

Genome editing – a game-changer in salmon farming: Conditions for social and moral acceptance (CRISPRsalmon)

1. Relevance relative to the call for proposals

Fish farming is the most important Norwegian bioeconomy industry, having great impact on the social and natural environment on the coast over the last decades. The basis for this production of biomass for food is the salmon, an iconic animal of high significance in Norwegian culture and history. One promising approach to a more efficient and sustainable production of salmon leading to higher value creation in aquaculture, is using genome editing, such as the CRISPR technology, for precise changes to the genetic basis of relevant salmon traits. However, unless these changes are introduced in a socially and morally acceptable way, promised improvements and solutions cannot be utilised. This project aims to determine the acceptability of genome edited salmon through an empirical ethics approach combining descriptive and normative studies.

The proposed project is particularly directed towards the fourth target of the call, concerning ‘cultural conditions and social ramifications’, as it will generate new knowledge about the moral and social acceptability of bioeconomically relevant developments of biotechnology for aquaculture, using a virtue ethics approach requiring engagement with the cultural conditions of everyday moral judgements. It is also relevant for the first target, ‘technology and solutions’, as it engages directly with the present and future possibilities of using technology to change salmon traits rather than adjusting its environment for overcoming obstacles in salmon farming. In addition, the project addresses the third target ‘consumer and market aspects’, through a qualitative study of public opinions on genome edited salmon. Thus, the proposed project is highly relevant for this call, at the intersection of the research programs BIONÆR, HAVBRUK, BIOTEK2021 and SAMKUL.

In order to answer our research questions, we have set up a relevant interdisciplinary research team supported by a network of national and international experts and industry representatives. The proposed project will contribute new knowledge to the international academic debate on several topics, notably animal ethics. The research team will develop a virtue ethical approach for analysing our obligations towards fish like salmon, entities with disputed moral status. It will also contribute to methodological discussions on empirical ethics. The knowledge generated is highly relevant for the aquaculture industry and other industries within Norwegian and international bioeconomies aiming for the use of genome editing for increasing sustainability and efficiency. By thematising ‘non-safety’ aspects of emerging biotechnologies (Zetterberg and Björnberg 2017), this project will also inform policy-directed debates and contribute to responsible governance. It has a concrete plan for dissemination and for the engagement of users.

The proposed project is a large-scale Responsible Research and Innovation (RRI) study of genome editing in salmon, in accordance with the RCN RRI framework. It is *anticipatory* in the study of potential future applications of genome editing, *inclusive* in engaging public and stakeholder values and opinion, *reflexive* in addressing the socio-technical complexities of aquaculture innovation and *responsive* in drawing up policy recommendations for genome editing in salmon farming.

2. Aspects relating to the research project

Background and status of knowledge

Among the key factors for successful salmon farming are healthy animals that have good lives and that the farming practises have low environmental impact. It is generally recognised that fish have the ability to feel pain and suffer, something that is reflected in the Norwegian Animal Welfare legislation and in mandatory welfare courses for all employees in aquaculture. One way to avoid suffering, health and environmental problems is by altering unwanted characteristics of the salmon. This is not new, as one of the reasons for the successful salmon aquaculture, is systematic breeding ensuring a fast-growing, healthy animal with a temperament suited for the life in pens. Today, the hopes for targeted changes to salmon traits are much better through the recent possibilities opened with genome editing, especially through the use of the CRISPR system. This causes challenges, as the aquaculture industry in Norway has been negative to any use of genetic modification due to public resistance to this technology. It is an open question whether this resistance also will encompass genome editing. However, even if the public can accept genome edited salmon; another

question is what kind of changes are *morally* acceptable. This brings us into the field of animal ethics. In this project, we will explore how to understand the social and moral acceptability of using genome editing in salmon breeding to solve the challenges for a more effective and sustainable salmon farming.

The salmon - an iconic animal

Salmon plays a significant cultural role in Norway, giving it a unique status, as is evident from the Norse and Sami mythologies, folk tales and its status as luxury food (NOU 9 1999). Historically, the salmon has been revered for its strength, freedom, beauty, intelligence and reliability by the different peoples inhabiting coastal Norway. Thus, it is among the iconic species of Norway, where an iconic species is understood as one with particular cultural significance, in the sense that they are useful, attractive or entertaining for humans (Small 2011). Recent research on migration patterns (Ulvan et al. 2017) and the genetic diversity of salmon connected to different river systems (Skaala et al. 2005), as well as the perception of it as cunning and strong add to the status of the animal as something special, and it is considered as “a symbol of Norway’s identity and enjoyment of the outdoors” (NOU 9 1999: 18) emphasising the cultural significance of the more recent angling culture. The combination of these old and new interactions with the animal gives the salmon a strong cultural status in Norway, fuelling the criticism of the growing fish farming industry. Today the total catch and the number of people who engage in subsistence sea and fjord fishing of salmon is sharply decreasing (Liu et al. 2011), and the restrictions on harvesting through river angling has become increasingly heavy (Øian et al. 2017). Salmon aquaculture is seen as the main cause of this combined decline in number of fish. There is more at stake than environmental harm and reduced catch. Salmon farming has altered how we interact with the salmon, and thereby its cultural and moral status. As Lien (2015) has described, aquaculture is enacting salmon in novel ways, for example as biomass and as sentient being. Our claim is that although salmon is not a fixed entity, all different ways of “doing salmon” is connected to this iconic status and this status has definable normative implications for how it is acceptable to behave towards the salmon.

Moral status and empirical ethics

A common assumption in animal ethics literature is that common sense morality accords fish little moral significance because humans lack the basis for empathizing with them due to their coldness, lack of facial expression and relatively inaccessible habitat under the surface of the sea (Børresen 2000, Michaelson and Reisner 2018). However, this is not necessarily the case for all species of fish, such as the salmon, as we have seen above. Humans have a complex moral relationship with iconic species. Dominant theories of animal moral status connect this status to mental capacities (Singer 1975, Regan 1985, McMahan 2005). There still are no conclusive evidence of fish sentience and intelligence, although the likelihood is increasing (Braithwait 2010, Allen 2013, Woodruff 2017, 2018). Even if there are sound reasons for giving fish the benefit of the doubt (LaFollette 2017), the discussion of the moral standing that should be accorded them on the basis of the current knowledge is hotly disputed (Bovenkerk and Meijboom 2012, Woodruff 2018, Michaelson and Reisner 2018). The dominant theories in animal ethics are ‘abolitionist’ (Francione 2008, 2018) and would mean the end of any form of fish farming. Welfarist positions, on the other hand, take for granted that it is not wrong to kill and eat animals, as long as it is done with proper concern for their well-being. They explore what constitutes welfare for these animals, which are highly species dependent although based on general principles (Applebye and Sandøe 2002, Huntingford et al. 2006). Animal welfare can be defined in different ways, for example as concerning a) the metabolic and physiological state of the animal, b) the animals’ subjective experience of its conditions, or c) whether an individual or as a population can lead a natural life and maintain itself within its natural habitats (Berqvist and Gunnarson, 2013, Lund et al 2007). In this project, we will seek a middle ground between abolitionism and pragmatic welfarism, grounding our moral duties in relationist, virtue-based approaches (Diamond 1978, Scruton 1996, Burgess-Jackson 1998, Hursthouse 2000, 2006, Gruen 2015). These approaches are capturing a broader notion of human moral responsibility for animals, emphasizing the moral significance of interactions, and they are not reducible to capacity-based approaches (May 2014, Grimm and Aigner 2016). These approaches open up for the value of empirical ethics in animal husbandry, studying the actual human-animal interactions and how to justify them morally. The integration of empirical data in normative studies has been subject to theoretical developments the last couple of decades, especially within bioethics (Ives et al. 2017, Ives et al. 2018). One dominant approach in animal ethics has been the ethical matrix (Mepham 2000). This has been employed in studies of fish farming (Grigorakis 2010), and for studies of GM fish (Bremer et al. 2015). It is a valuable

tool for structuring discussions, but will provide a more restricted access to lay opinions compared to studies based in standard qualitative studies. In the present project, the core group of researchers have been involved in a series of empirical ethics projects, and we will use this experience and recent theoretical work as basis for developing the methodology further.

Genome editing of salmon

Modern fish farming had not been possible due to technology developments in the use of hatcheries, net pens, fish feed, feeding stations, medication, harvesting methods, processing and breeding. A key factor to the continuous growth of the fish farming industry has been the development of effective fish vaccines (Berg et al., 2006), and breeding programs initiated in the 70s for enhancing growth, age of sexual maturity, disease resistance and quality. Today, the most significant problem is sea lice, which is also a threat to the non-domesticated salmon and a source of pollution and non-target effects due to chemical and pharmaceutical treatment (Torrissen et al. 2013). In addition, so-called escapes has been a continuous problem, with documented effects on the genetic variety of the wild salmon stocks (Ferguson et al. 2007). A solution to several of these problems may be altering salmon traits through the use of gene technology (Iversen et al. 2016). However, although gene technology has been used in recent breeding programs, as marker-assisted breeding approaches, the Norwegian fish farming industry has been explicit in its resistance to use of genetic modification, and states that the growth efficiency of the Norwegian farmed salmon makes the fast-growing American GM salmon uninteresting for Norwegian production. The market prospect of GM salmon is also poor in Norway (Mather et al. 2016). However, there are signs that genome editing may be a game-changer, as it can be used precisely to change genotypic characteristics and opens up a wide range of possible utilisations (Doudna and Charpentiere 2014). There is research indicating that public resistance to GM is related both to the kind of benefit the modification gives as well as the kind of genetic intervention (Gaskell et al. 2010, Mielby et al. 2013, Edenbrandt et al. 2018). Genome editing arguably opens for interventions that could be perceived by the public as more natural since the genetic change is small (NBAB 2018). There are currently a range of studies using genome editing in fish for basic research purposes (Zhu and Ge 2018), and in applied research, such as the sterile salmon (Wargelius 2016).

The question is whether using genome editing on salmon is socially and morally acceptable for solving the challenges causing loss, environmental harm and preventing further expansions of Norwegian salmon farming, especially considering its iconic status.

Approaches, hypotheses and choice of method

The primary research question for the proposed project is:

What are the conditions for a socially and morally acceptable use of genome editing for a more sustainable and efficient salmon farming?

It is not sufficient that genome editing is technically possible and can contribute to solving some of the present challenges of an expanding salmon aquaculture. The technology must also be socially acceptable, in the sense that most people find it to be justifiable. This is obviously important for keeping and expanding the market for the products, as social acceptability also means consumer acceptability, but it is as important for the legitimacy of the industry. Norwegian aquaculture is economically important, but the industry has significant privileges and is regularly criticised for its negative environmental impacts and for the way the multi-faceted domestication of the salmon is undermining the value also of 'wild' salmon. Thus, the legitimacy of the industry is precarious, and changing the salmon through technology must have public support. Genome editing can be considered a form of genetic modification, which has been regarded with scepticism by the Norwegian public, adding to the relevance of this study. It is likewise necessary that genome editing of salmon is morally acceptable, in the sense that it can withstand significant moral criticism. If not, the technology should not be used, even if most people support it, simply because it is wrong. An additional reason is that if it is morally unacceptable, the risk is that it will eventually become socially unacceptable because those who oppose it will have convincing arguments.

The secondary research questions that will be answered in dedicated work packages are:

1. What changes through genome editing is feasible, now and in the future, in the pursuit of a more sustainable and efficient salmon production?
2. What ethical issues do such interventions raise?
3. How are the moral value of salmon and the virtues in interacting with it presented in academic studies and public documents?
4. How do the representatives of public and people who interact with the salmon through subsistence fisheries, leisure fisheries and fish farming evaluate genome editing of salmon, and what kind of genome editing, if any, do they find to be acceptable?
5. What kind of genome editing of salmon is morally acceptable, given a virtue ethical framework based in the concept of animals as fellow creatures?

Approach: empirical virtue ethics based on qualitative studies

To answer our research questions, we have established an interdisciplinary project group and intend to apply a mixed set of theoretical and empirical methodological approaches, including literature studies, and qualitative methods within a general virtue ethical framework, taking departure from the concept of animals, including salmon, as our fellow creatures. Virtues are concerned with good or admirable ways of acting and living, and are descriptions of certain inner traits, attitudes and dispositions of individuals (Baron et al. 1997: 177). In animal ethics, this means we must determine the right attitudes or ways of relating to animals.

A virtue-based approach to industrial farming holds that ‘the practices that bring cheap meat to our tables are cruel, so we shouldn’t be party to them’ (Hursthouse 2006: 143). Furthermore, a notion of animals as fellow creatures is not compatible with regarding them ‘as *stages in the production of a meat product*’ (Diamond 1978: 475). Diamond states that taking “animals as our fellows in mortality, in life on this earth (...) depends upon a conception of human life” (Diamond 1978: 474). Morality belongs to the human world, to a shared understanding of life and of how to live it – and we enrol animals in this moral interaction. This does not provide a set of criteria to decide acceptable behaviour towards animals or their moral status. It is an account of attitudes that should form our behaviour towards them, based in our relations with them. This means that the question whether it is acceptable to use animals, including salmon, for food cannot be finally settled on this account (Myskja and Gjerris 2016). In this project we will work under the hypothesis that the right attitude towards animals allows eating them as long as they have good lives, as Scruton (1996) argues.

Relevant animal related virtues include charity, justice, friendship, companionship, respect and pity (Diamond 1978). According to Lien (2015), several of the fish farming practices can be described as expressing care, demonstrating the relevance of this virtue. The virtues play out differently in different human-animal interactions, and that is why an empirical engagement with the virtues in salmon related practices is required to provide basis for an adequate moral analysis. Human experiences of animals are often accompanied by “a sense of astonishment and incomprehension that there should be beings so like us, so unlike us, so astonishing capable of being companions of our and so unfathomable distant” (Diamond 2003: 14). This is clearly the case with fish, and this is why mapping the way people who do interact with salmon will provide essential input in two ways: both to understand what kind of interventions in the salmon genome that are socially acceptable, and as empirical sources for analysing their moral acceptability within this empirical virtue ethics framework. This is a novel approach to the empirical studies of the ethics of animal related practices, which usually concern only welfare or integrity issues. In the proposed project these concerns will be part of a thicker conception of moral responsibility, capturing the complexities of human-animal interactions and integrating them in a systematic philosophical analysis. We will conduct several studies within this framework in order to answer the research questions.

Genome editing salmon – technological possibilities and ethical issues

There is a continuous drive to improve salmon by breeding. Gene technology enabled a more powerful method for identification of interesting genes and has been used in marker assisted breeding approached. Gene technology also enabled a more directed method for introducing novel traits in live organisms, and at present several fish species has been genetically modified. GM salmon has been approved in the USA, but has not yet been adopted in Norway or the rest of Europe. Recently, engineered nucleases have been developed and they can enable that new (trans- or cis-) genes can be inserted, or DNA sequences in the organism can be deleted. If new genes are not inserted, the DNA repair mechanisms may lead to a mutation causing reduced or loss of function of a specific gene. The CRISPR systems has achieved highest interest as

a genome editing tool since it is easy to design, produce and use. With these new techniques it is possible to develop fish that are resistant to pests and diseases (Zhu and Ge 2018). Other potential changes include enhanced growth, feed utilisation and tolerance to vegetable diet; adaptation to climate change; modified appearance e.g. to size and colour; changes to taste and nutritional content; and altered temperament and behaviour. Present and possible future applications of genome editing will be explored in the proposed project and will be investigated in relation to relevant ethical issues (Research question 1).

The moral significance of the salmon in Norway

Normative statements and judgements are formulated and expressed in philosophical works, in public documents, laws and regulations, in different practices and in conversations. In order to provide a broad background for a study of the social and moral acceptability of genome edited salmon, we will seek to map different normative accounts of how to interact with salmon as it is expressed in different Norwegian documents and academic studies (Research question 2). This is particularly interesting in light of the iconic status of salmon and the aquaculture controversies. These sources seldom engage *directly* with the issues of salmon moral status or discuss the virtues in interacting with salmon or in intervening in their life. The study will therefore consist in making an extract of the explicit and implicit moral judgements and arguments to make a map of the moral landscape, and will be structured according to the major issues, positions and arguments presented in the academic literature on animal ethics and in particular the moral issues in using modern biotechnology in animal breeding. The intention is to make an oversight over issues that will be crucial for the subsequent qualitative interview study and the moral acceptability analysis.

Public and stakeholder views on human-salmon interactions and genome editing

According to Naylor et al (2000) there are two important factors that distinguish domesticated from ‘wild’ salmon; ownership of the stock and the deliberate human intervention in the production cycle. Stakeholders in Norway use different argumentative strategy to invoke aspects of the moral standing of the salmon, indicating that the issue is much more complex. In order to map and analyse the different opinions and arguments of the public on moral responsibilities humans have in interacting with salmon and – on this basis – the acceptability of altering it through genome editing, we will identify and conduct focus group and individual interviews with representatives of the public and of sector stakeholders (Research question 3 and 4). Analysis of this material will give an overview over opinions and arguments that are relevant for the social acceptability of genome editing salmon. This study will differ from previous studies of public opinion concerning fish farming and use of biotechnology because it will highlight the novel possibilities of genome editing, and due to the empirical ethics approach, as the interviews are based in a mapping of moral concerns and will be integrated in an systematic analysis of moral acceptability. We are aware of the RCN Bionær funded *GENEinnovate* project, with planned studies of public opinion concerning genome editing in animal breeding. This project differs essentially from the present proposal in scope and approach. We will, however, ensure synergies with this project as the Biotechnology Advisory Board is involved in both projects.

Genome-edited salmon – moral acceptability

Relating the findings from the empirical studies to the virtue ethical framework and central issues in animal ethics, this part will consist in a philosophical analysis of the moral acceptability of genome editing salmon for human purposes (Research question 5). The study will take departure from the common morality understanding and justifications, and analyse them in categories derived from animal ethics literature. Thus, the concepts that will be drawn on are novel since they include both describing virtues in animal relations, such as care, charity, justice, friendship, companionship, respect and pity as well as issues concerning the state of the salmon. These are drawn from the classical animal ethics literature, and include welfare, needs, natural behavior, flourishing, integrity of individual animals, integrity of species and commodification. It will also concern the moral difference between classical breeding methods, and other new breeding techniques, including genome editing.

The novelty of this approach concerns both the topic and the approach. First, the project analyses the use of modern technologies in the process of domestication of an iconic wild species in order to make it suitable for a growing bioeconomic industry. Second, it combines empirical data from the public and stakeholders with systematic studies in animal ethics to provide a genuine empirical virtue ethics analysis. This is valuable for the international debate on animal ethics and the ethics of genome editing in aquaculture, for

methodological discussions in empirical ethics and for regulatory discussions concerning genome editing in fish farming.

3. The project plan, project management, organisation and cooperation

WP 1: Genome editing salmon – technological possibilities and ethical issues

What changes through genome editing is feasible, now and in the future, in the pursuit of a more sustainable and efficient salmon production, and what ethical issues do such interventions raise?

Activities:

- a) Identification of the spectrum of genome-editing techniques to be used on salmon today and in the future, and which challenges that can be solved by the use of these techniques, based on relevant scientific literature. This work will be contrasted with other breeding options.
- b) Identification of the ethical issues raised in the literature concerning genome-editing, genetic modification and conventional breeding in animals.
- c) Conducting a foresight scenario workshop with scientists working in salmon breeding and genome editing, based on the study in a). Here we will identify feasible applications of genome editing in salmon breeding, now and in the future, for a more sustainable and efficient salmon production, and discuss the ethical issues identified in b).

Anne I. Myhr is responsible for this WP in collaboration with Bjørn Myskja and Anna Wargelius. Task a) and b) will be carried out by the GenØk PhD student.

Deliverables: A description of 1) possible applications of genome editing for salmon, now and in the future, and 2) the ethical issues identified in the literature relevant for genome editing of salmon. This will provide background and input for WP 3 and 4.

WP 2. The moral significance of the salmon in Norway

How are the moral value of salmon and the virtues in interacting with it presented in academic studies and public documents?

Activities:

- a) A desk study of academic literature on animal ethics with focus on the projects identified moral issues.
- b) A desk study of existing scientific knowledge about public and stakeholder views on genome editing and related technologies, including a review of existing empirical studies of public and stakeholder views of gene technologies in general and in fish/salmon breeding in particular.
- c) A desk study of normative accounts on how to interact with salmon, with relevance for the use of gene technology and genome editing in breeding, as it is expressed in Norwegian sources: public documents, different media (newspapers, popular science articles) and in research (ethnographic studies, environmental studies etc.).
- c) Workshop on the topics of a), b) and c) with the animal ethics reference group and researchers on human-animal interactions, to provide external reflection and to supplement and structure the results of the desk studies carried out under a), b) and c).

Bjørn Myskja is responsible for this WP in collaboration with Anne I. Myhr and Jesper Lassen. The NTNU PhD student will carry out task a) and b).

Deliverables: An overview of 1) the general moral issues relevant for this project, 2) the current knowledge of public and stakeholder opinions on genome editing and related technologies in salmon breeding, and 3) the current knowledge of the different views on the ethics of human-salmon interactions. This will provide input to WP 3 and 4.

WP 3. Public and stakeholder views on human-salmon interactions

How do the representatives of public and sector stakeholders (professional and leisure) evaluate genome editing of salmon, and what kind of genome editing, if any, do they find to be acceptable?

Activities:

- a) An identification of the relevant populations. Apart from the public (citizens and consumers) relevant populations includes aquaculture sector stakeholders (professional and leisure) to be identified through a stakeholder mapping. This task will result in descriptions of the populations to be interviewed in the following tasks.
- b) Development of interview guides to be used in the focus group interviews with the public and in the individual interviews with sector stakeholders. The interview guides will be developed on the basis of the knowledge produced in task b and c.
- c) Interviews. Five focus groups with 6-8 participants in each group will be carried out with members of the public. As the aim is not a representative study, focus group participants will be recruited to ensure max variety in perceptions of the issues at stake, based on existing knowledge of which sociodemographic factors influence assessment of genetic technologies. Altogether 25 individual interviews will be carried out with the most important sector stakeholders identified in task a).
- d) Analysis. All interviews will be recorded and subsequently transcribed verbatim. The following analysis will include thematic coding using software such as NVivo. A further analysis of the codes using a simplified version of Toulmin's (2003) theory of arguments will be carried out. This analysis will focus on determining: 1) Practices involving salmon as well as moral status of salmon as among the interviewed populations, 2) Views and acceptance of genome editing technologies related to salmon among public and sector stakeholders and the values these perceptions are based on, and 3) Criteria that the different interviewed populations find must be met, if the GE salmon should be acceptable.

Jesper Lassen is responsible for this WP in collaboration with Bjørn Myskja and Anne Myhr. The two PhDs will carry out the four tasks, working closely with Lassen.

Deliverables: 1) Overview over a variety of salmon related practices and the accompanying views on the moral status of salmon. 2) Public and stakeholder views and reasons for accepting different applications of genome editing in salmon. 3) Criteria for acceptability of genome-edited salmon among representatives of the public and sector stakeholders. The deliverables will serve as input to WP 4 and for policy recommendations.

WP 4. Moral acceptability of genome editing salmon

What kind of genome editing of salmon is morally acceptable, given a virtue ethical framework based in the concept of animals as fellow creatures?

Activities:

- a) Development of an adequate empirical ethics approach based on the state of the art (Ives et al. 2018).
- b) Employ this approach on the issue of genome editing of salmon within the virtue ethics framework, and based on the input from WP1-4 develop an initial account on the conditions for moral acceptability of genome-edited salmon.
- c) Conduct a workshop with the project group, ethics reference group, collaborators from research and industry discussing this preliminary account.
- d) Develop an account of the moral acceptability of genome editing for salmon breeding.

Bjørn Myskja is responsible for this WP in collaboration with Jesper Lassen and Anne I. Myhr. Task a), b) and d) will primarily be carried out by the NTNU PhD.

Deliverables: 1) A virtue-ethics analysis of genome-editing of animals, with salmon as case. 2) A novel approach to empirical ethics, based in virtue ethics. 3) Criteria for moral acceptability of the use of genome editing in salmon breeding, to be used in policy recommendations.

Project group and management

The project leadership group consists of leading experts in relevant fields:

The main project manager, Professor *Bjørn K. Myskja*, NTNU has long experience in academic and project leadership and partnership from several interdisciplinary biotechnology and empirical ethics projects, and has published widely within these field. He will be involved in all the research tasks in the project, as supervisor for the NTNU PhD and co-supervisor for the GenØk PhD, and will ensure communication among project partners and be responsible for progress reporting.

The co-manager Dr. *Anne Ingeborg Myhr* is director at GenØk-Centre of Biosafety. She has long experience in project leadership from interdisciplinary biotechnology and nanotechnology projects. She will be involved in all of the work packages of the project, and be supervisor for the GenØk PhD student and co-supervisor for the NTNU PhD. She and Myskja has collaborated in several previous projects.

Principal Scientist *Anna Wargelius*, Institute of Marine Research, heads a leading research group on genome editing in salmon and will primarily be involved as project partner in WP1. She will also be consulted on genome editing throughout the project period and in the working out of dissemination material.

Professor *Jesper Lassen*, Copenhagen University, has wide experience within the sociology of food and agriculture, including interdisciplinary biotechnology research. He will be involved in WP 2, head WP 3 and be consulted in the other WPs, and participate in the three workshops.

Senior Adviser *Sigrid Bratlie*, Norwegian Biotechnology Advisory Board, is an expert within biotechnology research, particular within genome editing. She will be involved in WP1 and consulted in other WPs. She has a wide experience with dissemination and will be responsible for the arrangement of the three open meetings.

The leadership group will meet twice a year, for discussing project progress, preliminary results and advice the project managers.

In addition, the following has confirmed active participation in the project:

Dr. *Petter Arnesen*, Federation of Norwegian Industries, has 30 years' experience of working in management positions in the salmon farming industry (Marine Harvest). He will be particularly involved in WP 3 both for recruitment and information on the industry, but will be consulted in all WPs.

Merete Kristiansen is commercial director at Nordlaks, one of the major aquaculture concerns in Norway. She will provide industry perspectives to the project, especially in WP 3, and will help with contact to keypersons within industry.

The project has set up an international animal ethics reference group. They will be consulted on animal ethics issues and participate in the two last workshops. The group consists of Professor *Herwig Grimm*, University of Veterinary Medicine, Vienna; Assistant Professor *Bernice Bovenkerk*, Wageningen University and Associate Professor *Mickey Gjerris*, Copenhagen University.

Table 1. Project plan with milestones

Work package	2019			2020				2021				2022				2023
	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1
WP 1	ME			FS	OP	PB	PP		PB	VV						
WP 2	ME				WS		PB			PP	PB					
WP 3				ME	FG	FG	FG			PP	OP		PB	PB		PB
WP 4								ME		WS	PB	ME	OP	PO	PP	PB ²

WS= Workshop

FG= Focus group/interviews

FS= Foresight scenario

ME=Management/experts meeting

PB= Publication of academic paper

PP= Popular press publication

OP= Open meeting with Biotechnology Advisory Board

VV= Presentation at exhibition centre (visningsenter)

PO= Policy brief

National and international expertise and networks

CRISPRsalmon is interdisciplinary and involves national and international experts in biotechnology, moral philosophy and sociology in its core research group. In addition, it will involve primarily national, but also international experts on genome editing, animal ethics and bioethics in the planned workshops. This will ensure national networking within these crucial research areas for Norwegian bioeconomy.

Institutional expertise, infrastructure and resources

NTNU, the Department of Philosophy and Religious Studies has a strong applied ethics research environment. *Siri G. Carson*, head of the NTNU Oceans research project HAVANSVAR, and *Lars Ursin*, researcher on a number of interdisciplinary empirical research projects, has both confirmed their participation in the CRISPRsalmon project. The staff of the faculty and department is experienced in running RCN projects, and has the resources for supporting this project and provide the necessary infrastructure. The PhD will be enrolled in the Programme in History and Cultural Studies, which will provide a suitable environment for carrying out the research and the education elements of the PhD degree.

GenØk has an interdisciplinary research environment. Dr. Arinze Okoli, head of the RFF project Genome-editing in Norwegian Aquaculture, and Dr. Odd-Gunnar Wikmark the research leader of the genome editing group has confirmed participation in the project. Synergies will be found with the recent SAMKUL funded project ReWrite, which focuses on environmental ethics in relation to genome-editing. The PhD student will be enrolled at the PhD program at UiT-The Arctic University of Norway.

4. Key perspectives and compliance with strategic documents

Compliance with strategic documents

NTNU's strategy states as development goal for interdisciplinary research: "Take advantage of strategic research areas and enabling technologies to realize ideas and solve problems in society through interdisciplinary research projects", where one of the research areas is NTNU Oceans, with biotechnology as one of the most important enabling technologies.

GenØk became in 2007 the national competence center on biosafety. The main objective is to contribute to the safe use of biotechnology. The proposed project follows GenØk's commitment to an integrated approach to researching the safe use of emerging biotechnologies, and with two of its priority research areas: Biosafety of genome editing and Responsible and sustainable biotechnosciences.

Relevance and benefit to society

The project will generate more understanding about the social, moral and cultural values by the use of biotechnology and in particular on genome-editing, hence offer important knowledge for responsible As such, the project can positively contribute to sustainable use of modern biotechnologies within aquaculture as well as impact the implementation of the Norwegian Gene Technology Acts provisions on social, ethical and sustainability considerations, as well as ongoing European processes for promoting broader impact assessments (i.e. ethical and socio-economic considerations) of food biotechnologies.

Environmental impact

The proposed project aims to inform food and aquaculture biotechnology policy through articulating the cultural and moral issues are and may be affected by the use of genome editing on salmon. This new understanding may enable that new and emerging genome-editing techniques and products may respond more adequately to societal and environmental challenges.

Ethical perspectives

The proposed project will follow procedures for survey and interview methods set by the Norwegian Social Science Data Services (NSD) and GDPR. All people participating in interviews and workshops during the course of the project will be provided with details of project objectives and how the collected data will be treated, prior to the interviews and workshop. For the production and use of any video materials, permissions will always be sought in written form after a full disclosure on the intended use of such information.

Gender issues (Recruitment of women, gender balance and gender perspectives)

The co-manager is female. Additionally, the group of expert advisors has a 3:2 women to men ration and the employment of the PhDs will be undertaken according to the principles of equal opportunity. In the work involving stakeholders, the researchers will also be particularly attentive to attaining an appropriate gender balance, voice and presence.

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