A social and ethical game-changer? An empirical ethics study of CRISPR in the salmon farming industry

Abstract: The genome editing technology CRISPR is described as a technological game-changer because of its flexibility and precision, and as an ethical game-changer due to its ability to engineer traits in living organisms without crossing species, avoiding a significant objection to GMOs. In salmon farming, applications of CRISPR in breeding hold the promise of handling environmental and fish welfare challenges yet require social acceptance. Adopting an empirical bioethics framework, this stakeholder interview study shows that respecting species borders is important, but not decisive, for acceptance among Norwegian stakeholders. The main objections are based on moral reflections about technology use and outcomes. These reflections combine principles and pragmatic deliberations of moral costs and benefits, suggesting that CRISPR applications with environmentally and ethically significant benefits can be socially acceptable. This indicates that the game-changing potential of CRISPR relies on the characteristics of the editing and the context in which the application takes place.

Keywords: Genome editing, salmon breeding, animal ethics, social acceptability

CRISPR – A GAME-CHANGER IN ANIMAL BREEDING?

The novel genome editing technology CRISPR holds the potential to change the landscape of animal breeding in agri- and aquaculture because it is cheaper, more versatile and more precise than previous genetic modifications (GM) technologies (Hallerman et al., 2022).

Hence, it is often presented as a biological and technological game-changer. By 'game-changer' we understand it as a newly introduced element that significantly alters established perceptions and practices. In the past, GM technologies have been met with scepticism by European populations (Gaskell et al., 2011). However, in contrast to other GM technologies, CRISPR does not require the insertion of foreign DNA and enables rewriting of the genetic code, thus altering the traits of any organism. Since no transfer of genetic material between species is needed, one of the main public objections against GMOs appears to be met, and on this account, CRISPR is sometimes also presented as an "ethical game-changer" (Schultz-Bergin, 2018, p. 222). There are therefore high hopes that this technology will be positively received by the public (Yang and Hobbs, 2020).

However, in the growing literature, there is still relatively little to be found on the ethical challenges and implications of using CRISPR in breeding animals and its public acceptance (Bartkowski et al., 2018, p. 173; de Graeff et al., 2019; Middelveld et al., 2023; Schultz-Bergin, 2018, p. 222). Policy reports, scientific literature and guidelines for risk assessment regarding the regulation of genome editing in agriculture tend to focus on plants (Ciabatti, 2021; Friedrichs et al., 2019; Okoli et al., 2021). Among the research revealing aspects of public acceptance concerning the use of CRISPR on animals, results vary between low (Yunes et al., 2021) and higher acceptability (Gatica-Arias et al., 2019; Tadich, 2022), depending on the objectives used or traits targeted. More research is thus needed to understand the ethical and social implications of using CRISPR on animals. Although domesticated salmon raises some special ethical issues due to its impact on wild relatives, it is at the same time a suitable case, since it is the only animal with an approved GM variety. In addition, fish are at the forefront of the use of CRISPR on animals, with multiple varieties already approved for commercial production (Matsuto and Tachikawa, 2022). As CRISPR is

implemented in breeding strategies, society, industry and regulatory authorities must take a stand on acceptable uses.

Recent years have seen a growing interest in empirical ethics, understood as "methodologies that seek to use empirical data about stakeholder values, attitudes, beliefs and experiences to inform normative ethical theorising" (Davies et al. 2015: 1). Our study seeks to contribute to this field by answering two questions: What are the main ethical concerns among stakeholders regarding the use of CRISPR in salmon farming, and is CRISPR a social and ethical game-changer, and if so, under which conditions will it be accepted by the public?

INDUSTRIAL SALMON FARMING IN NORWAY: CRISPR AS A CONTROVERSIAL KEY

One area that exemplifies both the opportunities and challenges brought forth by CRISPR is industrial salmon farming. Seafood is frequently pointed to as an important part of the transition to a more sustainable food future (Bogard et al., 2019). Norway has ambitions to become the world's leading seafood nation, and Atlantic salmon (*Salmo salar,* hereafter: salmon) plays a key role in reaching this goal (Ministry of Trade, Industry and Fisheries, 2021). However, several challenges with regard to animal welfare and ecological impacts stand in the way of further expansion (Afewerki et al., 2022). The farmed salmon frequently suffer from viral and bacterial disease and salmon lice infestations, the treatment of which causes suffering and pain (Sommerset et al., 2022). One of the most important environmental threats of the industry is escaped farmed salmon, which breed with the wild populations, leading to genetic introgression and potential viability constraints (Bradbury et al., 2020; Grefsrud et al., 2022; Thorstad et al., 2021). In 2021, wild salmon was listed as a threatened

species in Norway for the first time (Hesthagen et al., 2021), where a major cause is the impact of escaped farm salmon (Thorstad et al., 2021).

CRISPR holds a potential solution to environmental and welfare challenges in salmon aquaculture. There is ongoing research using CRISPR in salmon to induce sterility in farmed populations to eliminate the negative impact of escapees (e.g., Güralp et al., 2020; Wargelius et al., 2016) and induce resistance against parasites and diseases (Barrett et al., 2020; Nofima, 2021a,b). The potential use of CRISPR in salmon farming presents a paradigmatic case for the consideration of using CRISPR on animals in general: On the one hand it might solve substantial welfare and environmental problems, but on the other it raises questions about th moral and social acceptability of changes brought about by this novel technology.

THEORETICAL APPROACH: EMPIRICAL BIOETHICS AND ANIMAL ETHICS

Discussions on GM have been going on for decades, involving principled normative discussions as well as empirical studies of public opinion. There is a vast collection of philosophical literature discussing questions of moral status, animal welfare, integrity, animal rights and which duties humans have towards them. This general literature forms the basis for analyses of the ethics of GM animals (Bovenkerk, 2020; Ormandy et al., 2011). The other, empirical, approach to these questions seeks to map stakeholders, including laypeople, opinions and attitudes towards the use of GM and, in later years, genome editing technologies. This literature shows important public concerns, such as safety for humans and environment, the absence of benefits, uncertainty and unintended consequences, and social, moral and ethical issues as well as a lack of trust in relevant actors and institutions (Frewer et

al., 2004; Frewer, 2017; Kamrath et al., 2019; Lassen et al., 2002). Former empirical studies have shown that consumers are generally skeptical towards GM animals, among other reasons because of concerns surrounding environmental hazards, animal welfare and integrity (see, e.g., Behgin and Gustavsson, 2021; Bredal, 2003; Frewer, 2003; Grunert et al., 2001; Han, 2007; Marques et al., 2014). This refers to the understanding that the crossing of species in GM technologies is morally wrong and represents qualitatively new risks (Lassen and Jamison, 2006).

Philosophical work in this area has supplied a rich and nuanced debate of key topics in animal ethics and the ethics of biotechnology, including some of those central to the concerns of non-academic stakeholders. Likewise, empirical studies of stakeholder opinions provide important background material for ethical analyses and the regulatory debate. There is, however, still a need for more work in bridging the gap between the normative and descriptive to understand what is at stake ethically and socially in using CRISPR to alter the characteristics of animals such as domesticated salmon. This may provide important input for researchers, the industry and regulatory authorities in countries with salmon farming, as well as the general discussion on biotechnology in animal breeding.

The data gathered in this study are interpreted according to an empirical bioethics framework, which seeks to fill the gap between the philosophical and the empirical in its ambition to provide normative analysis that is grounded in lived experience (Ives et al., 2017). Since qualitative research methods, in addition to providing insight into what people's opinions and values are, can uncover the reasons and reflections behind these opinions (Ives, 2008), they can provide us with narratives and understandings with which we may think better about complex moral issues (XX 2022). Recent years have seen a rise of empirical bioethics

research in medical ethics that uses qualitative research methods, but there is a need for the further development of these methods for bioethical issues that arise outside the field of medicine (de Vries 2009; XX 2022, 10). This article follows Persson and Shaw (2015) and XX (2022) in defending the relevance of qualitative research methods in animal ethics, hence contributing to a broader thematic scope for empirical bioethics.

According to the dominant approach to animal ethics, the question that needs to be settled to determine how we ought to treat animals is their ability to suffer (Singer 1975). However, as de Vries has argued, this does not seem to capture what is at stake in the question of GM, since such concerns move beyond welfare and health (de Vries 2009, p. 5-6). Theoretically, CRISPR could be used to eliminate the farmed salmon's ability to feel pain altogether, apparently removing welfare challenges, but this is a morally problematic quick fix (Thompson 2010). By studying how stakeholders in different kinds of salmon-related practices reflect on the use of technological approaches to solve environmental and welfare challenges in salmon aquaculture, we aim to identify normative reflections and insights in the stakeholder responses. This may help us determine what is morally at stake when we want to figure out whether we should use CRISPR on farmed salmon.

In the following, we first describe our study design. We then proceed to present the study's findings about participants' moral deliberation on potential uses of CRISPR in farmed salmon. We analyse the key normative arguments by relating them to central contributions within environmental and animal ethics and indicate areas for further normative analysis.

METHODS

The study was conducted as part of a larger research project about conditions for the social and moral acceptability of genome-edited salmon (YYY). The study design includes qualitative semi-structured interviews with stakeholders in the salmon farming industry. Professional stakeholders were interviewed individually, while lay stakeholders were interviewed in focus groups.

Recruitment of participants

Table 1 shows the number of participants from each professional stakeholder group and the lay focus groups.

Relevant *professional stakeholders* were those directly or indirectly involved in the salmon farming industry in Norway, including people working with the protection and/or management of nature and wild salmon, and those conducting research on genome editing in, and/or the health of, fish. Thirty-eight individuals within these groups were invited to participate, and 19 accepted the invitation.

Participants in the *focus group* interviews were recruited from different regions in Norway by the market analysis company IPSOS, seeking maximum variation according to age (18-80), gender, ethnicity, and geographical location. For one group, individuals with Sámi background were recruited in addition to these criteria. All focus group participants received a compensation of 500 NOK (43 Euro).

The interviews

The interviews covered both personal experience and reflections related to salmon and its welfare, genome editing, and the sustainability of salmon farming. A semi-structured interview guide (Flick, 2009, p. 150) was used to help structure the interviews, but the order and wording of questions and probes were flexible and used to encourage participants to express their views freely and in their own words.

The first theme, *the salmon*, was introduced by asking informants to discuss their thoughts about salmon as an animal. From there, reflections on fish welfare and differences between fish and terrestrial animals were prompted. For the second theme, *genome editing,* participants were given a short, popularised description of what CRISPR is, and how it has been used thus far in research. Participants were then asked to reflect on possible advantages and/or disadvantages of genome editing the farmed salmon, and express their views on CRISPR technology compared to the older GM techniques. For the discussion about *sustainability,* we asked participants to describe what sustainable development meant to them and how this would relate to using genome editing in the salmon industry.

The professional stakeholder interviews lasted for about an hour and were conducted by the first two authors. The focus group interviews were moderated by the first two authors, with representatives from IPSOS solving practical matters and taking notes. The focus groups lasted between 1 hour 10 minutes, and 1 hour 37 minutes.

All interviews were audio recorded and transcribed verbatim.

Thematic analysis

The interview transcripts were coded in two rounds following standard social science principles (David and Sutton, 2011, p. 338-61), including both deductive and inductive approaches. First, pre-decided index coding was used to thematically organise the data in accordance with the themes of the research questions and the interview guide, such as 'View on salmon', 'View on CRISPR'; 'View on GMO'; and 'Sustainability' (Coffey and Atkinson, 1996). In a second, more inductive round, we focused on additional themes that emerged from the data during analysis, such as 'Wild salmon and sustainability;' 'Intrinsic value of farmed salmon' and on specifying considerations addressing, e.g., 'Sterility', 'Size and quality'. The coded segments were then analysed by meaning condensation (Brinkmann and Kvale, 2014, p. 231-235), resulting in a list of statements that were categorised into the following themes: concerns regarding the CRISPR technology; concerns regarding the wild salmon and the environment; concerns regarding the farmed salmon; and views on potential uses of CRISPR technology. This study has two first authors, who conducted the analysis in collaboration with the third author. The two rounds of coding were done separately in NVivo by the two first authors, and differences were thoroughly discussed between them and the second author until consensus was reached.

Since this is an empirical ethics study aiming to uncover opinions and arguments relevant for a broader normative debate, differences between professional stakeholders and focus group participants have not been considered relevant and have therefore not been analysed.

The Norwegian Agency for Shared Services in Education and Research (Sikt) was notified before the sampling and use of personal information (Sikt reference number 707095). All stakeholder participants signed a declaration of consent. IPSOS AS arranged a standard declaration about GDPR and data management with focus group participants.

RESULTS

The difference between CRISPR and GM

A narrative that was both affirmed and challenged in interviews and focus groups was the idea that CRISPR is a more natural technical tool than older GM technologies or less natural than traditional breeding. The idea of "naturalness" is, as one scientist pointed out, "highly debatable". Some participants saw CRISPR as the natural next step in breeding technologies, a "fast track of the natural selection", while others questioned its radicalness. As we saw in the introduction, CRISPR is frequently differentiated from older GM technologies through the fact that it does not require crossing species. The less invasive character of CRISPR, it was argued, leads to organisms with traits like those found in nature, e.g., with disease resistance and sterility. This was highlighted as important in the interviews. Indeed, several participants expressed concerns about crossing species. For example, one of the wild salmon management participants stated that "genetics makes us who we are", signalling that inserting genes from other organisms would make the salmon into something that it is not today, although one fish health researcher indicated that crossing different salmonid species would be more acceptable than crossing with less related species.

The elimination of the need to cross species is a qualitative difference between the two generations of technologies that was positively received. The crossing of species borders was rejected by most participants, with some saying that it is "unnatural" and breaches fundamental orders of nature. For instance, one scientist argued that applications of CRISPR should copy the order of nature:

> If we use genome editing to just, you know, change the genes in the animal so that they are like these naturally resistant animals, then I am very comfortable with it. [...] Whereas if someone […] made a protein that just chopped the sea lice or something like that and inserted this into the gene for the salmon I would be very uncomfortable with it because it's not something that is naturally occurring.

But since this no longer is an issue with the advent of CRISPR, a space is opened for exploring other concerns. Objections against CRISPR tended to unfold in objections about *how* the technology will be taken into use and for which purposes, raising concerns about the complexity of the intervention, the possible risks involved, and differences of degree rather than in the idea that altering an organism's genes is morally wrong in itself. For instance, a fish health worker argued that we should not change genes that would not mutate naturally, as this increases risks. Some scientists also pointed out the risk of reducing the genetic diversity in the farmed stock, thus reducing its resilience. Here, in the words of one scientist: "[…] we don't want to stop with one edited fish and lose all the genetic variation that is in the population." Concerns about our ability to predict unforeseen effects were also raised by several participants. One of the scientists captured this worry with a compelling metaphor:

> When you start thinking about making a salmon resistant against viral attacks, there are so many genes being upregulated and downregulated and signal pathways going here and there and criss-crossing, so it might be as if we were to take a city metro map in London or New York, throw it on the table and shut down one station and think it would only affect the green line and then you see oh shit, something happened in the orange and purple line that we had not thought of.

What is objected to is not so much the intervention in itself but the scale of it. In line with these concerns, several participants considered it reasonable to seek other solutions before applying genome editing. For example, it was argued that the pens should be fixed to avoid escapees altogether, with some pointing to land-based facilities as an option. Rather than designing a fish that takes up nutrition better, we should think about what kind of feed we are offering, another participant argued. One participant from wild salmon management said that genome editing should be a last resort:

> If we are to start genome editing to adjust the load we have imposed on the farmed fish, then I think that [for] Norway, with its wealth, there are other measures which should be applied. For example, we could be more modest, maybe. Halt the development a bit, change the modes of operation. It could cost us a bit more to produce one kilo of salmon, but that salmon fares better. And it will have a smaller environmental footprint, that's my main thoughts on that. This may be the reason I am a bit against applying genome editing. […] Something tells me it is for our profit we do it, we won't starve if we stop producing a million tons farmed salmon, I think we could produce a bit less.

Many emphasised that other solutions ought to be sought before considering CRISPR. As one NGO stakeholder pointed out, making the salmon more disease resistant still leaves the conditions that caused it. Similarly, making the salmon sterile does not reduce the number of escapees, even if it prevents interbreeding with wild stocks. Escapees will still compete with wild species for resources. This was therefore a good example of "symptom-treatment", which was strongly discouraged. However, given the reality of how the industry currently works, halting development and designing escape-proof pens were seen as unrealistic

suggestions – as one participant pointed out, since there are currently no economic sanctions on escapees, the industry has little incentive to fix the problem. Considering this, solutions that could improve the status quo for the environment and fish welfare were positively received. In the following, we discuss the reflections about both points respectively.

We see that, although there is still a widespread scepticism towards crossing species borders, staying within the species is not sufficient for the acceptance of CRISPR. 'Naturalness' is not primarily a metaphysical concept (Kaiser, 2009), but an umbrella term expressing concern about complexities of nature and a certain distrust of scientific knowledge and competence in handling unforeseen risk and uncertainties. One implication is that the virtues of humility and temperance are called for when employing technologies in biological and environmental systems, supplementing Sandler's (2007) environmental virtue theory. He states as a rule that "a particular technology should only be supported if there are reasons to believe that it will not disrupt the integrity of natural and agricultural ecosystems we depend upon." (Sandler, 2007, 126).

The wild salmon and the environment

While many participants confirmed the potential benefits of using genome editing technologies on farmed salmon, concerns about potential negative impacts on ecosystems, and particularly on wild salmon stocks, were widely shared. A general principle emerged that genome editing should not be used to obscure or enhance the negative impact on welfare and nature that the salmon aquaculture already poses in Norway. Environmental concerns were often expressed rather vaguely, for instance, by merely contrasting the environment to the laboratory and arguing that while experiments in the lab can be conducted in isolation, it is important to "keep nature clean". "What will happen […] if the technology is released in

nature?" one participant asked. In general, participants could point to few worries about specific events and negative impacts; rather, they seemed concerned about unforeseen effects on ecosystems and impacting nature in general. In keeping with this, some participants argued that a genome-edited salmon should be kept away from any possible interference with the surrounding environment and only be produced in land-based facilities. Significantly, these discussions tended to diverge from the confined case of genome edited salmon and raise questions about the sustainability of industrial salmon farming in general. If we raise concerns about whether a genome edited salmon can lead to a negative environmental impact, we should keep in mind that these concerns are also relevant for the farming industry in its current state, it was argued.

Notable in these discussions was the fact that questions of animal ethics and welfare are embedded in broader concerns about the value of biodiversity, the value of untouched nature and the intrinsic value of ecosystems, in keeping with central tenets in environmental ethics (Vetlesen 2023, 117-118). The greatest concern among stakeholders was the possible consequences of having genome-edited salmon escaping from the pens and impacting the wild salmon populations through interbreeding. Some participants described the wild salmon as "iconic" and an important species in Norwegian culture that Norway has a responsibility to preserve. Part of this "iconic" status is precisely that the wild salmon is an untouched animal, partly mystical to us with its ability to find its way back to the river in which it was born. This ability becomes even more marked by the stark contrast to farmed salmon, which cannot compete with this impressiveness. Some participants were eager fishers in their leisure time and had a significant relationship with wild salmon. Among the participants with a Sámi background, several pointed to the important role the wild salmon plays in their culture, and

among these participants, industrial salmon farming was by many seen as a threat towards these traditions.

Since a sterile salmon can contribute to protecting ecosystems by avoiding the genetic introgression into wild salmon, many participants found it possibly acceptable to use CRISPR for this purpose. Among all the possible applications of CRISPR that were discussed, this was the one most positively received. Even in cases where participants were sceptical towards using CRISPR on general grounds, they saw this, under the current conditions with a growing salmon farming industry, as a possible application in which the benefits would trump the potential costs. This is in line with our finding from the section above, namely that there is a certain pragmatism involved in the moral reflections about what kind of uses of genome editing people are willing to accept.

The farmed salmon

The other main concern about implementing CRISPR was how it will affect fish welfare on the farms. It was a shared view that applications of CRISPR on farmed salmon must be consistent with a good treatment of the salmon: "Obviously if you generate a farmed salmon that is worse off, this will not be acceptable," one scientist stated. Some made stronger demands that CRISPR should not only keep the status quo but must actively improve the welfare of the salmon: "[…] it must be clear that the positive effects are significantly larger than the negative, it has to be significantly bigger", one advisor argued. In line with this, benefits must relate to fish welfare rather than to increasing growth and production intensity in the salmon industry. Avoiding diseases and lice infestations were frequently pointed to as examples of alterations that may have considerable benefits, but concerns were raised that genome editing the farmed salmon might have a negative impact on welfare that we cannot

currently foresee. This supports our findings from the sections above, where concerns about possible side-effects are dominant, despite the assurance that CRISPR is a more precise technology than older generations of GM technologies. From wild salmon management, a warning was issued: "How will that affect the salmon lice as a pathogen to the wild salmon? We know very little about that," thus concluding that "making fast changes might not be very wise." When speaking about animal welfare, participants defended a broader notion that not only included the absence of pain and disease, but also allowing the fish to be able to perform their natural functions and live a good life. This is in line with the understanding of animal welfare as involving three different paradigms, emphasising (1) animal health and functioning, (2) the animals' mental states and (3) the connection between the animal and its environment, where animals should be able to perform species-specific behaviour (Gjerris 2015).

Participants were asked about their thoughts on the intrinsic value of the farmed salmon in relation to the use of CRISPR. This was a complex question to address, as 'intrinsic value' was seen as a difficult concept to define. While many participants argued that use of CRISPR must not infringe upon the intrinsic value of the salmon, they had diverging understandings of what this requirement means. For an NGO stakeholder, for example, respecting the intrinsic value of the fish is in principle incompatible with industrial salmon farming in its current state, and possibly all fish farming:

> [The intrinsic value] is clearly not being taken into consideration at all. [...] The Animal Welfare Act says that the individual and species-specific needs of the animals should be taken into consideration. And that is just nonsense. There is such a big contrast between the law, which has some really nice phrases, and we can be proud

> and say we have one of the best phrased animal welfare acts in the world. […] But it is allowed to keep animals in tight spaces that in no way satisfy their individual and species-specific needs. And farmed salmon is the worst example. Things are bad for agricultural animals too, but it is somehow particular to fish that they are not really considered to be animals at all.

Other participants also argued that domestication on some level interferes with intrinsic value, since the animal is designed to fit our needs. In these discussions, the interviewees would compare the intrinsic value of the farmed salmon to that of the wild ones. It became clear that some of the participants found that the wild salmon has a higher status than the farmed, and some participants even argued that it has a higher intrinsic value. However, the "lesser value" of the farmed salmon does not imply that anything goes in terms of what should be allowed, and genome editing should not change norms for acceptable treatment. One salmon farmer commented that "[...] breeding has been going on for centuries, so it has affected the intrinsic value of the animal." Still, he argued that "I think that even if the animal has been gene modified, you have to show respect for it." Even though its status was lower than that of the wild salmon, some argued that our responsibility for the farmed salmon might be higher than the responsibility we have for the wild salmon, since it is we who have brought it into existence. This understanding of moral responsibility as relational is recognisable in important contributions to animal ethics (Palmer 2010; Palmer 2018). Salmon farmers noted a high concern for the well-being of the farmed salmon, and a fish-health worker described it as "painful" whenever there is a health issue in one of the pens. As s/he put it: "I'm supposed to be there for the fish. It sounds weird to say it out loud, but it is an animal, and it has feelings, and it shouldn't feel any pain and [it should] be ok, and that is our job." In other words, respect for intrinsic value was related to the well-being of the salmon and a respectful

treatment of it, which is not necessarily incompatible with genome editing. This also echoes Marianne Lien's (2015) analysis of how care and compassion play significant roles in the reorientation towards fish as sentient beings in regulation and salmon farming practices.

DISCUSSION

Game-changer?

Some study participants maintained that even without crossing species, applying CRISPR involves a risk of off-target and unintended changes. These are concerns that are close replicas of what were important themes in public opposition to GM when first introduced (see, e.g., Lassen and Jamison, 2006), and these have been a key theme throughout the debates about GM (Frewer, 2017). This suggests that the qualitative difference between GM and genome editing, which is highlighted among proponents, is met with some suspicion among these study participants. The argument that "Precise edits do not necessarily result in precise outcomes" (Friends of the Earth NGO, as cited in Bain et al., 2020, p. 266) well summarises what was also brought forward in our interviews. The concern for potential unforeseen and irreversible consequences, which the original GM technology has been met with, also maps onto CRISPR. On the other hand, the flexibility of CRISPR in providing valuable solutions for real problems that concern sentient beings and affect valuable and threatened species and environments suggests that this novel technology does destabilise the debate. Not because it is fundamentally different, but because it shifts the balance between benefits and risks. This suggests that its potential in becoming an ethical game-changer lies more in its capacity for solving the extrinsic concerns with environmental and welfare harm and less in its ability for altering characteristics within the species barrier (Schultz-Bergin, 2018).

Deliberating risks, benefits, and morality

In research about public acceptance of GM technologies, moral objections about naturalness are often cited as grounds for rejection, due to conflicts with religious and other fundamental values, such as protection of the order of nature (Lassen et al., 2002; Lassen and Jamison, 2006; Scott et al., 2018). Moral values are found to be more important than other causes of concern (Frewer et al., 2004), and Scott et al. (2018) argue that morally-based opposition is treated as an absolute, exempt from consequence-based trade-offs, where information about risk and benefits has little impact. This position questions the rationale of the research on public attitudes towards gene technologies, which focuses on rational predictors of opposition, such as weighing benefits against costs and risks (Bruce, 2017; Kamrath et al., 2019). Our findings indicate a mean position where stakeholders can integrate a normative evaluation with a nuanced deliberation of risks and benefits.

While hardly any reference to religious principles was presented in the present study, ideas of nature as a self-organising system that should not be tampered with seemed to underlie the uneasiness about the uncertainty and unpredictability of using CRISPR. However, it was an overarching characteristic that study participants reflected pragmatically about specific costs and benefits associated with using genome editing in salmon farming. Even some who expressed a strong morally-based opposition did not insist on rejecting the technology altogether, but appeared to accept that a specific weighing of risks and benefits concerning CRISPR was unavoidable. As Frewer argues (2017), not all technologies to be used in agriculture are rejected, and similarly in the interviews, not all uses of CRISPR were rejected. The critical views on the salmon industry's potential aims and gains seem to express a strong

view that genome editing should be accepted only when seeking to obtain aims that are for the good of the environment, the wild salmon, or the health and wellbeing of the farmed salmon. This is in line with earlier research, which found that citizens maintain that genetic technologies should only be used to promote societal goods, not individual benefits (Bugge, 2020; Gatica-Arias et al., 2019; Lassen et al., 2002; NBAB, 2020; Yunes et al., 2021).

There are several explanations for this pragmatism, but with respect to our material, it is unlikely that it is simply because CRISPR has a less invasive character or because time has passed since GM technologies were originally introduced, making them more familiar. Studies from over ten years ago found that the lack of benefits was the most important reason for the rejection of GM food (Gaskell et al., 2004, Magnus et al., 2009, Gaskell et al., 2011). One factor may be that most participants acknowledge the inevitability of the salmon farming industry and are willing to accept some trade-offs to preserve the environment and the wild salmon populations. The fact that the crossing of species raised more severe opposition in the interviews may suggest that the pragmatic approach is reserved for CRISPR. Another explanation is that crossing species borders increases the complexity of the intervention and thereby increases risks. Given that acceptability depends on the relation between risks and benefits, increased risk would require much more significant benefits.

Responsibilities and relationships

According to Singer (1975), our treatment of animals ought to be determined by their moral status, which is settled based on capacities. For Singer, it is the ability to suffer as such that matters, and it is bad for whoever experiences it. On this model, we have no reason to distinguish between farmed and wild salmon, since they share an equal ability to suffer.

Palmer (2018), however, argues that special relationships, such as domestication, give extra responsibilities beyond those based in the animal's capacities. Similarly, Hursthouse suggests that we consider the appropriate virtues and vices in play in those specific relationships (Hursthouse, 2012). She argues that settling treatment based on moral status alone undermines the range of features that may be morally relevant in decision-making (Hursthouse, 2012, p. 121). Our study points to a few such relevant features. While the wild salmon is perceived to have a higher moral status than the farmed variety, this does not correspond to higher duties in terms of care. It seems more appropriate to say that the argument implies that wild salmon should be respected, whereas the domestic is subject to our care. We have a higher responsibility for the farmed fish because of our relationship to them as their domesticators, placing them in this vulnerable state. Settling the questions of moral status and intrinsic value might not be the appropriate approach to determining our treatment of animals; rather, considering contexts and relationships might be a more fruitful approach.

Ethics in context

The aim of empirical ethics is to use qualitative research data to provide a basis for arguments with relevance for the ethics of genome editing animals. In the present study, the responses suggest that farmed and wild salmon make different and occasionally competing claims on us: On the one hand, we ought to make sure the farmed salmon live as good lives as possible, but on the other, we ought to preserve wild salmon in its pristine state, and since they share the same environment, situations might arise where we cannot uphold both, as demonstrated in the case of the sterile salmon. Therefore, we argue that genome editing animals sharpens the need to develop our understanding of what respectful, compassionate and caring treatments of animals involve in different situations. In the cases brought up in the interviews, participants'

reasonings about these questions were highly context-dependent, adding specific conditions for use. This underlines the difficulty in abstracting normative principles, which can be applied to other animals in other contexts, and suggests that further research into this topic needs to deliberate risks and benefits in a context-sensitive manner, addressing what a virtuous treatment of animals and the environment will involve in different situations. Structuring the analysis in terms of virtues and context-sensitivity does not imply a rejection of principle-based approaches to animal ethics, such as utilitarianism and deontology, as these approaches also have room for context-sensitivity and virtues; instead, it suggests that we need to take both capacities and context into consideration in order to give a fuller account of animal ethics (Palmer, 2018, p. 18).

CONCLUSION AND PERSPECTIVES

CRISPR can be a social and ethical game-changer because its applications can reduce harm to the environment and salmon welfare caused by the industry. This is, however, perceived as benefits by several of the respondents, assuming that a radical reform of this industry is unlikely. Although the avoidance of crossing species barriers is considered positive, scepticism concerning interventions in the complexities of natural systems appears as more important. Thus, this is not a principle-based acceptance of CRISPR.

From the stakeholder reflections discussed above, we can unearth three lessons relevant for the ethics debate, moving from farmed salmon to the use of CRISPR on other animals. For some, concern with ‘naturalness’ captures the significance of the complexities of nature and a certain distrust in scientific knowledge and competence in handling unforeseen risk and uncertainties, calling for virtues such as humility and temperance. Questions of animal ethics

and welfare are in many cases embedded in broader concerns about the value of biodiversity, the value of untouched nature and the intrinsic value of ecosystems, and they should not be isolated from these broader concerns. This underlines the significance of care, compassion and respect as appropriate ways to relate to salmon according to how we encounter them – in captivity or in freedom.

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TABLES

Table 1 Interview groups with the number of interviews per group. For focus groups, the number shows the number of groups x and the number of participants per group.

Groups	**Number of interviews**
Scientists using genome editing in fish	4
Trade union participants	2
Salmon farmers	4
Fish health workers	3
NGO participants	2
Advisory body participant	1
Sámi resource management	1
Wild salmon management	2

Focus group Norwegian	3 x 6 participants
Focus group Sámi Norwegian	1 x 6 participants