Received: 6 December 2022 | Accepted: 26 September 2023

DOI: 10.1002/pan3.10553

PEOPLE AND NATURE | BRITISH ECOLOGICAL SOCIETY

RESEARCH ARTICLE

Recreational anglers in Norway report widespread dislike of invasive pink salmon

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Handling Editor: Ricardo Correia

Abstract

1. Pink salmon have returned to Norwegian rivers at high abundance in recent odd-numbered years (2017, 2019, 2021, 2023), presenting potential threats to native biodiversity and ecosystem services, including major sport fishing tourism for Atlantic salmon and sea-run brown trout in Norway. Presently, there exists a knowledge gap on angler perceptions and attitudes towards the presence of pink salmon in Norwegian rivers, resulting in difficulty assessing the socioeconomic repercussions of their invasion.
2. We distributed an online questionnaire to anglers who purchased the national salmon fishing licence in Norway in 2020 to assess their perceptions of pink salmon and the intentions of anglers to modify their fishing practices.
3. There were widespread negative perceptions of pink salmon in Norway. Perceptions were matched with intentions to modify fishing behaviour among some of the anglers, with 41% saying that they would modify fishing to increase the catch of pink salmon to help remove them before they spawned in the rivers. However, anglers were more prone to say they would decrease fishing effort if both pink salmon catches and fishing licence costs were to increase or if pink salmon were to dominate their catch.
4. Salmon anglers in Norway were strongly oriented towards their chosen recreational activity and do not plan to stop fishing their preferred rivers. They also do not want pink salmon to become established in Norway and are prepared to volunteer for stewardship roles that intervene against pink salmon. However, they overwhelmingly reported not wanting to eat pink salmon.
5. Fisheries managers must take into account the widespread desire for management intervention against pink salmon, even though eradication is not likely no matter how intensive removal efforts become. Efforts to change narratives about pink salmon to encourage fishers to harvest pink salmon from the fjords and rivers for consumption might lead to effective population control, relieving native salmon, trout and charr from potential negative impacts of this prolific colonizer.

KEYWORDS
angler behaviour, angler perceptions, fisheries management, human dimensions, invasive species, recreational fishing, socioeconomic

1 | INTRODUCTION

About 65,000–80,000 anglers actively target Atlantic salmon (*Salmo salar*) in Norway, along with sea-run brown trout (*Salmo trutta*) and sea-run Arctic charr (*Salvelinus alpinus*) by fishing in rivers each year (Aas et al., 2021; Stensland et al., 2015). Anglers spend approximately 1.26 billion[1] NOK (125 million EURO) per year on salmon fishing in Norway (Andersen & Dervo, 2019; Myrvold et al., 2019). These summertime river fisheries have been key to Norwegian culture and local economies for almost two centuries and the Atlantic salmon is an icon on the Norwegian coast (Aas et al., 2022). Contemporary changes to the distribution and abundance of Atlantic salmon have dramatically altered the supply of Atlantic salmon fishing opportunities. Many highly valued fisheries have been lost, particularly at the southern range edge of Atlantic salmon, increasing the demand for fishing in some of the last strongholds of the species such as northern Norway (Parrish et al., 1998).

Atlantic salmon fisheries are facing a major state change in parts of the northeast Atlantic Ocean where pink salmon (*Oncorhynchus gorbuscha*) have rapidly begun colonizing rivers in Russia, Norway, Iceland, Scotland and beyond (Lennox et al., 2023). For half a century following the introduction of pink salmon to White Sea rivers in Russia, pink salmon were observed in variable numbers in Norway, primarily in northern regions, and with more frequent sightings during odd-numbered years due to their 2-year life cycle (Sandlund et al., 2019). Suddenly and unexpectedly in 2017, the pink salmon population in Norway drastically increased and pink salmon entered rivers at unprecedented numbers along the entire coastline (Mo et al., 2018; Sandlund et al., 2019). The exceptional increase in pink salmon abundance has followed the odd-year life cycle pattern of the broodline, with further increasing numbers entering the rivers in 2019 (13,925 harvested) and 2021 (111,803 harvested; Diaz Pauli et al., 2023; SSB, 2022). In other European countries, the spread of pink salmon has also been observed since 2017. The sudden preponderance of pink salmon in rivers throughout the Arctic and Atlantic engenders uncertainty about how the valuable Atlantic salmon fisheries will respond to the state change and whether recreational fishers may modify their behaviour in the presence of this invasive fish that may threaten their preferred fisheries.

The theory of planned behaviour posits that people's behaviour may be predicted and explained by their intentions, which are influenced by a combination of their perceptions or attitudes towards the behaviour, subjective norms and perceived behavioural control (Ajzen, 1991). Attitude towards a potential behaviour, like fishing in a given river, is closely linked to personal values and lifestyle and involves how they feel about performing the behaviour or whether they perceive the outcome of the behaviour as favourable or unfavourable to them. Subjective norms reflect what actions they believe are expected of them by others, and perceived behavioural control reflects how capable they believe they are of performing the behaviour (Ajzen, 1991; von Lindern & Mosler, 2014). In fisheries, the theory of planned behaviour has been applied to better understand, for example, compliance among small-scale fishers (Vallejos et al., 2023), stocking practices among recreational anglers (von Lindern & Mosler, 2014) and SCUBA diver interactions with sharks (Apps et al., 2015). These studies sought to understand how the personal beliefs of the participants could predict their behaviour when observed in recreational encounters with fish and fisheries. Similar efforts can be used to apply the theory of planned behaviour to investigate whether fishers in Norway will engage in their preferred activities, such as fishing in their favourite rivers for their favourite fish, when confronted by the concept of invasive species (i.e. abundant pink salmon). However, we know little about angler perceptions and attitudes towards the presence of pink salmon in Norwegian rivers.

Given the invasion of pink salmon and the uncertain threats posed to the native salmonid fishery in Norway, understanding angler perceptions of pink salmon and how they might translate into behaviours are key in projecting how pink salmon may affect cultural and provisioning ecosystem services, which can inform managers in their efforts to maintain fisheries value (Shackleton, Larson, et al., 2019). In this study, we used a survey sent to local and tourist recreational salmon anglers in Norway to evaluate their perceptions of pink salmon and possible intentions for behavioural changes associated with encountering pink salmon while targeting Atlantic salmon, sea-run brown trout or sea-run Arctic charr in Norwegian rivers. Guided by the theory of planned behaviour, responses were modelled to investigate whether attitudes towards pink salmon reflected fishing intentions, providing a lens towards future challenges that might be confronted by fisheries management in Norway.

2 | METHODS

2.1 | Data collection

In 2020, we distributed an online survey via email to 19,510 recreational anglers who purchased a fishing licence in Norway to fish for salmon, sea-run brown trout or sea-run Arctic charr for that year

[1]1 EURO = 10.11 NOK, as of 14 September 2022. https://www.norges-bank.no/tema/Statistikk/valutakurser/?tab=currency&id=USD.

(2020). The licence is mandatory (NOK 286 for 2022) when freshwater fishing for anadromous species and is administered by the Norwegian Environmental Directorate, which collects the money and personal contact information. We were provided access to 50% of the entire fishing licence database from 2020 for this study. The survey consisted of 36 questions that addressed angler perceptions of the presence of pink salmon in Norwegian rivers, opinions of fishery management, angler behaviour, motivations, centrality of fishing to lifestyle, fishing specialization and sociodemographic data (see Supporting Information A for the full questionnaire). The survey filtered for participants who had fished for Atlantic salmon, sea-run brown trout or sea-run Arctic charr in Norwegian freshwaters, and was offered in four languages (Norwegian, English, German, Finnish) to accommodate foreign anglers fishing in Norway. Most of our survey questions were modelled based on similar studies, which included a combination of multiple choice, 7-point Likert scales, rank order and open-ended questions (e.g. Liberg & Stensland, 2018; Stensland et al., 2015; Sutton et al., 2001). This design allowed us to maintain consistency with similar questions in other studies and enable comparative analyses.

We distributed the survey via Qualtrics XM (2020) on 13 November 2020, followed by three reminder emails delivered 3 weeks apart to increase response rates, before closing the survey on 1 February 2021. From this list, 186 emails were undeliverable and 50 email addresses were duplicates, resulting in a total of 19,274 individuals receiving the survey. On 9 February 2021, a short 10-question 'recovery survey' was sent to 583 respondents (who had consented to follow-up contact) because a technical error in the original survey hid 10 questions from a subset of 1348 respondents. This was our attempt to collect responses from the missing questions and recover the missing data.

In 2022, we distributed a second survey to all participants from our 2020 survey who consented to follow-up communications (1396 participants). This survey focused on capturing angler perceptions during a year of high pink salmon abundance (end of 2021; SSB, 2022), which allowed us to compare angler perceptions of pink salmon between relatively low (2020) and high (2021) abundance seasons. The '2021 survey' used 18 questions pulled from our 2020 survey (see description above) assessing perceptions of pink salmon, opinions of fishery management and angler behaviour (see Supporting Information B for the full questionnaire). The 2021 survey was also offered in four languages (Norwegian, English, German and Finnish). We distributed this survey via Qualtrics XM (2022) on 27 January 2022, followed by two reminder emails before closing the survey on 1 May 2022. From this list, nine emails bounced, resulting in a total of 1387 individuals receiving the survey. The 2021 survey was used only to describe perceptions of pink salmon and to compare these perceptions between 2020 (low pink abundance) and 2021 (high pink abundance). All components of the surveys and research methods were approved and conducted in adherence to both the Carleton University Research Ethics Board (CUREB-B Clearance #114520) and the Norwegian Centre for Research Data (NSD case 352326 and 862568).

2.2 | Data analysis

2.2.1 | Assessing angler perceptions of pink salmon presence in Norwegian rivers

Both 2020 and 2021 surveys included four questions to evaluate angler perceptions of pink salmon (Table 2). We used the questions to develop a perception scale by adding responses from two of the four questions and divided each respondents' total by 56 (the maximum score) to obtain a proportion for ease of interpretation (Figure 1). The perception scale ranged from 0 to 1 with low perception scores (<0.5) representing positive perceptions of pink salmon, and high perception scores (>0.5) representing negative perceptions. Cronbach's alpha indicated internal consistency among these variables that were added together to develop the score (alpha = 0.704; Eisinga et al., 2013). We also checked that the perception score agreed with the responses to the other two questions that evaluated angler perceptions (Table 2): '*Please drag the options below to rank the following species in order of target preference when fishing.*' and '*What would you consider an acceptable amount of Pink salmon caught for you to be satisfied with your fishing trip?'*. The same index development was used for the 2021 survey to enable direct comparison of angler perceptions of pink salmon between 2020 (low pink abundance) and 2021 (high pink abundance).

2.2.2 | Model 0: Were perceptions different following angling in 2021 than in 2020?

A subset of the survey was sent to the respondents following the 2021 angling season (as described above). Perception scores were recalculated from 2021 responses and were compared to scores provided after the 2020 season. We compared angler perceptions from both fishing seasons using a paired *t*-test.

2.2.3 | Model 1: How do anglers perceive pink salmon?

The perception score (for both 2020 and 2021 survey data) was the sum of responses to questions related to pink salmon, which created a right-skewed distribution of responses. This could be treated with an exponential transformation or by conversion to a Gamma family; we opted for the latter. To convert this from a right-skewed distribution to a left-skewed distribution approximating a Gamma distribution, we subtracted each perception score from the maximum value (in its raw form, 56). This inverted the perception scale so that negativity towards pink salmon was represented by smaller numbers and positivity by larger numbers for ease of interpretation. A generalized linear model was fitted to this inverted perception score using a Gamma family with a log-link function. The model was fitted to explore the relationships between angler perceptions and both sociodemographic factors and fishing habits detailing fishing experience

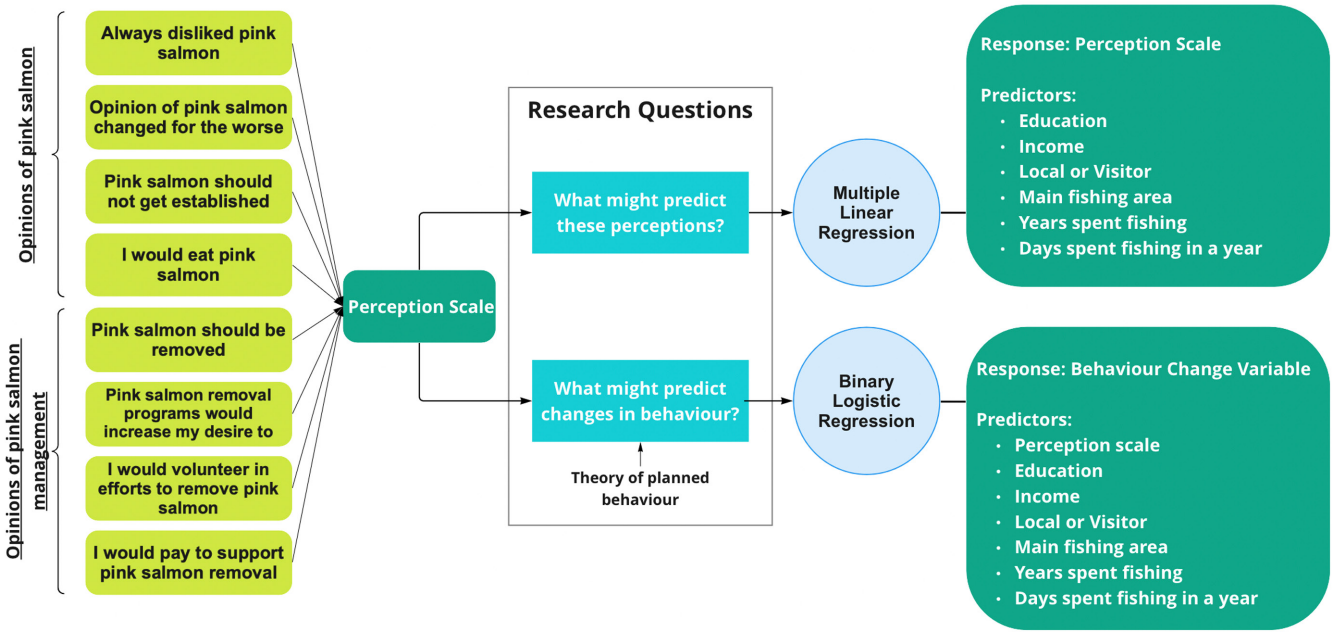

FIGURE 1 Flowchart of statistical analyses. The eight items in the left-most boxes are the eight variables used to create the perception scale, which was in turn used as the dependent variable in the first question 'What might predict these perceptions?' and as an independent variable in the second question 'What might predict changes in behaviour?'.

(e.g. years of fishing experience and fishing frequency). The six predictor variables included: education, annual household income, main fishing area, local or visitor status to their main river (not to be confused with residency status in Norway), total years spent fishing and days spent fishing in a year (Figure 1). The selection of predictor variables was guided by the conceptual framework to explain people's perceptions of invasive alien species developed by Shackleton, Richardson, et al. (2019).

2.2.4 | Model 2: Do some anglers plan to modify their behaviour?

We included three questions that evaluated potential changes in angler behaviour under the condition of increased pink salmon presence in Norwegian rivers in both 2020 and 2021 surveys, but only reported on the 2020 results in this study. The first question, labelled as the *behaviour change* variable, asked '*In future years where pink salmon counts may be high, would you modify your fishing habits to enhance or to avoid catching pink salmon while fishing*?'. This variable had three response options: '*Yes to avoid catching pink salmon*', '*Yes to enhance catching pink salmon*' and '*No, I would not modify my habits*' (Figure 2). The remaining two questions that assessed changes in behaviour explored the how and why for participants who indicated that they would change their behaviours. Here, we merged both '*Yes*' responses as they both indicated behaviour change and because the '*Yes to avoid catching pink salmon*' response received a low number of responses. This resulted in a binary variable for *behaviour change*, with '*Yes*' and '*No*' to changing behaviour categories.

We fitted a logistic regression to explore the relationship between angler perceptions and behaviour as well as sociodemographic variables and fishing habits as predictors of whether an angler reported an intention to change their fishing behaviour. We used the binary *behaviour change* variable as the response variable to represent behavioural intent within the theory of planned behaviour. Predictor variables consisted of the *perception scale*, as well as the six predictor variables included in the previous multiple linear regression. We included the same six predictor variables to maintain consistency and because these predictor variables fit within the theory of planned behaviour framework (Figure 1).

3 | RESULTS

3.1 | Survey response rate

For the 2020 survey, 2170 of 19,274 surveys were completed, resulting in an 11.3% response rate. After removing duplicate ($n = 64$), erroneous ($n = 765$) and incomplete (<95% complete) surveys ($n = 44$), and filtering for anglers who fished for salmon, we were left with 1178 surveys to include in the analysis. For the 2021 survey, a total of 789 surveys were completed, resulting in a 56.9% response rate among anglers that had also responded in 2020. After removing invalid and incomplete surveys (<95% complete), 722 surveys remained, of which 584 had fished for salmon in Norway that year (in 2021). Proceeding forward, we use the term 'salmon fishing' as fishing for Atlantic salmon, sea-run brown trout or sea-run Arctic charr and focus only on the 2020 survey to describe the

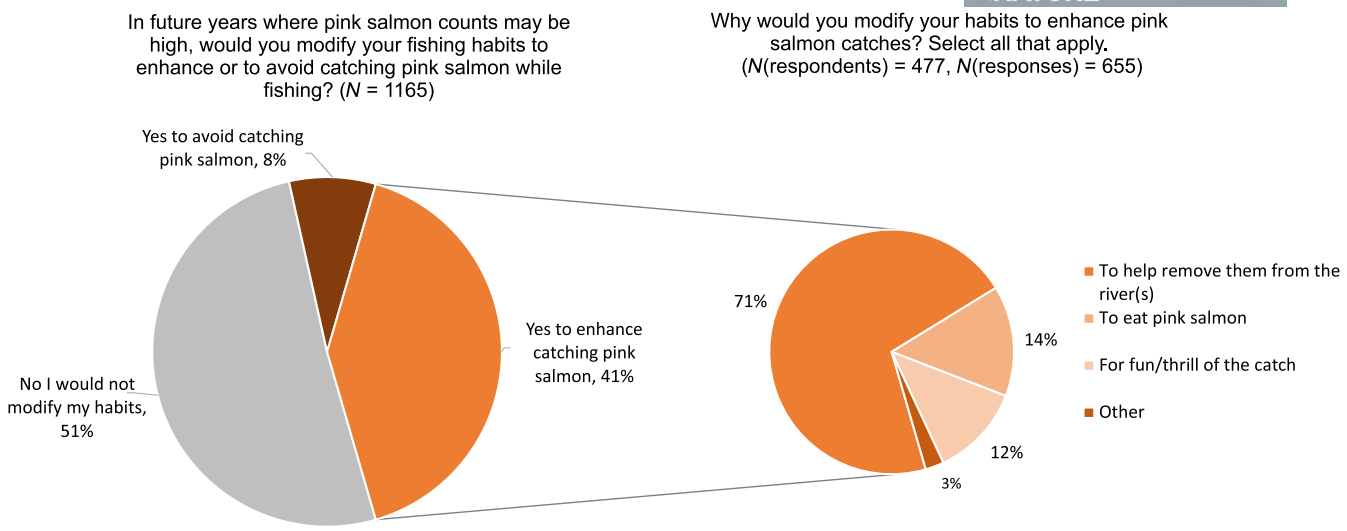

FIGURE 2 Percentage of participants who would modify their behaviour in future years when pink salmon counts may be higher than present levels (left), and the reasons why they would modify their behaviours to catch more pink salmon (right).

sample population because it includes the same participants from the 2021 survey.

3.2 | Description of sample population

3.2.1 | Sociodemographic information

The respondents were predominantly male (96.3%), middle age (average 54 years) and residents of Norway (97.6%) (note: various travel restrictions were in place in 2020 due to the COVID-19 pandemic) (Table 1). Education among anglers was relatively evenly distributed among the different levels of education, with the exception of primary and lower secondary education representing only a small percentage of respondents. Most anglers were employed full time (66.9%) or retired (21.3%).

3.2.2 | Angler characteristics

Nearly all anglers had fished for salmon in Norway in 2020 (96.9%) and had an average of 36.9 years of fishing experience ($s = 15.2$ years, $N = 1084$) for any species. Approximately 70% (of 1178) fished exclusively in Norway, with 58.9% (of 1159) of anglers being locals to their main fishing area within the country. During the 2020 fishing season, anglers commonly fished 11–15 days in the year (32.7% of 1171) for salmon, followed by 26–50 days (21.5%) and 6–10 days (18.9%). Most anglers fished for salmon in two to four different rivers (55.2% of 1146) or only one river (29.5%). Among our participants, more fish (Atlantic salmon, sea-run brown trout, sea-run Arctic charr) were harvested ($\bar{x} = 8.5$ salmon per angler, $s = 18.68$ salmon) than released ($\bar{x} = 7.9$ salmon per angler, $s = 11.25$ salmon) in 2020. The highest scoring motivators for fishing were '*To experience nature*' (89.7% agree or strongly agree), and '*To relax and get away from the regular routine*' (89.3% agree or strongly agree).

3.2.3 | Pink salmon catch rates and locations

Just over half of our 2020 survey respondents (663 of 1178) had caught or encountered pink salmon while fishing in Norway, of which 59.5% (of 663) reported catching them in the same rivers they caught Atlantic salmon. More than half of the rivers where anglers caught both species were in northern regions of Norway (Nordland, Troms and Finnmark counties; 59.9% of 394). Furthermore, we asked these respondents ($N = 663$) to indicate approximately how many pink salmon they caught between 2017 and 2020, and 545 provided an answer. Three respondents had caught a much higher number of pink salmon than the rest of the respondents (over 2000 pink salmon each), representing probable involvement in removal fishing programmes from these anglers. Of the remaining 542 responses, a total of 2098 pink salmon catches were reported, resulting in an average of four pink salmon catches per angler between 2017 and 2020 ($\bar{x} = 3.9$ pink salmon, $s = 14.5$). Two hundred and four of these respondents reported catching zero pink salmon during this time, and the maximum number of reported pink salmon catches was 200 from one individual.

3.3 | Model results

3.3.1 | Model 0: Were perceptions different following angling in high pink abundance (2021) than low pink abundance (2020)?

Both the 2020 and 2021 perception scales had a mean score of $\bar{x} = 0.78$ ($s = 0.12$ for 2020, $s = 0.14$ for 2021) out of 1, indicating general negative perceptions of pink salmon in Norwegian rivers among our participants. Our paired *t*-test revealed that there was no significant difference in angler perceptions between the 2020 and 2021 fishing seasons ($t(554) = 0.388$, $p = 0.698$). Therefore, we consider

TABLE 1 Summary of sociodemographic variables of anglers who have fished for salmonids in Norwegian freshwaters (*N* = number of respondents).

Sociodemographic variables	*N*	Percentage	Sociodemographic variables	*N*	Percentage
Gender (*N* = 1175)			Income (*N* = 1176)		
Man	1132	96.3%	Less than EUR 20,000	21	1.8%
Woman	41	3.5%	EUR 20,000–40,000	107	9.1%
Other	0	0.0%	EUR 40,001–60,000	227	19.3%
Prefer not to say	2	0.2%	EUR 60,001–80,000	236	20.1%
			EUR 80,001–100,000	167	14.2%
			EUR 100,001–120,000	126	10.7%
Residency (*N* = 1178)			EUR 120,001–140,000	66	5.6%
Permanent Resident	1150	97.6%	EUR 140,001–160,000	58	4.9%
Foreign Visitor	28	2.4%	EUR 160,001–180,000	29	2.5%
			EUR 180,001–200,000	23	2.0%
			More than EUR 200,000	35	3.0%
Education (*N* = 1174)			Will not/cannot answer	81	6.9%
Primary and Lower secondary school	50	4.3%			
High school degree or equivalent	251	21.4%			
Trade or Apprenticeship	275	23.4%			
Bachelor's or College degree	327	27.9%			
Post-graduate degree	271	23.1%	Persons in household (*N* = 1174)		
			I live by myself	176	15.0%
			2 persons	597	50.9%
Employment (*N* = 1176)			3 persons	153	13.0%
Full time	787	66.9%	4 persons	178	15.2%
Part time	30	2.6%	5 persons	60	5.1%
Casual or Contract	6	0.5%	6 persons	6	0.5%
Student	21	1.8%	7 or more persons	4	0.3%
On benefits	42	3.6%			
Retired	250	21.3%	Birth year (*N* = 1171)	Value	
Unemployed	7	0.6%	Mean	1966	
Other	33	2.8%	Median	1965	
			Minimum	1935	
			Maximum	2002	

that perceptions did not change dramatically between years with and without pink salmon spawning in the fishing rivers.

3.3.2 | Model 1: How do anglers perceive pink salmon?

Most anglers preferred Atlantic salmon, followed by sea-run brown trout in second, sea-run Arctic charr in third and pink salmon as the least preferred (Table 2). Among statements on perceptions of pink salmon, anglers most agreed that '*Pink salmon should not get established in Norwegian nature*'. The least agreed statement was '*I would eat pink salmon if I catch one*', although the mean value of all responses suggests general indifference (Table 2). Among the statements on pink salmon management, the most agreed statement was '*I think pink salmon should be removed from the river*', closely followed by '*I believe pink salmon threaten the viability of Atlantic salmon, Sea trout, and Sea char*' and '*I would volunteer in targeted efforts to remove pink salmon by angling or netting*'. The least agreed statement related to pink salmon management was '*I would pay an extra fee to support pink salmon removal*', although it still scored near 5 (somewhat agree), indicating general agreement. These results were consistent in both 2020 and 2021 surveys (Table 2). The average proportion of pink salmon that anglers would be satisfied catching was only 0.53 pink salmon out of 10 total catches per fishing trip in 2020, and 0.88 pink salmon in 2021 (Table 2). For reference, 61.5% selected '*No pink salmon at all*', 18.2% selected '*1 out of 10 catches are pink salmon*' and 10.2% selected '*It does not matter*'.

TABLE 2 Summary of all variables assessing angler perceptions of pink salmon in Norway.

Variables	$\bar{x}$ (2020)	*s* (2020)	*N* (2020)	Median (2020)	$\bar{x}$ (2021)	*s* (2021)	*N* (2021)
Perceptions of pink salmon in Norway (1 = Strongly disagree, 7 = Strongly agree)							
I have always disliked pink salmon	5.40	1.87	1150	6	5.33	1.84	678
My opinion of pink salmon has changed unfavourably	5.35	1.84	1152	6	5.17	2.01	681
Pink salmon should not get established in Norwegian nature	6.51	1.30	1171	7	6.30	1.55	687
I would eat pink salmon if I caught one	4.19	2.35	1110	4	3.43	2.30	641
Opinions on pink salmon management (1 = Strongly disagree, 7 = Strongly agree)							
I think pink salmon should be removed from the river	6.36	1.49	1166	7	6.26	1.54	690
The implementation of efficient pink salmon removal programs would increase my desire to fish in a river with high pink salmon counts	5.00	1.77	1119	5	5.06	1.67	673
I believe pink salmon threaten the viability of Atlantic salmon, sea trout, and sea char	6.10	1.45	1130	7	6.02	1.54	674
I would volunteer in targeted efforts to remove pink salmon by angling or netting	6.00	1.48	1158	7	5.89	1.60	684
I would pay an extra fee to support pink salmon removal	4.91	1.92	1165	5	5.02	2.01	684
Species preference (1 = Most preferred, 4 = Least preferred)							
Atlantic salmon	1.24	0.51	1130	1	–	–	–
Sea trout	2.02	0.55	1130	2	–	–	–
Arctic char	2.78	0.59	1130	3	–	–	–
Pink salmon	3.96	0.24	1130	4	–	–	–
Satisfactory pink:other salmon catch ratio (0/10 to 10/10 pink salmon)							
What would you consider an acceptable amount of pink salmon caught for you to be satisfied with your fishing trip (assuming that salmon catches are held constant)?	0.53	1.07	1053	0	0.88	1.55	618

Note: Mean values, standard deviation (*s*) and number of respondents (*N*) for each applicable variable are shown for both 2020 and 2021. Median values are shown for 2020 only.

Our regression model (Table 3, model 1) that assessed the relationship between angler perceptions of pink salmon and various sociodemographic and fishing habit variables was statistically significant ($R^2 = 0.02$, $p < 0.001$). Angler perceptions towards pink salmon were nearly more positive among anglers with higher education ($t = -1.83$, $p = 0.07$). Surprisingly, there was no trend in perception as the main fishing area moved from south to north ($t = -0.15$, $p = 0.88$), nor did more seasoned anglers hold a different perception of pink salmon ($t = 1.11$, $p = 0.27$). However, there was a trend for visitor anglers to hold pink salmon in higher esteem ($t = -2.48$, $p = 0.01$). Ultimately, the most important effect was the number of days spent fishing, with more days on the water increasing the negativity of the perception of pink salmon ($t = -3.50$, $p < 0.001$).

3.3.3 | Model 2: Do some anglers plan to modify their behaviour?

Among the respondents, 41% stated that they would modify their behaviours to *enhance* catching pink salmon, but only 7.6% reported that they would modify their behaviours to *avoid* catching pink salmon (Figure 2). Among those who stated they would like to enhance catching pink salmon ($N = 478$), 70.9% reported they would do so to help remove pink salmon from the river, while the other 26.4% stated they would do so to both help remove pink salmon from the river and a combination of one of the following: for food, for the thrill of the catch or for other reasons. The remaining 2.7% of anglers who would enhance catching pink salmon stated they would do so for a combination of food, thrill of the catch or for other reasons. Among anglers who stated they would modify their behaviours to avoid catching pink salmon ($N = 89$), 34.1% stated that it was because they disliked pink salmon and 12.5% because pink salmon is not fun to catch. Only 1% stated that they would avoid pink salmon because they did not like the taste of pink salmon even though very few had responded elsewhere that they would actually intend to eat pink salmon. Moreover, 42% explained their behaviour to be a combination of the four reasons listed (i.e. disliked pink salmon, not fun to catch, did not like the taste and other). All respondents who reported that they would modify their behaviours were directed to a question assessing how frequently they would perform the behaviour using a 7-point scale

TABLE 3 Description of predictor variables included in both regression models, where model 1 is the multiple linear regression modelling the relationships between perceptions of pink salmon and sociodemographic and fishing habit variables ($R^2 = 0.03$), and model 2 is the binary logistic regression modelling the relationships between changes in behaviour and perceptions, sociodemographic variables and fishing habits.

Predictor variables	Type	Description	Estimate/slope (model 1)	*p* (model 1)	Odds ratio (model 2)	*p* (model 2)
Education	Binary	Categories include: Primary and Secondary Education/Post-Secondary Education	−0.095	0.067	0.963	0.828
Local/Visitor	Binary	Categories include: Local/Visitor	−0.117	0.013[a]	0.636	0.002[a]
Income	Ordinal	Lowest to highest income value	−0.014	0.141	1.000	0.207
Years Spent Fishing	Continuous	As described	0.003	0.267	0.996	0.425
Days Spent Fishing	Ordinal	Ordered categories based on increasing number of days spent fishing in a year (1 = 1–5 days fishing, 5 = More than 101 days fishing)	−0.065	<0.001[a]	1.059	0.345
Main Fishing Area	Ordinal	Ordered 10 categories by latitude (1 = Most southern, 10 = Most northern)	−0.001	0.877	1.055	0.047[a]
Perception Scale	Continuous	Composite scale with values between 8 and 56	N/A	N/A	1.029	0.002[a]

[a]Significance at or above the 95% level.

(1 = Do much less, 4 = About the same, 7 = Do much more). The behaviours measured included '*Time spent fishing overall*' ($\bar{x} = 4.42$, $s = 1.37$), '*Time spent fishing in a river that has pink salmon*' ($\bar{x} = 3.86$, $s = 1.72$), '*Plan trips to/in Norway in general*' ($\bar{x} = 4.11$, $s = 1.24$), '*Plan trips to/in Norway specifically during even-numbered years when pink salmon are less prevalent*' (3.75, $s = 1.48$) and '*Use specific gear to avoid catching pink salmon*' ($\bar{x} = 3.51$, $s = 1.92$). Furthermore, when asked whether a 10% increase in the cost of a fishing licence would affect their fishing efforts, there was a general trend that efforts would remain the same as long as Atlantic salmon dominated their catches but would decrease if pink salmon were equally or more highly represented in catches (Figure 3; Table 4).

Several factors predicted a change in behaviour among salmon anglers (Table 3; Figure 4). Importantly, the perception of pink salmon was a key predictor suggesting a higher propensity to change fishing behaviour with increasing negative pink salmon perception ($z = 3.09$, $p < 0.01$). Visitors were less likely than locals to change behaviour ($z = -3.08$, $p < 0.01$). There was also a trend towards behaviour change as the main fishing area moved northward, suggesting that fishers in Finnmark county where pink salmon are presently most abundant are more prone to change their fishing behaviour ($z = 1.98$, $p = 0.047$).

4 | DISCUSSION

In this study, we evaluated angler perceptions and social consequences of the presence of abundant pink salmon in Norwegian rivers and found that most anglers held negative perceptions of pink salmon for a variety of reasons. With the near-certain probability that pink salmon will continue to return every other year to Norwegian rivers, and the eightfold increase in total caught fish from 2019 to 2021 (Diaz Pauli et al., 2023; SSB, 2022), their presence may significantly impact fishing experiences, considering that most anglers reported they would only be satisfied with one or zero pink salmon catches per trip. We also found that almost half of the participants would modify their fishing habits to enhance pink salmon catches with the motivation to remove them from the rivers. More anglers agreed to volunteer their time to remove pink salmon than to pay an additional fee to manage the pink salmon invasion. In general, our work demonstrates the potential for disruption of angler satisfaction as a result of increased pink salmon abundance, but not participation in their main fishery. Indeed, our results show potential for stewardship action among anglers to manage the pink salmon invasion through enhanced fishing and removal efforts, which future research could address as a potential source of social cohesion and conservation ethos in rivers.

4.1 | Comparison of 2020 and 2021

Our survey was sent out in 2020 following the 2020 angling season when there were very few pink salmon captured nationwide, and the

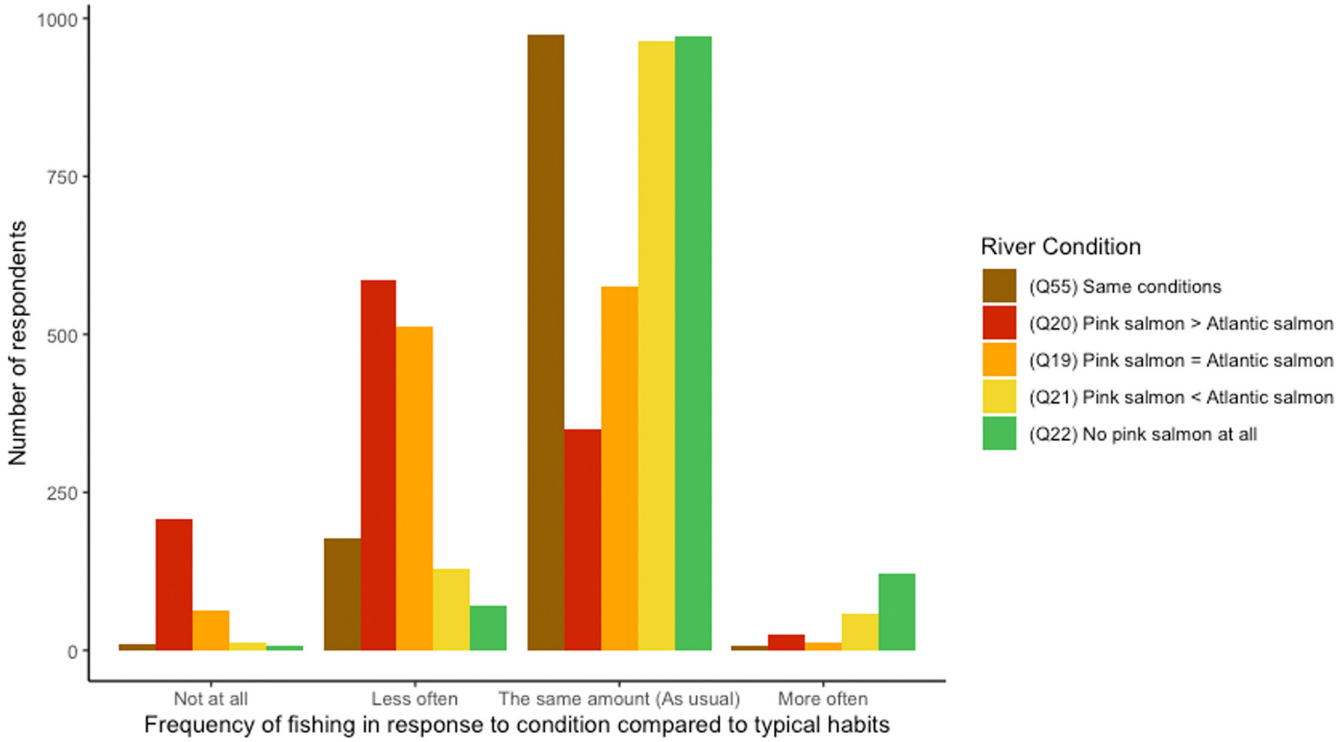

FIGURE 3 Distribution of responses to the questions described in Table 4, assessing impacts to angler participation via changes in fishing frequency in response to pink salmon abundance levels in the anglers' main rivers.

TABLE 4 Descriptions of the questions referred to in Figure 3, assessing angler participation as a result of pink salmon abundance.

	Question
Q55	If the cost of a fishing permit increased by 10% in your main Norwegian river, would you go fishing there…
Q19	If the cost of a fishing permit increased by 10% in your main Norwegian river, and the probability of catching Pink Salmon were **equal** to the probability of catching other salmon, would you go fishing there…
Q20	If the cost of a fishing permit increased by 10% in your main Norwegian river, and the probability of catching Pink Salmon was **higher** than the probability of catching other salmon, would you go fishing there…
Q21	If the cost of a fishing permit increased by 10% in your main Norwegian river, and the probability of catching Pink Salmon was **lower** than the probability of catching other salmon, would you go fishing there…
Q22	If the cost of a fishing permit increased by 10% in your main Norwegian river, and there were **no Pink Salmon at all**, would you go fishing there…

Note: Q55 serves as a control for effects of increased permit costs on fishing frequency.

fish could arguably have not been at top of mind among anglers, even if they likely encountered them in 2017 and 2019. Concerns that our survey was not representative due to the timing of its delivery to anglers were mitigated by rerunning the survey in 2021, following an extremely large pink salmon catch in Norway, when there were no significant changes in the perceptions provided by anglers. Such a comparison provided greater reliability of our findings. Whether these perceptions can be expected to remain stable in the coming years is uncertain, but we suggest that perceptions will change as new knowledge about pink salmon emerges. Many anglers may not know whether pink salmon will remain in their rivers or continue to spread, and there are almost no scientific studies on the impacts of pink salmon on native European fishes (Lennox et al., 2023). As such information becomes more available, and perhaps as media narratives or social norms begin to shift towards catching and consuming pink salmon, the change in perception towards pink salmon may be of great interest to follow in these Norwegian fisheries. These changes in perceptions and interests of pink salmon are important for fisheries managers to understand to maintain satisfaction and participation of anglers.

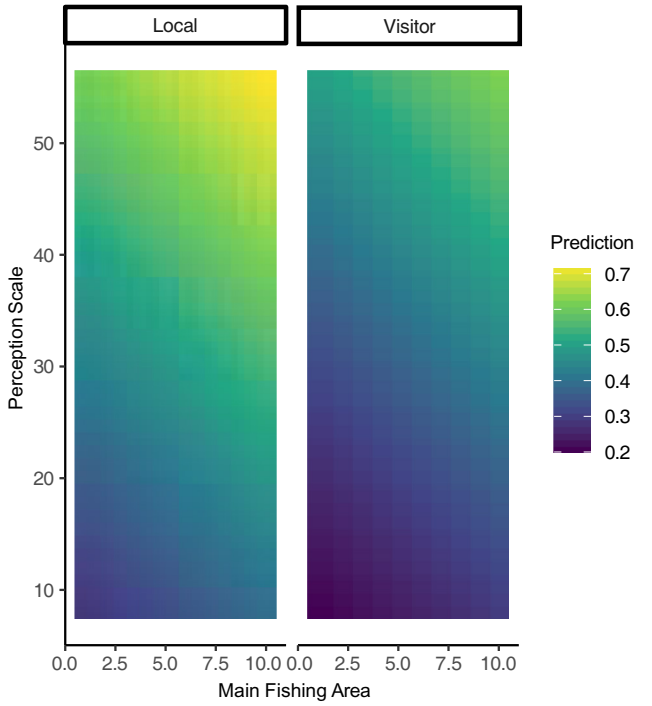

FIGURE 4 Colour-coded binary logistic regression model predictions considering all significant predictor variables (Graph on the left = Local anglers to their main river ($N = 455$) and graph on the right = Visitor anglers to their main river ($N = 376$). Main fishing area along the *x*-axis in order of increasing latitude (10 is most northern). Perception scale along the *y*-axis (perception scores from 0 to 56) where 0 indicates a positive perception of pink salmon) and 56 indicates a negative perception of pink salmon. Model prediction values <0.5 = No change in behaviour (dark blue), >0.5 = Change in behaviour (green to yellow).

4.2 | Perceptions of pink salmon

Anglers who fished for salmon in Norway in 2020 held overwhelmingly negative perceptions of invasive pink salmon. Perceptions of invasive alien species vary widely, ranging from positive perceptions and preferences for alien species to negative perceptions and desires to protect native species (Banha et al., 2017; Bravo-Vargas et al., 2019; Crowley et al., 2019; Edwards et al., 2016; Potgieter et al., 2019). This is because invasive species do not have universally negative impacts and may provide ecosystem services that are enjoyed by people, complicating management decisions (Sax et al., 2022). Perhaps nowhere is this more relevant than in northern Norway where invasive red king crab is carefully managed as a resource in parts of Finnmark County, overlapping spatially with the areas where pink salmon are intensely disliked according to our surveys (Sundet & Hoel, 2016). The polarity in perceptions of these two alien species may be explained by many factors at various levels, ranging from individual demographic characteristics and values to sociocultural factors, to even how policies can influence and shape perceptions (Shackleton, Richardson, et al., 2019). The findings suggest that perceptions may be primarily influenced by factors at the level of the angler and at the level of the *effects imposed by* the species rather than at the level of the species (Shackleton, Richardson, et al., 2019). These findings are complicated by a lack of biological data on the potential impacts of pink salmon on native ecosystems in Norway (Jonsson & Jonsson, 2018; Lennox et al., 2023), such that concepts of impact rely on hearsay, conjecture and own observations rather than scientific evidence for certain impacts. The predominant negative perceptions may also be influenced by factors at the governance and policy level (as described by Shackleton, Richardson, et al., 2019), which can shape angler values, attitudes and behaviours.

At the level of the angler, our model found evidence of two main factors influencing angler perceptions: days spent fishing and local or visitor status (Shackleton, Richardson, et al., 2019). As anglers spent more time fishing in rivers, they likely gained increasing exposure to pink salmon and had first-hand experiences with them that provided lived experience and exposed them to peers whose attitudes toward pink salmon could influence their own feelings. Observed consequences of interacting with pink salmon while fishing for native salmon, trout or charr may include unsightly and smelly pink salmon carcasses washing ashore (Bailey et al., 2018), changes in species composition of catches during trips (SSB, 2022) and observations of the behaviour of pink salmon and native salmonids in clear water rivers (e.g. pink salmon behaving aggressively towards native salmonids (Sandlund et al., 2019)). These experiences with pink salmon may influence the perceptions of the species and could be exacerbated by a perceived lack of value of pink salmon for food. These perceptions may further be amplified by an angler's desire to maintain their known environment, stemming from emotional factors and one's sense of place (Humair et al., 2014; Shackleton, Richardson, et al., 2019).

4.3 | Implications of the presence of pink salmon on angler behaviour

Our study was guided by the theory of planned behaviour and its application to the case of pink salmon invasions in Norwegian rivers. Although most anglers reported that they would not change their fishing behaviour, 41% reported a willingness to change their fishing behaviour not to avoid catching these fish they reported so disliking, but to enhance catches and try to quell the impacts of the fish on their local fisheries. A scenario-based study in the Laurentian Great Lakes showed that overall recreational fishing participation would not substantially decrease because of invasive species, but rather fishers would fish other opportunities (Lauber et al., 2020). Salmon anglers in Norway may not have overwhelmingly reported that they would change their fishing behaviour because of pink salmon, but some might consider giving up on salmon fishing if both pink salmon become more abundant and licences also become more expensive. How this might actually unfold at a landscape scale will be interesting to study as some anglers may substitute their normal fishing for fishing in different areas or targeting different species like landlocked trout or marine fish, whereas others may quit fishing altogether

rather than making a change (Stensland et al., 2015). Future research on substitution behaviour (e.g. Gentner & Sutton, 2008) will be important for managing a potentially changing fishery. Our survey also scarcely reached an audience of anglers that prefer to fish for pink salmon, who may not have been in the licence database and therefore would not have received the survey. Future research should attempt establish whether such anglers exist, because while our survey results suggest they may be a minority, they could play a role in the future of this fishery.

Northern regions of Norway have encountered pink salmon at much higher rates than elsewhere in Norway (Diaz Pauli et al., 2023; Sandlund et al., 2019). Correspondingly, anglers, particularly locals with negative perceptions of pink salmon, were more likely to report that they would change their behaviour if the reported main fishing area was in Finnmark County, the northernmost area of Norway where pink salmon are now extremely abundant (Figure 4). This portends a potential shift in the national sentiment towards pink salmon should the species spread further in rivers elsewhere in the country, exposing more people to capture of pink salmon. Recent evidence in Scotland suggests that pink salmon are successfully spawning, and juveniles are migrating out of rivers at lower latitudes than they had previously been recorded in the Atlantic (Skóra et al., 2023) where salmon have been thought to only survive in the cold rivers of northern Norway (Lennox et al., 2023). Therefore, we may expect that perceptions of change, threats to ways of life and overall sentiments towards pink salmon could be liable to change further in the coming years. Indeed, there remains much uncertainty about the trajectory of pink salmon in the Atlantic and Arctic (Lennox et al., 2023).

4.4 | Evidence for the theory of planned behaviour

Our design explored concepts related to the theory of planned behaviour, which posits that attitudes of people, such as recreational fishers, can predict the behaviour of those people when confronted with a specific scenario (Ajzen, 1991). The theory suggests that individuals with a negative perception of an invasive species can be expected to modify their effort when fishing in rivers where these species are prevalent. Indeed, we found that recreational fishers in Norway that had negative attitudes towards pink salmon were advocates for their control against establishing in Norwegian salmon rivers. Anglers who reported disliking pink salmon were also liable to modify their behaviours to catch more pink salmon to remove them from rivers or to volunteer their time to remove pink salmon before they spawned in the river. These observations align very well with the theory of planned behaviour. As the status of pink salmon in Norway may continue to change with increasing spread of the species to different regions of the country, the perception of pink salmon among anglers may continue to change, which our study suggests would be reflected in commensurate changes to fishing behaviour. Two important messages are embedded here for management, (1) that salmon anglers have overwhelmingly negative perceptions of pink salmon, which shift based on how exposed the anglers are to pink salmon (corresponding to where they fish in the country), and (2) that management may rely on anglers to help remove pink salmon from rivers as long as their perceptions are negative.

4.5 | Study design limitations

We acknowledge limitations within our study as our survey only captured a sample of the entire fishery but did access a major component of the overall fishing population. We aimed to reduce sampling bias by randomly distributing the survey to 50% of all anglers who purchased a fishing licence in Norway to fish for salmon, sea-run brown trout or sea-run Arctic charr. Non-response bias may be a result of invitation emails being missed or going to respondents' junk or spam folders, respondents opting out mid-way, forgetting to return to the survey or being too busy to respond (Gigliotti & Henderson, 2015). It is possible that individuals wishing to express their displeasure for pink salmon may have been more eager to respond to the survey than agnostic counterparts. Unfortunately, no data are available to provide further assessment of the nonresponse bias. Our response rate is lower than a similar study with the same licence database in previous years (e.g. 40% response rate in Stensland et al., 2017). Nonetheless, our survey received a substantial number of responses with an average response rate for targeted online surveys (Nulty, 2008; Sheehan, 2001; Shih & Fan, 2009). Finally, it is important to note that our participants had experienced the drastic increase of pink salmon in Norway for only 2 years (2017, 2019) before taking our 2020 survey and that we initially surveyed the anglers in an even-numbered year (2020) when pink salmon counts were low. As such, past recollection of their perceptions and attitudes during the 2017 and 2019 fishing seasons may have diminished, and responses may differ in future years should anglers continue to experience high abundance of pink salmon.

5 | CONCLUSIONS

Recreational fishers in Norway have widespread and strong negative perceptions of the invasive pink salmon that has colonized Norwegian rivers and is actively spreading every 2 years. These findings were stable when comparing survey results in a non-pink salmon year (2020, 47 pink salmon caught) and a pink salmon year (2021, 111,803 pink salmon caught). The relative consensus on pink salmon was striking and provides a strong mandate towards management regarding the expectations of the angling community; however, we note that our survey clearly excluded other potential interest groups whose voices also merit being heard. Other questions of invasive species are not so aligned, with stakeholders often having conflicting opinions about whether to remove or enjoy the benefits of new species (Crowley et al., 2017). It was interesting to note how few anglers were interested in potentially eating pink salmon, despite the fish being of reasonable quality when it freshly entered the river from the sea. There may be opportunities to promote the harvest of

pink salmon in fjords and rivers when the meat quality could be considered very good by some consumers. Educating fishers about how to make the most of the pink salmon that they can catch should be a priority, given that the species is more likely than not to become a mainstay in the catch composition of salmon fishers. More research is needed to understand the impacts of pink salmon on ecosystems to make more holistic decisions about the costs and benefits of pink salmon removal efforts.

AUTHOR CONTRIBUTIONS

J. D. Guay, V. M. Nguyen, K. W. Vollset and R. J. Lennox conceived the ideas. J. D. Guay led the questionnaire design, guided by V. M. Nguyen, R. J. Lennox, E. B. Thorstad, K. W. Vollset and S. Stensland who each contributed to the development and refinement of the questionnaire for data collection. K. W. Vollset, S. Stensland and J. Erkinaro assisted in the translation of the questionnaire. J. D. Guay and R. J. Lennox analysed the data with V. M. Nguyen's assistance. J. D. Guay led the writing of the manuscript, supported by R. J. Lennox and V. M. Nguyen. All authors contributed to revising the drafts and gave final approval for publication.

ACKNOWLEDGEMENTS

We would like to thank all anglers who participated in our questionnaire for their time and contribution. Funding for this research came from the Norwegian Environment Agency (Miljødirektoratet) and Jessika Guay's scholarship (Queen Elizabeth II Scholarship in Science and Technology (QEII-GSST)). We appreciate the fishing licence email list provided to us by the Norwegian Environment Agency. We would also like to thank Elisabeth Stöger for translating the questionnaire materials to German. Finally, we are grateful for the valuable feedback provided by the reviewers that significantly improved our manuscript.

CONFLICT OF INTEREST STATEMENT

There is no conflict of interest declared in this article.

DATA AVAILABILITY STATEMENT

We have archived the anonymized survey data in accordance with the Norwegian Centre for Research Data and the Carleton Research Ethics Board. The data may be found in Zenodo, a cloud-based storage platform at https://doi.org/10.5281/zenodo.8437146 (Guay et al., 2023).

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

Supporting Information A: Questionnaire 2020.

Supporting Information B: Questionnaire 2021.

How to cite this article: Guay, J. D., Lennox, R. J., Thorstad, E. B., Vollset, K. W., Stensland, S., Erkinaro, J., & Nguyen, V. M. (2024). Recreational anglers in Norway report widespread dislike of invasive pink salmon. *People and Nature*, *6*, 41–53. https://doi.org/10.1002/pan3.10553