Public perception of river fish biodiversity in four European countries

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DOI
10.1111/cobi.13180

Original publication date
28 June 2018 (Version of record online)

Document version
Accepted version

Published in
Conservation Biology

Citation
Kochalski S, Riepe C, Fujitani M, Aas O, Arlinghaus R. Public perception of river fish biodiversity in four European countries. Conservation Biology. 2018.

Public perception of river fish biodiversity in four European countries

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Abstract: Public support for biodiversity conservation is shaped by people's values and their knowledge, beliefs, and attitudes toward the environment. We conducted the first multinational representative survey of the general public's perceptions of river fish biodiversity in France, Germany, Norway, and Sweden. For the online survey, 1000 respondents per country were randomly selected from large panels following country-specific quotas set on age, gender, and educational level. Questions covered people's level of knowledge, beliefs, values, and attitudes toward river fish, environmental threats, and conservation measures. We found that the public had limited knowledge of freshwater fishes. Two non-native species, rainbow trout (*Oncorhynchus mykiss*) and brook trout (*Salvelinus fontinalis*), were widely perceived as native, whereas native Atlantic salmon (*Salmo salar*) was mostly classified as native in Scandinavia and largely as non-native in central Europe. These results suggest an extinction of experience paralleling the extirpation or decline of salmon stocks in countries such as Germany and France. Respondents thought pollution was the dominant threat to riverine fish biodiversity. In reality, habitat loss, dams, and the spread of non-native fishes are equally important. Despite limited biological knowledge, respondents from all countries held an overwhelmingly pro-ecological worldview, supported conservation stocking, and appreciated native fishes, although only a minority interacted with them directly. Differences among the 4 countries related to several conservation issues. For example, threats to biodiversity stemming from aquaculture were perceived as more prevalent in Norway compared with the other 3 countries. Promoting fish conservation based on charismatic species

and use values of fishes may work well in countries with a strong economic and cultural link to the freshwater environment, such as Norway. In countries where people rather abstractly care for nature, focusing conservation messaging on broader ecosystem traits and non-use values of fishes is likely to win more support.

Keywords: attitudes, biodiversity loss, communications, conservation planning, environmental threats, freshwater ecosystems, public opinion, species introduction

Introduction

The intense use of rivers by humans worldwide has affected riverine biodiversity and freshwater fishes through habitat modification and simplification, water abstraction, alteration of flow regimes, pollution, eutrophication, and local overfishing (Dudgeon et al. 2006). Consequently, species extinction rates in freshwater ecosystems are surpassing those in terrestrial and marine ecosystems (Pimm et al. 2014), with between one quarter and over one-third of freshwater fish species being threatened or extinct in Europe (Freyhof & Brooks 2011), North America (Jelks et al. 2008), and Africa (Darwall et al. 2011). A prominent example is sturgeon (*Acipenser* spp.), for which all but 1 species are listed as critically endangered (Freyhof & Brooks 2011). New threats posed by climate change (Heino et al. 2015) and the invasion of ecosystems by non-native species (Gozlan et al. 2010) will likely increase over the next decades with the potential to further reduce freshwater biodiversity.

Environmental policies introduced to address the freshwater biodiversity crisis are driven and affected by people's priorities and their support for conservation (Walker-Springett et al. 2016). These priorities follow prevailing cultural values and material conditions (Inglehart 1997), meaning they are based on both objectively measurable conditions of the environment and the people's subjective interpretation of nature (Eder 1996). For example, the degree to which people are willing to tolerate wildlife close to their homes is more strongly correlated with the perceived danger from wild animals than with the

number of dangerous incidents (Kansky & Knight 2014). In a similar vein, political ideology can be more important for the perception of climate change as environmental threat than scientific descriptions of the phenomenon (Weber 2010). In short, it is the social and cultural context that shapes the mental classification scheme through which an individual and collectively society makes sense of the world; therefore, people in different countries are likely to vary in what they find acceptable, desirable, and important (Schwartz 2006; Manfredo 2008).

Several multi- and cross-national studies have been conducted to examine the impact of sociocultural factors on the public's perception of the marine environment (Ahtiainen et al. 2013; Gelcich et al. 2014; Potts et al. 2016). In comparison, it is less known how the public in different countries perceive freshwater biodiversity (Closs et al. 2015). Based on studies of other environmental issues, the expectations among conservation biologists and fisheries scientists are somewhat bleak. The public is expected to be largely ignorant and complacent about environmental quality and biodiversity loss (Angermeier 2007; Monroe et al. 2009; Closs et al. 2015). People are thought to have a weak connection to freshwater fish and to prefer birds and charismatic mammals (Cooke et al. 2013; Closs et al. 2015) as well as to value direct use of freshwater environments more than biodiversity (Monroe et al. 2009; Beard et al. 2011; Cooke et al. 2013).

Using a cross-cultural online survey, our objectives were to understand whether the members of the public in 4 European countries care about freshwater fishes (values), what people know about fish biodiversity (knowledge), how they view threats to native fish species (beliefs), and what this means for public support for specific conservation measures (attitudes). We used measures of values, knowledge, beliefs, and attitudes following sociopsychological theory that has shown that these constructs play a large role in driving pro-environmental behaviors (Stern 2000; Manfredo 2008; Klöckner 2013). The selection of surveyed countries was based on the study's interest for charismatic migratory fish species. We surveyed 2 central European countries – Germany and France – where rivers are heavily altered by humans and Atlantic salmon (*Salmo salar*) has been extirpated (Germany) or is rare (France), and 2

76 Scandinavian countries – Norway and Sweden – where Atlantic salmon is still present. We also assumed
77 the 4 countries differ in how the public uses and interacts with freshwater ecosystems. Taking
78 recreational fishing as an example activity, previous research suggests the 4 countries form clusters of
79 low (Germany, 4.0%; France, 8.2%) and high recreational use (Norway, 32.2%; Sweden, 23.0%)
80 (Arlinghaus et al. 2015).

81

82 Methods

83 Survey administration and sampling

84 The survey was administered over the internet in September 2015 using large, high-quality online
85 panels with 40,000–100,000 members/country. Panel members were recruited previously by phone
86 with a random digit-dialing method as sampling frame. This probability-based approach to panel
87 recruitment avoids the self-selection bias of nonrandom consumer panels that rely on voluntary
88 participants (opt-in panels) (Baker et al. 2010). To avoid respondent fatigue, panel members are invited
89 to participate in a survey at a maximum of 6 times/year.

90 Respondents were randomly selected from the panels and invited via email to participate in the survey.
91 Up to 3 reminder emails were sent during the survey period of 21 days. Data collection conformed to
92 the rules given by the national Data Protection Acts as well as standards for social research as outlined
93 by the European Society for Opinion and Market Research (ESOMAR & GRBN 2015; ICC & ESOMAR
94 2016). The sample selection followed country-specific quotas set on age groups, gender, and the
95 highest education level achieved according to census data (Eurostat 2015). We removed 287
96 respondents from the sample with implausibly low response times (speeding), 3 respondents who gave
97 the same answers in more than 3 grids (straight lining), and respondents who answered <20% of all
98 questions (item nonresponse) (Groves et al. 2011). Aside from these cases of potentially fraudulent or

99 inattentive participants, 4844 persons started the questionnaire. Overall, 17.4% (n = 844) of the initial
100 sample quit participating.

101 The final sample of 1000 respondents/country, aged 16 to 74 years, approximated a
102 representative sample relative to the previously defined quota characteristics. Further respondent
103 characteristics are described in Supporting Information. We defined our study population as the general
104 population with internet access, which covered from 83% (France) to 97% (Norway) of all private
105 households (Germany, 90%; Sweden, 91%) (Eurostat 2016). In December 2016, 61% of the respondents
106 took part in a follow-up survey of which one question about Atlantic salmon was relevant for this study.

107 **Survey questions**

108 The 2015 questionnaire covered human values and the value of native fish populations; self-reported
109 and revealed knowledge; beliefs about environmental threats; and attitudes toward conservation and
110 management measures. The assumption that the countries would differ in relation to outdoor activities
111 bound to water was verified by asking respondents about their recreational activities (Supporting
112 Information). In 2016, respondents were surveyed again and asked whether they thought that salmon
113 and Atlantic salmon were native to 6 European countries, including their own. All questions were
114 worded using neutral and accessible language. The questions were pretested with experts in freshwater
115 ecology and members of the public. The final survey was translated professionally into German, French,
116 Norwegian (Bokmål), and Swedish. Pilot interviews (n = 4 × 30) resulted in only minor adaptations of the
117 questionnaire.

118 Environmental values were measured with 3 items from the Schwartz (2012) value scale (e.g.,
119 "respecting the earth, living in harmony with other animal and plant species") using a 5-point response
120 format (1, not at all important, to 5, very important). Cronbach's reliability coefficient for this scale was
121 high ($\alpha = 0.89$). See Supporting Information for the scale's item wording. The use and non-use values of
122 native fish populations were assessed (from 1, strongly disagree, to 5, strongly agree) using 6 items

adapted from ecosystem valuation frameworks (Hein et al. 2006) (e.g., "Native fish populations should be protected for their own sake").

Concerning knowledge about native biodiversity and threats from non-native fishes, respondents were asked for a self-assessment (1, not informed at all, to 4, very well informed). Familiarity with river fish species was assessed by presenting the respondents with 3 native freshwater (brown trout [*Salmo trutta*], grayling [*Thymallus thymallus*], and bream [*Abramis brama*]), 2 non-native salmonids (rainbow trout [*Oncorhynchus mykiss*] and brook trout [*Salvelinus fontinalis*]), and 3 native diadromous species (Atlantic salmon, sturgeon, and European eel [*Anguilla anguilla*]). In Scandinavia, sturgeon is only native to the south. Another species, barbel (*Barbus barbus*), is a key species for the fish-based zonation of rivers in central Europe, but is not native to Scandinavia. Respondents were asked whether they had heard of the species and, if they answered affirmatively, whether they thought the species was native to the inland waters of their country.

People also rated the contribution of 5 threats to fish biodiversity loss (1, no contribution at all, to 4, a very strong contribution). The items reflected major threat categories for freshwater biodiversity (Dudgeon et al. 2006). Attitudes toward conservation and management actions were assessed based on 10 items ranked in a 5-point response format (1, very bad, to 5, very good). The items represented factual information about non-native fish species, stocking as a common practice in fisheries management, and coastal aquaculture.

Data analysis

We used factor analysis with orthogonal Varimax rotation to structure our data and identify indicator items of underlying latent constructs for the established Schwartz value scale. We used principal component analysis to reduce correlated observed attitude items to a smaller set of composite scores. Items with high loadings on the same factor were aggregated to form composite scores as measures of these constructs. Individual items and composite scores that were collected on Likert-type rating scales

were analyzed for country differences using the Kruskal–Wallis test and the Tukey–Kramer (Nemenyi) test for pairwise post hoc comparisons. The familiarity with native and non-native fish species was compared between countries with Pearson's chi-squared tests. All data were analyzed with R version 3.2.2.

Results

Environmental values and the value of native fish populations

Basic environmental values were assessed with 3 items representing one construct (73% explained variance); it was labeled harmony with nature. This construct was rated, on average, as important in all 4 countries. However, for Norwegians (n = 1000, M = 3.6, SD 0.9) followed by the French (n = 1000, M = 3.8, SD 0.9) achieving harmony with nature was slightly less important than for the respondents in Germany (n = 995, M = 3.9, SD 0.9) and Sweden (n = 999, M = 3.9, SD 0.9). This difference was statistically significant (Kruskal–Wallis $H = 75.3$, df = 3, $p < 0.001$).

Coinciding with their values, respondents in all countries highly appreciated native fish populations for their non-use value and less so for their use value (Table 1). The French agreed significantly less than the other countries with the importance of the existence value ($H = 61.9$, df = 3, $p < 0.001$) and bequest value ($H = 53.6$, df = 3, $p < 0.001$) of native fish populations. Norwegians appreciated native fish populations not only for their non-use but also for the use value that fish bring to humans (Table 1). In comparison to other countries, Norwegians also disagreed most strongly with the idea that they would not personally benefit from the protection of native fish populations (option value: $H = 264$, df = 3, $p < 0.001$), and they agreed most strongly with the need to preserve fish populations for the benefits of others (altruistic value; $H = 700$, df = 3, $p < 0.001$). French respondents, on average, expressed stronger use values relative to the other 3 countries (Table 1). The other respondents, particularly the Germans and Swedes, tended to disagree on average with the direct-use value of native fish populations for the

171 respondents' own benefit (H = 297, df = 3, p < 0.001) and human benefit in general (H = 186, df = 3, p <

172 0.001) and focused on the non-use benefits derived from the existence and bequest value of fishes

173 (Table 1).

174 **Table 1. Mean (SD) approval (1, strongly disagree, to 5, strongly agree) of survey respondents from 4 countries to protect**
175 **native fish populations for their non-use (existence and bequest value) or use values (direct use, option and altruistic**
176 **value).**[a,b,c,d]

Value category	*Survey item*	*Germany*	*France*	*Norway*	*Sweden*	*H* [e]
Existence value	Native fish populations should be protected for their own sake.	4.2a (0.8)	4.0c (0.9)	4.1b (1.0)	4.0bc (0.9)	61.9
Bequest value	I think it is good to preserve native fish populations to maintain an environment worth living in for our children and future generations.	4.3a (0.8)	4.1b (0.9)	4.3a (0.9)	4.3a (0.9)	53.6
Altruistic value	Native fish populations should primarily be preserved for the benefit of others.	2.6d (1.2)	3.3b (1.0)	3.9a (1.0)	2.8c (1.1)	700
Option value	I wouldn't benefit in any way from the protection and conservation of native fish populations. [f]	3.3b (1.2)	3.1a (1.0)	3.8c (1.2)	3.1a (1.2)	264
Direct use value	Native fish populations should primarily be managed for human benefit.	2.5d (1.1)	3.2a (1.2)	2.9b (1.2)	2.7c (1.2)	186
	Native fish populations are valuable only if I get to use them in some way.	2.0b (1.0)	2.6a (1.2)	1.9c (1.0)	2.0b (1.1)	297
Number of observations		998	998	998	992	

177 [a,b,c,d] *Any 2 means in a row that do not share a letter are significantly different (p < 0.05) according to pairwise comparisons*
178 *made with the Tukey–Kramer (Nemenyi) test.*
179 [e] *Differences between countries were tested for significance with the Kruskal–Wallis test.*
180 [f] *Scoring reversed because of negatively worded item.*

181

182 **Self-reported and revealed knowledge related to fish biodiversity**

183 A large majority of the respondents stated that they did not feel well informed about fish biodiversity

184 (89%) and the potential threats posed by non-native fishes to the rivers in the respective countries

185 (86%). Norwegians felt, on average, significantly better informed about fish biodiversity (H = 1

71.9, df = 3, $p < 0.001$) and about possible biological threats posed by non-native fishes ($H = 208.2$, df = 3, $p < 0.001$) than the respondents in the other 3 countries (Fig. 1).

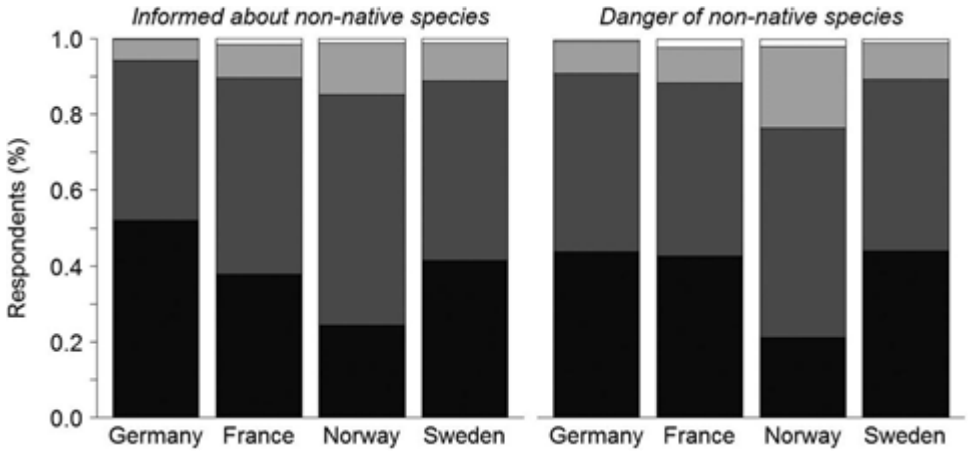

Figure 1. Self-reported level of feeling informed about fish biodiversity ($n = 4000$) and the threats caused by the introduction of non- native fish species ($n = 3991$) (black, not informed at all; dark gray, not well informed; light gray, well informed; white, very well informed).

Over 85% of the respondents in Germany, Sweden, and Norway indicated they had heard of the salmonids brown trout and rainbow trout, whereas in France, these species were significantly less known (brown trout: 64%; rainbow trout: 70%). Two other salmonids, brook trout and grayling, were less well known overall (Fig. 2). Atlantic salmon and the other diadromous fishes in the survey – sturgeon and European eel – were recognized in the 2015 survey by at least 85% (salmon, eel) and at least 79% (sturgeon) of the respondents. Atlantic salmon and European eel were well known in Norway and Sweden (>96%), but significantly less so in France (81%) and Germany (58%). In contrast, sturgeon was significantly better known in Germany (92%) and France (84%) than in Norway (65%) and Sweden (76%). The same was true for the cyprinid barbel, which was recognized by less than 5% of respondents in the Scandinavian countries, but by about half of the respondents in Germany and France (Fig. 2). Bream was recognized by half of the respondents in Germany, France, and Norway, and by 85% of the Swedish respondents (Fig. 2).

When a respondent indicated familiarity with a fish species, the next question asked whether the respondent believed the fish species was native or non-native. Rainbow trout and brook trout – 2

salmonids introduced to Europe a century ago – were perceived by over half the respondents as native (Fig. 2). Two native migratory fish species, Atlantic salmon and sturgeon, were perceived by only 40% of the respondents as native species (Fig. 2). The exception to this pattern was Norway, where 90% of the respondents correctly considered Atlantic salmon as a native species to their country.

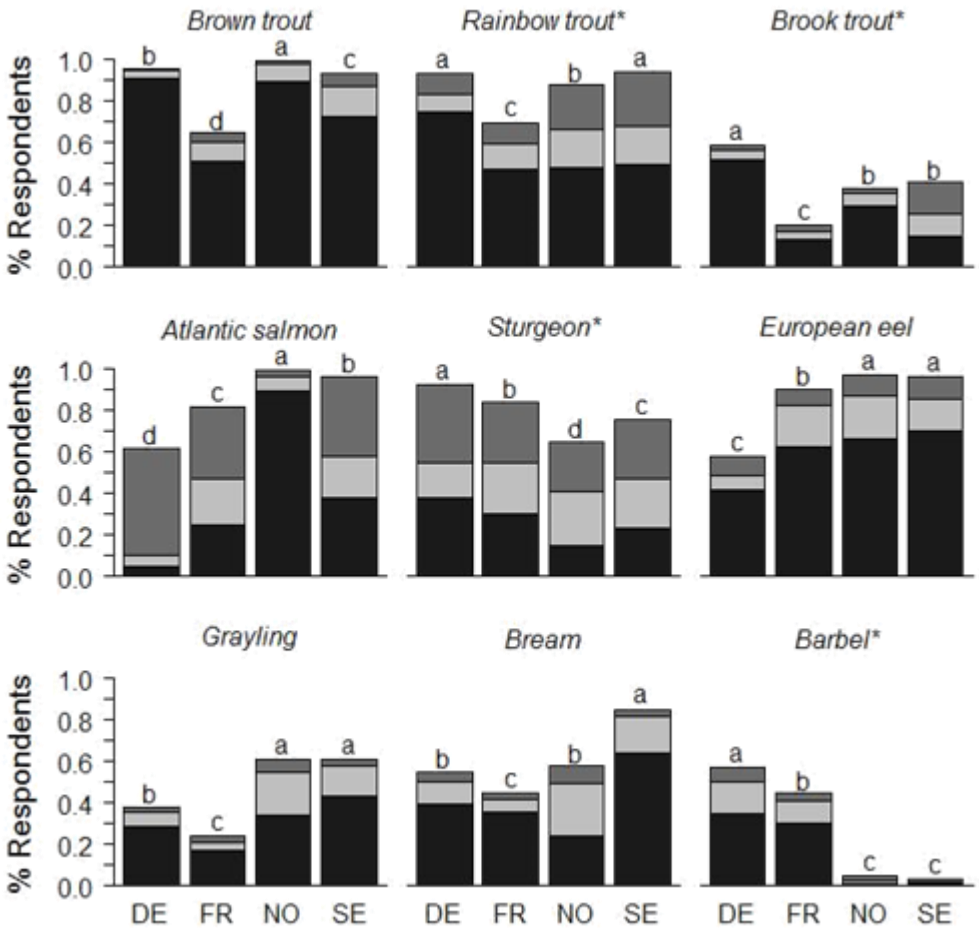

Figure 2. Familiarity of 1000 respondents in Germany (DE), France (FR), Norway (NO), and Sweden (SE) with fish species (1, familiar; 0, unfamiliar) and their perceived native⁎ or non-native origin to inland waters (black, native; light gray, unsure or don't know; dark gray, not native) (species not native to all, some, or parts of the 4 countries). Differences between countries for the familiarity with fish species were tested for significance with the Kruskal-Wallis test. Any 2 bars that do not share a letter are significantly different ($p < 0.05$) according to pairwise comparisons made with the Tukey–Kramer (Nemenyi) test.

A follow-up question that was asked in 2016 showed that respondents from all countries associated salmon with the Scandinavian countries Norway (82-97% of respondents) and Sweden (77-92%), but to a lesser degree with the central European countries Germany (34-58%) and France (28-61%), the landlocked Czech Republic (28-36%), and the southern European country Spain (8-29%) (Table 2),

223 although in reality, Atlantic salmon is native to all 6 countries. This pattern remained the same when
224 asking about Atlantic salmon rather than salmon (Table 2). In comparison with salmon, more people
225 believed Atlantic salmon to be native in France (32-59% of respondents across countries) and Spain (21-
226 26%), and fewer people believed it to be native in Norway (78-95%), Sweden (56-74%), Germany (18-
227 35%), and the Czech Republic (6-21%).

228 **Table 2. Percentage of survey respondents *a* in Germany (*n* = 642), France (*n* = 578), Norway (*n* = 500), and Sweden (*n* = 586)**
229 **who perceived salmon and Atlantic salmon as native in 6 European countries (Czech Republic [CZ], France [FR], Germany**
230 **[DE], Norway [NO], Spain [ES], and Sweden [SE]).**
231
232

	Salmon native to country						*Atlantic salmon native to country*					
Respondent country	*CZ*	*FR*	*DE*	*NO*	*ES*	*SE*	*CZ*	*FR*	*DE*	*NO*	*ES*	*SE*
Germany	30	32	58	96	8	92	8	42	29	87	24	74
France	33	61	44	82	27	77	21	59	31	78	26	72
Norway	36	40	51	97	29	92	11	32	35	95	23	70
Sweden	28	28	34	94	18	92	6	36	18	88	21	56

a Most of the data presented in this study was obtained in 2015. The information underpinning this table was obtained during a follow-up survey in 2016.

233 **Beliefs about environmental threats to riverine fishes**

234 With regard to environmental threats, respondents in all 4 countries believed that water pollution
235 contributed most to fish biodiversity loss (mean [SD] = 3.4 [0.72]) (Fig. 3). Averaged across the 4
236 countries, the second most serious threat was perceived to be habitat loss (mean = 3.0 [0.76]), followed by
237 the introduction of non-native species (mean = 2.9 [0.80]) and overfishing (mean = 2.9 [0.86]). Dams built
238 for hydropower plants were overall seen as the least serious threat (mean = 2.9 [0.77]) (Fig. 3), and the
239 concern about this threat was equal in all 4 countries (H = 0.7, df = 3, p = 0.878). The French were
240 significantly more concerned about water pollution (H = 65.9, df = 3, p < 0.001) than respondents in the
241 other countries. Habitat loss was seen as a significantly more pronounced threat in Germany and France
242 than in Sweden and Norway (H = 242.7, df = 3, p < 0.001). Norwegians were significantly more concerned
243 about non-native species (H = 65.4, df = 3, p < 0.001), and the Germans about overfishing (H = 123.1, df

= 3, $p < 0.001$) compared with the respondents in the other 3 countries. The Swedes were least concerned of all countries about both non-native species and overfishing (Fig. 3).

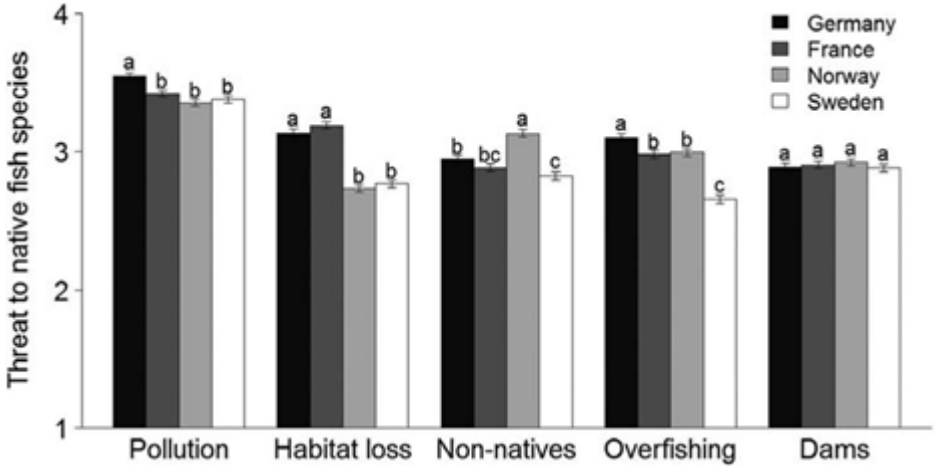

Figure 3. Mean (SE) survey respondents' perceived degree to which water pollution, loss of natural river bank habitat, introduction of non-native species of plants and animals, including fishes, to rivers by humans, overfishing, and the construction of dams for hydroelectric power generation threaten native fish species in Germany (n = 898), France (n = 831), Norway (n = 809), and Sweden (n = 789) (1, no contribution at all, to 4, very strong contribution). Differences between countries were tested for significance with the Kruskal–Wallis test. Any 2 means for each threat that do not share a letter are significantly different ($p < 0.05$) according to pairwise comparisons made with the Tukey–Kramer (Nemenyi) test.

Attitudes toward fish conservation and management measures

The reestablishment of Atlantic salmon and sturgeon to rivers where they had been extirpated through human influence was supported in all 4 countries, and the approval was significantly highest in Germany (H = 312, df = 3, $p < 0.001$; Table 3). Culture-based enhancement stocking of rainbow trout and brook trout (both non-native species) for fisheries purposes received less support than conservation stocking of Atlantic salmon and sturgeon; however, people did also not oppose it on average (Table 3). In Germany, culture-based stocking of brook trout and rainbow trout was viewed more positively relative to the other 3 countries (H = 295, df = 3, $p < 0.001$).

Table 3. Mean (SD) attitudes (1, very bad, to 5, very good) of survey respondents from 4 countries toward conservation stocking (2 items), culture-based enhancement stocking (3 items), aquaculture management (3 items), and the biodiversity risk of aquaculture (2 items).[a,b,c,d]

Survey item	*Loading*	*Germany*	*France*	*Norway*	*Sweden*	*H* [e]
Conservation stocking	–	*4.2a (0.8)*	*3.7b (1.0)*	*3.5c (1.1)*	*3.6bc (1.0)*	*312*
Sturgeon are being reintroduced by	0.904	4.2a (0.8)	3.7b (1.0)	3.4c (1.1)	3.6c (1.0)	330

stocking to some European waters where they were native and extirpated through human influence.						
Atlantic salmon are being reintroduced by stocking to some European rivers where they were native and extirpated through human influence.	0.899	4.1a (0.8)	3.6b (1.0)	3.6b (1.1)	3.6b (1.0)	217
Culture-based stock enhancement	–	*3.3a (0.9)*	*2.7d (1.0)*	*2.9c (0.9)*	*3.0b (0.9)*	*295*
At the end of the 19th century, brook trout and rainbow trout were deliberately introduced from North America as edible fishes to the rivers of (insert country).	0.742	3.2a (0.8)	3.0b (0.9)	3.0b (0.9)	3.2a (0.8)	60.7
Some nature conservationists demand that non-native brook trout and rainbow trout be extirpated from the rivers in (insert country) to protect the native species biodiversity.[f]	0.725	3.4a (0.9)	2.5c (0.9)	2.9b (0.9)	2.8b (0.9)	474
Fisheries managers release hatchery-bred brook trout and rainbow trout into the wild to increase fisheries catch.	0.648	3.1a (0.9)	2.7c (1.0)	2.8bc (1.0)	2.9b (1.0)	113
Aquaculture management	–	*2.2c (1.0)*	*2.4ab (1.1)*	*2.5a (1.1)*	*2.4b (1.0)*	*112*
Rainbow trout raised in fish farms can be made infertile by thermal treatment of eggs. As a result they achieve a higher slaughter weight.	0.860	2.0d (0.9)	2.3b (1.0)	2.5a (1.0)	2.2c (1.0)	143
It is possible to intentionally alter the expression of specific genes of salmon and trout to achieve a higher slaughter weight.	0.795	1.7b (0.9)	2.2a (1.0)	2.2a (1.0)	2.1a (1.0)	135
Across Europe, Atlantic salmon and rainbow trout are often bred in net cages placed in coastal zones or in fish farms on land for human consumption.	0.585	2.7b (1.1)	2.8ab (1.0)	2.8ab (1.1)	2.9a (1.0)	14.9
Biodiversity risk of aquaculture	–	*2.1b (0.9)*	*2.4a (1.1)*	*1.7d (0.8)*	*2.0c (0.9)*	*442*
Sometimes Atlantic salmon and rainbow trout unintentionally escape from fish farms into the wild and then interbreed with their wild conspecifics.	0.861	2.6a (0.8)	2.7a (1.0)	1.9c (0.9)	2.5b (0.9)	488
Sometimes Atlantic salmon and rainbow trout unintentionally escape from fish farms into the wild and then transmit parasites or diseases to their wild conspecifics.	0.784	1.6b (0.7)	2.0a (1.0)	1.4c (0.7)	1.6b (0.8)	201
Number of observations	–	998	999	997	996	

[a,b,c,d] *Any 2 means in a row that do not share a letter are significantly different ($p < 0.05$) according to pairwise comparisons made with the Tukey–Kramer (Nemenyi) test. Survey items grouped by principal component analysis with Varimax orthogonal rotation.*

[e] *Differences between countries tested for statistical significance with the Kruskal–Wallis test.*

[f] *Scoring reversed because of negatively worded item.*

Respondents in all countries felt rather negative toward escapees from aquaculture (Table 3). Despite this concern, respondents did not support the treatment of farmed fish that could render the fish infertile, thus reducing the genetic risks associated with escapees. Norwegians felt significantly more positive toward these aquaculture management measures (H = 112, df = 3, $p < 0.001$) and significantly more negative toward escapees from aquaculture (H = 442, df = 3, $p < 0.001$) than the public in the other 3 countries. Despite being more concerned about the associated risks, Norwegian respondents did not have a more negative attitude toward aquaculture than the other 3 nations (Table 3).

Discussion

Most of the previous social science studies on freshwater fish and biodiversity have been conducted on specific stakeholder groups and single countries (Bremner & Park 2007; Riepe & Arlinghaus 2014; Walker-Springett et al. 2016). Our study broadens the perspective in relation to the public's perception of river fish biodiversity in central and northern Europe using identical questionnaires. Cross-national studies, such as ours, shed light on which perceptions are confined to or shared by single countries or cultures. We found that the publics of our 4 countries shared high levels of pro-environmental concern, positive attitudes toward fish conservation, and limited knowledge about biological realities under water. But we also found important differences in the beliefs and attitudes reflecting national specificities.

General patterns held across countries

The public in all 4 countries valued native fish species for their existence (Table 1) and supported conservation stocking (Table 3). These findings coincided with the predominantly pro- environmental values of the public. Modernization and postindustrialization have resulted in a rise of abstract pro-environmental values within many wealthy societies (Inglehart 1990, 1997) and fostered the cultural value of egalitarianism, broadly defined as the desire to take care of the well-being of fellow humans, but also animals and the environment (Schwartz 2006). In this study, people cared about fish

298 conservation in a positive way, likely because this animal group was perceived as part of nature that
299 they felt should be protected. We would expect to find similar results in other western European
300 countries featuring high scores in egalitarian cultural values (Schwartz 2006). However, there is the
301 limitation that we did not study the relative importance of different taxa or ecosystem characteristics,
302 such as water quality (Hanley et al. 1998). Further studies on the perceptions of freshwater fishes in
303 countries with other national value priorities (Schwartz 2006) and on people's preferences for various
304 ecosystem traits are needed to fully understand the values underlying freshwater fish conservation.

305 The self-reported level of knowledge of river fish biodiversity was low in all 4 countries (Fig. 1), in line
306 with the expectations expressed in the scientific literature (Monroe et al. 2009; Cooke et al. 2013; Closs
307 et al. 2015). Well-known species included both native (e.g., brown trout) and non- native (e.g., rainbow
308 trout) salmonids, but there were also native (e.g., grayling) and non-native (e.g., brook trout) salmonids
309 that were less well known (Fig. 2). Respondents were familiar with migratory fish, such as sturgeon and
310 Atlantic salmon, but were less certain about these species' range of natural occurrence. It is highly likely
311 that this pattern represents an example of an "extinction of experience" (Miller 2005) because, for
312 example, Atlantic salmon were extirpated from Germany in the mid-20th century (Wolter 2015) and its
313 abundance declined greatly in other European countries (Chaput 2012). Given that all surveyed
314 countries showed that loss of memory with regard to the situation in their own or other countries (Table 2),
315 we would expect similar results for other European countries.

316 Relative to environmental threats, the respondents perceived pollution to pose the biggest threat to
317 freshwater biodiversity (Fig. 3), possibly remembering high level of discernible pollution in the 1960s and
318 1970s. Since then water quality has improved across many rivers due to advances in water purification and
319 the implementation of the European Water Framework Directive (Directive 2000/60/EC). Our results
320 parallel findings for the marine environment where pollution was also perceived to be the dominant
321 threat in many different countries (Gelcich et al. 2014; Potts et al. 2016), possibly because of the high
322 media coverage of marine pollution events. Similar incidents in the freshwater environment date back

323 decades (Reinhard 2008), but recent media campaigns on plastic waste, micro-pollutants, and micro-
324 plastics could have had an impact on public perception. For river conservation, it will be important to
325 increase people's awareness about less visible threats (Dudgeon et al. 2006; Gozlan et al. 2010; Freyhof
326 & Brooks 2011).

327 **Country-specific patterns**

328 Norwegians felt better informed and were more concerned about non-native species (Figs. 1 & 3) and
329 biodiversity risks from aquaculture farms than the members of the public in the other countries (Table
330 3). This may be related to the debate about the expanding salmon aquaculture industry in Norway and its
331 significant media coverage (Olsen & Osmundsen 2017). Through escapees and introgression of
332 aquaculture genotypes into wild stocks, there is evidence that farmed salmon have had direct and
333 indirect negative impacts on wild salmon populations (Bolstad et al. 2017). Despite being more
334 concerned with risks, Norwegian respondents did not have a more negative attitude toward
335 aquaculture than the other nations (Table 3), possibly trading off the biodiversity risks related to
336 aquaculture against the economic benefits to Norwegian society.

337 The use value of fish populations was seen as less important than their non-use value in Germany and
338 Sweden compared with Norway (Table 1), where fish and fisheries are important for recreational and
339 commercial purposes (Borch et al. 2008; Arlinghaus et al. 2015). Despite low use values, Germany
340 evaluated culture-based stocking comparatively positive (Table 3), possibly because brook trout and
341 rainbow trout are legally considered to be native and intensively stocked into German waters
342 (Arlinghaus et al. 2015) seemingly with limited ecological impacts (Wolter & Röhr 2010). An interesting
343 case is France, where the public expressed a comparably high use value and a lower importance of the
344 non-use values bequest and existence. In cross-cultural studies, France showed less egalitarian cultural
345 values compared with the other 3 countries, and it scored higher on intellectual autonomy as cultural
346 value (Schwartz 2006). This may explain why the instrumental use value of fish populations was larger in
347 France compared with the other 3 countries. Overall, country-specific factors were more important for

348 explaining use values than non-use values, because western Europeans share high levels of environmental
349 values (Schwartz 2006), but differ with regard to other value dimensions, have differently structured
350 economies, and different preferences with regard to recreation and food (EUMOFA 2017).

351 **Implications for fish conservation**

352 Human behavior is complex and multifaceted. It is informed by a person's psychological disposition as
353 well as by situational and contextual factors (Stern 2005; Steg & Vlek 2009). Psychological constructs
354 (such as knowledge, values, beliefs, and attitudes) do not always translate into action (Kollmuss &
355 Agyeman 2002), but they can be important drivers of pro-environmental behavior when the contextual
356 factors are favorable (Stern 2000, 2005; Riepe et al. 2017). Given that we did not observe actual
357 behavior, we limit our conclusions for fish conservation to implications for conservation messaging.

358 Conservation messaging can achieve behavioral change, especially when combined with other
359 interventions (Osbaldistan & Schott 2012). Our results suggest that public outreach campaigns
360 promoting fish conservation based on use values may not be effective in those European countries
361 where society cares abstractly about fishes and considers overfishing to be a key reason for population
362 declines (e.g., in Germany). Threat-related messages with the purpose of increasing support for aquatic
363 conservation measures are well known from the marine environment (e.g., campaigns focusing on by-
364 catch or marine litter) but are currently limited in the freshwater context due to misconceptions of the
365 public (as seen in this study) and the complexity of interacting threats (Dudgeon et al. 2006; Cooke et al.
366 2013). Instead, focusing messaging on broader ecosystem traits (e.g., unpolluted and free-flowing
367 water) that will indirectly help extirpated or threatened riverine species recover is likely to win more
368 public support.

369 A new approach to freshwater conservation is concentrating conservation messages on charismatic
370 species (Carrizo et al. 2017; Kalinkat et al. 2017), such as migratory fish (Bolster 2008; Kalinkat et al.
371 2017). This approach may be effective in countries where the public has a connection to a species (e.g.,
372 Atlantic salmon in Norway). For central Europe, we found the situation was more complex: the general

373 public supported conservation stocking despite not recognizing the species. This finding suggests
374 knowledge is not essential for conservation support, but what matters are pro-ecological beliefs and
375 attitudes (Manfredo et al. 2017). We suggest enhancing the connection between native fish biodiversity
376 and the general public by involving groups, such as anglers, that directly interact with the aquatic
377 environment (Fujitani et al. 2017), as well as historians and artists who can highlight historical
378 relationships with native fish species (Rathwell & Armitage 2016), in conservation research and
379 outreach activities.

380

381 Acknowledgements

382 This project received funding from the German Research Foundation within the project SalmoInvade in
383 the BiodivERsA 2012–2013 Pan-European call (grant AR 712/4-1) and from the European Union's Horizon
384 2020 research and innovation program under the Marie Sklodowska-Curie project IMPRESS (grant 642893).
385 Funding in Germany was also received from the German Federal Ministry of Education and Research (BMBF)
386 to R.A. within the project Besatzfisch (grant 01UU0907) in the Programme for Social-Ecological Research. We
387 thank D. Behr, J. Cucherousset, J. Johnsson, K. Hindar, and all other members of the SalmoInvade project
388 and the team of Language Connect for their support related to the translation of the questionnaire. We give
389 our special thanks to F. Funke, M. Reich, A. Wachenfeld, and all other people of LINK and Norstat for
390 collecting the data and to all participants for their cooperation.

391

392 Supporting information

393 Respondents' characteristics (Appendix S1), details for the Schwartz value scale (Appendix S2), the
394 recreational activities respondents performed in the 12 months prior to the survey (Appendix S3), and
395 the survey questions (Appendix S4) are available online. The authors are solely responsible for the

content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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Supporting information

Table SI1: Overview of sample characteristics (n = 1.000 per country). Differences between countries in the age distribution were tested for significance ($p < 0.05$) with the Kruskal-Wallis test. Distribution of gender and educational levels were tested for differences with Pearson's chi-squared tests.

		Germany	France	Norway	Sweden	Test statistic (df)	
Gender (in %)	female	48.4	48.9	47.5	47.7	χ^2	0.5 (3)
	male	51.6	51.1	52.5	52.3		
Mean age in years (SE)		43.1 (0.5)	41.5 (0.5)	42.3 (0.5)	43.2 (0.5)	H	7.7 (3)
Education [a] (in %)	low (0 - 2)	11.1	17.8	18.4	18.2	χ^2	94.3 (6) *
	medium (3 - 4)	59.0	45.6	38.6	44.1		
	high (5 - 8)	29.9	36.6	43.0	37.7		

[a] According to UIS (UNESCO Institute for Statistics). 2012. International standard classification of education: ISCED 2011. UNESCO-UIS, Montreal.

* p-value < 0.001

Table SI2: Mean (SD) importance of harmony with nature as a guiding principle in life measured with three items from the Schwartz value scale (Cronbach's alpha = 0.89) on a 5-point scale from 1 (not at all important) to 5 (very important). Differences between countries were tested for significance with the Kruskal-Wallis test (H = 75.3, $p < 0.001$).

	Germany	France	Norway	Sweden
Harmony with nature	3.9^{ab} (0.9)	3.8^{b} (0.9)	3.6^{c} (0.9)	3.9^{a} (0.9)
Scale items				
Respecting the earth, living in harmony with other animal and plant species	4.1 (0.8)	3.9 (0.9)	3.7 (0.9)	4.0 (0.9)
Protecting the environment, preserving nature	4.0 (0.8)	3.9 (0.9)	3.9 (0.9)	4.0 (0.9)
Unity with nature, fitting into nature	3.6 (1.0)	3.7 (1.0)	3.3 (1.0)	3.7 (1.0)
Number of observations	995	1.000	1.000	999

[a,b,c] Any two means in a row that do not share a letter are significantly different ($p < 0.05$) according to pairwise comparisons using the Tukey- Kramer (Nemenyi) test

548 **Table SI3: Recreational activities that respondents (in %) indicated to have had performed in the 12 months**
549 **prior to the survey, multiple answers were possible. Differences between countries were tested for significance**
550 **with Pearson's chi-squared test (activities) and one-way ANOVA (number of activities per person).**

Activity	Germany	France	Norway	Sweden	χ^2	*p*
Moving around, on or near the banks (e.g., taking a walk, jogging)	66.5[a]	49.5[c]	69.6[a]	59.0[b]	101.5	<0.001
Bathing, swimming	50.6[b]	61.8[a]	49.4[b]	59.0[a]	45.8	<0.001
Staying on the beach or on the banks (e.g., lying in the sun)	54.3	53.9	58.1	53.4	5.5	0.133
Observing plants or animals near or on the water	28.9[b]	37.2[a]	38.5[a]	32.8[b]	25.5	<0.001
Angling, fishing	4.6[c]	18.2[b]	28.6[a]	27.3[a]	232.2	<0.001
Going on a cruise ship / on a tourist boat	26.4[a]	12.7[c]	13.8[bc]	16.6[b]	81.4	<0.001
Navigating a motorboat	4.4[c]	12.7[b]	22.1[a]	15.4[b]	136.4	<0.001
Camping near the waterside	11.1[b]	12.7[b]	17.6[a]	8.4[c]	40.9	<0.001
Navigating a pleasure boat without an engine (e.g., sailing, surfing, rowing, kayaking)	7.5[b]	13.8[a]	13.5[a]	15.0[a]	30.8	<0.001
Winter sports (e.g., ice skating)	4.4[c]	11.3[b]	15.5[a]	10.3[b]	67.3	<0.001
Diving, snorkeling	5.2[b]	10.7[a]	6.5[b]	6.1[b]	27.3	<0.001
Hunting near the water (e.g., water fowl)	0.1[b]	2.0[a]	2.4[a]	1.9[a]	19.8	<0.001
Number of activities per person (mean ± standard deviation)	2.6[c] (1.7)	3.0[b] (2.5)	3.4[a] (2.3)	3.1[b] (2.1)	***F*** 18.6	<0.001
Number of observations	998	996	998	993		

551 [a,b,c,d] Any two means in a row that do not share a letter are significantly different ($p < 0.05$) according to post hoc pairwise
552 comparisons with Pearson's chi-squared test (activities) or according to Tukey's range test (number of activities per person).
553

554 **Table SI4: Wording and order of the survey questions underlying the study results.**

Part of the survey	Wording in the survey
Survey introduction (2015)	Dear participant. Thank you very much for participating in this survey on the topic "Humans-Rivers-Species Diversity in <INSERT COUNTRY NAME >"! This survey is conducted on behalf of <INSERT NAME DEPENDING ON COUNTRY>. Your answers will help provide politics and science with a planning guide for the management of our rivers taking the interests of the citizens into consideration. The survey does not serve any commercial interests. Your answers will be kept strictly confidential and any results will be reported anonymously.
Age	What is your age?
Gender	What is your gender?
Education	Which is your highest finished education level?
Recreational activities	Which recreational activities related to inland water bodies have you pursued at least once in the last 12 months? We mean any activities related to lakes, rivers or streams excluding the sea and excluding artificially created very small water bodies such as garden ponds. Tick all activities that apply.
Familiarity with species	Which of these fish species have you heard of? Tick all that apply.
Perceived native or non-native origin of fish species	According to your opinion, which of these fish species are native to the inland waters of <INSERT COUNTRY NAME> and which are not? Native species have naturally colonized the waters in the past without human assistance. Mark your answer for all species shown.
Self-reported level of feeling informed about biodiversity in fishes	Let's turn to the topic of biodiversity. Biodiversity denotes the diversity of all living organisms and their habitats including species diversity, the diversity of genes and populations of a given species in a region, and the diversity of ecosystems in terms of types of lakes, rivers etc. How informed do you feel about the topic of biodiversity in fishes? Tick one box only.
Beliefs about threats	According to independent research, the earth's biodiversity is threatened by human impact. This is said to be true also for many rivers of <INSERT COUNTRY NAME> and the fishes that are native to them. Here is a list with potential human-made causes for the loss of biodiversity of native fish species in the rivers of <INSERT COUNTRY NAME>. For each of them, indicate how strongly you believe the factor contributes to fish biodiversity loss. To the loss of native fish biodiversity in the rivers of <INSERT COUNTRY NAME>, this factor makes ...
Self-reported level of feeling informed about the threats caused by the introduction of non-native fish species	The intentional or accidental introduction of fish species by humans to rivers to which they were originally not native can cause biodiversity loss of native fish species. Non-native fish species may, for example, compete with native fish species and other aquatic animals for food and living space or they may transmit diseases and parasites to native fishes or even interbreed with native species. How informed do you feel overall about the potential threats caused by the introduction of non-native fishes to the rivers of <INSERT COUNTRY NAME>? Tick one box only.
Attitudes	Now comes a list with statements related to the topic of fishes in the rivers of <INSERT COUNTRY NAME>. All these statements express correct facts. How do you personally evaluate them? There are no right or wrong answers, we are interested in your personal view. In my opinion, this is ...
Use and non-use value of fish	Please indicate the degree to which you agree or disagree with these statements about native fish populations.
Schwartz value scale	Please indicate how important each of the following values is as a guiding principle in your life. As a guiding principle in my life, this value is ...
Open control question	The survey is now over. How did you like it? Is there anything that you want to tell us about the survey or the topics addressed in it? Any remarks or criticisms are more than welcome.
Survey ending (2015)	We might want to get in touch with you again for another survey about the topic of "Humans-Rivers-Species Diversity in <INSERT COUNTRY NAME>" at the beginning of next year. For participating, you would receive an additional bonus. Thank you very much for your patience and cooperation!
2016 survey question about salmon	Thinking of rivers only, according to your opinion in which of these countries are salmon native and in which are they not native? Native species have naturally colonized the waters in the past without human assistance
2016 survey question about Atlantic salmon	Still thinking of rivers only, according to your opinion in which of these countries are Atlantic salmon native and in which are they not native? Native species have naturally colonized the waters in the past without human assistance

555