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RESEARCH

The potential impact of sea lice agents on coastal shrimp in Norway: risk perception among different stakeholders

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Abstract
In this article, we investigate how the uncertain consequences of sea lice agents on the environment affect the management process, focusing on the coastal shrimp in Norway. In this context, the key stakeholders (shrimp fishers and aquaculture owners) have conflicting interests and understand uncertainty from different perspectives. We ask: (1) How do fishers and aquaculture representatives translate uncertainty into risk, and do they link uncertainty to the precautionary approach or not? (2) How is uncertainty dealt with scientifically and related to decisions made by the authorities? Finally, we address organizational aspects related to a "post-normal approach" and ask: (3) Is it possible to organize the risk assessment process differently, to ensure more effective and legitimate advice? In order to answer these questions, we understand these issues as post-normal ones, and lean on both Science and Technology Studies and Risk Governance theory. We use a mix of social scientific methods including literature review, participatory observation, and semi-structured interviews. Our findings indicate that since the effect of sea lice agents is an uncontrollable problem ridden with uncertainty, science alone is insufficient, calling for a more participatory approach.

Introduction

In Norway, there are numerous coastal zone stakeholders with claims that are often competing. This includes representatives of the different primary industries and the tourist sector, scientists, government agencies, NGOs, universities, and firms (Hersoug and Johnsen 2012). In this context, the aquaculture industry is a key player, generating opportunities as well as challenges (Sandersen and Kvalvik 2015). On the one hand, the aquaculture industry is considered an important employer in rural regions, a sustainable source of protein in a world with growing demand for food, as well as Norway's "next petrol," essential to maintain the country's welfare level (Olafsen et al. 2012; Almås and Ratvik 2017). On the other hand, powerful images and stories of how Norwegian fjords are destroyed by the aquaculture industry have caused highly politicized debates and pose a threat to the industry's legitimacy (Sterud 2016; Friends of the Earth Norway 2016).

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In this context, the governance of the coastal ecosystems, with its complexity and intrinsic uncertainties, presents a formidable series of challenges. This is a characteristic shared by other complex contexts where uncertainty is a persistent issue, such as food safety (Jasanoff 1990), nuclear power (Wynne 1989), and climate change (Shackley and Wynne 1996). This is, at least in part, because uncertainty opens for a variety of interpretations and can become a political battlefield for different interest groups (Wachinger and Renn 2010). How people translate uncertainties into risk or not, and what they consider appropriate actions to take, are important issues to address in developing an effective and legitimate management. Due to contexts influenced by political as well as cultural matters, uncertainties and unknowns may be perceived as a threat or risk for some stakeholders while for others, they may rather be considered opportunities (e.g., Renn 1998). In this article, we focus on two key stakeholder groups in the coastal zone, shrimp fishers and aquaculture representatives, and their different views with regard to the aquaculture industry's use of chemicals to limit salmon sea lice infestations on wild salmon. Furthermore, we address the view and advice of the main advisory body in this context, the Institute of Marine Research (IMR).

At the governance level, the identification of risk is often considered a technical matter, where political and cultural considerations are left to subsequent stages in the management process. This understanding of risk is quite universal across

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institutions (Scott 2016). There are, however, many circumstances where the risk of a given threat goes beyond a strict definition of uncertainty, where possible outcomes and probabilities are difficult or impossible to quantify. This is demonstrated by a substantial body of social science research, where risk identification also turns out to incorporate values, politics, and assumptions. Here, we are particularly interested in the insights from Science and Technology Studies (STS) (e.g., Jasanoff et al. 1995; Funtowicz and Ravetz 1993) and the Risk Governance literature (e.g., Klinke and Renn 2002). Within the post-normal science (PNS) tradition in STS, it is argued that science alone is not enough to face issues where "facts are uncertain, values in dispute, stakes high and decisions urgent" (Funtowicz and Ravetz 1993: 187). In this view, a more democratic approach is needed. In line with this perspective, the potential impact of sea lice agents on coastal shrimp in Norway represents a situation where "traditional" risk assessment methods become problematic and less applicable, as uncertainty may not be reducible. The conflict between the industries of shrimp fishery and aquaculture, and the conflict's ramifications, thus serves an interesting starting point to investigate how uncertainty is dealt with in a post-normal management context.

In the following, we investigate how uncertainty is perceived to constitute risk, and whether the risk perception leads to the call for action among different stakeholders. Scientific uncertainty is a term that covers a broad range of ways and qualities of not knowing (Scott 2016). For some issues, the uncertainty can be controllable through a "normal science" approach, and statistical, quantitative methods and models are useful without any other tools. Other issues are too complex, and the uncertainty may be uncontrollable (Funtowicz and Ravetz 2003: see also Bjørkan and Hiis Hauge 2019; Strand and Oughton 2009; Wilson 2009). The term risk typically refers to a situation where it is possible to confidently quantify both the magnitudes of and the probabilities for a defined range of outcomes (Wachinger and Renn 2010). How we understand uncertainty is key to how Risk Governance is organized, because "just as dominant views of knowing are co-produced with systems to govern the known, dominant understandings of uncertainties are co-produced with systems to govern what is not known" (Scott 2016). Accordingly, risk management is also an epistemological issue. This means that the answer to the question of how to manage the unknown is highly dependent on how risk is understood; as objective and quantifiable where knowledge gaps can be filled in line with a positivistic viewpoint; or value-based and uncontrollable in line with a relativistic, post-normal viewpoint (van der Sluijs 2012).

In dealing with risk, decisions will evolve around the appropriate actions to take. In the following, we relate action to the implementation, or rejection, of the precautionary approach as a principle used to benefit the environment when there are conflicting values and interests at stake. To investigate the uncertainty complex involved in the use of chemicals to limit salmon sea lice infestations, we ask: (1) How do fishers and aquaculture representatives translate uncertainty into risk, and do they link uncertainty to the precautionary approach or not? (2) How is uncertainty dealt with scientifically and related to decisions made by the authorities? Finally, we address organizational aspects related to a "post-normal approach" and ask: (3) Is it possible to organize the risk assessment process differently, to ensure more effective and legitimate advice?

Conceptual framework

The governance of complex issues such as coastal zone management is typically solved by risk analysis (Wachinger and Renn 2010). This process often includes the three steps of risk assessment, risk management, and risk communication (Wachinger and Renn 2010). If the identification of risk is based on purely technical measures and hence understood in a positivistic perspective as objective and measurable, the cultural and political considerations only enter at the management stage. However, from a postmodern and relativistic viewpoint, identification of risk necessarily precedes the risk assessment phase and is inevitably formed by values, politics, and assumptions. Accordingly, the issue of framing is imperative, as this "encompasses the definition of the respective problem and the setting of the terms of reference for the assessment" (Dreyer and Renn 2008: 108). With the terminology of Funtowicz and Ravetz (1993), controllable problems represent reducible uncertainty where agreement and consensus on norms are settled. Here, normal scientific risk analysis can be sufficient. In situations with uncontrollable problems and irreducible uncertainty however, where there is no consensus and little agreement on norms and standards, simple probabilistic risk analysis or standard statistical methods are not able to fill all knowledge gaps (Strand and Ougthon 2009).

For the purpose of our discussion and in line with Funtowicz and Ravetz (1993), we differentiate between controllable and uncontrollable uncertainty. When faced with uncontrollable problems where the uncertainty is irreducible, it becomes necessary to emphasize stakeholders' participation and reflexive science (Funtowicz and Ravetz 1993). Reflexive science refers to the importance of explicitly addressing and discussing the choices of research, and the ways these choices affect uncertainty. Furthermore, reflexivity may be relevant throughout the process from problem formulation to decision, in making choices about what knowledge is relevant to understand a problem, what indicators to use as well as how to map and handle uncertainty. This requires the inclusion of stakeholders or even the general public in risk assessments, and not only the scientific perspective of risk (Dreyer and Renn 2008; Wachinger and Renn 2010). A participatory approach can also solve, at least in part, the controversies concerning Risk Governance and the contested legitimacy of science in knowledge-based management (Jaeger et al. 2001; Wachinger and Renn 2010), as well as addressing "the mismatch between different knowledge and different interests of different stakeholder groups, including experts" (Wachinger and Renn 2010: 67). Referred to by Holm (2003) as Fishers Ecological Knowledge (FEK) research, an influential body of research has problematized the conventional scientific rejection of fishers' knowledge (e.g., Berkes 1999; Johannes et al. 2000; Neis and Felt 2000). Today, the argument that fishers' knowledge serves an important complement to scientific knowledge is widely accepted (Brattland 2013; Joks and Law 2016; Lauer and Aswani 2009; Mackinson 2001). Ensuring stakeholders participation is also considered to improve legitimacy issues (Wilson et al. 2003; Bjørkan 2011). Simultaneously, there are challenges related to stakeholder participation and knowledge co-production. These challenges regard, among others, the question of shared responsibility to ensure participation is more than lip service, (e.g., Linke et al. 2011), the classification of who the relevant stakeholders are, and how to properly address the vested interests and power differences involved (Buanes et al. 2004). Importantly, in line with Mouffe (2005, 2013), we question the assumption that participatory processes will result in consensus-based, win-win scenarios and argue that we must accept disagreement in decision-making processes.

Following PNS and Wachinger and Renn' (2010) "risk escalator," we argue that as the level of knowledge changes, so will the necessity of participation change. In situation with controllable uncertainty, science can deal with the issue alone. This picture changes gradually as more uncertainty requires more participation effort, varying from limited participation by those directly affected towards the inclusion of stakeholders representing the general civil society (see Wachinger and Renn (2010) for a more detailed description of the risk escalator). For this article, the notion of a gradual need for more participation with increasing uncertainty suffices. In PNS, the extended peer community is the proposed solution to deal with new problems with high uncertainty and high stakes (Funtowicz and Ravetz 1990; Wilson 2009). The extended peer community is primarily a different kind of quality control when traditional mechanisms are not adequate, and the situation requires open dialogue, different knowledge forms, and perspectives on the policy (Funtowitz and Ravetz 1990). Linking this to risk management, we add that it matters at which stage in the risk assessment process stakeholders are included: at the stage of risk identification, risk management, or risk communication.

Methods

The empirical data of this article is primarily based upon the 2016 consultation process, where the Norwegian Government suggested measures against adverse environmental effects of medical treatment against salmon lice (www.regjeringen.no). These data include the consultation document and the various relevant hearing letters, providing a window into key stakeholders' perceptions of delousing chemicals. These documents are all available online.[1] Furthermore, reviews of media sources and key policy documents are central data sources in this article. Particular focus is given to Fiskeribladet, the main fisheries newspaper in Norway (fiskeribladet.no), which is the key arena for the sea lice agent discourse, the national broadcaster (www.nrk.no), a web-based newspaper for national and international scientific news (www.forskning.no), as well as the Norwegian Governments webpage (www.regjeringen.no), the Institute of Marine Research (IMR) webpage (www.imr.no), and the eight Risk Reports[2] produced each year by the IMR since 2011. No articles published after August 2018 are included as data.

In addition, the article is based on data collected using a mix of ethnographic methods including participation during the annual Norwegian Reference Fleet meetings[3] in 2016 and 2017, participatory observation on board a shrimp vessel in 2016, and semi-structured interviews with shrimp fishers ($N = 2$) and aquaculture representatives ($N = 7$) in four coastal communities in Nordland County: Alstahaug, Brønnøy, Lurøy, and Rødøy (see Fig. 1) in 2016 and 2017. The interviews included multiple research topics beyond those in this article, and the interview guide was designed to elicit perspectives on changes in the coastal zone in general and over time. These interviews gave us reason to look into the use of sea lice agents as a post-normal problem and serve as background material that has been important in order to understand the different perspectives on sea lice prohibitors. All quotes from stakeholders referred to in this article are from newspaper articles or policy documents, however. The reason for this is twofold. First, we find that this material is rich enough; and second, the few shrimp fishers still operating along the coast of Nordland make it difficult to ensure their anonymity if quoted. The statements cited here are thus from shrimp fishers who actively engage in the public debate. Finally, two IMR scientists have been contacted by e-mail to ensure correct references to the IMR investigations. All citations included in the paper have been translated from Norwegian to English by the authors.

[1] https://www.regjeringen.no/no/dokumenter/horing%2D%2D-tiltak-mot-negative-miljoeffekter-av-medikamentell-behandling-mot-lakselus/id2505480/?expand=horingssvar

[2] https://www.imr.no/publikasjoner/andre_publikasjoner/risikovurdering_miljovirkninger_av_norsk_fiskeoppdrett/risikovurdering_miljovirkninger_av_norsk_fiskeoppdrett_2010/nb-no

[3] The Norwegian Reference Fleet is an IMR run project using fishers to collect data (see https://www.hi.no/temasider/referanseflaten/nb-no)

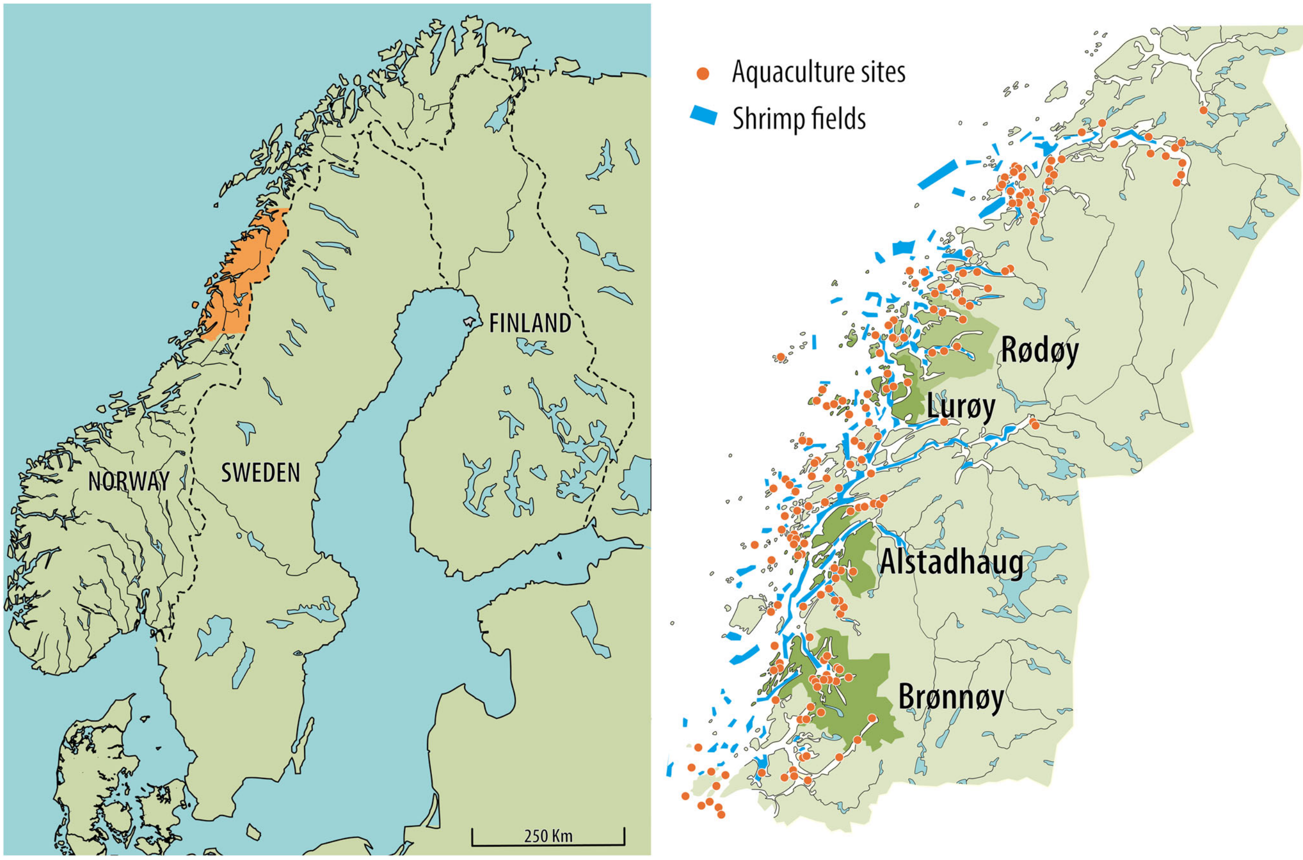

Fig. 1 Map of Norway and case study area, including aquaculture sites and shrimp fields in the municipalities of Brønnøy, Alstahaug, Lurøy, and Rødøy. As the figure illustrates, the location of shrimp fields and aquaculture pens often overlaps

Context

A sea of lice and the use of chemicals as a post-normal problem

Norway holds a particular responsibility to protect its wild Atlantic salmon populations as a measure of biodiversity conservation in a global context. About 1/3 of all Atlantic salmon spawn in Norwegian rivers, and Norway is a member of the North Atlantic Salmon Conservation Organization (NASCO). Hence, the Norwegian government has an explicit goal and international agreements binding them to ensure that aquaculture activity will not affect the wild salmon negatively (St.prp.nr.31 1982–1983). Currently, salmon sea lice are identified as one of the greatest threats to wild Atlantic salmon in Norway (Anon 2016), and the large amount of salmon gathered in the aquaculture pens has provided the naturally occurring sea lice with ideal conditions for expansion. To aquaculture firms, it is thus pressing to keep the number of sea lice under control, and strict regulations such as target limits of sea lice numbers are now in place to protect the wild salmon from sea lice infestation.[4] Here, a variety of mitigation measurements are utilized, such as fresh water treatment, wrasse as cleaner fish, mechanical removal, and chemicals. Chemicals against sea lice are applied as baths[5] or in the fodder.[6] In this article, we focus on the use of chemicals distributed in the fodder, more specifically chitin synthesis inhibitors targeting the shell production of the sea lice. As sea lice are a type of crustaceans, medicaments targeting their shell production may also target any other crustacean. The chitin synthesis inhibitors thus have the potential of effecting crustaceans like the Northern shrimp (*Pandalus borealis*) and Norway lobster (*Nephrops norvegicus*).

The use of chemicals in the aquaculture industry rose dramatically and peaked in 2009, when the sea lice became resistant towards several sea lice agents (Svåsand et al. 2017). Simultaneously, the Northern shrimp distributed along the coast of Norway received increasing attention in the media regarding their vulnerability to sea lice controlling agents from salmon farming.[7] While chemicals had already been used for

[4] See https://www.barentswatch.no/fiskehelse for an updated map over sea lice numbers. These numbers are reported to the Norwegian Food Safety Authority every week.

[5] Cypermethrin, deltamethrin, azamethiphos, hydrogen peroxide

[6] Teflubenzuron, diflubenzuron, emamectin benzoate

[7] See for instance Aftenposten, 2014 (https://www.aftenposten.no/norge/i/21xeR/Bruken-av-gifitige-lakselusmidler-eksploderer) and a large number of articles in the fisheries papers such as "Fiskeribladet fiskaren" https://fiskeribladet.no/.

delousing for years, with fishers voicing their concern both in the media and to the authorities,[8] warning calls did not hit Norwegian headlines before 2014. From 2015 and onwards, there have been a growing number of reports from fishers on declining abundance or disappearance of shrimp in their fishing grounds. Fishers relate this to aquaculture in general and the use of chemicals to treat sea lice in particular. They refer to how shrimps disappear from grounds where salmon farms are established nearby, while shrimp can still be found in areas with no salmon farms. Fishers contend to a direct link between the use of chemicals and the decline in shrimp stocks but worry about the lack of proofs available to support their experiences.[9] The aquaculture sector, however, questions this causation.[10]

In 2015, the IRIS research institute published experimental results proving that sea lice chemicals with flubenzurons caused high mortality in shrimp, among larvae as well as adults, especially during molting (Bechmann, to www.forskning.no, 2015). However, the scientists underlined the uncertainty of these findings, emphasizing how causes like climate change or alterations in shrimp locations may influence a decline in shrimp catches. Still, they expressed concerns: “we are surprised that a chemical with such a clear effect is allowed to be released in our fjords in such amounts” (Bechmann, to www.forskning.no, 2015). Also, the Directorate of Fisheries addressed the need for stricter regulation of the use of chemicals from 2015 (official webpage, 24.02.2015[11]). With regard to the use of flubenzurons, they announced that its use was not permitted on “localities where it is not considered environmentally accountable.”[12]

In representing the expert knowledge desired by the coastal management authorities for decisions to be made, the IMR considers it important to convey the uncertainty involved in linking sea lice chemicals to declining shrimp stocks along the coast. While the laboratory forms a controllable environment, the sea does not and may include several conditions that affect shrimp stocks such as climate change, river regulations, and overfishing (IMR scientist Søvik to NRK Nordland, 2017). The target limit of chemicals that causes shrimp death can be so low that they are not traceable by current laboratory methods, and the IMR has done laboratory tests demonstrating that shrimp exposed for a combination of toxins died even if it was impossible to detect toxin traces in the shrimp (Søvik in Sandvik 2018).

The issue of salmon sea lice chemical treatment illustrates a situation of uncertainty, complexity, unanticipated effects and conditions, knowledge gaps, and surprises that may be beyond control. According to Norwegian legislation, aquaculture regulation must follow the precautionary approach as part of achieving sustainable development (Nature Diversity Act 2009). The precautionary approach implies that uncertainty in knowledge should benefit the environment, in case of contradictions with other values and interests. According to Stirling (2007), the precautionary approach is not a specific methodology but a more general principle. It does not provide a precise protocol for how to derive at a precise understanding. Rather, it provides a general normative guide to policy-making under uncertainty, ambiguity, and ignorance, to let doubt benefit the protection of human health and the environment, rather than competing organizational or economic interests (Stirling 2007). For different stakeholders to reach an agreement on what amounts to the benefit of human health and the environment in a complex and uncertain context, however, is not straightforward. Hence, complexity and uncertainty have implications for the level of proof required in the management of sea lice chemicals (see also St.Mld.42 2000–2001).

The coastal shrimp fisheries and aquaculture farms in Norway

The aquaculture industry and the fisheries represent two of the main industries of coastal Norway. Since 2009, aquaculture has outgrown fisheries in economic terms (NSC 2018). In 2017, the farmed seafood sector exported for 94.5 million NOK (NSC 2018). In this context, Nordland is the leading aquaculture and fishery county in Norway in terms of production of farmed salmon as well as wild fish exported (KPB 2018). In the municipalities studied, the aquaculture industry is more economically important than traditional fishing activities.

In Nordland, the coastal shrimp grounds sustain a smaller fishery of only local importance, and only a marginal portion of the shrimp catches in Northern Norway comes from the coastal areas (IMR 2016a). While the Northern shrimp is well studied in general, the patchily distributed stocks along the Norwegian coast are poorly known and have received little scientific attention. The Norwegian coastal shrimp has neither been monitored nor assessed, and present stock status is unknown. Hence, there are knowledge gaps related to abundance as well as demographic and genetic structure of fjord populations, and to how the different shrimp grounds are interconnected (IMR scientists Søvik, pers.com., 2017 and Ellen Sofie Grefsdal, pers.com., 2018). The coastal shrimp is targeted by

[8] The Norwegian Fishermen’s Association sent the first letter to the Ministry of Trade, Industries and Fisheries demanding a full stop in the use of kitin synthesis prohibitors in 2011.

[9] https://www.fiskarlaget.no/index.php/nyheter-fiskarlaget-liste/arkiv-2014/item/forby-bruk-av-flubenzuroner

[10] See for instance Ystmark, 16 September 2015, in interview with Hagen JM. (2016) Ingen føre-var i havbruksnæringa. *Fiskeribladet.* https://fiskeribladet.no/nyheter/?artikkel=48982

[11] https://fiskeridir.no/Akvakultur/Nyheter/2015/0215/Tydeligere-miljoekrav-ved-bruk-av-lusemidler-i-oppdrett

[12] https://fiskeridir.no/Akvakultur/Nyheter/2015/0215/Tydeligere-miljoekrav-ved-bruk-av-lusemidler-i-oppdrett

the coastal fleet within the 12-mile zone. Only a few vessels are still targeting shrimp in the coastal areas of Nordland, however, and in 2017, the number was as low as 17 vessels (Godliebsen, pers.com 15.02.2018). In Norwegian coastal waters, fishing pressure for shrimp decreased in the beginning of the 1980s due to restructuring of the shrimp industry (IMR 2016a, b). Coastal landings declined and have since remained at a low level. According to The Norwegian Fishermen's Sales Organization, 17 vessels in Nordland County landed 171 tons of coastal shrimp with a value of 15.9 million NOK in 2017 (Godliebsen, pers.com., 15.02.2018). In the Helgeland region of Nordland where we carried out fieldwork, the shrimp catches fell 75% from 2014 to 2015 (Thonhaugen 2017). Accordingly, the shrimp fishery is small in terms of landings and economic aspects. Still, shrimps hold an important position in Norwegian cultural traditions as a especial treat in the summer months.

The aquaculture sector differs radically from the shrimp fishery. In the late 1960s and early 1970s, small-scale farming of Atlantic salmon evolved along the western and northern Norwegian coastline (Liu et al. 2011). In just a few decades, however, this emergence of the Norwegian aquaculture industry has grown to make Norway the world's largest producer of farmed salmon, with 53% of the global production (NSC 2018). While aquaculture constitutes an important economic activity, the industry is increasingly criticized for its negative impact on the ecosystem (Anon 2016). The industry is also railed against for negatively influencing other coastal livelihoods, like restricting fishers' access to fishing areas. Sometimes, these issues can re-enforce each other. While belonging to different sectors, the activities of aquaculture and shrimp fishers often take place in the same type of space: in the numerous fjords along the Norwegian coastline. Quite a few of the traditional shrimp fjords are now occupied by aquaculture pens, generating tension between the actors. The exact number of shrimp fjords is unknown due to a lack of data from the coastal zone (Søvik, pers.com. 2018).

In Norway, the Ministry of Trade, Industry and Fisheries is the main fishery authority, with the Minster of Fishery responsible for the fisheries policies. The Ministry is supported by the fisheries directorate, whose role is to "promote profitable economic activity through sustainable and user-oriented management of marine resources and the marine environment" (www.fiskeridir.no). The key advisory body is the IMR. While the fisheries management organization is quite straightforward, the management of aquaculture is a different story. There are several Ministries involved in the aquaculture management, including the Ministry of Transport and Communication, Ministry of Agriculture and Food, Ministry of Trade, Fisheries and Agriculture, Ministry of Local Government and Modernization, and the Ministry of Climate and Environment; and the decisions are delegated to three different management levels—municipality, county, and national levels (Robertsen et al. 2016). The management of aquaculture is exceedingly specialized, and the different authorities have veto-rights. One example is the aquaculture permissions, where the Food Safety Organization, the County Governor, the coastal guard, and the Norwegian Water Resources and Energy Directorate all have the power to veto decisions concerning aquaculture (Robertsen et al. 2016). The Fisheries Directorate and the Norwegian Food Authority Organization is the authority responsible for keeping the use of chemicals at an environmentally acceptable level.

Perceptions of sea lice agents use

In 2016, the Ministry of Trade, Industries and Fisheries started a consultation process to reduce the potential negative environmental effects of chemical sea lice treatment[13]. The measures suggested were considered by the Minister of Fisheries to be a precautionary action, stating that "[t]he use of different sea lice chemicals has increased, and it is now necessary to take on a precautionary approach" (NFD 2016).

The Ministry's consultation evolved around three main areas of measures: (1) prohibition of discharge of treatment water after medical treatment, (2) imposition of aquaculture firms to assess the risk of adverse environmental effects to a greater degree than today, and to incorporate risk-reducing measures in the treatment of salmon lice in their planning, (3) prevention of residue accumulation from chitin synthesis inhibitors/flubenzurons where such substances are used, through extending the interval between treatments from 3 to 6 months and require documentation of satisfying environmental condition of the benthos. Furthermore, the Ministry proposed a ban on the use of chitin synthesis inhibitors at sites closer than 1000 m from shrimp fields (NFD 2016) (see also Table 1).[14]

These hearing amendments were sent to the consultative bodies in 2016 including all Ministries, authorities, advisory bodies, and directorates as well as a large number of stakeholder organizations such as the Norwegian Fishermen Organization, the Aquaculture associations, and NGOs such as Bellona.[15]

[13] https://www.regjeringen.no/no/dokumenter/horing%2D%2D-tiltak-mot-negative-miljoeffekter-av-medikamentell-behandling-mot-lakselus/id2505480/

[14] https://www.regjeringen.no/no/aktuelt/strammer-inn-reglene-for-lusemiddelbruk/id2505478/

[15] For a full list, please see https://www.regjeringen.no/no/dokumenter/horing%2D%2D-tiltak-mot-negative-miljoeffekter-av-medikamentell-behandling-mot-lakselus/id2505480/

Table 1 Summary of suggested regulations in 2016 and regulations implemented after the hearing in 2017

Suggested regulations 2016	New regulation implemented from 2017
Prohibition of discharge of treatment water after medical treatment	It is not allowed to empty water added medicinal products against salmon lice from well boats in and near shrimp and spawning grounds (prohibition zones). Drainage shall take place at least 500 m from the fields.
Imposition of aquaculture firms to assess the risk of adverse environmental effects to a greater degree, and to incorporate risk-reducing measure in the treatment of salmon lice in their planning	The Directorate of fisheries, in cooperation with the Norwegian Food Safety Authority and the Environment Directorate will create guidance material. Both the prohibition zones and the guidance materials must be updated as the knowledge base is expanded.
Prevention of residue accumulation from chitin synthesis inhibitions (flubenzurons) where such substances are used, through extending the time interval between treatments from 3 to 6 months and require documentation of satisfying environmental condition of the benthos. Furthermore, the Ministry proposes a ban on the use of chitin synthesis inhibitors at sites closer than 1000 m from shrimp fields.	A minimum of 6 months between flubenzuron treatments. It is not allowed to use these types of chemicals closer than 1000 m to a shrimp area

The IMR: risk assessment must be based on data

The IMR official hearing letter to Ministry of Trade, Industries and Fisheries starts with a general comment on sea lice chemical effects on the environment:

> The IMR supports the measures suggested and considers it probable that the measures will contribute to reducing the environmental effects from sea lice agents used by the aquaculture sector (2016a: IMR consultative statement).

While clearly acknowledging sea lice chemicals to have environmental effects, the IMR moves on to emphasize the uncertainty aspect of the use of chitin synthesis inhibitors, and that more knowledge is needed. The IMR does not use the word uncertainty nor risk in the letter. However, they do mention the need for a precautionary approach with regard to the need to protect shrimp fields and suggest that aquaculture pens closer than a 1000 m from shrimp fields should not be allowed to use chitin synthesis inhibitors as a precautionary approach.

The statements presented through the hearing are supported and more substantially described in the IMR's yearly risk report. This report is requested by the Ministry of Trade, Industries and Fisheries on an annual basis. While several institutions and research agencies are involved in the report, the IMR is the responsible advisory body. The risk report forms the knowledge base describing what is known. It does not provide advice as such, and the report's risk assessment does not necessarily affect the advice, rather, it offers the Ministry of Fisheries a knowledge base upon which they can make decisions or request further research. In the risk report of 2017, the IMR states the following:

> In areas where the knowledge base is good enough, we make a risk assessment (Part 1), while we provide a knowledge update and initial assessments in areas where there is still not sufficient data to complete a risk assessment (Part 2) (Svåsand et al. 2017: summary).

In order to evaluate whether the concentrations found in animals will have a negative impact on their survival, the IMR points to knowledge gaps, i.e., in measures and the effect of long-term exposure. They conclude that with the current level of knowledge, it is not possible to make an adequate assessment. Accordingly, the IMR defines the situation as one where more knowledge is needed (Svåsand et al. 2017: 135). In their call for further research, the precautionary approach is not mentioned. This, we argue, may be founded upon a positivistic knowledge view, where uncertainty can be controlled and reduced through more knowledge. In official reports from 2011 to 2017, the IMR relates to sea lice chemical from a traditional "simple risk" perspective, rather than considering a post-normal problem demanding a different approach.[16] There is nothing extraordinary about this; it is the common way of approaching problems by advisory bodies. Still, Strand and Oughton (2009) point to how models of environmental or biological processes can cause uncertainties depending upon the assessment context, the type of information available to represent these processes, and the extent to which extrapolation is necessary.

The shrimp fishers: risk too big to be ignored

According to the Norwegian Fisherman's Association (NFA), in their hearing letter dated 30 September 2016, the

[16] Throughout the reports from 2011 to 2017, the risk report was organized the same way. In their latest report (February 2018), however, the risk report is organized a bit differently.

knowledge about chitin synthesis inhibitor impact on the marine environment is now sufficient to take action: “they should be completely taken out of use” (NSL 2016). As the official regulations still allow the use of these chemicals, NFA considers the stricter regulations suggested by the Ministry of Trade, Industries and Fisheries to be only a small step in the right direction. In their letter, NFA is quite clear in their critique of the regulations suggested. They seem to argue that the environmental sustainability is ignored on a general level:

> Both the Parliament and the Government have established that environmental sustainability should be the most important prerequisite for regulating further growth in the aquaculture industry. The Norwegian Fisheries Association argues that the use and discharge of sea lice agents (…) should have been included in this understanding of environmental sustainability (NSL 2016).

Correspondingly, the leader of Nordland Fisherman’s Association states to the media that “in the fisheries sector, we have always operated within the frames of the precautionary approach. There seems to be no trace of this in the aquaculture sector” (Fiskeribladet 2016). Hence, he relates this lack of action to an absence of a precautionary approach in the aquaculture sector and thus disagrees with the Ministry of Trade, Industries and Fisheries that the suggested regulations address the precautionary approach. Moreover, in their response to the hearing, the NFA underlines that neither the marine environment and species nor the coastal fishers are given priority by the suggested regulations (Table 1). In addition, they call for more knowledge and funds for knowledge production and question the lack of recognition of fishers’ knowledge in this context. They write:

> In the consultation note, it is underlined that the salmon farmers are those with the most relevant knowledge about the natural diversity in the area where the lice products will spread, and that dialogue with fish health professionals about this is important. The Norwegian Fisherman’s Association wants to address that salmon farmers and fish health professionals are not the only ones with expertise in the marine environment outside the pens. We are surprised that the fishermen’s experience and expertise are is not considered important (NSL 2016).

To the NFA, the suggested regulations are far from sufficient and hence will not “contribute to a substantially improved co-existence between the aquaculture actors and the fishers along the coast” (NSL 2016). The shrimp fishers’ livelihoods are directly affected by the decrease in coastal shrimp. According to the Fisherman’s Association Nordland, many of the aquaculture farms are located in shrimp fields or very close to these (Jan Fredriksen, in Fiskeribladet, 2016). As stated in the hearing letter:

> [The] Norwegian Fisheries Association wants a good and knowledge-based coexistence with other industries, not least the aquaculture industry. At the same time, it is a prerequisite that further [aquaculture] growth should not be at the expense of marine and fjord environments, wild stocks or operating conditions and profitability for Norwegian fishermen (NSL 2016).

To the fishers, there is a clear link between the use of chemicals by aquaculture farms and the declining catches and dead shrimp in their trawls. Hence, they translate the uncertainty involved into risk. To them, the lack of scientific evidence does not prove that there is no need for action, rather, they argue that the risk is too big to be ignored and that fishers’ knowledge is valuable. Action is thus needed to safeguard the shrimp stocks.

The aquaculture industry: risk is too small to take action

A rejection of a direct link between chemical use and shrimp stock reduction is detailed in the hearing answers from the three main organizations for aquaculture farms. These consists of the Norwegian Seafood Association, an association of about 190 small and medium size enterprises in fisheries, aquaculture, and seafood processing businesses; the Norwegian Seafood Federation, representing approximately 550 members and according to their webpage, members cover the entire value chain from fjord to dinner table in the fisheries and aquaculture sectors; and Marine Harvest (now MOWI), the world’s largest aquaculture company, representing themselves in the hearing.

In the hearing letter, the Norwegian Seafood Association (NSL)[17] questions the evidence for claiming that the use of sea lice chemicals negatively impacts the biodiversity:

> NSL is also wondering if there are sufficiently strong indications that natural diversity is affected negatively when the allegations of impact are difficult to determine and that field surveys on long-term exposures are lacking. NSL does not disagree with the amendment of §15, but [thinks] that this has already been taken care of (NSL 2016).

[17] Recently, the NSL changed its name to “Sjømatbedriftene”.

In their view, the measures in place concerning chitin synthesis inhibitors are sufficient, while they do not oppose the stricter ones suggested. They underline the difficulties of reducing the uncertainty of the issue, as it is hard to determine the chemicals' negative impacts. As regards the longer intervals suggested between the use of chitin synthesis inhibitors, they state that "[the NSL] does neither agree nor disagree" (NSL 2016).

The Norwegian Seafood Federation (NSF) states to be positive towards several of the measurements, in part because it clarifies ambiguities in the regulations. However, they "question the use of the precautionary approach in order to safeguard the biological diversity in this context" (NSF 2016). The NSF queries if the measures suggested is based on facts about the risk of their use, since no connection between the declining shrimp stocks and the use of chemicals has been proven. In their view,

> it would be natural for the Ministry to wait for the results from the [ongoing] investigations before deciding on measures that takes as a starting point that "there is a serious or irreversible risk/hazard for shrimp stock from the use of sea lice agents". (NSF 2016)

Hence, the NSF underlines the lack of documentation of the causal relationship between aquaculture and declining shrimp stocks along the coast. Overall, they are concerned with the knowledge gaps not being an indication of "unacceptable risk" (NSF 2016), and they underline the difference between a laboratory study and the complex reality in a coastal zone area, where winds, currents, and local conditions will play a role. They further address how the use of chemicals is caused by obligations to protect wild salmon. According to the Norwegian Seafood Federation, it is necessary to ensure that any new measurements will actually generate a positive impact on the environment. Still, with regard to chitin synthesis inhibitors, the NSF supports the suggested measurement regarding how often the treatments can take place (from the previous 3- to the suggested 6-month intervals). They consider the current knowledge about this group of sea lice agents to support a restrictive use. Importantly though, they seem to relate this to the challenges of the sea lice developing resistance towards the sea lice agent, and that they are used according to the clear instructions on the leaflet emphasizing the environmental risks.

Interestingly, the NSF is the only aquaculture organization focusing explicitly on the precautionary approach and appears more concerned about the use of the precautionary approach as a rationale for the new regulations than the regulations themselves. They argue that the knowledge base available must support that the precautionary approach is the right step to take. NSF cannot find scientific evidence of sea lice agents causing a threat of serious or irreparable threat, emphasizing that the "PA [Precautionary Approach] cannot be used as a rationale for measurement to decrease the actual impact on the environment" (NSF 2016). In their view, there can only be local effects of the sea lice agents, which cannot have an impact at the stock level. To the NSF, the lack of knowledge is consequently not an indication of unacceptable risk. Moreover, the NSF also—indirectly—questions the use of fishers' knowledge by pointing to the Norwegian Directorate of Fisheries maps, where shrimp fields are "mainly based on interviews [of fishers[18]]".

Marine Harvest is the world's largest aquaculture company and is organized through Norwegian Industry from 2015. It used to be a member of the Norwegian Seafood Association, but while the Norwegian Seafood Association and the Norwegian Seafood federation represent several aquaculture firms and write the consultation letter on behalf of their members, Marine Harvest wrote their own consultation letter. Hence, this is not the letter from a representative body. Marine Harvest supports the new stricter regulations of how often chitin synthesis inhibitors can be used:

> Marine Harvest shares the Ministry's view that there is a need for regulations that clarify acceptable use and release of sea lice agents. The proposed regulations will further ensure responsible use, and make sure the use of such agents is environmentally acceptable. It is crucial that new regulations are based on thorough assessments based on available scientific knowledge (Marine Harvest 2016)

They further argue that there should be some opportunity for exceptions in special situations, but overall appear to be positive—more so than the other two associations—towards the regulations suggested.

The three letters all have in common that they call for more knowledge about the effects of sea lice agents. The aquaculture representatives communicate the complex aspects of the ecosystem with regard to the possible risks that the chemicals pose to the coastal system. From their point of view, the uncertainty of the chemicals' effect on shrimp stocks is too big and the risk too small to implement measures that constrains the use of chemicals. The hearing statement from Marine Harvest still gives the impression of being slightly more positive towards constraining the use than the other two.

Discussion

The results above show that perceptions of risk and how they are linked to uncertainty vary across the groups (see Table 2).

[18] Since 2003, the Norwegian Directorate of Fisheries has gathered information from the local fishermen's organization to map spawning grounds and fishing fields, available here: https://kart.fiskeridir.no/ (see for instance Brattland 2012 for more information about this process).

Table 2 A summary of how stakeholders perceive uncertainty differently and how they relate the declining shrimp stocks with chitin synthesis prohibitors or not; their risk perception, what the proper action should be; as well as their view on the precautionary approach (PA)

	Perceived uncertainty	Risk perception	Proper action	View on precautionary approach (PA)
Fishers				
	Certain that direct link between chemical and declining shrimp stocks. Fishers knowledge should be taken seriously and need more science.	High risk.	Use of sea lice agents must stop.	PA would imply to stop all chemical use.
Aquaculture				
NSL	Lack of evidence and no proven link between declining shrimp stocks and chemicals. Need more science, but uncertainty is difficult to reduce.	No risk.	Use of sea lice agents must continue.	The stricter regulations are a PA but not necessary.
MH	Maybe a link between chemical and declining shrimp stocks. Need more science.	Risk present.	Use of sea lice agents can continue but stricter regulations are necessary.	The stricter regulations are a PA.
NSF	Existing knowledge supports a restrictive use of kitin synthesis prohibitors, especially because of resistance issues. Regulation should only be relevant for verified, active shrimp fields. Need more scientific evidence.	Risk is small.	Use of sea lice agents must continue and the use is already restrictive.	The situation does not call for a PA. The PA should not be used unless there is scientific proof.
IMR				
	Maybe a link between chemicals and declining shrimp stocks.	Risk present.	Use of sea lice agents should be followed closely.	The lack of a proved link calls for a PA.

Fishers regard the risk to be too high, for the ecosystem in general and the shrimp in particular, to continue using chemicals. Due to the risk involved, they argue for a precautionary approach in terms of stopping the use of chemicals within the aquaculture industry. The aquaculture industry, on the other hand, regards the uncertainty as too big to form basis for actions that will affect their operations. Or put differently, for shrimp fishers, the uncertainty about the impact of chemicals on crustaceans is small enough to take action to safeguard the shrimp, while the opposite conclusion is made by the aquaculture industry. This is not very surprising given these stakeholders' different positions and interests in the marine context. The point is that they understand the risk surrounding sea lice chemicals from different perspectives and comes to different conclusions about what action to take.

What we have learnt about the IMR risk perception is that they understand and treat uncertainty as reducible and quantifiable. This is in line with how risk assessment is done by most advisory bodies (Scott 2016). In contexts where the uncertainty is controllable, this approach is well suited to solve the problem as the knowledge requirements are lower. In contexts where the uncertainty is uncontrollable, the knowledge requirements are large, and more knowledge may actually generate more questions rather than answers. Note that the IMR and the aquaculture industry overlap in their risk perceptions, as they understand the uncertainty to be high and the risk to be small while still present. The fishers, on the other hand, argue that the uncertainty is minimal, and the risk is high.

The precautionary approach

The debate between the shrimp fishers and the aquaculture sector can be seen as a disagreement between actors about how the precautionary approach principle should be operationalized (see Table 2). Actors from the aquaculture industry indicate that the uncertainty about cause and effect between shrimp death and delousing chemicals is too great for the precautionary approach to be implemented. The fishermen's association, on the other hand, is very vocal about the need to implement the precautionary approach. For the fishers, the uncertainty is too big to risk a negative impact on the shrimp stock in particular and the ecosystem in general. Considering the uncertainty low and the risk high, the precautionary approach is called for to avoid further negative impacts despite other stakeholders' emphasis on uncertainty.

In economic terms, the coastal shrimp fishery is insignificant compared with the aquaculture industry. In this sense, the lack of regulations and measures concerning sea lice agents can be justified. This regulation is, after all, a political question. Nevertheless, according to Norwegian legislation, aquaculture regulations must follow the precautionary approach as part of achieving sustainable development (Nature Diversity Act 2009), and the main actor in the precautionary approach is nature. Even if shrimp catches are small in terms of landings and revenue, crustaceans are key to maintain a healthy ecosystem. The principle implies that uncertainty in knowledge should benefit the environment at the expense of vested interests. With regard to the sea lice chemicals issue, the precautionary approach seems to give more importance to the wild salmon than crustaceans and in this sense turn "nature against nature." Paradoxically, the efforts to protect the wild salmon by means of sea lice reduction cause danger to all crustaceans. While the precautionary approach should safeguard the ecosystem in cases of doubt, it contains no explicit formulations as to how it should be operationalized. Thus, it is still an issue of interpretation how much uncertainty you can afford while still following the principle, or how you emphasize contradictions between the values at stake. Open discussions about the various foundations upon which different interpretations are based are thus needed.

The precautionary approach requires plausible knowledge and assessments of uncertainty founded on science. Still, the way in which uncertainty is considered is also based on political weighing. Therefore, researchers, as knowledge providers, should preferably collaborate with relevant actors in the preparation of how the principle should be operationalized (NENT 2016) in line with PNS and the risk escalator. This is especially the case in contexts with uncontrollable uncertainty where the traditional linear risk approach is not sufficient, even if it would be suitable for simple and controllable risk situations. However, due to the growing systematic use of uncertainty as a strategy to ensure inaction, a word of caution is necessary. As stated by Gleick (2007):

> there is a serious misunderstanding among some policy-makers of the nature of scientific certainty and knowledge, and a corresponding misuse of uncertainty. Absolute certainty in science, or even in politics, is a rare luxury, and never guaranteed. Insisting that scientists provide certainty before setting vital public policy is a recipe for inaction and delay (Gleick 2007; 4).

A related challenge is the growing use of tactics by powerful actors to delay decision-making processes (see for instance Oreskes and Cornway 2010; Gleick 2007). Here, the aquaculture sector's emphasis on the uncertainty of sea lice agents' effect on shrimp can be understood in this light. However, the resistance to accept responsibility can be reasonable since also the IMR underlines the high level of uncertainty and that more knowledge is necessary. In August 2018, an IMR scientist explained:

> Even though there are many indications, it is still difficult to document the relationships. The Norwegian authorities did not monitor the shrimp stock until 2016. (...) Currently, we have no science telling us how much the shrimp stock has declined, nor why it disappears. We can only confirm that it is happening (Søvik to Dagbladet, 2018).[19]

Hence, it is difficult to argue that the aquaculture industry is misusing uncertainty as a tactic to delay stricter policies with regard to sea lice treatment, since they share their viewpoint with the IMR researchers. With time, uncertainty about sea lice agent impacts will presumably be reduced, making it interesting to follow how the stakeholders will then react to the advice. As we discuss below, in line with PNS perspectives, one way of reducing uncertainty and improve quality of advice is to establish an open dialogue with stakeholders to include other forms of knowledge and to develop a shared understanding of the uncertainty in question.

Stakeholders' participation: possibilities and barriers

Above, we have described how the complexity of the ecosystem makes it difficult or even impossible to quantify the effect of all the factors playing their part in the sea lice chemical issue. The state of the shrimp stock, for example, is among others impacted by the size of cod stocks, the sea temperatures, the uptake of chitin synthesis prohibitors by the shrimps themselves, and also by the biota upon which they feed and how the chitin synthesis prohibitors spread in time and space due to wind and currents. The uncertainty involved thus cannot be represented by statistical methods. More knowledge may reduce the uncertainty in part, but not entirely. Hence, we argue that this corresponds to an uncontrollable post-normal problem, and that uncertainty is irreducible. Currently, however, the use of chitin synthesis inhibitors is mainly treated as a controllable uncertainty in line with the "normal" science approach. This means that only scientists are involved in the framing of the problem and the assessment stage. With the consultation process described, the authorities invite stakeholders to give input at the management stage. Still, while the consulted parties are all free to suggest alternative management solutions in their letters, they are only invited to comment on the already-defined solutions. They are not authorized to define the problem at the assessment

[19] 15 August 2018: https://www.dagbladet.no/mat/mystisk-kollaps-skaper-dramatisk-rekedod%2D%2D-vanskelig-a-fa-ferske-reker-neste-sommer/70091829

stage, nor in suggesting solutions for the management stage. Handling this issue as a post-normal problem, we argue for a more reflexive approach including stakeholders at an earlier stage of the process—the framing stage. Accordingly, the timing of such inclusion is important. Today, stakeholders' views are included only after risk has been identified, and the risk is hence identified and assessed based on scientific perspectives alone. However, identification of risk necessarily precedes the risk assessment phase and is inevitably formed by values, politics, and assumptions (Klinke and Renn 2010).

So how could a more reflexive approach look like in this context? Organizing the assessment process in line with a more reflexive approach would entail a change of practice among the advisory bodies and knowledge providers, such as the IMR. A growing body of literature suggests a number of practical solutions for how to include stakeholders in management processes (see, e.g., Callon's (1999) three models). In the following, we discuss the potential of the new risk management process described by the IMR to guide their coming risk management processes in their Risk Report (Fig. 2). This is a new approach introduced in 2018, and it is important to note that this is not yet put to work (IMR scientist Grefsrud, pers.com.). The approach seems promising, however, as it aims at including stakeholders in all phases from framing the problem to all stages in the risk management process: risk assessment, risk management, and risk communication.

Here, we understand the "context definition" in Fig. 2 as the appropriate stage where problem framing starts. As argued above, it is essential to involve stakeholders already at this stage. Importantly, to actually include stakeholders in line with this IMR new risk management approach requires a different organizational setup than today's arrangement (Fig. 2, with the black box representing a practical and formal arena for communication and consultation). Stakeholders' inclusion at the framing stage in the risk management process is basically a practical issue. This means that some form of arena enabling participation must be established for stakeholders to voice their concerns. Such a formal arena could for example be an annual meeting where all stakeholders are represented as a part of the preparatory work of the Risk Report produced by the IMR. In practical terms, the key stakeholders' organizations, i.e., the Norwegian Fishermen's Association, the Aquaculture organizations, and the environmental NGOs (and possibly others with expertise on the issue), could have a voice here. This means that for this particular issue, the arena for participation would take the form of an extended peer community in line with PNS, since those included would be different types of experts. However, who relevant stakeholders are is a dynamic question that would have to be considered for each context. Note that the "communication and consultation" category in Fig. 2 can be understood as two very different forms of stakeholders' participation, since they vary from one-way information flow towards real impact on the decision-making. To ensure real impact, we suggest that the formal arena for participation must take into consideration power issues between stakeholders—including scientists. Here, stakeholders and scientists could all discuss what issues to include in the risk assessment process (the gray box in Fig. 2). This would be a realistic starting point where stakeholders could inform the IMR about their risk perceptions. Together, stakeholders and scientists could pinpoint limitations to the knowledge base and decide upon contributions of relevant experience-based knowledge, dependent on the issue at hand (see for instance Bjørkan 2011; Tengö et al. 2014). Moreover,

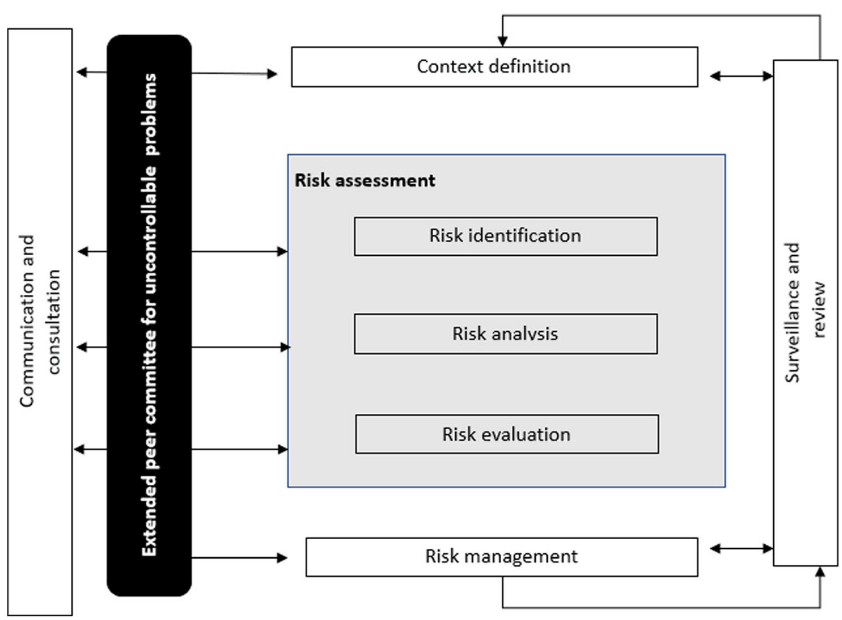

Fig. 2 The IMR illustration of the risk management process in the 2018 risk report (Grefsrud et al. 2018) is here visible as white and gray boxes. The black box is our addition. The arrows from the "communication and consultation" box show interaction with stakeholders—at all stages of the process, including the framing of the problem. As suggested below, the risk report could be a practical starting point for including (expert) stakeholders in line with the idea of extended peer committee

such cooperation may develop suitable research questions and identify knowledge needs for the future and investigate how other forms of knowledge than science could be included.

If the IMR arrange a formal arena as described above, stakeholders could discuss how to minimize the side effects of chemical agents on other species, address the competitiveness between shrimp fishers and aquaculture farms, and debate the environmental quality (Klinke and Renn 2010). Moreover, one could discuss the fairness of the different management actions available, and the degree to which they are acceptable from a cultural, moral, or ethical perspective (Klinke and Renn 2010). In this way, also the issue of power distribution among the various stakeholders involved could be openly confronted and addressed.

Due to the differences in how uncertainty and risk involved is perceived in the case at hand, the inclusion of stakeholders at the framing stage of the problem could ensure a less conflict ridden and hence more effective and legitimate advice. If this would be, the actual outcome remains an empirical question. Given the high probability for a win-lose scenario, it would still be necessary to handle conflicts. As underlined by Klinke and Renn (2010), one of the most difficult tasks in Risk Governance is to come to a shared understanding in situations with a dispute about what should count as acceptable risk. In our case, it is difficult to imagine dialogue as a means for solving the controversy. Rather, conflicts must be expected to arise as they are an inherent part of processes where stakes are high, and the outcome creates winners and losers (see, e.g., Bjørkan and Veland 2019; Lundberg et al. 2018; Mouffe 2005). However, some of the "noise" and polarized views in the media about sea lice agents' effect on shrimp stocks could have been avoided even if the conflict itself would be present.

Importantly, as the scientific perspective of risk is not sufficient to understand the problem at hand here, the inclusion of key stakeholders like shrimp fishers and aquaculture representatives could help narrow the knowledge gap. But this raises new challenges, since there are several societal stakeholders that potentially have a stake in the question, including environmental NGOs and the wider society (Buanes et al. 2004). Hence, two main concerns regarding stakeholders' participation can be pointed to here. The first is that of power. Some stakeholders will be more powerful and successful in promoting their concerns, while other issues will be ignored. This is the nature of political activities and priorities in general. Importantly, the power imbalance between shrimp fishers and aquaculture actors is significant. Secondly, knowledge claims may eventually be based on vicarious motives, and open dialogues and efforts of increasing the various participants' awareness of their values and priorities, the scientists included, is thus highly recommended. As stated by Weber et al. (2014), no knowledge production, verification, and use are completely detached from political processes.

Before 2018, the IMR risk reports were divided into two sections. The first was called "risk assessments" and here the knowledge level was considered high enough for giving advice. The second section was labelled "knowledge-updates," referring to areas where there was not enough knowledge to do a risk analysis. Since 2018, the IMR is exploring a new approach, acknowledging the "many methods for risk analysis that is adjusted to the level of knowledge" (Grefsrud et al. 2018: 8). As a starting point, we argue that the issues earlier described under "knowledge updates" would be relevant candidates for an extended peer committee—in line with PNS. Or, it could even include the wider society—in line with Risk Governance. Organizing a meeting with relevant stakeholders as a part of the risk management process is not very ambitious. But, it is a realistic first step—a tweak from the traditional, positivistic approach, towards a more reflexive view on risk assessment in line with the post-normal approach. Based on this formal arena, it would be possible to follow up with more fundamental changes by, for instance, establishing ways of authorizing stakeholders to also be part of the knowledge-production itself.

Conclusion

In post-normal science, the significance of involvement in important societal issues with conflicting interests and high uncertainty is stressed (Funtowicz and Ravetz 1993). As this case demonstrates, values and facts are often woven together, and the uncertainty makes the interpretation space large. We have described how stakeholders understand the risk involved in the aquaculture sea lice situation from different perspectives, and how they come to different conclusions about appropriate actions. At a first glance, it may seem that the controversy mainly concerns the scientific basis of the chemicals' possible effects on shrimps on the population level. However, the results from this study have shown how the disagreement is primarily about whether and how uncertainty constitutes risk or not, and what knowledge is considered legitimate to determine this. This article suggests that the discussion about sea lice agents could be less polarized if organized differently and in line with PNS and Risk Governance approaches. Instead of arguing about who is wrong or right about the effect of sea lice agents, the discussion could focus on how to take the uncertainty involved into account. We also point to the intrinsic challenges of a more reflexive approach, and that conflicts are inherently part of processes where stakes are high. Still, establishing arenas for participation in situations with uncontrollable uncertainty where stakeholders differ in their risk perception has the potential to generate more legitimate and hence effective management systems, by including different forms of knowledge and developing a shared understanding of the uncertainty in question.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

References

Almås, A.K and Ratvik, I. 2017. Sjøkart mot 2050. SINTEF rapport. https://www.sintef.no/contentassets/b26c5aed53be4385b4ab770c24761a95/sjokart%2D%2Dendelig-versjon-7.april-2017.pdf.

Anon. 2016. The status for Norwegian Atlantic salmon populations in 2016 report from the Norwegian Scientific Advisory Committee for Atlantic Salmon Management. Norway.

Berkes, F. 1999. *Sacred ecology: Traditional ecological knowledge and resource management*. Philadelphia: Taylor & Francis.

Bjørkan, M. 2011. Fishing for advice - the case of the Norwegian fishing fleet. PhD thesis. Tromsø: University of Tromso, Faculty of Biosciences, Fisheries and Economics, Norwegian College of Fisheries Science.

Bjørkan, M., and K. Hiis Hauge. 2019. Kunnskapsbasert forvaltning og dilemmaer knyttet til usikkerhet. In *Interessekonflikter i forskning*, ed. H. Ingierd, I. Bay-Larsen, and K. Hiis Hauge. Oslo: NENT. https://doi.org/10.23865/noasp.63.

Bjørkan, M., and S. Veland. 2019. Beyond consensus: Perceptions of risk from petroleum developments in Lofoten, Vesterålen and Senja, Norway. *ICES J Mar Sci*. https://doi.org/10.1093/icesjms/fsz056.

Brattland, C. 2012. Monstertorsk, vitenskap og politikk i Storfjord. Produksjon av fiskerkunnskap i forvaltningen. Senter for samiske studier, skriftserie nr. 18. Tromsø.

Brattland, C. 2013. Proving fishers right. Effects of the integration of experience-based knowledge in ecosystem-based management. *Acta Borealia: A Nordic Journal of Circumpolar Societies* 30 (1): 39–59.

Buanes, S.A., S. Jentoft, G.R. Karlsen, A. Maurstad, and S. Søreng. 2004. In whose interest? An exploratory analysis of stakeholders in Norwegian coastal zone planning. *Ocean & Coastal Management* 47: 207–223. https://doi.org/10.1016/j.ocecoaman.2004.04.006.

Callon, M. 1999. The role of lay people in the production and dissemination of scientific knowledge. *Science, Technology & Society* 4 (1): 81–94 London. https://journals.sagepub.com/doi/pdf/10.1177/097172189900400106?casa_token=qmJ-qbF_LUoAAAAA:yIPwbLXOOEm_j4a1T3HBVAlwZp03Sa89rgTrlU1L6270UUMXqEO3hiGuue_Y9H55kb_vyfF9IdEd.

Dreyer, M., and O. Renn. 2008. Some suggestions for a structured approach to participation in food risk governance with a special emphasis on the assessment-management interface. In *European risk governance its science, its Inclusiveness and its effectiveness*, ed. E. Vos. Mannheim: CONNEX Report Series.

Fiskeribladet. 2016. Ingen "føre var" i havbruksnæringa. 16th of September 2016. https://fiskeribladet.no/nyheter/?artikkel=48982.

Friends of the Earth Norway. 2016. Hva gjør utslipp fra 400 millioner oppdrettslaks med havet vårt? Kloakk, lusemidler, medisiner, miljøgifter og myriader av lakselus flyter rett ut i fiskens fødestuer i Norske hav og fjorder. Facebook page accessed 13th of June, 2018.

Funtowicz, S.O., and J.R. Ravetz. 1990. *Uncertainty and quality in science for policy.* Dordrecht (Netherlands): Kluwer.

Funtowicz, S., and J. Ravetz. 1993. Science for the post-normal age. *Futures* 25: 739–755. https://doi.org/10.1016/0016-3287(93)90022-L.

Funtowicz, J.R., and J. Ravetz. 2003. Post-normal science. Internet Encyclopaedia of Ecological Economics. International Society for Ecological Economics.

Gleick, P.H. 2007. Testimony to the Senate Committee on Commerce, Science, and Transportation. For the Hearing on Climate Change Research and Scientific Integrity. Threats to the Integrity of Science. Committee on Commerce, Science, and Transportation. http://pacinst.org/wp-content/uploads/2007/02/Gleick_Senate_Commerce_2-7-07.pdf.

Grefsrud, E.S., K. Glover, B.E. Grøsvik, V. Husa, Ø. Karlsen, T. Kristiansen, B.O. Kvamme, O.B. Mortensen, L.H. Stien, and T. Svåsand(red) (2018). Risikorapport norsk fiskeoppdrett 2018. Fisken og havet, særnr. 1–2018. Hagen, J.M. (2016) Ingen føre-var i havbruksnæringa.Fiskeribladet. https://fiskeribladet.no/nyheter/?artikkel=48982.

Hersoug, B., and J.P. Johnsen. 2012. *Kampen om plass på kysten - interesser og utviklingstrekk i kystsoneplanleggingen*. Oslo: Universitetsforlaget.

Holm, Petter. 2003. Crossing the border. *Maritime Studies (MAST)* 2(1): 5–33.

IMR. 2016a. Reke i fjorder og kystnære områder. http://www.imr.no/filarkiv/2016/05/reke_kyst_og_fjord.pdf/nb-no.

IMR. 2016b. consultative Statement: https://www.regjeringen.no/no/dokumenter/horing%2D%2D-tiltak-mot-negative-miljoeffekter-av-medikamentell-behandling-mot-lakselus/id2505480/?factbox=horingssvar.

Jaeger, C.C., O. Renn, E.A. Rosa, and O. Renn. 2001. *Uncertainty and rational action*. London: Earthchan Publications Ltd. https://doi.org/10.4324/9781315071817.

Jasanoff, S. 1990. *The fifth branch: Science advisers as policymakers*. Cambridge: Harvard University Press.

Jasanoff, S., G.E. Markle, J.C. Petersen, and T. Pinch. 1995. *The handbook of science and technology studies*. London: Sage publications.

Johannes, R.E., M.M.R. Freeman, and R.J. Hamilton. 2000. Ignore fishers knowledge and miss the boat. *Fish and Fisheries* 1(3):257–271. https://doi.org/10.1111/j.1467-2979.2000.00019.x.

Joks, S. and J. Law. 2016. Sámi Salmon, State Salmon: LEK, Technoscience and care. http://www.heterogeneities.net/publications/JoksLaw2016SamiSalmonScienceSalmon.pdf.

Klinke, A., and O. Renn. 2002. A new approach to risk evaluation and management: Risk-based, precaution-based, and discourse-based strategies. *Risk Anal* 22: 1071–1094. https://doi.org/10.1111/1539-6924.00274.

Klinke, A., and O. Renn. 2010. Risk governance: Contemporary and future challenges. In *Regulating chemical risks: European and global challenges*, ed. J. Eriksson, M. Gilek, and C. Rudén. Springer. https://doi.org/10.1007/978-90-481-9428-5_2.

KPB. 2018. Indeks Nordland: En rapport om utviklingen gjennom 2017 og utsiktene for 2018. Kunnskapsparken Bodø. https://indeksnordland.no/wp-content/uploads/2019/01/2018.pdf.

Lauer, M., and S. Aswani. 2009. Indigenous ecological knowledge as situated practices: Understanding fishers' knowledge in the Western Solomon Islands. *Am Anthropol* 111: 317–329.

Linke, S., M. Dreyer, and P. Sellke. 2011. The regional advisory councils: What is their potential to incorporate stakeholders knowledge into fisheries governance? *Ambio: A Journal of the Human Environment* 40: 133–143.

Liu, Y., J.O. Olaussen, and A. Skonhoft. 2011. Wild and farmed salmon in Norway—A review. *Mar Policy* 35: 413–418. https://doi.org/10.1016/j.marpol.2010.11.007.

Lundberg, A.K., T. Richardson, and E. Hongslo. 2018. The consequences of avoiding conflict: Lessons from conservation planning for Europe's last wild reindeer. *J Environ Plan Manag* 62: 266–285. https://doi.org/10.1080/09640568.2017.1409197.

Mackinson, S. 2001. Integrating local and scientific knowledge: An example in fisheries Science. *Environ Manag* 27 (4): 533–545.

Marine Harvest. 2016. Tiltak mot negative miljøeffekter av medikamentell behandling mot lakselus. https://www.regjeringen.no/no/dokumenter/horing%2D%2D-tiltak-mot-negative miljoeffekter-av-medikamentell-behandling-mot lakselus/id2505480/?factbox=horingssvar.

Mouffe, C. 2005. *On the political*. London and New York: Routledge, Taylor and Francis Group.

Mouffe, C. 2013. *Agonistics: Thinking the world politically*. London: Verso.

Nature Diversity Act. 2009. Lov om forvaltning av naturens mangfold. Klima- og miljøverndepartementet.

Neis, Barbara, and L. Felt (Eds.). 2000. *Finding our sea legs: Linking fishery people and their knowledge with science and management*. St Johns: ISER books.

NENT. 2016. Forskningsetiske retningslinjer for naturvitenskap og teknologi. The Norwegian National Research Ethics Committees: https://www.etikkom.no/globalassets/documents/publikasjoner-som-pdf/60124_fek_retningslinjer_nent_digital.pdf.

NSL. 2016. Norwegian Fishermens Associoation. Consultative statement . https://www.regjeringen.no/no/dokumenter/horing%2D%2D-tiltak-mot-negative-miljoeffekter-av-medikamentell-behandling-mot-lakselus/id2505480/?factbox=horingssvar.

NFD. 2016. Strammer inn reglene for lusemiddelbruk. Ministry of Trade, Industry and Fisheries. https://www.regjeringen.no/no/aktuelt/strammer-inn-reglene-for-lusemiddelbruk/id2505478/.

NSC. 2018. Norwegian Seefood Council. Sjømateksport for rekordhøye 94,5 milliarder i 2017. Norges Sjømatråd. https://seafood.no/aktuelt/nyheter/sjomateksport-for-rekordhoye-945-milliarder-i-2017/: Norges Sjømatråd.

NSF. 2016. Norwegian Seafood Federation.Tiltak mot negative miljøeffekter av medikamentell behandling mot lakselus. https://www.regjeringen.no/no/dokumenter/horing%2D%2D-tiltak-mot-negative-miljoeffekter-av-medikamentell-behandling-mot-lakselus/id2505480/?factbox=horingssvar.

Olafsen, T., U. Winther, Y. Olsen, and J. Skjermo. 2012. Verdiskaping basert på produktive hav i 2050. På oppdrag fra NTVA og DKNVS. Oslo. SINTEF rapport. https://www.sintef.no/globalassets/upload/fiskeri_og_havbruk/publikasjoner/verdiskaping-basert-pa-produktive-hav-i-2050.pdf.

Oreskes, N., and E.M. Conway. 2010. Merchants of doubt. Bloomsbury Press.

Renn, O. 1998. Three decades of risk research: Accomplishments and new challenges. *Journal of Risk Research* 1: 49–71 http://www.ask-force.org/web/Discourse/Renn-Three-decades-risk-research-accomplishments-new-challenges-1998.pdf.

Robertsen, R., O. Andreassen, B. Hersoug, K.M. Karlsen, T. Osmundsen, A.M. Solås, B. Sørgård, F. Asche, R. Tveterås. 2016. Regelrett eller rett regel? Håndtering og praktisering av regelverket for havbruksnæringen.Nofima rapportserie. Tromsø. https://brage.bibsys.no/xmlui/handle/11250/2417179.

Sandersen, H., and I. Kvalvik. 2015. Access to aquaculture sites: A wicked problem in Norwegian aquaculture development. *Maritimes Studies* 14. https://doi.org/10.1186/s40152-015-0027-8.

Sandvik, K. 2018. HI er bekymret for sammenfall av avlusning og krilldød. Fiskeribladet fiskaren. https://fiskeribladet.no/nyheter/?artikkel=58758.

Scott, D. 2016. Framing and responding to scientific uncertainties: Biofuels and synthetic biology at the convention on biological diversity. Jurimetrics J: 245–260. https://www.americanbar.org/content/dam/aba/administrative/science_technology/2016/framing_and_responding.authcheckdam.pdf.

Shackley, S., and B. Wynne. 1996. Representing uncertainty in global climate change science and policy: Boundary-ordering devices and authority. *Sci Technol Hum Values* 21: 275–302.

St.Mld.42. 2000–2001. Biologisk mangfold - sektoransvar og samordning. Oslo: Miljøverndepartementet. https://www.regjeringen.no/en/dokumenter/report-no.-42-to-the-storting-2000-2001/id194978/.

St.prp.nr.31. 1982–83. Om samtykke til å ratifisere konvensjonen av 2. mars 1982 til vern av laks idet nordlige Atlanterhav. Oslo: Miljøverndepartementet. https://stortinget.no/nn/Saker-og-publikasjonar/Stortingsforhandlingar/Lesevisning/?p=1982-83&paid=2&wid=a&psid=DIVL678&s=True.

Sterud, E. 2016. Aftenposten. [Wild Salmon Sacrificed]. www.aftenposten.no/meninger/debatt/Ofres-villaksen%2D%2DErik-Sterud-424565b.html.

Stirling, A. 2007. Risk, precaution and science: Towards a more constructive policy debate. Talking point on the precautionary principle. *EMBO Rep* 8: 309–315. https://doi.org/10.1038/sj.embor.7400953.

Strand, R., and D.H. Oughton. 2009. *Risk and uncertainty as a research ethics challenge. NENT report*, 42. Oslo: The National Committee for Research Ethics in Science and Technology (NENT).

Strand, R., and D. Ougthon. 2009. Risk and Uncertainty. Publication no. 9. The National Committee for Research Ethics in Science and Technology (NENT).

Svåsand, T., E. Grefsrud, Ø. Karlsen, B.O. Kvamme, K. Glover, V. Husa, and T.S. Kristiansen. 2017. *Risikorapport norsk fiskeoppdrett. Fisken og Havet. særnr*. 2nd ed. Bergen: IMR https://www.imr.no/filarkiv/2017/05/risikorapport_2017.pdf/nn-no.

Tengö, M., E.S. Brondizio, T. Elmqvist, P. Malmer, and M. Spierenburg. 2014. Connecting diverse knowledge systems for enhanced ecosystem governance: The multiple evidence base approach. *Ambio* 43 (5): 579–591. https://doi.org/10.1007/s13280-014-0501-3.

Thonhaugen, M. 2017. NRK Nordland: Rekefisker: – Det har aldri vært så dårlig som i år. 04.03.17 ed. https://www.nrk.no/nordland/rekefisker_-_-det-har-aldri-vaert-sa-darlig-som-i-ar-1.13409411. NRK Nordland.

van der Sluijs, P.J. 2012. Uncertainty and dissent in climate risk assessment. *Nature and Culture* 7: 174–195. https://doi.org/10.3167/nc.2012.070204.

Wachinger, G., and O. Renn 2010. Risk perception and natural hazards. In: WP3 C-N (ed). Stuttgart: DIALOGIK Non-Profit Institute for Communication and Cooperative Research.

Weber, E.P., J.M. Belsky, D. Lach, and A.S. Cheng. 2014. The value of practice-based knowledge. *Soc Nat Resour* 27 (10): 1074–1088. https://doi.org/10.1080/08941920.2014.919168.

Wilson, D.C. 2009. *The paradoxes of transparency: Science and the ecosystem approach to fisheries management in Europe*. MARE publication series no. 5. Amsterdam: Amsterdam University Press.

Wilson, Douglas C, Jesper Nielsen, and Poul Degnbol (Eds.). 2003. *The fisheries comanagement experience*. Accomplishes, Challenges and Prospects: Kluwer Academic Publishers.

Wynne, B. 1989. Sheep farming after Chernobyl, a case study in communicating scientific information. *Environment* 31: 10–15.