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Culturally sensitive boundary work: A framework for linking knowledge to climate action

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ABSTRACT

Although it is increasingly recognized that scientific knowledge about climate change needs to be framed and conveyed in ways that resonate with people's livelihoods to motivate societal change, these insights are often neglected in discussions about science-policy interactions. Drawing on empirical studies from Norwegian renewable primary industries, this paper presents a novel conceptual framework for culturally sensitive boundary work for climate change transformation. Our framework combines boundary work theory with cultural theory and examine the production of and engagement with knowledge in innovation and development processes in agriculture, aquaculture and fisheries from three case studies in Norway. The innovation processes are analyzed across four dimensions: degrees of knowledge integration, degrees of participation, learning and negotiation over boundaries. By combining this with an analysis of the actors' way of life according to cultural theory, we are able to compare different configurations of boundary work with ways of life. We find that in innovation processes with egalitarian users there is a high level of knowledge integration, learning and participation, while there is a greater need for dedicated boundary workers in processes with individualist users. We argue that the framework can inform the design and implementation of deliberate coproduction of knowledge for transformation among actors that adheres to different ways of life.

1. Introduction

Science has in many cases profound, proven and transformative impacts on society, through for example technological development and innovation (Brooks, 1980; Latour, 1993). However, despite overwhelming scientific evidence that climate change can be attributed to human activities, society has been slow in responding. This begs the question of why climate science does not result in reduced levels of GHG emissions. Why do we do not act on climate change science similarly to other societal threats, such as tobacco and the ozone layer? In sectors that are both exposed and sensitive to weather and climate (see Hovelsrud and Smit, 2010), it seems fair to hypothesize that climate change is a concern, because it alters weather patterns, both in the short and long term. Jasanoff observes: "That the climate changes is not news to communities with long histories of living with nature, but 'climate change' – the scientific phenomenon – employs techniques of aggregation and deletion, calculation and comparison that exhaust the capacities of even the most meticulously recorded communal memories." (Jasanoff, 2010:237). This suggests that climate change is articulated as a scientific enterprise that does not resonate well with people's daily lives and activities. Additionally, the need to act on climate change is perceived differently, if at all, across various parts of society (Hulme, 2009). A well-established insight in social sciences is that the *framing* of the message that we need to act on climate change matters (Hermansen, 2015; Kahan et al., 2012; Thompson and Rayner, 1998). Thus, if scientific climate change knowledge is to motivate action and change in society, it has to be framed and conveyed in ways that resonates with people's livelihoods, world views and cultural bias (Dannevig and Hovelsrud, 2016; Meadow et al., 2015). Previous studies have found that the willingness to act on climate change differs widely between occupational groups and sectors, corresponding to different cultural biases outlined in the cultural theory of risks framework (Dannevig and Hovelsrud, 2016; Hovelsrud et al., 2015). The findings in these studies build on a decade of bottom-up driven research into local level adaptation to climate change in agriculture, fisheries and local governments in the Nordic countries. How the renewable resource-based primary industry actors, from the same communities, perceive climate science and the need for action on climate adaptation

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clearly differs between the sectors (Dannevig et al., 2019; Dannevig and Hovelsrud, 2016; Dannevig et al., 2013; Hovelsrud et al., 2010, 2015; Kvalvik et al., 2011). These findings have inspired us to conduct more in-depth investigations into the role of scientific knowledge in promoting action and policy on climate change. This is what we present here.

The classic model for conceiving science-policy or expert-user interactions is the linear model (or positivist model) of expertise (Beck, 2011), assuming a one-way direction of knowledge from science to policy, or expert to user. This model applies predominantly to hierarchical systems, such as governments (Dannevig and Hovelsrud, 2016; Ney, 2009), but has shortcomings when applied to sectors, organizations and individuals that are characterized by less hierarchical and more individualistic or egalitarian values and sub-cultures (Ney, 2009). Livelihood practitioners engaged in fisheries, agriculture or aquaculture increasingly address the two-pronged challenge of climate change adaptation and mitigation of GHG (e.g. Kvalvik et al., 2011). Given documented differences in how these sectors perceive the risks from climate change (Dannevig and Hovelsrud, 2016), it follows that the way climate change knowledge is produced, communicated, and translated will have to be tailored to be relevant and usable. The challenge of coproduction of climate change knowledge has received immense attention from scholars, but as Clark and colleagues point out "(..) the very success of science and society studies as a field of fundamental scholarship has tended to make its practical implications increasingly inaccessible to many of the researchers who might use it in their struggles to produce more usable knowledge" (Clark et al., 2016:4571). This raises the question of how scientific approaches ensure that systems for coproduction and boundary work are sensitive and responsive to different types of organizations, livelihoods, and cultural values. The research on knowledge exchange, coproduction and boundary work in studies of climate change and social-ecological systems is rapidly increasing (Bremer and Meisch, 2017), but is not adequately addressing the gap between the approaches that theorize about the nature of coproduction and boundary work (e.g Jasanoff, 2004), and frameworks and approaches for practical coproduction of knowledge (Bremer and Meisch, 2017; Kerkhoff and Pilbeam, 2017; Lemos, 2015). This is particularly pronounced when it comes to dealing with differing world views and cultural biases.

Below we outline key theoretical perspectives on coproduction, boundary work and cultural theory of risk. These are employed in the analysis of empirical data from case studies on agriculture, aquaculture and fisheries in Western and Northern Norway. Through an inductive approach we investigate how actors' way of life according to cultural theory corresponds to four dimensions of boundary work. By way of conclusion we suggest that arrangements for boundary work and coproduction for climate change action are more likely to succeed if they are tailored to fit with the particular culture or way of life characterizing the system, organization or community it is applied in.

2. Theoretical concepts

2.1. Coproduction of knowledge and boundary work

STS-scholars and other critical and interpretive social scientists have in general been engaged in revealing and problematizing the privileged position of science in decision making compared to other forms of knowledge (Kerkhoff and Pilbeam, 2017; Wynne et al., 1996). Less attention has been given to how central insights from this school of thought may be applied to develop practical arrangements for bridging science and policy (Sundqvist et al., 2015; Clark et al., 2016). A tension remains between the descriptive/critical/reflexive goal as represented by Jasanoff (2004) (cf. Lövbrand, 2011), and the instrumental/utilitarian goals of understanding science-society relations as represented by the prescriptive, deliberative coproduction approach, represented by Lemos, Kerkhoff and others (Bremer and Meisch 2017). The processes associated with prescriptive coproduction have also been discussed in neighboring conceptual frameworks such as post-normal science (Funtowicz and Ravetz, 1994); mode 2 knowledge production (Gibbons, 1994) and joint knowledge production (Hegger et al., 2012). The revolving perspective for the empirical part of this study is prescriptive coproduction, that is, deliberate processes for producing actionable knowledge for climate transformation.

Previous work has demonstrated that successful science-policy interface and knowledge exchange hinge on well-functioning boundary work (Dannevig et al., 2019; Hegger et al., 2012; Dannevig and Aall, 2015; Westskog et al., 2017). The concept of boundary work was originally coined by Gieryn, who asserted "the boundaries of science are ambiguous, flexible, historically changing, contextually variable, internally inconsistent, and sometimes disputed" (1983: 792). Gieryn was initially concerned with how scientists performed boundary work to demarcate science from non-science, and falls within the descriptive lens of coproduction (Bremer and Meisch 2017). Later the concept has been applied to analyze the relationship between practitioners and outside experts (Star and Griesemer, 1989; Cash et al., 2003), and to denote activities aimed at tailoring scientific knowledge for policy purposes. This is often carried out by dedicated boundary organizations, which corresponds to the prescriptive lens of coproduction (Bremer and Meisch, 2017). Gibbons' two modes of knowledge production is still a widely used heuristic for degree of user involvement (Gibbons, 1994), with mode 1 corresponding to the linear model mentioned above and an increasing level of participation of users and their knowledge in mode 2. Boundary work takes place in both modes, but with different purposes. In mode 1, it takes place to protect and maintain the borders, while in mode 2 it takes place to coproduce usable and actionable knowledge (Offermans and Glasbergen, 2015). The latter corresponds to prescriptive boundary work, which means that if science is to retain credibility and at the same time be usable and salient for policy purposes, communication, translation and mediation is necessary between different realms (Cash et al., 2003). This process entails social learning, participation and capacity building, and it must be tailored to the goals and motivations for involved users and deemed legitimate by actors in both realms. The concept of boundary work has been criticized for not paying sufficient attention to knowledge processes in which the different actors' frames or "ways of knowing" converge, and how the boundaries between experts and users are dissolved (Lejano and Ingram, 2009), moving from "two worlds" into "one world" (Sundqvist et al., 2018).

Drawing on insights from existing frameworks for analysis of boundary work and joint knowledge production processes, in particular Kerkhoff and Lebell (2006), we identify four dimensions of boundary work:

Integration captures the degree to which the users' knowledge are included in the innovation process and the in the final outcome of the process (e.g. Cash et al., 2003; Kerkhoff and Lebel, 2006; Lejano and Ingram 2009; Offermans and Glasbergen 2014). This dimension also captures whether there is a divergent logic (lack of integration) or convergent logic of users and expert's knowledge (Hoppe and Wesselink, 2014).

Participation includes the extent and degree of collaboration between users and experts in the process, including the distribution of influence and power (Offermans and Glasbergen 2014). Participation is probably the most recognized requirement for boundary work and coproduction (e.g. Arnstein 1967), and a precondition for well-functioning communication and learning. Participation also includes process leadership and management. The specific roles taken by users and experts in the process may differ between processes, but it is crucial that they are deliberate and clearly defined (Hegger et al., 2012).

Learning captures whether it is intentional and a desired part and outcome of the process (e.g. Kerkhoff and Lebel, 2006), or arbitrary and not an explicit focus. Mutual social learning will inevitably take place in any innovation process, but its importance for coproduction hinges on

the extent to which participation is organized in order to facilitate understanding and "leveling of the playing field" between users and experts (e.g. Reed et al., 2014).

Negotiation refers to activities by users and experts to either dissolve or maintain boundaries that exist between them, be it cultural or the science-industry boundary (e.g. Cash et al., 2003; Kerkhoff and Lebel, 2006). It takes place when there is a polarization between users and experts and when there is a need to find the optimal tradeoff between experts' autonomy and the desires and requirements of the users (Cash et al., 2003; Kerkhoff and Lebel, 2006).

2.2. Cultural theory of risk and ways of life

In managing wicked problems such as climate change (cf. Grundmann, 2016), knowledge-based decisions with inherent uncertainties inevitably depend on judgement and interpretation of knowledge and information (Sundqvist et al., 2015). These judgements are partly based on a range of values and worldviews, therefore wicked problems tend to generate persistent conflicts or disagreements about solutions (Ney, 2009). One way to categorize and characterize these differences is found in the cultural theory of risk framework (CTR).

The cultural theory of risk framework is based on a group-grid typology that outlines four archetypes of social solidarities or 'ways of life' found in any social unit. These are typically distinguishable by culture or sub-culture (e.g. nations, firms, occupation, livelihoods): the *individualist*, the *fatalist*, the *egalitarian*, and the *hierarchist* (Thompson et al., 1990). The ways of life can also be used to characterize organizations and systems (Thompson, 2008). The *individualist* is characterized by a low degree of social regulation and social contact, a combination that produces an opportunistic attitude (Thompson et al., 1990). *Egalitarians* tend to have strong internal norms and prefer collective action to solve problems, *hierarchists* typically find themselves bound by prescription and defined roles while *fatalists* feel that they exercise little control over their own situation (Thompson et al., 1990).

Actors' and organizations' 'way of life' highly likely influences processes of coproduction and boundary work, both in how the boundaries are defined and how to understand what constitutes relevant and salient knowledge (Dannevig and Hovelsrud, 2016). One attempt to synthesize theories of boundary work with cultural theory is found in Hoppe and Wesselink's work, in which they have developed a typology of boundary arrangements and cultural theory, categorizing boundary arrangements along two dimensions (Hoppe, 2002; 2005; Hoppe and Wesselink, 2014). The first dimension is *primacy,* which straddles the continuum between scientists and users in terms of authority and control. The second refers to the *logic of social function*, which straddles the continuum from divergence to convergence. Expert knowledge can raise *individualist's* awareness, but they are likely to trust their own knowledge when seeking solutions to a problem (O'Riordan and Jordan, 1999). For individualists, primacy rests with the practitioner, and the divergent logic between academic and the users' knowledge persists (Hoppe, 2005; Hoppe and Wesselink, 2014). *Hierarchists* on the other hand might lend primacy to science, and adhere to the technocratic, one-directional linear model of science advice (Ney, 2009). *Egalitarians* are willing to accept primacy of science if the knowledge production involves users and there is a negotiation of interest, so that the logic of users and experts are converging. *Fatalists* will either accept or reject all configurations of boundary work (Hoppe and Wesselink, 2014).

However, Hoppe and Wesselink (2014) do not pay attention to how boundary work is carried out in the different knowledge production processes in which actors with different ways of life take part. They do not discuss how the way of life affect learning or extent and degree of participation. Thereby they miss the critical point that knowledge and coproduction processes must be tailored to ways of life for solving a given problem. We build on their work regarding the logic of knowledges in boundary arrangements preferred by the adherents to different ways of life (convergence versus divergence), and combine with other studies that has looked into how adherents to the different ways of life relate to climate change knowledge (Dannevig and Hovelsrud, 2015; Kahan et al., 2012; O'Riordan and Jordan, 1999; Thompson and Rayner, 1998)

After investigating the degree of integration, participation, learning and negotiation in our cases, we compare how the different configurations of boundary work relate to the actors and organizations way of life. We discuss the consequences the different configurations of dimensions of boundary work and way of life have for how deliberate coproduction more effectively can result in actionable knowledge. By applying the CTR framework we increase the understanding for why different types of deliberate coproduction processes and knowledge exchange is rejected or embraced by the different industry actors.

3. Case areas and methods

We approach innovation processes and knowledge exchange in relation to climate change and broader sustainability issues in fisheries, aquaculture, and agriculture through case studies in two regions in Western and Northern Norway. Studies of societal transformation to a low-emission society, in itself (cf. Amundsen et al., 2018), and the role of primary industries in such transformations, are both relatively new (Karlsson and Hovelsrud, in review). This motivates the exploratory nature of our research and the central need to gain in-depth and situated examples of how innovations and knowledge exchange take place within different sectors and regions in Norway. Our three cases, one from each sector, will provide in-depth examples of such processes. The focus on process ensure transferability to other areas and give the cases relevance beyond Norway.

Two geographic case areas (Fig. 1) were selected on the basis of different climatic, geographical and market conditions: Sogn and Fjordane, Western Norway, Lofoten Islands, Nordland (See Table 1).

3.1. Interviews

The project team applied a common research framework and consistent methodology across the case areas, allowing generalizations to be formulated with higher validity than if each case was treated in isolation (Gerring, 2008). We conducted semi-structured interviews with 19 informants. See Table 2 for distribution across sectors and case

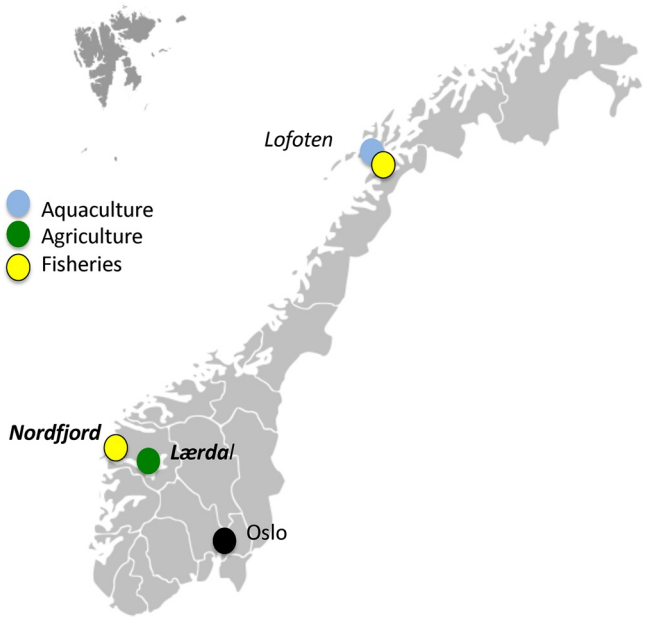

Fig. 1. Map of the case study areas.

Table 1
Distribution of informants according to industry and region.

Case area	Agriculture	Fisheries	Aquaculture	Total
Sogn og Fjordene	4	4	3	11
Lofoten Islands	3	4	1	8

areas. In addition, we conducted survey interviews with 30 informants from the same sectors in order to determine way of life (how this was done is outlined below).

Informants represent farmers (6), agricultural extension services (1); aquaculture companies (4); independent fishermen (3); larger fisheries companies (3); bureaucrats and organizations (2).

We located informants by purposive and snowball sampling (Bryman 2012). Informants were approached and selected solely based on their broad engagement in activities that could be labelled as transformation and innovation in respective sectors. They are therefore not necessarily representative for their sectors or occupations. The interview guide was fitted to the particularities of the different sectors and focused on a set of main themes: the role of the sector in the green transformation towards a low-emission society, perceptions of climate change, experience with adaptation and demands for mitigation, the use of scientific and other forms of knowledge, collaboration within and outside the sector, participation in research and collaboration with scientists.

Some interviewees were involved in several innovation and development processes. The processes we chose to study were selected based on expressions of being fully or partly motivated by saving energy, reducing CO_2 emissions, adapting to climate change or other sustainability issues.

In addition, we reviewed marketing material, web pages and followed news media coverage about the industry actors and companies to obtain key and publicly available information about the innovation processes.

3.2. Operationalizing and determining ways of life

To assess the way of life that best characterizes the actors, we conducted survey interviews containing various statements and questions around three themes: the urgency of and most appropriate response to climate change; the role of science in society, and knowledge based natural resource management. Based on the literature review the statements and questions were formulated to correspond to the four ways of life: hierarchist, individualist, egalitarian and fatalist (Hoppe, 2002; Kahan et al., 2012; O'Riordan and Jordan, 1999; Thompson and Rayner, 1998).

The survey interviews were conducted with 30 informants, of which 19 are included in the selected cases. The additional respondents were asked to evaluate the different statements and rank them according to their own degree of agreement, which also triggered broader discussions, in line with methods outlined in Marris and colleagues (1998). We combined the results from the survey interviews with analyses of the semi-structured interviews and the document review to determine ways of life most likely correlating with the actors' perspectives (Dannevig and Hovelsrud 2016).

3.3. Coding and operationalization of the analysis

Most of the interviews (n = 19) were recorded and transcribed. Were the informants uncomfortable with being taped the interviews were recorded through extensive note taking. The interviews were coded and analyzed in the software NVivo (Bazeley and Jackson, 2013). Categories for coding boundary work was defined on the basis of the four dimensions of boundary work mentioned above: integration, participation, learning and negotiation. Categories for coding way of life

Table 2
The innovation processes in three sectors according to the culturally sensitive boundary work model.

	Integration of different knowledges in knowledge coproduction	Degree of participation and cooperation	Learning	Negotiation	Way of life
Case 1: Kelp farming	Yes, with converging logic of knowledge	High	Deliberate	No need	Individualist or egalitarian
Case 2: New fisheries vessels	Partly, without converging logic of knowledge	Medium	Arbitratrary	Cultural boundaries	Individualist
Case 3: New varieties of fruit trees	Yes, with converging logic of knowledge	High	Deliberate	No need	Egalitarian

included attitudes towards climate change, and the role of science in society and environmental policies. In addition, the material in Table 2 served as a coding matrix for types of boundary work.

To determine which way of life that matched the innovation processes in our cases, we compared the coding categories with the statements from the survey interviews.

4. The innovation processes

Below we outline three selected innovation processes in agriculture, aquaculture and fisheries. While the innovation processes in agriculture and fisheries are taking place within well-established industries, the kelp farm case represents an entirely new type of industry. The different innovation processes also show how the role of industry actors, boundary workers and experts can vary in terms of leadership, initiative and involvement. They have a common motivation, albeit to varying degree, to reduce carbon footprint or in other way increase the sustainability of the industry (see also Karlsson and Hovelsrud in review).

In general, farmers and aquaculture actors interact more closely and continuously with experts and boundary workers than fishers. Below we present how the actors in the different sectors worked together with external experts and boundary workers to create new knowledge and develop new technology and solutions.

4.1. Case 1: developing kelp farming in Lofoten

Kelp or macro algae is a promising resource globally and in Norway, for fodder, bioenergy, chemical ingredients and foodstuff. The clean, cold and nutritious water off the coast of the Lofoten Islands in northern Norway is well suited for kelp cultivation. In 2015, one local entrepreneur previously involved in aquaculture, developed a kelp farm to produce food stuffs. Kelp cultivation is relatively new industry in Norway and involves considerable research and innovation to understand where different algae species thrive, how to improve cultivation and harvesting techniques and not the least, building and locating markets for products. Cultivating kelp is considered an environmentally sustainable industry, providing ecosystem services such as reducing CO_2 levels locally, releasing oxygen, using nutrients and reducing eutrophication. The environmental benefits are seen as important in the Lofoten case, however, the primary motivation for kelp farming is to take advantage of emerging business opportunities.

4.1.1. Integration

Expert knowledge about how to farm kelp has been developed by applied research institutions but has been transferred and applied locally in the kelp farming company. Practical knowledge about how different technical solution and approaches work in the local sites, for example about the cultivation conditions at specific locations, are also transferred to industry networks and partners. The combination of specialized research- based knowledge and an industry in its infancy with daily and seasonal practical challenges to solve is an example of convergence between practical and expert knowledge. According to the manager

> "*there is quite a lot of knowledge in the industry clusters we participate in and the other kelp farmers in Norway. We have a good overview of who is active in Norway, and we meet the research institutions both in direct collaboration, we will for example be part of a research project…*"

Expert knowledge is also held by larger industry actors within the kelp cultivation industry, for example suppliers of organic and technical goods. This is an industry that is based on a high level of integration of research based – and expert knowledge in the development process.

4.1.2. Participation

The manager stresses the importance of collaborating with other firms, industry actors and researchers, because solving common challenges will benefit the whole sector:

> *(…)it is very important for us to collaborate, because all of us are more or less struggling with the same challenges (…). When we solve these (challenges) together, we can develop a much larger market than we as a single business can deliver to.*

The kelp farm participates in several knowledge networks and industry clusters that support learning and innovation. They engage directly with researchers through involvement in research projects, and indirectly through participation in networks and workshops where research institutions are present. Large industry actors such as suppliers of seedlings and technical material provide their expertise through active participation in the industry network arenas. Major Norwegian applied research institutes also drive the development of some networks, which function as arenas for industry and research actors to meet and share knowledge. The entrepreneur himself is doing boundary work by being involved in the networks, the industry clusters and organizing the cooperation with research institutions. The company also collaborates with local aquaculture industry on finding technical solutions to floating structures. Kelp farming in its current state depend on a high degree of collaboration between different experts and users to develop products and markets.

4.1.3. Learning

By starting small-scale, the kelp farm is set up to facilitate experimentation and learning about different techniques and site-specific growth condition. The entrepreneur's idea is to acquire as much knowledge about how to cultivate kelp and keep the costs down before applying for larger site concessions. Learning occurs by trial and error, ongoing problem solving and by collaboration with other industry actors (within kelp and aquaculture) and research institutions. The manager gave an example:

> *"For example, can we seed kelp spores by hand or use a machine? We find out what the problem is and solve it as we go along, it is both creative and systematic work (…). [Research institutions[1]] are also part of the industry cluster that we participate in so [they] participate one way or another in almost all the companies. And the knowledge exists within the research institutions today so it has to be transferred to the companies, that is an ongoing process. Knowledge transfer occurs through the clusters but we also develop things together."*

Learning is thus an essential part of the company's *modus operandi* and it is an explicit focus and highly valued outcome of activities.

4.1.4. Negotiation

Macroalgae cultivation is a knowledge intensive activity, and the manager combines research-based knowledge with his own "trial and error" practical knowledge. His possession of and reliance on research-based knowledge makes communication and collaboration with researchers and other experts easier. The boundaries between the kelp farmer, researchers and experts from larger industry actors seems to be dissolved. This does not necessarily mean that cultural differences and tensions between the entrepreneur and expert collaborators are absent, but these were not visible in this study.

4.1.5. Way of life and boundary work

The survey interviews indicate a mix between egalitarian and individualist attitudes: in resource management questions the kelp farmer displayed agreement with the individualist statements, while on the climate change statement he was closer to the egalitarian way of life. Other aquaculture respondents (n = 4) answers as egalitarians on all sets of questions. In terms of the actors' role – a business entrepreneur, we may expect preference for an individualist way of life (e.g.

[1] Company name is anonymized.

Thompson et al., 1990). But on the other hand our findings align nicely with Hoppe and Wesserlink's framework, where egalitarians are found to prefer boundary arrangements with converging knowledges and learning (2014). Learning and converging knowledges is characteristic for the development process in this case.

4.2. Case 2: developing new fish vessels in Sogn and Fjordane's coastal areas

Clusters of ship designers, fisheries shipping companies, fish buyers, the regional branch of the fisheries directorate and a maritime college are active in small coastal towns and communities. One fisheries company has commissioned new vessels with technology for better utilization of fish by-products. The inspiration and motivation for the innovation are new national requirements for minimizing organic discharge from fishing vessels. This company has sought funding from several government agencies and involved several consultancy companies, among them a regional ship design company, for the development of the solutions. Fish are fileted on board the vessels, and recently a hydrolysis reactor was installed in one boat to produce protein from the fish cuttings that previously were discharged at sea. Another company has commissioned vessels with new types of diesel electric propulsion engines that are much more energy efficient than traditional diesel engines. For both innovations, the companies have taken part in research projects and have received substantial financial support from the government.

4.2.1. Integration

Based on the demands from the owners, the shipyard, ship designers and producers of the various components develop new technical solutions, such as the hydrolysis reactor and the new vessel with a new type of propulsion system. The ship designers are acting as consultants and lead the process on behalf of the fisheries company. According to the representative from the company management, the fishers' and captains' practical, experience-based knowledge is not paired with that of technical consultants and experts in these development processes. He further stated that "research-based knowledge does not reach through to the fishermen" because that fishers, researchers and fisheries management "lack an interface for cooperation". The fishermen's knowledge is thus not directly used in development processes. The company's reliance on external consultants to follow up the development processes on their behalf, further limits the potential of integration of user knowledge. Input from fishers may still trickle through to the experts via the company management, who are in continuous dialogue with the experts. However, the management representative admitted that there is a need to facilitate better integration of the fishers' and skippers' knowledge in development and innovation processes. The lack of integration and limited emphasis on cooperation indicate that a diverging logic of knowledge production is present (Hoppe and Wesselink, 2014).

4.2.2. Participation

As noted, the fishers and crew are usually not involved in the innovation and development processes. The management representative stated that "they are hard to get hold of and therefore not easy to involve in projects". The fishermen tend to not being physically present at the sites where the development processes takes place. Instead, the representative served as a boundary worker between external experts and consultants and the fishermen. He was originally hired as a communication officer and worked in the leadership group of the company. The consultants that are engaged to follow up on the development and construction of new vessels and its equipment also acts as boundary workers. But they report to the company management, and not directly to the fishers. Paradoxically, their presence may therefore contribute to less cooperation between fishers and experts. One of the fishermen that was interviewed explained that they sometimes had researchers on board when they were fishing, and that these researchers were developing new methods and techniques, for instance for storage of catch. This was a researcher-initiated project, and even though the results were highly relevant for the fisheries company, the main motivation for cooperating with the researchers was that the fisheries company received an additional quota for "research catch". As the fishermen replied when asked if the result of this project was useful for them: "no, but it was fun to have the female researchers on board".

4.2.3. Learning

According to several interviewees, fishermen are good at exchanging experience-based knowledge among themselves. But learning did not emerge as a salient part of the development processes in this case and was not a deliberate part of the process. There was no mention of "trials and errors" or "learning by doing" as we heard in the previous case. This is obviously tied to the limited participation by fishers in the processes. But because the management representatives did increase their knowledge by taking part in the processes, some learning did take place.

4.2.4. Negotiation

While the knowledge and expertise of the fishers are recognized by the management of the fisheries company, it is not deliberately included in the innovation processes. Such processes are carried out by experts under the leadership of the company management. As stated by the management representative that acted as boundary worker there is "a culture for fishers excluding researchers and the public fisheries management". The roles and domains of expert and users was thus clearly defined and no negotiation over the boundary was detected. Such negotiations are needed if the fishers' knowledge is to be better included in the innovation processes. The boundary workers in this process were however likely to ease potential tensions between users and experts and aid translation.

4.2.5. Way of life and boundary work

Statements from the survey interviews indicate adherence to the *individual* way of life, which we also have found in previous studies (Dannevig and Hovelsrud, 2015). Several of the fisheries actors express an opportunistic attitude towards climate change. This also corresponds to how they view the application of knowledge, and the divergent logic of knowledge production corresponds to an individualistic way of life (Hoppe and Wesselink, 2014). The partly antagonistic relationship indicated above between researchers and fishermen also suggest that fishermen will not let scientists have primacy in a boundary work processes. This corresponds to individualist preferences (Hoppe and Wesselink, 2014). Even though the mode of knowledge production in this case aligns more with mode 2 than mode 1, it is closer to mode 1 than the two other cases. In this case we find that the individualist way of life corresponds with weak integration of knowledges, less participation than in the other cases. The boundaries between experts and fishers are maintained and learning is not an explicit desired outcome of the innovation and development processes. Diverging logics of knowledge is also tied to maintenance of the boundary between the domains of experts and users.

4.3. Case 3: new fruits for a warmer climate in Lærdal

Lærdal, located in the inner fjord regions of Sogn and Fjordane county, is renowned for its agricultural traditions and extensive fruit and vegetable farming. The farmers benefit from exceptional local climatic conditions that allow for intensive agricultural production, otherwise not common in this part of Norway. The farmers explained that they have a culture for experimenting with high value crops. In the past 10 years they have invested heavily in cherry (*cerasus*) and raspberry (rubus idaeus)

cultivation aided by the regional agricultural extension service and a local agricultural research company. They have established their own

distribution company that aid research and development activities. The more recent innovations, in particular apricot (*prunus armeniaca*) cultivation, but also elderberry (*sambucus)* and seabuckthorn (*hippophae*), are partly motivated by a longer growing season and increasing temperatures. Such responses are therefore primarily adaptation to climate change, in seizing new opportunities.

4.3.1. Integration

Farmers are either initiating projects themselves, or they lease their land to the extension service and the research company for projects. In the projects where they identified and developed varieties of cherry, apricot and raspberry for local cultivation, this was a result of initiatives taken by farmers. Researcher-initiated projects included elderberry and seabuckthorn cultivation. The farmers are the key actors; they plant the trees and bushes, experiment with different systems for climate control for the crops, using their existing expertise and skills as experienced fruit growers, while at the same time they rely on the scientific knowledge of the research company to select the best varieties and methods for growing. As one farmer put it: "we grow a lot of different varieties of crops we receive from the research company (…), and some test different types of tunnels and other test different types of cover, it is testing all the way to see if we can control nature". Both the very idea of cultivating cherries, and the methods they use for preventing frost damages on cherry blossom in May, have been identified by the farmers themselves during study trips to South Tirol in Northern Italy. The result - fruit and berry varieties that are both successfully cultivated and sold - builds on and integrates the farmers practical knowhow with the extension service and research company's scientific agricultural knowledge. This signifies a converging logic between the experts and user knowledge in this case.

4.3.2. Participation

The farmers participate in an extensive fruit grower's network, and frequently visit fruit growing regions elsewhere in Norway or Europe to learn and be inspired. The role of dedicated boundary workers in this case is crucial. The boundary workers are both the managers of the farmers' joint distribution company, as well as agricultural extension services. This group of people organizes the networks, study trips and creates bridges between research institutes and the farmers. As noted, the farmers are in control of the innovation process. But they do also take part in research and development projects managed by the agricultural extension service or the research company. This activity fosters cooperation and learning.

4.3.3. Learning

The farmers learn by trial and error through their own practices, but also directly from cooperation with experts from the extension service and research company. Several of the informants mention the importance of learning from the study trips: "The study trips are important for getting inspiration and knowledge about new varieties and cultivation techniques, but also for us farmers to get time together to talk and discuss different matters", stated one farmer. Learning about new modes of producing fruit is highly intentional but also an integral part of being a farmer.

4.3.4. Negotiation

There was no indication of tensions between users and experts in this case, contrasting cultures or polarization. The boundaries between the domain of users and experts are in many ways dissolved, and the farmers are taking the role as experts, through their active and dominating role in the processes.

4.3.5. Way of life and boundary work

The farmers that were interviewed, expressed clear agreement with statements that correspond with an egalitarian way of life, for instance they recognize the need for rapid societal transformation that would include changes in their own lifestyles. The converging logic of knowledges is also indicative of egalitarian way of life according to Hoppe and Wesserlink's framework (2014). As in the first case, an egalitarian way of life goes along with converging logic of knowledges, which also is supported by other studies (Hoppe and Wesselink, 2014); as well with a high degree of participation and learning.

4.4. Summary of the cases

While the three innovation processes appear more or less successful in terms of the end results, there are substantial differences in how the boundary work takes place in each. This corresponds closely to differences in ways of life. The fisheries actors adhere to an individualist way of life, the farmers adhere to an egalitarian way of life, and the kelp farmers display a mix between the two. Table 2 categorizes the configurations of boundary work in the innovation processes in terms of how they relate to the four dimensions and ways of life. We did not encounter hierarchical or fatalist ways of life in this study, which is not surprising, giving the role and profession of the informants (e.g. Thompson et al., 1990).

Converging logics of knowledges, which is a consequence of integration of user knowledge with expert knowledge in the innovation and development processes, has in other studies been found to be associated with egalitarians, while converging knowledges, indicating a lack of integration, has been found to be associated with individualists (Hoppe and Wesselink, 2014, Hoppe 2005), in line with our findings.

Boundary arrangement that are characterized by learning is also found to be preferred by egalitarians (Hoppe 2005). In case 1 and 3, integration, learning by trial and error and through collaboration with experts, where all salient features of the processes. Dissolving of boundaries between experts and users which we found in case 1 and 3, and a requirement of deliberation, is also characteristic of egalitarians (Hoppe and Wesselink, 2014; O'Riordan and Jordan, 1999).

5. Towards culturally sensitive boundary work

This study shows how livelihood actors solicit knowledge to address the challenges and find solutions relevant to their operations. Culturally sensitive boundary workers, such as agricultural extension services and technical consultants, engage industry actors in the innovation processes and help bridge the cultural divide between experts and practitioners. For example, researchers may typically fit into an egalitarian way of life, while industry actors adhere to an individualist way of life (e.g. Thompson, 2008). This goes beyond mediation, translation and communication (see Cash et al., 2003), and aligns with Swedlow's (2017) notion that boundary work can span boundaries that are also created by different ways of life.

The dedicated boundary workers (consultants in case 1 and 2 and agricultural extension service in case 3) involved in the specific co-production processes in this study have gained the trust of the users through long term collaboration and exchange of experience and expertise. Fig. 2 highlights the differences in alignment along the four dimensions for the two ways of life identified in our case:

Differences between the sectors emerge in how researchers and experts interact with the industry actors, from the most frequent engagement in the egalitarian oriented agricultural sector to the least in the individualist oriented fisheries. These differences can only partially be explained by how primary industries in Norway are organized and regulated at the national level (Amundsen and Hermansen, 2020). At the heart of the differences between these sector practitioners we find their cultural biases and way of life. These nuances are difficult to capture, explain and understand without being sensitive to such biases.

While there are limits to how much we can generalize from the three case studies, they show that there are differences in how actors with different ways of life organize and take part in boundary work (see Table 2). Our study shows that achieving mode 2 (coproducing usable

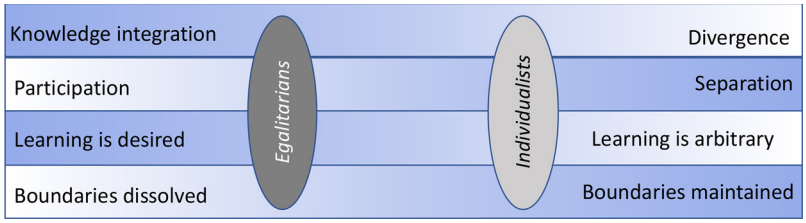

Fig. 2. Configurations of boundary work and ways of life.

and actionable knowledge) processes might be more challenging with the individualists in case 2 than egalitarians in case 3. We argue that it is likely a greater need for dedicated boundary work among actors or in organizations that adhere to an individualist way of life, particularly negotiation, to achieve higher degrees of participation, knowledge integration and learning in innovation processes. However, we are not saying that the innovation and development processes analyzed in case 2 is less successful than in the other two. In order to design successful boundary work processes with individualists, one need to respect the preferences for the various aspects of boundary work, such as a desire for primacy of users and not experts in innovation processes and that the end result is more important than the process. We surmise that successful innovation processes in case 2 hinge on the ability of the boundary workers to manage these preferences. We also note that the boundary workers feature more prominently in case 2 than in the other two cases, acting as middlemen between user and expert throughout the processes studied. In case 1 and 3, dedicated boundary workers were also involved, but here the users collaborated directly with experts and they did most of the development work (e.g. trials and errors) themselves. If egalitarians are more directly involved and cooperate more closely with experts than individualists, and it is clear that boundary work is beneficial for a successful outcome, it follows that dedicated boundary workers are more important in innovation and development processes with individualist users.

6. Conclusion

In our case study, boundary work in terms of high degree of participation, knowledge integration and learning, as well as dissolving boundaries was found to align with egalitarian ways of life. A lesser extent of participation, integration and learning was found in the individualist case. While three cases is not sufficient to generalize from, an in-depth study such as this illustrates well the mechanisms behind the results. The results are also largely in line with previous studies (e.g. Hoppe and Wesselink, 2014; Dannevig and Hovelsrud, 2015).

Our results show that by being culturally sensitive, boundary work is more likely to gain acceptance among practitioners. By applying the CTR framework we have increased our understanding for why different types of deliberate coproduction processes and knowledge exchange is rejected or embraced by the different industry actors. By applying and being sensitive to the ways of life underpinning the different industries, we are better equipped to understand how knowledge is understood, exchanged and coproduced between the different domains. This in turn has consequences for whether and how science spurs action. Our results show the potential for ensuring a high level of impact from the processes by deliberately crafting boundary arrangements to suit actors' way of life.

Deliberate coproduction, or mode 2 knowledge production, tends to be contrasted with the mode 1, or the positivist model, for knowledge production, and the literature often points to the success of mode 2 compared to mode 1 in the face of complex issues such as climate change (Kerkhoff and Pilbeam, 2017; Beck, 2011). As other studies have pointed out (e.g. Ney, 2009), mode 1 is also tied to the particular way of life of hierarchists, which we did not encounter in this study. From a culturally sensitive boundary work perspective it is not surprising that mode 1 is not successful when applied in groups and systems that do not align with the hierarchical way of life. Our study helps to enhance the understandings of why mode 2 might be more successful than mode 1. And importantly it shows that it is not just a question of mode 1 versus mode 2, because there is not one mode 2 model that fits all types of users and systems. We conclude therefore that the mode 2 model needs to be subdivided into different configurations.

There is a trend among research funders to push for mode 2 types of research and development processes. But as we have shown, if these are to involve industries and entrepreneurs that are likely to be individualists, they might not be so interested in the extensive extent of participation, learning and integration that mode 2 might require. This means that opportunities for transformative solutions may be lost because the researchers are not sensitive to the cultural bias of the user segment. With skilled and culturally sensitive boundary workers, deliberation and coproduction can still be ensured.

While we realize that our culturally sensitive approach to boundary work needs to be tested and refined by further studies, we believe the approach is transferrable and relevant for coproduction of knowledge for adaptation and transformation to a low-emission, sustainable and resilient society.

CRediT authorship contribution statement

Halvor Dannevig: Conceptualization, Methodology, Investigation, Formal analysis, Writing - original draft. **Grete K. Hovelsrud:** Methodology, Investigation, Formal analysis, Writing - review & editing, Supervision, Project administration. **Erlend A.T. Hermansen:** Conceptualization, Methodology, Writing - review & editing. **Marianne Karlsson:** Investigation, Writing - review & editing.

Declaration of Competing Interest

None.

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