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

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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

45 species (Gozlan et al. 2010) will likely increase over the next decades with the potential to
46 further reduce freshwater biodiversity.

47 Environmental policies introduced to address the freshwater biodiversity crisis are driven and
48 affected by people's priorities and their support for conservation (Walker-Springett et al. 2016).
49 These priorities follow prevailing cultural values and material conditions (Inglehart 1997),
50 meaning they are based on both objectively measurable conditions of the environment and the
51 people's subjective interpretation of nature (Eder 1996). For example, the degree to which
52 people are willing to tolerate wildlife close to their homes is more strongly correlated with the
53 perceived danger from wild animals than with the number of dangerous incidents (Kansky &
54 Knight 2014). In a similar vein, political ideology can be more important for the perception of
55 climate change as environmental threat than scientific descriptions of the phenomenon (Weber
56 2010). In short, it is the social and cultural context that shapes the mental classification scheme
57 through which an individual and collectively society makes sense of the world; therefore, people
58 in different countries are likely to vary in what they find acceptable, desirable, and important
59 (Schwartz 2006; Manfredo 2008).

60 Several multi- and cross-national studies have been conducted to examine the impact of
61 sociocultural factors on the public's perception of the marine environment (Ahtiainen et al.
62 2013; Gelcich et al. 2014; Potts et al. 2016). In comparison, it is less known how the public in
63 different countries perceive freshwater biodiversity (Closs et al. 2015). Based on studies of other
64 environmental issues, the expectations among conservation biologists and fisheries scientists
65 are somewhat bleak. The public is expected to be largely ignorant and complacent about
66 environmental quality and biodiversity loss (Angermeier 2007; Monroe et al. 2009; Closs et al.
67 2015). People are thought to have a weak connection to freshwater fish and to prefer birds and

68 charismatic mammals (Cooke et al. 2013; Closs et al. 2015) as well as to value direct use of
69 freshwater environments more than biodiversity (Monroe et al. 2009; Beard et al. 2011; Cooke
70 et al. 2013).

71 Using a cross-cultural online survey, our objectives were to understand whether the members
72 of the public in 4 European countries care about freshwater fishes (values), what people know
73 about fish biodiversity (knowledge), how they view threats to native fish species (beliefs), and
74 what this means for public support for specific conservation measures (attitudes). We used
75 measures of values, knowledge, beliefs, and attitudes following sociopsychological theory that
76 has shown that these constructs play a large role in driving pro-environmental behaviors (Stern
77 2000; Manfredo 2008; Klöckner 2013). The selection of surveyed countries was based on the
78 study's interest for charismatic migratory fish species. We surveyed 2 central European
79 countries – Germany and France – where rivers are heavily altered by humans and Atlantic
80 salmon (*Salmo salar*) has been extirpated (Germany) or is rare (France), and 2 Scandinavian
81 countries – Norway and Sweden – where Atlantic salmon is still present. We also assumed the 4
82 countries differ in how the public uses and interacts with freshwater ecosystems. Taking
83 recreational fishing as an example activity, previous research suggests the 4 countries form
84 clusters of low (Germany, 4.0%; France, 8.2%) and high recreational use (Norway, 32.2%;
85 Sweden, 23.0%) (Arlinghaus et al. 2015).

86

87 # Methods

88 **Survey administration and sampling**

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

95 Respondents were randomly selected from the panels and invited via email to participate in the
96 survey. Up to 3 reminder emails were sent during the survey period of 21 days. Data collection
97 conformed to the rules given by the national Data Protection Acts as well as standards for social
98 research as outlined by the European Society for Opinion and Market Research (ESOMAR &
99 GRBN 2015; ICC & ESOMAR 2016). The sample selection followed country-specific quotas set on
100 age groups, gender, and the highest education level achieved according to census data (Eurostat
101 2015). We removed 287 respondents from the sample with implausibly low response times
102 (speeding), 3 respondents who gave the same answers in more than 3 grids (straight lining), and
103 4 respondents who answered <20% of all questions (item nonresponse) (Groves et al. 2011).
104 Aside from these cases of potentially fraudulent or inattentive participants, 4844 persons
105 started the questionnaire. Overall, 17.4% (n = 844) of the initial sample quit participating.

106 The final sample of 1000 respondents/country, aged 16 to 74 years, approximated a
107 representative sample relative to the previously defined quota characteristics. Further
108 respondent characteristics are described in Supporting Information. We defined our study
109 population as the general population with internet access, which covered from 83% (France) to
110 97% (Norway) of all private households (Germany, 90%; Sweden, 91%) (Eurostat 2016). In

December 2016, 61% of the respondents took part in a follow-up survey of which one question about Atlantic salmon was relevant for this study.

Survey questions

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

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

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

160

161 Results

162 Environmental values and the value of native fish populations

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

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

180 Swedes, tended to disagree on average with the direct-use value of native fish populations for
181 the respondents' own benefit (H = 297, df = 3, p < 0.001) and human benefit in general (H = 186,
182 df = 3, p < 0.001) and focused on the non-use benefits derived from the existence and bequest
183 value of fishes (Table 1).

184 **Table 1. Mean (SD) approval (1, strongly disagree, to 5, strongly agree) of survey respondents from 4 countries to**
185 **protect native fish populations for their non-use (existence and bequest value) or use values (direct use, option**
186 **and altruistic 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	

187
188 [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*
189 *comparisons made with the Tukey–Kramer (Nemenyi) test.*
190 [e] *Differences between countries were tested for significance with the Kruskal–Wallis test.*
191 [f] *Scoring reversed because of negatively worded item.*
192

193

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

195 A large majority of the respondents stated that they did not feel well informed about fish
196 biodiversity (89%) and the potential threats posed by non-native fishes to the rivers in the
197 respective countries (86%). Norwegians felt, on average, significantly better informed about fish
198 biodiversity (H = 171.9, df = 3, p < 0.001) and about possible biological threats posed by non-
199 native fishes (H = 208.2, df = 3, p < 0.001) than the respondents in the other 3 countries (Fig. 1).

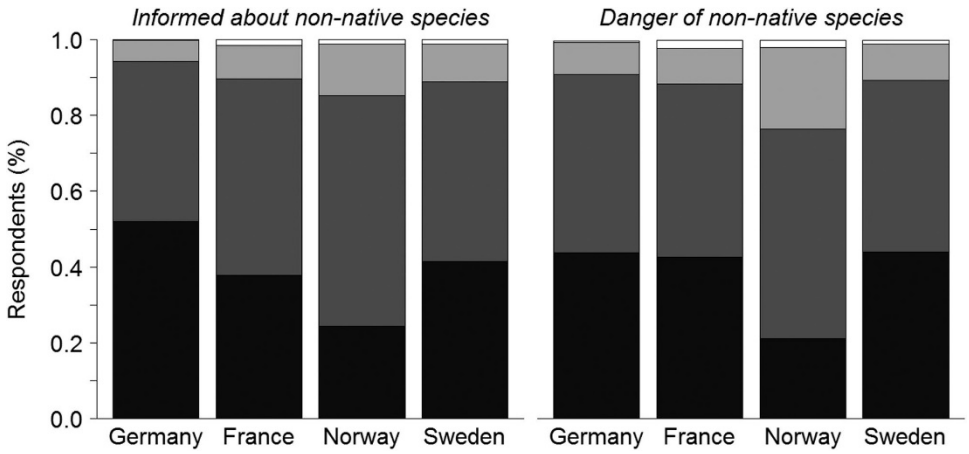

Figure 1. Self-reported level of feeling informed about fish biodiversity (n = 4000) and the threats caused by the introduction of non-native fish species (n = 3991) (black, not informed at all; dark gray, not well informed; light gray, well informed; white, very well informed).

200

201 Over 85% of the respondents in Germany, Sweden, and Norway indicated they had heard of the
202 salmonids brown trout and rainbow trout, whereas in France, these species were significantly
203 less known (brown trout: 64%; rainbow trout: 70%). Two other salmonids, brook trout and
204 grayling, were less well known overall (Fig. 2). Atlantic salmon and the other diadromous fishes
205 in the survey – sturgeon and European eel – were recognized in the 2015 survey by at least 85%
206 (salmon, eel) and at least 79% (sturgeon) of the respondents. Atlantic salmon and European eel
207 were well known in Norway and Sweden (>96%), but significantly less so in France (81%) and
208 Germany (58%). In contrast, sturgeon was significantly better known in Germany (92%) and
209 France (84%) than in Norway (65%) and Sweden (76%). The same was true for the cyprinid
210 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.

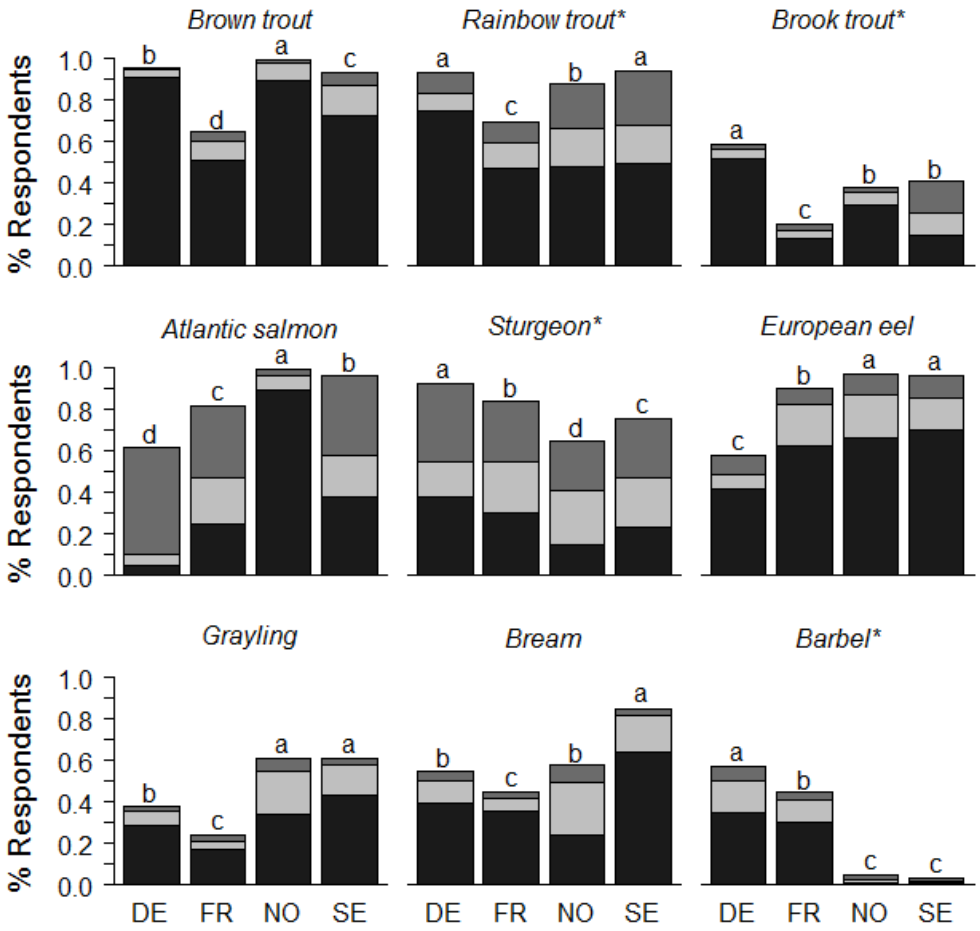

Figure 2. Familiarity of 1000 respondents in Germany (DE), France (FR), Norway (NO), and Sweden (SE) with fish species (1, familiar; 0, unfamiliar) and their perceived native or non-native origin to inland waters (black, native; light gray, unsure or don't know; dark gray, not native) (∗ species not 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), although in reality, Atlantic salmon is native to all 6 countries. This pattern remained the same when asking about Atlantic salmon rather than salmon (Table 2). In comparison with salmon, more people believed Atlantic salmon to be native in France (32-59% of respondents across countries) and Spain (21-26%), and fewer people believed it to be

native in Norway (78-95%), Sweden (56-74%), Germany (18-35%), and the Czech Republic (6-21%).

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

	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.*

Beliefs about environmental threats to riverine fishes

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

258 3, $p < 0.001$) compared with the respondents in the other 3 countries. The Swedes were least

259 concerned of all countries about both non-native species and overfishing (Fig. 3).

260

261 **Attitudes toward fish conservation and management measures**

262 The reestablishment of Atlantic salmon and sturgeon to rivers where they had been extirpated

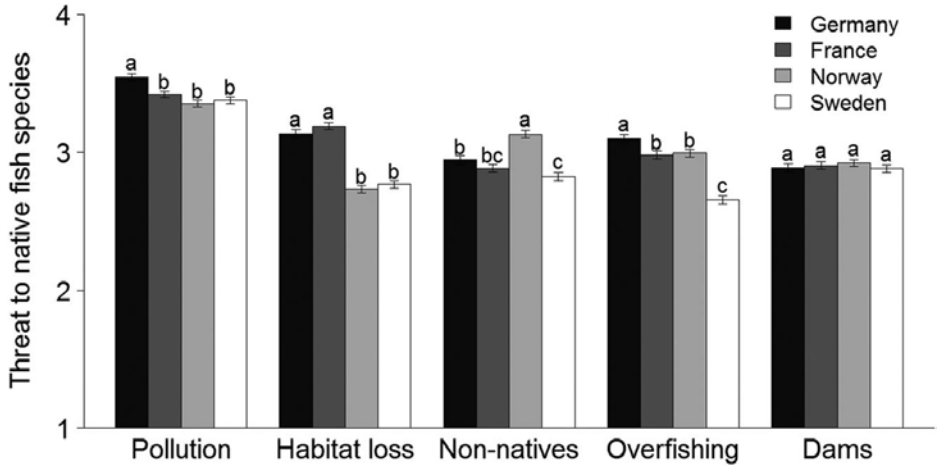

Figure 3. Mean (SE) survey respondents' perceived degree to which water pollution, loss of natural river bank habitat, introduction of non-native species of plants and animals, including fishes, to rivers by humans, overfishing, and the construction of dams for hydroelectric power generation threaten 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.

263 through human influence was supported in all 4 countries, and the approval was significantly

264 highest in Germany (H = 312, df = 3, $p < 0.001$; Table 3). Culture-based enhancement stocking of

265 rainbow trout and brook trout (both non-native species) for fisheries purposes received less

266 support than conservation stocking of Atlantic salmon and sturgeon; however, people did also

267 not oppose it on average (Table 3). In Germany, culture-based stocking of brook trout and

268 rainbow trout was viewed more positively relative to the other 3 countries (H = 295, df = 3, $p <$

269 0.001).

270

271 **Table 3. Mean (SD) attitudes (1, very bad, to 5, very good) of survey respondents from 4 countries toward**
272 **conservation stocking (2 items), culture-based enhancement stocking (3 items), aquaculture management (3**
273 **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 stocking to some European waters where they were native and extirpated through human influence.	0.904	4.2a (0.8)	3.7b (1.0)	3.4c (1.1)	3.6c (1.0)	330
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	

274
275 *[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*
276 *comparisons made with the Tukey–Kramer (Nemenyi) test. Survey items grouped by principal component analysis with*
277 *Varimax orthogonal rotation.*
278 *[e] Differences between countries tested for statistical significance with the Kruskal–Wallis test.*
279 *[f] Scoring reversed because of negatively worded item.*

280 Respondents in all countries felt rather negative toward escapees from aquaculture (Table 3).
281 Despite this concern, respondents did not support the treatment of farmed fish that could
282 render the fish infertile, thus reducing the genetic risks associated with escapees. Norwegians
283 felt significantly more positive toward these aquaculture management measures (H = 112, df =
284 3, $p < 0.001$) and significantly more negative toward escapees from aquaculture (H = 442, df = 3,
285 $p < 0.001$) than the public in the other 3 countries. Despite being more concerned about the
286 associated risks, Norwegian respondents did not have a more negative attitude toward
287 aquaculture than the other 3 nations (Table 3).

288

289 ## Discussion

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

299 **General patterns held across countries**

300 The public in all 4 countries valued native fish species for their existence (Table 1) and supported
301 conservation stocking (Table 3). These findings coincided with the predominantly pro-
302 environmental values of the public. Modernization and postindustrialization have resulted in a
303 rise of abstract pro-environmental values within many wealthy societies (Inglehart 1990, 1997)
304 and fostered the cultural value of egalitarianism, broadly defined as the desire to take care of
305 the well-being of fellow humans, but also animals and the environment (Schwartz 2006). In this
306 study, people cared about fish conservation in a positive way, likely because this animal group
307 was perceived as part of nature that they felt should be protected. We would expect to find
308 similar results in other western European countries featuring high scores in egalitarian cultural
309 values (Schwartz 2006). However, there is the limitation that we did not study the relative
310 importance of different taxa or ecosystem characteristics, such as water quality (Hanley et al.
311 1998). Further studies on the perceptions of freshwater fishes in countries with other national
312 value priorities (Schwartz 2006) and on people's preferences for various ecosystem traits are
313 needed to fully understand the values underlying freshwater fish conservation.

314 The self-reported level of knowledge of river fish biodiversity was low in all 4 countries (Fig. 1),
315 in line with the expectations expressed in the scientific literature (Monroe et al. 2009; Cooke et
316 al. 2013; Closs et al. 2015). Well-known species included both native (e.g., brown trout) and non-
317 native (e.g., rainbow trout) salmonids, but there were also native (e.g., grayling) and non-native
318 (e.g., brook trout) salmonids that were less well known (Fig. 2). Respondents were familiar with
319 migratory fish, such as sturgeon and Atlantic salmon, but were less certain about these species'
320 range of natural occurrence. It is highly likely that this pattern represents an example of an
321 "extinction of experience" (Miller 2005) because, for example, Atlantic salmon were extirpated
322 from Germany in the mid-20th century (Wolter 2015) and its abundance declined greatly in
323 other European countries (Chaput 2012). Given that all surveyed countries showed that loss of

memory with regard to the situation in their own or other countries (Table 2), we would expect similar results for other European countries.

Relative to environmental threats, the respondents perceived pollution to pose the biggest threat to freshwater biodiversity (Fig. 3), possibly remembering high level of discernible pollution in the 1960s and 1970s. Since then water quality has improved across many rivers due to advances in water purification and the implementation of the European Water Framework Directive (Directive 2000/60/EC). Our results parallel findings for the marine environment where pollution was also perceived to be the dominant threat in many different countries (Gelcich et al. 2014; Potts et al. 2016), possibly because of the high media coverage of marine pollution events. Similar incidents in the freshwater environment date back decades (Reinhard 2008), but recent media campaigns on plastic waste, micro-pollutants, and micro-plastics could have had an impact on public perception. For river conservation, it will be important to increase people's awareness about less visible threats (Dudgeon et al. 2006; Gozlan et al. 2010; Freyhof & Brooks 2011).

Country-specific patterns

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

347 trading off the biodiversity risks related to aquaculture against the economic benefits to
348 Norwegian society.

349 The use value of fish populations was seen as less important than their non-use value in
350 Germany and Sweden compared with Norway (Table 1), where fish and fisheries are important
351 for recreational and commercial purposes (Borch et al. 2008; Arlinghaus et al. 2015). Despite
352 low use values, Germany evaluated culture-based stocking comparatively positive (Table 3),
353 possibly because brook trout and rainbow trout are legally considered to be native and
354 intensively stocked into German waters (Arlinghaus et al. 2015) seemingly with limited
355 ecological impacts (Wolter & Röhr 2010). An interesting case is France, where the public
356 expressed a comparably high use value and a lower importance of the non-use values bequest
357 and existence. In cross-cultural studies, France showed less egalitarian cultural values compared
358 with the other 3 countries, and it scored higher on intellectual autonomy as cultural value
359 (Schwartz 2006). This may explain why the instrumental use value of fish populations was larger
360 in France compared with the other 3 countries. Overall, country-specific factors were more
361 important for explaining use values than non-use values, because western Europeans share high
362 levels of environmental values (Schwartz 2006), but differ with regard to other value
363 dimensions, have differently structured economies, and different preferences with regard to
364 recreation and food (EUMOFA 2017).

365 **Implications for fish conservation**

366 Human behavior is complex and multifaceted. It is informed by a person's psychological
367 disposition as well as by situational and contextual factors (Stern 2005; Steg & Vlek 2009).
368 Psychological constructs (such as knowledge, values, beliefs, and attitudes) do not always
369 translate into action (Kollmuss & Agyeman 2002), but they can be important drivers of pro-

370 environmental behavior when the contextual factors are favorable (Stern 2000, 2005; Riepe et
371 al. 2017). Given that we did not observe actual behavior, we limit our conclusions for fish
372 conservation to implications for conservation messaging.

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

385 A new approach to freshwater conservation is concentrating conservation messages on
386 charismatic species (Carrizo et al. 2017; Kalinkat et al. 2017), such as migratory fish (Bolster
387 2008; Kalinkat et al. 2017). This approach may be effective in countries where the public has a
388 connection to a species (e.g., Atlantic salmon in Norway). For central Europe, we found the
389 situation was more complex: the general public supported conservation stocking despite not
390 recognizing the species. This finding suggests knowledge is not essential for conservation
391 support, but what matters are pro-ecological beliefs and attitudes (Manfredo et al. 2017). We
392 suggest enhancing the connection between native fish biodiversity and the general public by

involving groups, such as anglers, that directly interact with the aquatic environment (Fujitani et al. 2017), as well as historians and artists who can highlight historical relationships with native fish species (Rathwell & Armitage 2016), in conservation research and outreach activities.

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Supporting information

Respondents' characteristics (Appendix S1), details for the Schwartz value scale (Appendix S2), the recreational activities respondents performed in the 12 months prior to the survey (Appendix S3), and 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

572 **Table SI3: Recreational activities that respondents (in %) indicated to have had performed in the 12 months prior**
573 **to the survey, multiple answers were possible. Differences between countries were tested for significance with**
574 **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		

575 [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
576 pairwise comparisons with Pearson's chi-squared test (activities) or according to Tukey's range test (number of
577 activities per person).

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581 **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

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