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DOI: https://doi.org/10.3897/arphapreprints.e122267

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ARPHA Preprints *Author-formatted, not peer-reviewed document posted on 05/03/2024* DOI: https://doi.org/10.3897/arphapreprints.e122267

Abstract

1. Over the last century, intensification of human movement worldwide has resulted in a large-scale redistribution of species, which has been compounded in recent decades by climate change. The interaction of these two phenomena have resulted in a number of complexities and challenges for regarding management of non-native species. As effective management can be hampered by disconnects between scientific researchers, natural resource managers and the general public, assessing consensus between these groups is crucial.
2. Here, we undertake an explorative approach to analyse three groups of people concerned with the management of freshwater ecosystems - recreational fishers, natural resource managers and scientific researchers - in order to better understand consensus or lack thereof regarding the interaction between non-native species and climate change.
3. We found that while scientific researchers and managers had varying opinions on the management of non-native species as driven by climate change, recreational fishers were almost unanimously opposed to the potential presence of non-native species, regardless of the nature of their introduction. Additionally, definitions of what constitutes a non-native species varied greatly between and within the different groups.
4. Our results underline both the current lack of consensus on the definition and management of non-native species and a disconnect between and within the three groups regarding both the nature of non-native species and the range-shifting effects of climate change.

Introduction

Over the last century, intensification of human movement worldwide has resulted in a large-scale redistribution of species, a trend that is predicted to continue at a similar pace in the coming decades (Seebens et al. 2020). The majority of the redistribution of these non-native species have historically been driven by human translocation (Carpio et al. 2019; Mack et al. 2000). If these non-native species become established and begin to spread, their local impacts can include population declines and even local extirpations of native species, and restructuring of food webs (Mack et al. 2000; Gallardo et al. 2016). Human activity has also resulted in climate change, which can reduce species' populations through warming temperatures and an increase in the frequency of extreme weather events (IPCC 2021). In recent decades climate change has compounded the effects of this redistribution of species. This can happen in a number of ways (Rolls et al. 2017). Firstly, through the direct movement - often termed 'range-shifting' - of species to higher latitudes and altitudes as a response to warming temperatures (Chen et al. 2011). Secondly, through allowing species to establish and spread upon introduction to ecosystems that were previously too cold for either process (Comte and Grenouillet 2013). And thirdly, through changing interactions between already-established non-native species and native species they had previously co-occurred with, such that native species are negatively impacted (Gilman et al. 2010; Hein et al. 2014; Perrin et al. 2020a).

The complexity of the interaction between the non-native species and climate change mean increasingly complex management challenges. Successful management approaches, such as preventing the introduction of non-native species

and conserving native species and communities, are dependent on three different groups - a) scientific researchers, who provide the research upon which management decisions are based (Pecl et al. 2017; Beaury et al. 2020), b) natural resource managers, who make and implement management decisions (Pietrzyk-Kaszyńska and Grodzińska-Jurczak 2015), and c) public stakeholders, whose approval is often necessary for the success of management decisions (García-Llorente et al. 2008; Gozlan et al. 2013; Verbrugge et al. 2013; Deak et al. 2019; Kapitza et al. 2019; Kochalski et al. 2019).

There are already a plethora of examples of disconnects within natural resources managers (henceforth referred to as managers), scientific researchers (henceforth referred to as researchers) and public stakeholders in regards to non-native species terminology and management. Within research communities there is substantial debate over both the terminology and management of non-native species, with traditionally popular terms such as ‘invasive’ and ‘alien’ viewed by some researchers as at best subjective and at worst pejorative (Shackelford et al. 2013; Head 2017; Abbate and Fischer 2019). The indirect role of climate change in range shifts in species means that range-shifting species are generally not termed as invasive or alien within the research community, though this is not always the case (Peterson and Robins, 2003), and there has been objection to the application of invasive frameworks to range-shifting species (Urban 2020). Many natural resource managers (henceforth referred to as managers) have begun to incorporate the effects of climate change into management actions regarding non-native species (Rahel et al. 2008; Beaury et al. 2020), including habitat manipulation and restriction of dispersal in areas where native species are of conservation concern (Scheffers

and Pecl 2019). Yet even here there are problems, as strict maintenance of species assemblages in areas where the climate has rendered habitats unsuitable for native species may become resource-intensive and ultimately untenable (Scheffers and Pecl 2019). Among public stakeholders, climate change itself is enough of a controversial issue, with the phenomena sometimes rejected as a threat by members of the public, even those whose livelihoods are directly affected (van Baal et al. 2023). Knowledge of risks and management techniques regarding invasive species also varies from region to region (Bremner and Park 2007; Verbrugge et al. 2013; Deak et al. 2019).

Disconnects between managers, researchers and public stakeholders can have a severe effect on the success of non-native species management, and examples of such disconnects are also plentiful. Whether the attitudes of managers align with those of researchers and public stakeholders can have a large impact on the effectiveness of programs which aim to mitigate the potential effects of any non-native species, as many examples demonstrate (Temple 1990; Manchester and Bullock 2000; Bertolino and Genovesi 2003; Deak et al. 2019). Disconnects between the public and managers can also hamper conservation efforts, sometimes resulting in legal action, even when a species is undoubtedly non-native and having demonstrable negative impacts (Bertolino and Genovesi 2003; Arts et al. 2016; Anderson et al. 2019). These disconnects often occur when public perception of the nature or ecological impact of a non-native species does not reflect the species' demonstrated impact (García-Llorente et al. 2008; Gozlan et al. 2013; Verbrugge et al. 2013; Kapitza et al. 2019; Kochalski et al. 2019). This can be particularly harmful

in situations where public stakeholders can be a significant vector for translocation of non-native species.

Here, we take an explorative approach to identify causes of discord within and between these three groups. We used semi-structured interviews to assess perception of interactions between non-native species and climate change in an area where a) climate change is progressing at an accelerated rate compared to the rest of the world (IPCC 2021) , b) low endemic species richness means the impact of non-native species can carry particular ecological and cultural significance (Hesthagen and Sandlund 2007), and c) public stakeholders can be a significant vector for translocation of non-native species (García-Díaz et al. 2018; Carpio et al. 2019; Chapman et al. 2020). In exploring said perceptions we aim to identify pathways to integrate scientific, practical and lay knowledge and strengthen collaboration between the three groups. This allows for identification of appropriate management actions to handle these interacting effects of climate change and non-native species.

2. Methods

2.1. Personal Interviews

2.1.1. Study system

In order to assess the contrast between the perception of the interacting effects of climate change and non-native species between three groups - those who produce the scientific research (researchers), those who implement it (managers), and those who provide public approval of its implementation and experience its effects (recreational fishers) - we interviewed respondents from diverse locations throughout Norway in relation to freshwater ecosystems. Norway's location in the sub-Arctic and Arctic, immigration history and topography means that large parts of the country are relatively species-poor, and subsequently vulnerable to the effects of non-native species (Hesthagen and Sandlund 2007). Translocations from well before the 1900s until the modern day by various institutions - including the church, the government and recreational fishers from inside and outside of Norway - have resulted in the spreading of native Norwegian species to areas they would not have previously been able to naturally disperse to, as well as the arrival of species non-native to all of Norway, and in some cases to Europe (Sandlund and Hesthagen 2011; Hesthagen and Sandlund 2007). Many of these species can have negative effects on native ecosystems and species that are adapted to relatively cold temperatures, many of which are of cultural importance (Winfield et al. 2008; Borgstrøm et al. 2010; Sandlund et al. 2013; Hesthagen et al. 2015; Eloranta et al. 2019). The increased rate of climate change experienced in the sub-Arctic and Arctic means that in coming decades, many species which may not have been able to establish and spread

157 through colder ecosystems may be able to do so (Rahel and Olden, 2008; Hayden et
158 al. 2017). Effective management of freshwater systems is therefore crucial.
159 Rotenone treatment of freshwater ecosystems is common throughout Norway to
160 remove harmful non-native species, and while effective, it is expensive and
161 ecologically damaging, so if rotenone treatment is applied there needs to be
162 assurance that invasive species cannot return easily (Perrin et al. 2020b).
163 Additionally, there is an ongoing trend of dam removal throughout much of Europe,
164 dams which could potentially currently act as dispersal barriers for non native
165 species (Sun et al. 2020). This makes consensus in the management of non-native
166 and range-shifting species between researchers, managers and public stakeholders
167 crucial in the quest for effective management of Norwegian freshwater ecosystems.
168
169 Our study looks at contrasts in perceptions of the interactions between climate
170 change and non-native species throughout Norway. As an explorative study
171 necessitates an understanding of respondents' reasoning we took a qualitative
172 approach to data collection. There has been a bias towards quantitative methods in
173 similar research in the past, which can limit understanding of social context in which
174 perceptions are founded (Kapitza et al. 2019). As such, we conducted personal
175 interviews with subjects from three different groups; researchers, managers and
176 recreational fishers (table 1), in line with previous studies (Schüttler et al. 2011;
177 Selge et al. 2011).

178 ### 2.1.1. Respondent Selection

179 A total of 30 interviews were conducted between August of 2019 and April of 2020.
180 Interview respondents were chosen using the snowball method, as described by
181 Miles and Huberman (1994). This requires an initial pool of contacts, who

subsequently nominate other respondents that are suitable for the study. Our initial pool included contacts from a variety of organisations and regions, in order to avoid shared viewpoints potentially based on similar educational and career histories.

In compliance with requirements of the Norwegian National Research Ethics Committee, all respondents were given an overview of the topic beforehand, assured that their responses would be anonymous, and informed of the intended use of their responses. Participation was voluntary and it was possible for respondents to withdraw consent. All interviews were anonymously recorded and subsequently transcribed verbatim. Any details which might have allowed the individuals to be identified based on descriptions of their roles or locations were removed.

Table 1: Description of respondents

Interest group	Description	Number respondents
Researchers	Professionals associated with public or private research institutes not directly responsible for taking management decisions. Expertise in fish biology or ecology, or freshwater ecology or hydrology.	8
Managers	Professionals associated with public organisations who are directly responsible for management decisions regarding freshwater bodies.	12
Recreational fishers	Individuals who participate in recreational fishing on a regular or semi-regular basis.	10

2.1.2. Interview structure

We used a semi-structured interview approach, in order to ensure that interviews flowed as naturally as possible with room for tangential discussions, while ensuring that several basic topics were covered (refer to Supplementary Material S1 for interview guide). The first was their perception of a non-native species, and whether or not several key factors played into their definition, including a) method of introduction of the species, b) native habitat of the species and c) societal perception of the species. All three factors have been previously shown to influence perception of a non-native species, both among scientific researchers and the public (Warren 2007; Selge et al. 2011). While the English term ‘alien species’ can be considered as

pejorative, it was used in the interview, as it corresponds more accurately to the widely used Norwegian term ‘fremmede art’. So as not to lead respondents into mentioning factors a-c, we asked them to define a non-native species, encouraging them to use examples when needed. We also wanted to gauge whether their view of non-native species changed if climate change had influenced the species arrival and/or subsequent impact. As recent research has suggested shifting management and research to focussing on the impact of non-native species (Jeschke et al. 2014; Wallingford et al. 2020), we wanted to present respondents with a hypothetical situation in which a non-native species established itself and had a demonstrable and reasonably immediate impact, in this case the extirpation of a local species. This hypothetical situation was presented firstly as a result of climate-induced range expansion, and secondly as a result of human translocation.[1] For fishers, non-native species with which they were familiar were used as an example, in most cases the northern pike (*Esox lucius* Linnaeus, 1758) or European perch (*Perca fluviatilis* Linnaeus, 1758). They were asked how they would react to both situations.

Additionally, we asked the researchers and managers to name the primary concerns to their region, to capture whether or not non-native species and/or climate change were an acknowledged concern. We also asked researchers and managers which species of fish they considered to be of high conservation status. We asked recreational fishers questions relating to their fishing habits, including how long they had been fishing, which regions they had fished in, which species they preferred,

1 While every effort was made to assure respondents that the first scenario was hypothetical, two fishers rejected the premise outright, as they felt that introduction of novel species into their local environments was impossible in the absence of human translocation.

and whether their preferences changed on a seasonal or longer-term basis. This gave us insight into their perception of particular species.

No time limit was set on the interviews. Interviews lasted anywhere from 10 to 50 minutes. Respondents were invited to talk freely, and none expressed discomfort discussing the topic. Respondents occasionally had to be prompted to elaborate on answers in order to better understand their reasoning. Although not always relevant, tangents were encouraged in order to allow respondents to better explain opinions or recount experiences. All respondents were offered the opportunity to be interviewed in Norwegian, however 24 of the 30 were comfortable enough to complete the interview in English. Respondents were encouraged to switch to Norwegian any time they felt unable to adequately express themselves in English. 16 interviews were conducted in person, while the remaining 14 were conducted via web meeting. Whether or not the interview was conducted in person did not have a notable effect on the outcome, and was therefore not used in further analysis.

2.2. Response analysis

Responses were categorised based on two sections of analysis, one of which was common to all groups, and one that differed for recreational fishers. The first section analysed which fish species recreational fishers preferred, so as to ascertain whether potential future extirpations would affect the species for which they preferred to fish. We also determined whether or not these preferences had changed over time. For researchers and managers, the first section sought to analyse which species were of high conservation status to their region, and for what reasons. We also determined whether or not non-native species and/or climate change were of primary concern, and which other factors were considered as primary concerns.

The second section concerned non-native species. We first determined, based on given definitions, whether or not subjects considered a) method of introduction, b) societal perception and c) whether or not the species was native to part of the country as an important facet of the definition of a non-native species. We then determined whether or not subjects reacted negatively to the possibility of species extirpations in their local freshwater ecosystems driven by a range-shifting species, and whether this response varied when turnover was driven by a non-native species that had been directly translocated by humans. We also determined (although this was not directly elucidated by several respondents) whether or not they thought management action was appropriate in such situations.

In presenting our results, we begin by summarising general findings, then elucidate these findings using quotes from select respondents. Respondents are referred to by an acronym referring to their interest group and order in which they were interviewed. As such, our seventh respondent, a recreational fisher, would be referred to as F-07.[2]

Results

The following section will present results in the order they are addressed in the interview guide. Preferences of recreational fishers are described first, followed by species of conservation concern and local anthropogenic stressors according to

2 Respondent F-04 was in fact three individuals who chose to be interviewed at the same time. As they almost exclusively fished together as a group and responses generally corresponded with one another, their responses were collated into one.

managers and researchers. Perceptions of non-native species are then described, followed by reactions to the two hypothetical scenarios.

For the sake of brevity, henceforth the extirpation of local species as driven by range-shifting species will be referred to as climate change driven turnover. Extirpation of local species driven by non-native species which arrived as a product of direct human translocation will be referred to as translocation driven turnover.

Extended responses from all respondents are openly available in Perrin et al. 2020c (https://doi.org/10.5281/zenodo.3991516).

3.1.1. Fishing tendencies

Nearly all fishers interviewed expressed a preference for salmonids, namely brown trout and arctic charr. Several respondents mentioned the value of their preferred species as food fish.

> ***F-18:*** *I went consistently for brown trout since I was a kid, because that's the most common fish in our region. Here, the population of brown trout is dominant in rivers and lakes. It's the most exciting fish to do sportfishing for.*

With a few exceptions, these tendencies did not change on any short or long-term basis. Most respondents had fished for their preferred species since they were children. There was some preference for ice-fishing in the winter which restricted fishers to catching charr.

Several respondents also mentioned a dislike of pike as a food fish, and specifically stated that they would not fish for it.

> ***F-07:*** *I've never fished for pike. But I know lots of people who fish for pike. It's not a good eating fish, like trout is.*

3.1.2. Species of high conservation status

Among managers, arctic charr, brown trout and salmon were each mentioned seven times as species of concern. Grayling, eel, pearl mussel, european bullhead, asp, fourhorn sculpin, white bream and vendace were also mentioned. Several admitted that while they would like to see more focus on the latter species, salmonids were prioritised primarily for economic reasons, although in some regions salmonid species were also declining.

> ***M-24:*** *From a biological point of view I guess all species have the same value, from a financial point of view I guess trout and char are the biggest resource...*

All eight researchers mentioned at least one salmonid as a species of concern. Burbot, pearl mussels, lampreys, sculpins, cyprinids and notostracan crustaceans were also mentioned.

3.2. Local anthropogenic stressors

Alien species were mentioned as a primary concern to their freshwater ecosystem by five of the eight researchers, with climate change mentioned as a primary concern for six. Eight of the twelve managers mentioned non-native species as a primary concern, and eight mentioned climate change.

3.3.1. Perception of alien species

Three of ten fishers mentioned method of introduction in their definition of a non-native species. Respondent F-14 claimed that species that dispersed naturally were non-native, with respondent F-29 feeling that species dispersing naturally were “not necessarily alien” and respondent F-11 claiming that a non-native species “had to be introduced by humans”. No fishers mentioned social perception of species in their definition. Two fishers mentioned the species native range, with respondent F-26 defining non-native species as those that are “not native in Norway”, and F-05 defining species from the east of Norway as ‘unnatural’. All definitions referred generally to fish not belonging in the region or specific lake.

> ***F-18:*** *It means species who aren’t originally from that environment. So species you wouldn’t have found there originally.*

> ***F-27:*** *The definition for me became quite narrow because one of my favourite waters became infected by pike, by some people placing it there because they think it’s fun to fish for it. So for me that would be an alien species in that water, it’s not supposed to be there.*

Seven of 12 managers mentioned method of introduction in their definition of a non-native species. Of these seven, two definitively named species that spread naturally as non-native species.

> ***M-02:*** *Alien species are primarily those set out by humans. I maybe don’t have a clear definition, but if they come here by themselves they can also be alien species.*

Two managers stated that non-native species needed direct human help to move.

> ***M-21:*** *I think of course you have had a natural extension and retraction of species always throughout the history of the earth. And of course climate change is affecting this in an unnatural way, but still it's not the same as human transportations of species.*

The other three did not have a definitive stance either way, but gave impressions on the subject.

> ***M-09:*** *I'm mainly thinking about those who are not spreading by themselves but who are spread by humans. But also those who are coming because of human induced climate change. I think that's not so easy to point out if it's totally alien species or just slightly expanding because of a natural variation.*

Three managers mentioned social perception when defining non-native species. Respondent M-20 defined non-native species as something "we don't like", whereas respondents M-24 and M-10 admitted that social perception could influence management approaches to non-native species, though they still classed species as non-native regardless of social perception.

Seven managers mentioned whether or not the species was native in Norway as an aspect of the definition. All stated that species which were native to Norway but not to a local region should also be classified as non-native in that region.

Six of eight researchers mentioned method of introduction as an aspect of the definition of a non-native species. Of those, four stated that species which moved on their own into new regions were non-native.

> ***SR-17:*** *I think it's a species that's coming to an area where it hasn't been for decades. So it varies, it can come naturally, moving slowly through freshwater species, like some of the alien species we have here that are coming from Sweden.*

The other two stated that non-native species needed direct human help to move. Only one researcher mentioned social perception in their definition, with respondent SR-25 claiming the definition was "value-based". Two researchers included whether or not the species was native to Norway in their definition, with both stating that species native to a certain region of Norway could still be classified as non-native in other areas.

> ***SR-19:*** *I know when we use this term we need to specify if we mean truly alien, like not even belonging in this country, or just having moved to a new area. But for me they mean both...*

3.3.2. Perception of climate change driven versus translocation driven turnover

All fishers felt negatively about climate change driven turnover, with all citing their inability to fish for their preferred species as the main reason. Several used strong or emotive language in their reaction to the hypothetical scenario.

> ***F-18:*** *F*** off. Would be my answer. It would be a terrible situation for my passion. It's that easy. I don't have a big interest in dry fly fishing for perch or pike.*

Only one respondent mentioned ramifications for the local ecosystem as a contributing factor to his reaction. Several respondents recognised that climate change may make lakes more suitable for other species, but that these lakes should still be preserved.

> ***F-27:*** *That would feel bad, it would ruin my waters. I wouldn't like that, and I think we should try to prevent it, even though it's climate change, we should stop those things from happening.*

There was no inversion of response when asked how they felt about translocation driven turnover, however four felt even more negatively about this possibility.

> ***F-14:*** *I think I would get more angry if it was humans. But I wouldn't be happy either if it was climate change. People should know... the consequences of moving species over.*

While some fishers did feel negatively about the prospect of climate change driven turnover, they felt it was unlikely to occur in their local ecosystems in the near future.

Nine of 12 managers felt negatively about climate change driven turnover. Three of those managers cited potential effects on local fishers as a contributing factor to their reactions. Of the nine, only four felt that management steps should be taken to prevent non-native species from establishing in lakes as a result of range-shifts.

> ***M-22:*** *...some species will spread, even though they're alien species, because you simply don't have the possibility to stop them. But in other respects, I would resent or try to stop such a development... Because you also have to bear in mind that these are alien species and you should give the native species a possibility to adapt from climate change...*

Of the managers who did not feel that management actions were warranted in the case of climate change driven turnover, most stated that they felt it was futile to combat long-term changes.

> ***M-21: ...****it's a result of a new climate situation, and it's not possible to try to fight this I think. I think the species living in the environment has just adapted, and we lose some and we get some… It's not possible to try to maintain the status quo if the climate changes.*

The manager who did not feel negatively about climate change driven turnover, respondent M-01, also did not feel negatively about translocation driven turnover, stating that as their region of concern did not have any incoming non-native species of concern, no action would be needed.

Five of the nine managers who felt negatively about climate change driven turnover stated that they would feel more negatively about translocation driven turnover.

> ***M-24:*** *I think then I could direct, my anger, my mood I guess, my emotions would be directed. More disappointment and anger, those kinds of feelings I guess. We would*

have to look at how this was allowed to happen, and adapt a management scheme to it I guess.

Of the five managers who felt negatively about, yet did not feel that management steps should be taken to mediate climate change driven turnover, four felt that management steps would be warranted in cases of human driven translocation, with one explicitly stating that they had in fact performed management actions in such cases.

M-21: *If a species is moved by humans into a new area we will actively try to remove it again. We have a lot of examples of that, we've spent money on that. It's very difficult to succeed with such an approach, but we do it.*

Four of the eight researchers did not feel negatively about the possibility of climate change driven turnover, with many feeling it was a natural process.

SR-25: *If for some reason a new species is able to survive in an area now that it couldn't before, I think that's life. And to put a lot of management efforts into avoiding that, I think that's a bad solution. There are so many other things to use limited resources on.*

Four felt negatively about the process, but two did not feel that management was warranted and would be futile.

> ***SR-19:*** *I would also feel that it was nothing we could do, and accept it, and try to focus on something else... because it would be very difficult to artificially keep other species alive in systems which isn't suitable for them any more.*

All researchers felt negatively about the prospect of translocation driven turnover. Of the six who did not feel that management action should be taken to avoid climate change driven turnover, all six felt that it was appropriate to combat translocation driven turnover.

> ***SR-16: ...****obviously if there is a human introduction, then I would view that more negatively … with human induced temperature increase, that would be a pretty strong concern, but then with a direct introduction, that would be even more of a concern, because we have the knowledge, to know that we shouldn't really do that, that that will mess up the natural ecosystems.*

Discussion

Ensuring that there is correlation between the views of scientific researchers, managers and the general public is critical when implementing conservation strategies. This is especially the case when the strategies involve complex and controversial subjects, such as the interacting effects of non-native species and climate change (Pecl et al. 2017). Here, we aimed to identify possible causes of disconnect between these different groups in their perception of the interacting nature of climate change and non-native species and their subsequent impact on freshwater ecosystems. Our analysis shows that attitudes vary within and between managers and researchers to the impacts of non-native species when they are in part driven by climate change. However the same impacts are almost unanimously negatively viewed by a public group - in this case recreational fishers - with the influence of climate change on the nature of the non-native species having very little effect on their opinions.

The most prominent contrast between the groups was the fishers' response to climate change driven turnover compared to that of the managers and researchers. While there were conflicting feelings about climate change driven turnover among the managers and researchers, the prospect was unanimously rejected by recreational fishers. Although some admitted they would be more angry if human translocation were the sole culprit, many stated that they would view the presence of a non-native species and/or the loss of native species negatively regardless of whether or not climate change had influenced the outcome. Many felt that management action should be taken to prevent such turnover wherever possible.

513 This lack of consensus between groups is not unexpected, as instances in which
514 there are disagreements between local stakeholders who are directly impacted and
515 managers and researchers are far from uncommon (Redpath et al. 2013; Manjarrez-
516 Bringas et al. 2018).
517
518
519 Contrast in the impacts and management of non-native species and climate change
520 was present within groups as well, most notably among managers and scientific
521 researchers. While most felt negatively about the process, there was a variety of
522 opinions in both groups regarding whether or not management action should be
523 taken. While some supported removal, many felt it would be futile - even in cases
524 where lack of removal would result in a local extirpation - while others felt it would be
525 unwarranted even if removal were possible. This is unsurprising, as dialogue
526 regarding the concept of range-shifting species is often polarised (Shackelford et al.
527 2013). However it does suggest a lack of consensus on a management issue that
528 may become more pressing in the coming decades. Open dialogue between
529 managers and scientific researchers at this stage could help establish consensus on
530 the management of the impacts of non-native species and climate change early,
531 which could substantially aid management going forward (Pecl et al. 2017).
532
533 The unanimous rejection of new species by fishers was often mentioned in
534 conjunction with the new species having little or no perceived value as a food
535 resource. Further investigation into how heavily this factors into decision-making is
536 warranted, including whether perception would shift if the incoming species had
537 more in common with preferred species, such as the previously introduced species

brook or lake trout. Familiarity with a species has previously been shown to affect public perception of them as non-native or not (Kochalski et al. 2019), and emotion can often play a larger role than rationale in shaping opinions on fish as a food resource (Verbeke et al. 2007). While pike does not appear to be a preferred food-fish in Norway, it is well-regarded elsewhere in Europe (Linhart et al. 2002). Qualitative studies in areas where species have been established for longer periods of time may shed more light on the role of the public's familiarity with non-native species in their reaction to them.

Similar contrasts between groups on the perception of climate change driven turnover are reflected in the definitions of non-native species across the different groups. While it featured in the definitions of over half both the managers and researchers, method of introduction was generally not addressed by the fishers in their definition of non-native species. Furthermore, although several fishers acknowledged that climate change would likely alter nearby ecosystems, only one alluded to the possibility of new species arriving. This could be a result of a lack of knowledge regarding the effects of range shifts as a product of climate change, or an association of non-native species as primarily being a product of human translocation.

Given the global restructuring of ecosystems that is currently taking place as a product of climate change gradually altering species ranges, more open communication between all three groups should be a priority for anyone concerned with conservation of ecosystem management. Going forward, perhaps the most notable area of disconnect between the groups is the question of whether

563 management actions should be taken to prevent the impacts of non-native species,
564 even when such impacts are driven by climate change. The reluctance to commit
565 resources to stopping such impacts among managers and researchers compared to
566 the insistence that such management was required by the fishers represents the
567 most obvious source of potential future conflict. Previous research in marine systems
568 has suggested that fishers do not tend to automatically link climate change to the
569 arrival of new species (van Putten et al. 2016), and that educating public
570 stakeholders is crucial in the success of future policy regarding climate change and
571 range-shifts (Nursey-Bray et al. 2012; Pecl et al. 2017). Further communication
572 between the public and both managers and scientific researchers regarding the
573 interacting effects of climate change and non-native species could therefore be a
574 useful preventative measure, and make management actions more widely supported
575 in the future.
576

577 ## Acknowledgements

578 The authors would like to thank Bastian Poppe for his help translating the interview
579 guide into Norwegian and performing several interviews. We would also like to thank
580 Rachel Paterson, Rune Knudsen and Karolyn O'Connor for their help in creating our
581 initial pool of respondents. We would also like to thank Brooke Deak and Karin
582 Beland Lindahl, whose comments were valuable in rewrites of the manuscript. Sam
583 Wenaas Perrin was supported by a PhD grant from the ERA-Net BiodivERsA project
584 ODYSSEUS (Norwegian Research Council 266574).

Data Availability Statement

Extended responses from all respondents are openly available at https://doi.org/10.5281/zenodo.3991516.

Author Contributions

SP and CL conceived the idea. SWP, CPW and CL designed the methodology. SP and AGF sourced the initial pool of respondents. SP collected and analysed the data. All authors contributed critically to the drafts and gave final approval for publication.

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