers, with nearly 75 % perceiving a negligible or even positive influence on the ecosystem, while only 46 % of non-catfish anglers second these opinions. Furthermore, 71.5 % of catfish anglers prefer C&R, in contrast to 49.8 % of non-catfish anglers. This motivation of anglers to protect the fish species they favour to catch (here: dont kill the caught fish), in spite of evidence of invasiveness and negative impacts on the natural fish community and aquatic ecosystem, has also been shown for another popular but highly problematic sportfish such as the smallmouth bass (*Micropterus dolomieu*) (Carey et al., 2011), with most smallmouth bass anglers also practicing C&R (Aday et al., 2009). Our results show the practice of C&R to be strikingly size-dependent, with half of catfish anglers stating that they take only small catfish, resulting in a disproportionate number of mean larger catfish being released. This outcome is surprising, given that catfish anglers normally prefer to catch and keep larger individuals (Reitz and Travnichek, 2006), and highly pertinent to impact mitigation as piscivory in catfish increases exponentially with total length (Ferreira et al., 2019) and fecundity shows a linear increase with body length (averaging 14.2 oocytes per gram total weight, see Gkenas et al., 2023). Furthermore, it is known that the release and protection of especially large catfish has a negative impact on the size structure of various prey fish species (Wysujack and Mehner, 2005). Catfish can dramatically affect local fish communities, especially small-bodied species, and other vertebrates such as waterfowl which has been known for decades (Carol et al., 2009; Copp et al., 2009). Furthermore, high predation pressure from catfish on migratory species may impair conservation efforts and limit the efficacy of enhancement strategies for endangered fish species (Boulêtreau et al., 2021, 2018). These negative effects and the range expansion of catfish into formerly catfish-free areas as well as its overall population increase resulted in the abolishment of a legal size limit and special harvest regulations for the species in the study area. Furthermore, according to paragraph 1section 1 of the German Animal Protection statute, nobody is allowed in Germany to inflict pain, suffering or damages to an animal without a well-justufued reason. Angling for consumption is deemed an accepted reason, but angling with the

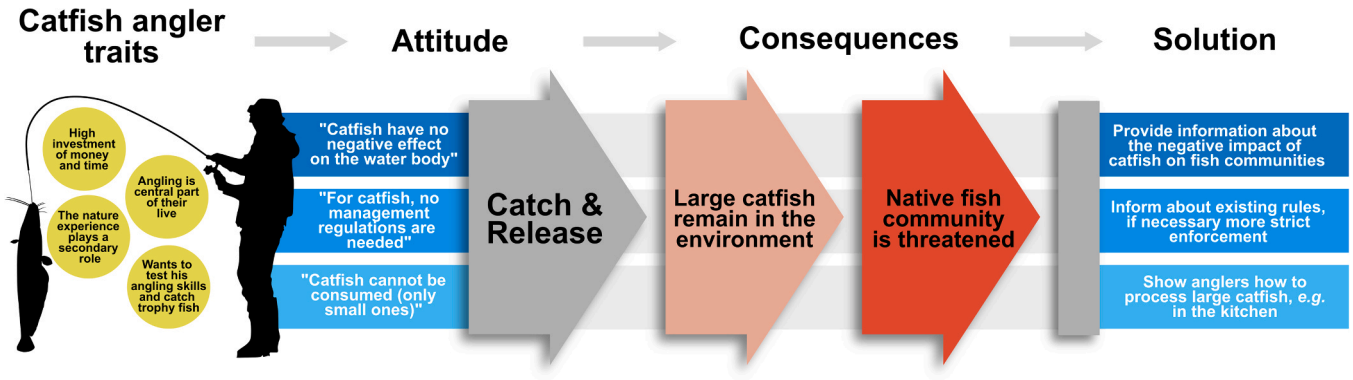

Fig. 3. Characterisation and attitudes of catfish anglers in southern Germany: implications and possible solutions for future management.

intention to release every individual caught is not, meaning that C&R is generally prohibited. This legal constraint is one likely reason why the majority of both catfish anglers (52.8 %) and non-catfish anglers (45.6 %), which both, according to the questionnaire, practise high percentages of C&R, are unsatisfied with the existing regulations with only a minority claiming to be happy (26.8 % of catfish anglers and 24.4 % of non-catfish anglers). It is a fact that a majority of both groups (87.3 % of catfish anglers and 78.6 % of non-catfish anglers) understand that there are no regulations such as legal size limits or closed seasons to protect catfish in the study area. This implicates that a majority of anglers is knowingly flouting the law by practicing C&R. On the other hand, 58.6 % of non-catfish anglers and 26.3 % of catfish anglers regard an obligation to take every catfish as a reasonable management action given the species expanding range and population, which questions the awareness concerning existing fisheries regulations. Nevertheless, as the obligation to take every caught catfish is already in effect by law, no additional legislative process is at hand to increase the harvest rate of catfish. The challenge thus largely lies in surveillance and implementation, and enforcement by the responsible authorities. For anglers who may not be aware of the situation, an information campaign could be fruitful and help to increase the harvest rate of catfish further. Furthermore, an increase in fines for infringement or an intensification of fishery wardening may encourage more anglers to desist from C&R, but it is known that increasing punishment is not always an effective solution (Stensland and Aas, 2014). We instead propose that a campaign promoting the excellent edibility of catfish of all sizes and ages, along with demonstrations of techniques for processing and preparation especially for large-sized catfish, might be a more effective means of increasing take and consumption, as 55.7 % of non-catfish anglers and 52 % of catfish anglers stated a mistaken belief that large catfish cannot be eaten (Linhart et al., 2002). This differs strongly from the perception of commercial fishermen from Lake Constance and the River Rhine who process every caught catfish, regardless of size, and sell at high prices to the restaurant and wholesale trade. Training courses and/or brochures aimed at anglers have the potential to influence both the motivations and actions of anglers.

Prohibition of catfish stocking is a subject for urgent consideration in future management, as nearly one third of catfish anglers consider that that this practise is necessary, even under the continuing trends of range and population expansion. This is surprising since the species is already present in most waterbodies and natural reproduction occurs in most of them (Dußling et al., 2018).

5. Conclusion

In conclusion, catfish anglers in southern Germany can be characterised as a specialized group for whom catfish fishing is a central part of life, who invest notable time and money in catching trophy sized catfish and increasing their angling skills, but for whom the associated overall nature experience is of secondary importance (Fig. 3). Inherent problems arise because most catfish anglers think that catfish have no negative effect on the local fish community, are unaware of relevant catfish-related fishery regulations (or ignore them), and consider only small catfish to be edible. In consequence, they practise a high degree of unlawful C&R, especially of trophy size catfish, rendering targeted fisheries management ineffective (Fig. 3). These circumstances and motivations have to be reckoned with in the development of future conservation and management strategies aiming to reduce the impact of European catfish in southern Germany. There is much promise in an approach incorporating angler education around the possible ecological negative impacts of catfish, promoting the edibility and processing of catfish of all sizes, explanation of existing regulation and updates to fishery rules (Fig. 3). In combination these measures could increase the harvest rate of catfish and reduce predation pressure on endemic species (Boulêtreau et al., 2021; Vagnon et al., 2022; Vejřík et al., 2017). Moreover, there is evidence that anglers accept management objectives better when they are not solely directed at ecosystem or species conservation, but also support successful fishing (Klefoth et al., 2023). Therefore, we suggest a participatory approach, developing and implementing new management regulations and education in which anglers and angler associations play an active role. Such an inclusive, participatory process should increase the transparency of decision-making, provide an opportunity for stakeholder input, take into account fears and expectations, and promote consensus building (Irwin et al., 2011). Such efforts can lead to rules “from anglers for anglers”, enhance a sense of ownership, boost acceptance and ultimately result in more effective management (Granek et al., 2008; Klefoth et al., 2023).

CRediT authorship contribution statement

Alexander Brinker: Writing – review & editing, Writing – original draft, Visualization, Validation, Resources, Project administration, Methodology, Formal analysis, Conceptualization. **Samuel Roch:** Visualization. **Juergen Geist:** Writing – review & editing, Writing – original draft. **Jan Baer:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis. **Matthias Fromherz:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation.

Declaration of Competing Interest

None

Data Availability

The data that has been used is confidential.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.fishres.2024.107144.

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