frontiers in Marine Science

ORIGINAL RESEARCH
published: 20 December 2016
doi: 10.3389/fmars.2016.00267

Stakeholder Perceptions of Links between Environmental Changes to their Socio-Ecological System and their Adaptive Capacity in the Region of Troms, Norway

Rachel Tiller[1, 2]*, Jean-Luc De Kok[3], Karolien Vermeiren[3], Russell Richards[4], Murat Van Ardelan[5] and Jennifer Bailey[2]

[1] SINTEF Fisheries and Aquaculture, Trondheim, Norway, [2] Department of Sociology and Political Science, Norwegian University of Science and Technology (NTNU), Trondheim, Norway, [3] Unit Environmental Modelling, Flemish Institute for Technological Research (VITO), Antwerp, Belgium, [4] School of Agriculture and Food Sciences, The University of Queensland, Brisbane, QLD, Australia, [5] Department of Chemistry, Norwegian University of Science and Technology (NTNU), Trondheim, Norway

OPEN ACCESS

Edited by:
Maria Lourdes D. Palomares, FishBase Information and Research Group, Philippines

Reviewed by:
William W. L. Cheung, University of British Columbia, Canada
Vasilis D. Valavanis, Hellenic Centre for Marine Research (HCMR), Greece

***Correspondence:**
Rachel Tiller
rachel.tiller@sintef.no

Specialty section:
This article was submitted to Marine Fisheries, Aquaculture and Living Resources, a section of the journal Frontiers in Marine Science

Received: *28 April 2016*
Accepted: *02 December 2016*
Published: *20 December 2016*

Citation:
Tiller R, De Kok J-L, Vermeiren K, Richards R, Ardelan MV and Bailey J (2016) Stakeholder Perceptions of Links between Environmental Changes to their Socio-Ecological System and their Adaptive Capacity in the Region of Troms, Norway. Front. Mar. Sci. 3:267. doi: 10.3389/fmars.2016.00267

Climate change affects the marine environment at all levels of governance. At a global level, researchers expect the projected increase in sea surface temperature to facilitate large changes in the marine food web, which in turn will affect both global fisheries and aquaculture. At the local level, government and stakeholders want to know whether and how this affects their local communities and their adaptive capacity in light of this. Research suggests that risk communication of the effects of changes in the marine food web suffers from stakeholders' short-term mentality and narrow boundaries. This in turn can lead to an underestimation of the potential risks associated with climate change. We explore this theory by mapping the perceptions of marine stakeholders in the region of Troms, Norway. We first developed cognitive maps in a workshop setting, and then used system conceptualization to analyze the feedback mechanisms of the system qualitatively using fuzzy cognitive mapping. We examined the outcomes and compared them for different scenarios using a simple MatLab script. Results demonstrated that stakeholders did not underestimate their risks to climate change. They were aware of environmental changes, and they perceived that a changing climate was the cause of this change, and that it was indeed affecting their livelihoods—and would continue to do so in the future.

Keywords: stakeholders, climate change, policy makers, coastal communities, adaptive capacity, participatory modeling, scenarios, fuzzy cognitive map

INTRODUCTION

A changing climate is affecting the marine environment and all levels of governance thereof. Globally, the projected increase in sea surface temperature is expected to facilitate large changes in the marine food web, which in turn will affect coastal communities depending on marine eco system goods and services, including global fisheries, tourism, aquaculture, and others (Intergovernmental Panel on Climate Change IPCC, 2013; Holmyard, 2014). This change is ongoing and will take place on different time scales, but coincides in the current with increased global demand for seafood

(Pauly et al., 2002; Chiu et al., 2013; World Bank, 2013), seen in combination with a growing middle class globally, and the marine sector covering potential future food security challenges (Garcia and Rosenberg, 2010). Simultaneously, there is a decline in global commercial fish stocks. After years of overfishing, estimates suggest the collapse of an estimated 24–36% of global fish stocks. Additionally, estimates suggest the total overexploitation or collapse of in total in the range of 68–72% (Worm et al., 2006; Pauly, 2007, 2008; FAO Fisheries and Aquaculture Department, 2010). This collapse and decline in wild fisheries also need to be seen in connection with political priorities in many nations to protect the traditional industries of coastal communities. In the case of Norway, this specifically links in with the cultural heritage of what some consider remnants of former hunting and gathering past, namely artisanal and commercial fishing industries (Barnard, 1983; Barkin and DeSombre, 2013; Ministry of Trade Industry and Fisheries, 2013).

The primary method alleviating this increase in demand for seafood has been to expand the aquaculture industry for all farmed species, from shrimp to Atlantic salmon (Abdallah and Sumaila, 2007; Garcia and Rosenberg, 2010; van Vliet et al., 2010; Islam, 2014). When we remove aquaculture from the equation, however, the demand for seafood, and the willingness of consumers to pay a premium for wild-caught seafood (Davidson et al., 2012; Vanhonacker et al., 2013), spurs a need to fish, by many, or as famously said, "*...too many fishing boats chasing too few fish*" (Stone, 1997). To balance this, at the regional level, Regional Fisheries Management Organizations (RFMOs) use the biological and ecological information provided by scientists to determine regime management for fisheries in their area based on short- and long-term changes in fisheries productivity. At the local level, on the other hand, government and stakeholders want to know whether and how climatic changes to the marine environment will affect their local communities and their adaptive capacity in light of this.

Social forces and factors such as the latter are some of the key drivers of ocean stressors, both climatic and non-climatic, and its resultant consequences including ocean acidification, change in sea surface temperature (SST), pollution and nutrient loading, but also an overharvesting of marine species. Human responses to changes in oceans (and to other factors), and the effects this has on eco-system goods and services, produce feedbacks to natural systems as well, though. This "coupled system" approach is a foundational characteristic of the work of the (Intergovernmental Panel on Climate Change IPCC, 2014), and is known and understood as a socio-ecological system (SES) (Anderies et al., 2004). There is broad scientific agreement that climate change, in combination with other stressors, will impact natural systems to different degrees, in different ways and at varying rates of speed, and that the oceans will be affected. There is also broad agreement that human communities vary with respect to how climate change (or another "hazard") will affect them. History demonstrates that traditional single sector management is unable to address with effectiveness the cumulative impacts of multiple stressors. This in turn could result in a decline in ocean ecosystem productivity, which could spur an increase in user groups challenging one another for limited marine and coastal resources (Lester et al., 2010; Lubchenco and Sutley, 2010). Along with biological, oceanographic, and economic analyses, interactions with stakeholders is a key element of integrated ocean management. Understanding how groups of key stakeholders perceive potential changes will affect them is essential in guiding managers to identify and assess how stakeholder perceptions compare to scientific analysis of impacts, and their adaptive capacity to these.

However, risk communication of the effects of changes in the marine food web suffers from stakeholders' need for short term returns, leading to their putting off long-term investments and representing a "dictatorship of the present" (Mazmanian et al., 2013), suffering from myopia[1]. This in turn can lead to an underestimation of the potential risks associated with a changing climate to their situation. In light of this, the following article explores the projected effects of climate change to stakeholders dependent on the marine ecosystem goods and services, with a case study of the region of Troms in Northern Norway, concentrating specifically on the commercial fisheries sector. We explore to what extent the projected cascaded risks and effects of climate change to the marine environment reaches the consciousness and in turn the adaptive capacity of stakeholders at the local level, a critical factor given the interconnectedness of the governance levels in Norway. The article first discusses the background of the study relative to climate change as well as the Norwegian regulatory system as it cascades from the international RFMO to the local implementation level. This is followed by a description of the methodologies used for the purposes of this study, the results of the stakeholder workshop, scenario development and a discussion of the adaptive capacity of commercial fishers, and for regional and local fisheries management in the northeast Atlantic in an uncertain climatic future.

BACKGROUND

Management regimes are conceptual and de factor organizations of human activity. These regimes, formal or informal, generally consist of a set of processes or standards related to its ability to make decisions in a given issue area, whether it is tuna fisheries or telecommunications or the management of zebras. The goal of the regime is to ameliorate or solve an issue that could (or already has) become a challenge if unmanaged (Krasner, 1983; Hasenclever et al., 2000; Stokke, 2007). The prevention of illegal, unreported and unregulated (IUU) harvest of marine species on the high seas, for instance, or the devastation of the natural environment either on land or in marine environments are other examples of when management regimes could be a necessity. Norway is a member of a number of management regimes for fisheries related issues. These include annual bilateral, three-way and five-way negotiations and agreements with Russia, the EU, Iceland, the Faeroe Islands and Greenland over shared fish-stocks in the Northeast Atlantic, in addition to being members of the North East Atlantic Fisheries Commission (NEAFC). These

---

[1] Myopia is also known medically as "short-sightedness" or "near-sightedness" (Morgan et al., 2012).

are regimes that cover such issue areas as the sharing of cod-quota between Norway, Russia and third nations in the Barents- and Norwegian Sea; North Sea harvesting by the EU; mackerel quota in the northeast Atlantic shared between Norway, EU and the Faeroe Islands and others (Tiller, 2008; Ministry of Fisheries and Coastal Affairs, 2011). Article 63 in Section V of the UN Law of the Sea sums up the relevance of management regimes, both current and within future climate affected marine environments. It specifies that coastal states much coordinate the management of shared fish stocks when it occurs within more than two Exclusive Economic Zones (EEZs), or adjacent to one (as in international waters) (UNCLOS, 1982). This coordination is what constitutes a management regime.

This is relevant because data from the IPCC shows that a number of fish species are migrating northwards with increasing sea surface temperatures (point 4 above). This migration of new species into old fishing areas with existing actors and interests has already been observed with the Atlantic mackerel (Scomber scombrus) (ICES, 2013) shifting its distribution pattern to new areas because of warming waters (Hughes et al., 2015). This shift resulted first in Iceland entering the mackerel regime with Norway, Faeroe Islands and the EU, followed by both it and the Faroe Islands leaving it because of disagreements of quota distributions they considered unfavorable given the new spatial distribution of the stock (Jensen et al., 2015). This conflict is a taste of those to come, when shifts in spatial distributions of commercial fish stocks will materialize much more frequently, with resultant managerial challenges at the international, national and local levels of governance. These changes will entail a host of regulatory challenges both nationally and internationally, and management authorities would have to have the most current knowledge to understand these challenges and hypothesize about future scenarios.

THEORETICAL FRAMEWORK

Regionally, *RFMOs* must use the best available information to determine regime management based on short- and long-term changes in fisheries or aquaculture productivity, such as that from climatic stressors. At the national level, where the national and local policy debates takes place before the issue is taken up at the international negotiation stage, government and stakeholders want to know *whether and how* changes to the marine environments because of a changing climate will affect their *local* communities and their *adaptive capacity* in light of this. For the purposes of this study, we define stakeholders as "*... any group or individual who can affect, or is affected by, the achievement of the organization's objectives*" (Freeman, 2010). This is a broad definition and leaves the concept of having a stake, or invested interests, unequivocally open to include virtually anything, any topic, and the jurisdiction of a given stakeholder open to anyone. The importance in upholding a principle of stakeholder involvement is to ensure that local stakeholders are involved at all level of interest in the governance process. This is critical in that governments of democratic nations continuously make laws that have different effects on different stakeholders. Some stakeholders are in addition more powerful than others and therefore have the opportunity to actually shape policy (Mitchell et al., 1997; Tiller et al., 2015). Some still argue that stakeholders *should* play a role in shaping and determining the outcome of public policy in any given issue area that is of importance to them. This inclusion in the process could facilitate a feeling of process legitimacy, and in turn more satisfaction with outcome and in turn higher rates of legislation compliance (Young et al., 2007; Gopnik et al., 2012).

This latter is of utmost importance, since, in order for stakeholders to actually be able to influence the system, they have to comply with proscribed regulations. These are developed within a given political and social setting in which the given stakeholder operates. As such, stakeholder groups manoeuver within a political culture that reflects and reinforces the political context of their system. Within the Norwegian context, the political structure provides stakeholder groups access to government officials that earns them the ability to have the aforementioned effect on shaping policy. Stakeholder groups in a given democratic country belong to a pluralist or corporatist classification system, with Norway characterized as an example of a corporatist system within the consensus model of democracy. Within this system, stakeholders and industry work closely with both the state and labor organizations, and is incorporated into the policy making process (Lijphart, 1999). Two important aspects identifies it as *corporatist concertation* in turn, namely the required elements of vertical participation of key stakeholder groups. These include that (1) the government consults stakeholder organizations regarding government bills and that (2) stakeholder groups are represented on advisory and administrative committees within their issue area. There is also a correlation between a centralized and monopolistic interest organization and successful concertation (Lehmbruch, 2003). **Figure 1** visualizes this situation in Norway, and the consultation and inclusiveness of stakeholder participation in the decision making process in Norway, in that representatives of stakeholder groups are included at all levels of negotiations, both nationally and internationally (Tiller, 2008). Their perceptions of commercial fishers relative to their social vulnerability and adaptive capacity to changes as such are thus of utmost importance to investigate.

Shifts in distribution are not the only effects on marine environments projected by the IPCC however (see **Table 1** for details). Key findings from the IPCC Fifth Assessment Report also point to other implications from a changing marine environment resulting from climate change. These effects include not only stock displacements, but also changing spawning and feeding patters, stock size (smaller, because of lower oxygen carrying capacity due to higher SST), and shellfish mortality on account of ocean acidification. The latter also affects coral reefs that support many fish species globally. In addition is the fact that 400 million people all over the world depend on fish as a source of food (Intergovernmental Panel on Climate Change IPCC, 2013; Holmyard, 2014).

Figure 2 visualizes how the fisheries sector specifically both has an effect on stressors as well as the physio-chemistry of the ocean though. In addition, these stressors also affect the sector

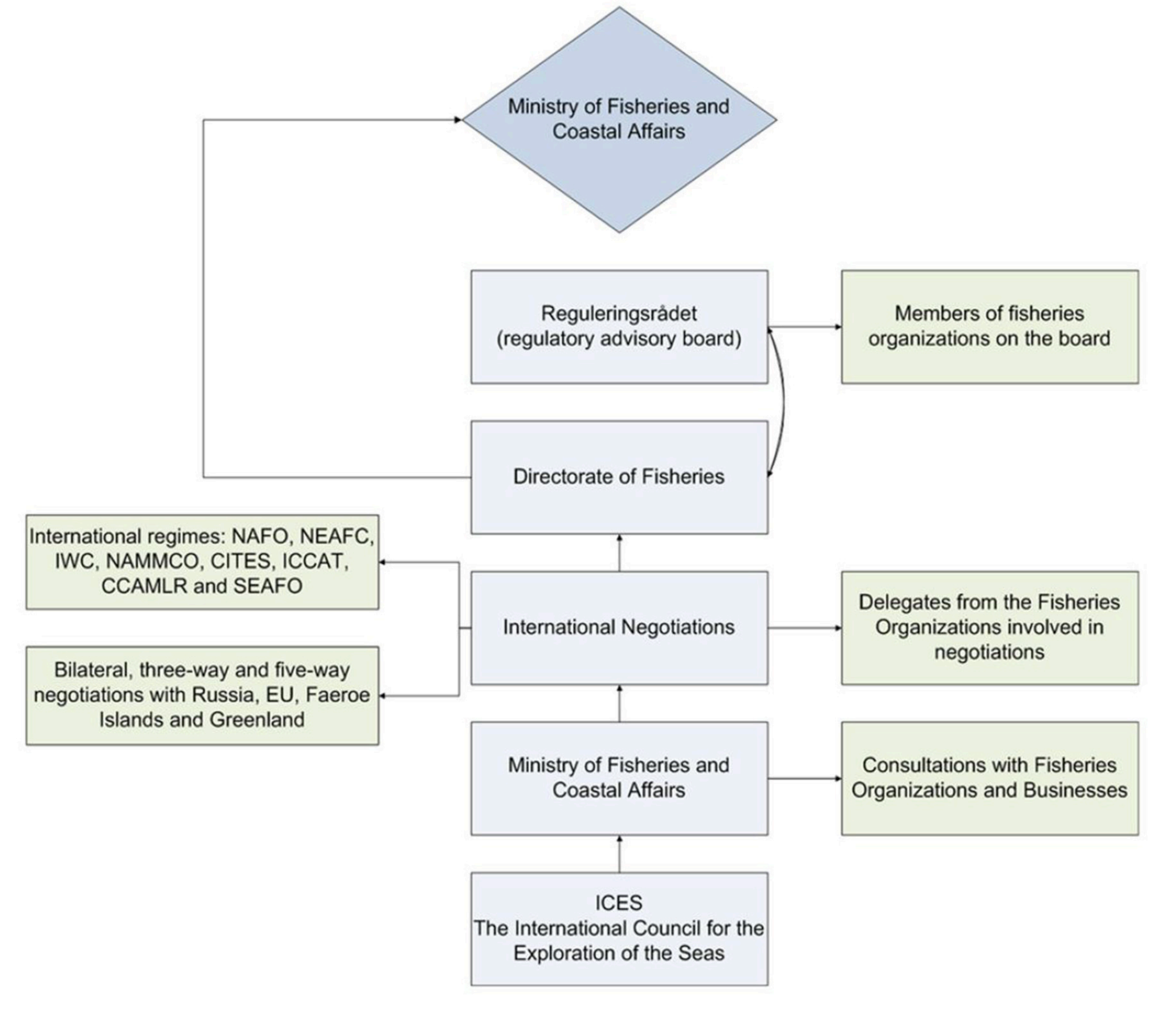

FIGURE 1 | The cascading decision making system in Norway.

TABLE 1 | Climate change impacts of relevance to our case area in Northern Norway are according to the IPCC (2013) and Holmyard (2014).

1 **Sea level rise** as well as extreme rain fall will lead to flood risk and damages;
2 **Cold and hot weather extremes** could lead to economic benefits if it gets warmer in winter – such as reduction of maintenance costs – and economic damages where the temperatures rise dramatically during summer;
3 **Tourism is expected to increase** in Northern Europe after 2050;
4 **Marine fish species will shift to higher latitudes** however, they will also be reduced in body size – this has already been observed as well. The economic impact will depend on market value of the new invasive species;
5 The production of wild and farmed salmon are adversely affected by higher water temperatures;
6 **Frequency of harmful algal blooms** could be an effect as well, in that they generate higher levels of toxins under higher ocean acidification; and
7 Climate change may affect and **damage cultural heritage sites**, which in turn could affect tourism that is based on this.

through changes in fish biomass and plankton and microbial life, potentially leading to changes in algae bloom frequencies, eutrophication to name some effects. This would in turn also have an effect on the management of the species of that area, the RFMOs and other management regimes, locally and internationally. The cascading effects on local communities can in turn as such have feedback to the system itself, in that the organizations are woven into the decision making system.

METHODOLOGY

There is a strong motive for engaging with stakeholders in order to access the expertise that they possess (i.e., "knowledge-base" data), which is characteristically strongly qualitative. The fields of climate change adaptation and resource management have strong human dimensions and therefore draw heavily upon this knowledge-base. However, quantifying this narrative-rich

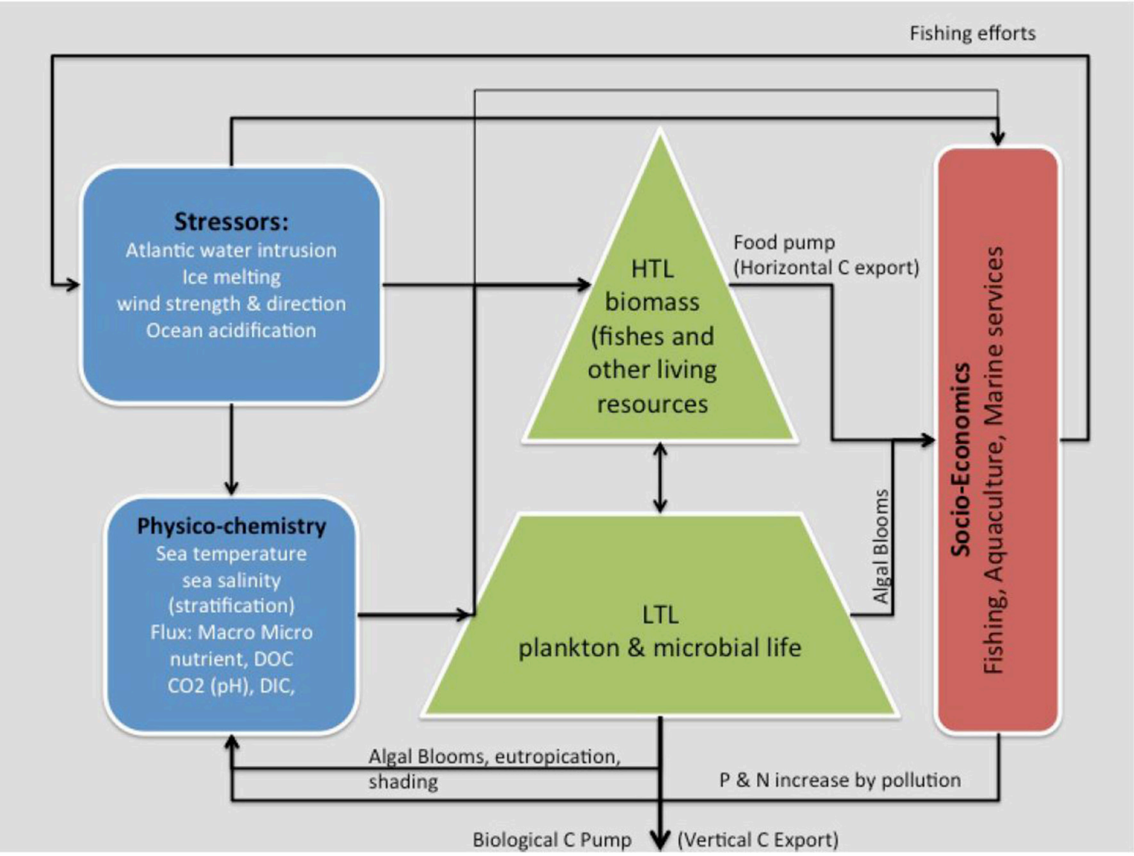

FIGURE 2 | Conceptual Model of climate effects on the marine system and feedbacks.

knowledge-base for the purpose of making management decisions (e.g., adaptive management scenario testing) is difficult. On these grounds, we used an integrated approach of "*Systems Thinking*" (Sterman, 2000) and "*Fuzzy Cognitive Mapping*" (Kosko, 1986; Kok, 2009; Gray et al., 2015). We used the freeware version of Vensim (2015) (www.ventanasystems.co.uk) for developing the Systems Thinking model concurrently with analyzing the narratives from the recorded session, followed by translating these into a semi-qualitative model based on Fuzzy Cognitive Mapping using Mental Modeler (MentalModeler, 2015). The aim of the workshops, and the consecutive steps, was to analyze and understand the system and from this explore the adaptive capacities of the given stakeholders groups. Adaptive capacity can be framed in a number of ways (Smit and Wandel, 2006), but in its most raw form, it signifies "... *an ability to become adapted (i.e., to be able to live and to reproduce) to a certain range of environmental contingencies.*" (Gallopín, 2006). In the current study, we chose the following definition: "... *the capacity of any human system from the individual to humankind to increase (or at least maintain) the quality of life of its individual members in a given environment or range of environments.*" (Gallopin et al., 1989). Our main focus during the workshop as such was thus to determine to which degree a sample of commercial fishers in Northern Norway perceived their adaptive capacity, or maintain their current quality of life, to changing marine environments.

Dooropener Workshop

In order to ensure that the stakeholders selected for the study were appropriate, we chose to commence with a "dooropener" workshop with independent experts from the selected stakeholder categories, in addition to researchers in the field. This initial dooropener workshop was a methodological choice that we expected would raise the quality of the later workshops. It was held with 9 representatives from fisheries, aquaculture, tourism, management as well as the scientific community in the region of Troms. We selected the representatives directly, using the researchers' own network. It was not a random sample, given that it was for informative purposes for the research group. The purpose of the workshop was to test the methodology on these experts, and gain location and topic specific background information about the main issue of contention for climate change and marine scenarios were the marine climate to warm, and thus become more suitable to increased marine production in this more northern and colder area.

The importance in this workshop also lay in exploring the baseline of stakeholder perceptions in the area prior to the actual workshops. One finding, for instance, from the dooropeners, was that they expected the fishers to be adamant that "… *a changing climate was not something they were not already experiencing on a daily basis* …". This was in reference to fishers going out to fish in all weathers, and that in their perception, they were used to adapting to changing temperatures. They argued that most probably would be critical to climate change even having an effect, which reinforced the theoretical framework of the study on risk communications. This could be a reflection of stakeholder reluctance to embracing effects of a changing climate that is not immediate (Chilvers et al., 2014). Another important function of the dooropener workshop was to establish the drivers for the ensuing workshops, to ensure that they were understandable and relevant for stakeholders in the region (explained in "Developing the Drivers" later). Finally, this group was instrumental in setting the boundaries for stakeholder selection for the workshop with commercial fishers. The research group had initially considered the city of Tromsø as a representative case study. The meeting participants suggested, however, expanding the stakeholder search area to include the island of Senja 2h south of the city of Tromsø (**Figure 3**) instead. They argued that commercial fishers on this island were equally likely to deliver their catches in Tromsø as they were locally, and were as such representative of the coastal fishers in this region. These local groups of fishers were also arguably easier to engage for stakeholder workshops, as they were anchored locally in smaller communities.

Developing the Drivers

The *initial* drivers that researchers presented at the dooropener workshop were developed during an initial workshop at the startup of the Ocean Certain project. The experts from that startup meeting were consortium members with expertise in biology, micro-biology, environmental modeling, oceanography and political science, and the final drivers decided upon were (1) Food web; (2) Biological pump function; (3) Sea Surface Temperature; (4) Ocean CO2; (5) Ocean Acidification; (6) Water Quality; (7) Water Pollution; and (8) Algal blooms. During the dooropener workshop, however, the stakeholders

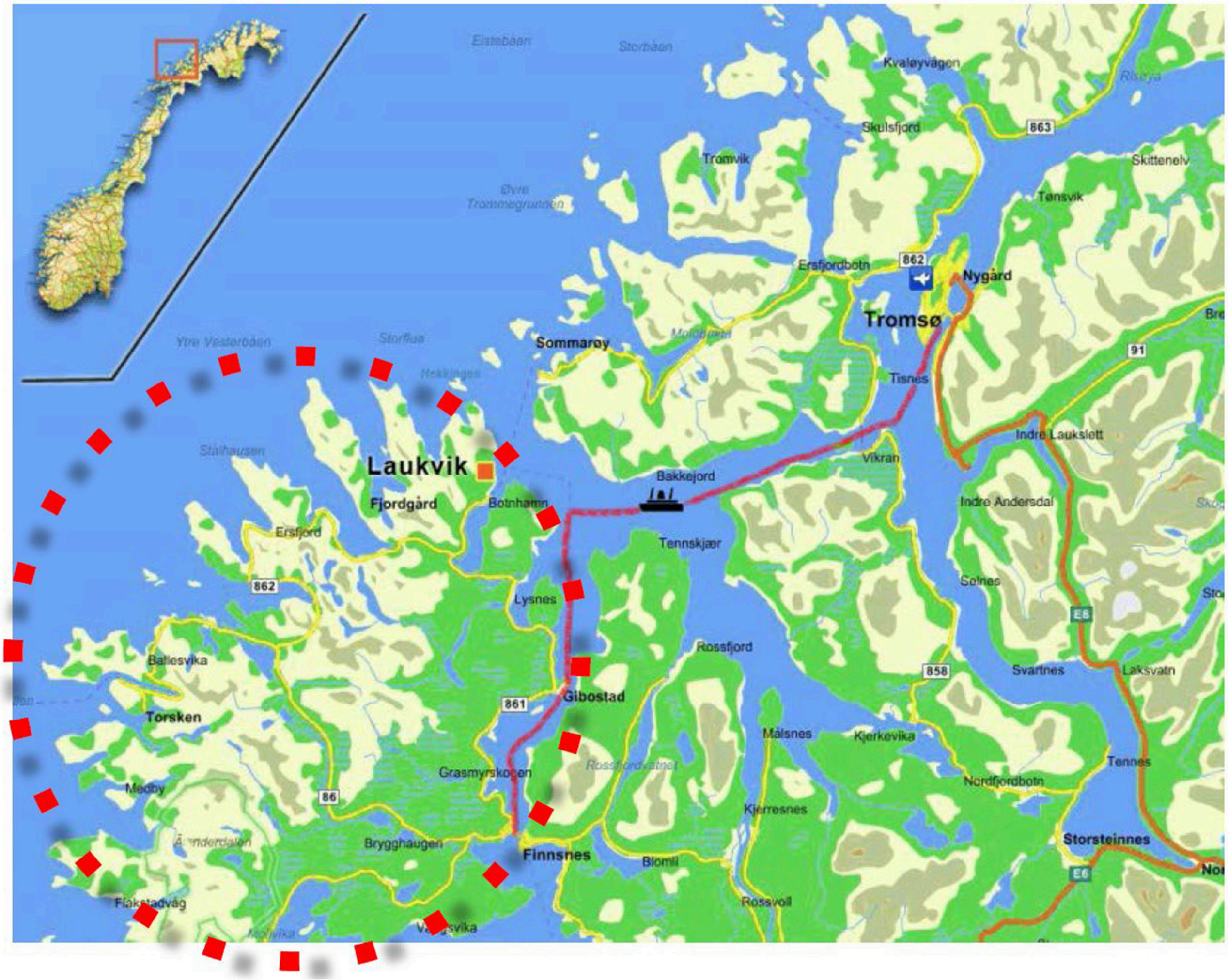

FIGURE 3 | The island of Senja is located about 2 h south of Tromsø by boat or car. The red line signifies the route of the boat.

considered these too vague and removed from stakeholder realities. Therefore, the dooropeners suggested the research group change them to (1) Aquaculture management laws; (2) Carbon Cycle in the Ocean; (3) Sea Surface Temperature; (4) Coastal zone management; (5) Water quality; (6) Water Pollution; and (7) Algae Blooms. The two additions in the latter case were related to aquaculture and to coastal planning, both of which mirrored the ocean-space zero-sum game between fisheries and aquaculture. The drivers that the dooropeners considered too vague or academic for the stakeholders were (1) Food web; (2) Biological Pump function; and (3) Ocean Acidification.

Stakeholder Workshops

Based on the recommendations from the expert panel in the Dooropener workshop, we narrowed our search for an appropriate case area to the island of Senja in the southern part of the region of Troms, the second largest island in Norway. There are four municipalities on the island of Senja, namely Berg (34 fishers), Torsken (43 fishers), Tranøy (16 fishers), and Lenvik (192), with 285 registered fishers total in 2015. The total population of all these four municipalities is 14 612, which includes the on shore municipal center of Lenvik, namely Finnsnes (Senjavandrer.no, 2016). The island community represents 22% of the 1322 registered fishers total in the entire region of Troms (Directorate of Fisheries, 2016).

We recruited the stakeholders using the snowball method (Biernacki and Waldorf, 1981) through project contacts. The snowball approach was selected because the quality of the results sampled from this group would outweigh the relative small number of informants the method usually produces. This is often the case in qualitative research studies, where large samples can at times be ineffective and do not provide the detailed and contextual information wanted by the researcher. For the purposes of this workshop, the primary researcher judged fifteen to be the maximum of what would provide a holistic narrative where all participants were provided ample opportunities to share their perceptions. The sample size can be as small as one or two as well, if this participant has information that is of critical value for the given sector and advances the research toward a specific goal (Sandelowski, 1995). The workshop with the commercial fishers was held at the end of June 2015 and four representatives of the Norwegian Fishermen's Association/Norges Fiskarlag—a politically independent organization that is built on voluntary membership. Norges Fiskarlag was established in 1926 to safeguard the collective interests of the Norwegian capture fishermen, and it is the largest fisheries organization in Norway, with some 7000 members. It consists of eight local chapters spread along county lines, as well as two group organizations (*Sør-Norges Notfiskarlag* and *Fiskebåtredernes Forbund*). Members are both coastal fishermen with small smacks, as well as the crew of ocean-going trawlers, thereby ensuring a broad and encompassing membership base, and the group taking part in the participatory workshop represented the same mix of fishing vessels. By prior consent from all participants, the project group recorded the session using the Voice Memo app on an iPhone 6. The facilitator emphasized that these narratives from the workshop would be used to illuminate and ensure the correctness the results, and would later be deleted. The workshop upheld the rules on anonymity from the Data Protection Official for Research in Norway (NSD), and the participants were given written information about this as well, and were informed that they were free to leave the workshop at any time and were not obligated to participate.

During the session with the stakeholders the researchers started the group model building experience by presenting relevant background information about the project and the project aims (Impson, 2011), including comments about the language of systems thinking (e.g., explaining feedbacks are, how the "system" is bounded (what the system includes and what it excludes), and what "adaptive capacity" means. Given these, the facilitator asked the stakeholders to consider a context in which they were to give their perceptions on the current adaptive capacity of their stakeholder group to suggestions of changing marine environmental conditions, and effects thereof, due to climatic and non-climatic stressors.

Systems Thinking

The facilitator initiated the system conceptualization process by presenting the stakeholder representatives with the seven "drivers" established earlier (see "Developing the Drivers" above). Systems thinking is a methodology that develops shared mental models of a given "system" as the involved stakeholders perceives it. This gives us a group model building process that develops a stakeholder driven system conceptualization, or map, based on their group-level beliefs and personal or shared experiences. It also facilitates the identification of system drivers (see "Developing the Drivers" above) and consequences within the context of the study (i.e., changing management objectives relative to for instance prioritizing aquaculture licenses in the northern part of Norway because of changes in sea surface temperatures, and its effect on commercial fishers in the area). This process also helps to identify central elements or variables that influences or is influenced by other variables or elements within the same system. In this way, the relationship between system behavior (e.g., events and trends), system structure (interconnections and feedback pathways) and cognitive understanding (mental models) can be explored (Maani and Cavana, 2007). This facilitates the exploration of the focus system (i.e., fisheries in the Troms region) to be developed at the local scale (in this case, commercial fishers in a local community in the Troms region of northern Norway) using the expertise of the stakeholders themselves.

The facilitator explained to the stakeholders that the drivers were variables that had the ability to influence other variables, though were not typically affected by other variables themselves. The drivers list was not exhaustive and the facilitator emphasized that the stakeholders could change it during the workshop. The fact that stakeholders can change these drivers or put in new ones is one of the benefits of this methodology. The facilitator then posted the drivers on the board with colored "sticky" notes, and the stakeholders were then encouraged to identify the causal interrelationships/connections between these elements or components of the system that could represent variables or could represent a state, in the form of associations with direct causations. This could for instance be links that highlighted that sea surface temperature (variable "A") affected new species of fish availability in the area (variable "B"), or that algae blooms (variable "C") directly affected the target fish species of the given fishers (variable "D"). The result of this process took close to 2 h. The result was a group mental model, or system conceptualization, that represented how this particular stakeholder group (commercial fishers in the region of southern Troms in Norway) collectively considered the causal pathways between variables. It also demonstrated where possible conflict lines were between other user groups.

Fuzzy Cognitive Mapping

A system conceptualization was also used to analyze the feedback mechanisms of the system qualitatively. Fuzzy Cognitive Maps or FCMs (Kosko, 1986; Kok, 2009; Gray et al., 2015) are directed, causal graphs that can be used to describe the dynamic feedback behavior of systems of varying complexity and help bridge the gap between qualitative and quantitative knowledge. Rather than predicting the time-dependent changes, FCMs can be used to analyze the key feedback mechanisms and causalities of systems by means of step-wise iteration. Methodologically, FCMs are semi-quantitative and take a position in between purely qualitative, conceptual models and quantitative system dynamics models using a mathematical representation of the system, potentially including time delays. Therefore, the scenarios are to be interpreted with care as long as time is not explicitly included. The step-wise iteration of the model and analysis of the resulting changes can help understand the role of system feedbacks and effectiveness of management options under different scenarios. It is very useful for the researcher's understanding of the dynamics of the model that the system evolves. Fuzzy cognitive mapping allows semi-quantitative analysis of the system feedback that surpasses the conceptual nature of complex, inter-disciplinary discussions or narrative storylines as used in e.g., participatory modeling such as those developed during our system thinking exercise alone. This is because FCMs take conceptual modeling (Systems Thinking) assigns weights to the visible causal links in the system and apply matrix algebra to derive the change of the system state. The combination of semantic, conceptual networks with iterative computation of state changes makes this semi-qualitative modeling technique transparent in nature, adaptable to problems of arbitrary complexity and highly interactive.

A Fuzzy Cognitive Map or FCM (Kosko, 1986; Dickerson and Kosko, 1994; De Kok et al., 2009) is a causally directed graphical model consisting of the relevant variables of the system and relations between these variables. Variables refer to state variables whereby the state can vary from high (represented by value 1) to low (represented by value 0). Each variable has an initial state, which represents the starting situation of the variable. An initial state of 0,5 refers to an "average" or "medium" level of the state of the considered variable. E.g., when the variable "Jellyfish" has an initial state of 0,5 this means an average number of jellyfish in the marine system. The relations are depicted in the FCM as arrows which are assigned "fuzzy" weights in the range [−1,+1] expressing the strengths of the causal relations. The weights are representations of the strengths of the positive (reinforcing) and negative (balancing) direct impacts variables have on one another, and usually defined in a range between −1 and +1, with the number of values discerned depending on the level accuracy of understanding the causalities. In this case a distinction between the values "low," "medium," and "high" was considered sufficient. A positive weight in the FCM implies that a variable is affected positively: In case of an increase of the influencing variable will increase as well or it will decrease in case the influencing variable decreases. In case of a negative weight the variable affected decreases when the influencing variables increases or vice versa.

MentalModeller (www.mentalmodeller.org) was used to construct the FCMs because of its user-friendliness and the in-built functionality to export the model to spreadsheets. Starting from a vector of initial states of the variables adjacency matrix is used to calculate the state vector for the next iteration step. Thereby, the state of each variable is obtained from the value for the previous step and the weights and states of the other variable(s) (**Figure 4**). In case the values exceed the allowed range [0;1] the results can be clipped off, using so-called "squashing" functions. In this work, a sigmoid squashing function for each iteration step n, the new state of a variable S is quantified using the following expression:

$$\mathrm{S}_{\mathrm{i,n+1}} = \frac{1}{1 + \mathrm{e}^{-\lambda * ((\mathrm{S}_{\mathrm{i,n}} + \mathrm{w}_{\mathrm{i,j}} * \mathrm{S}_{\mathrm{j,n}}) - \mu)}} \qquad (1)$$

with:

i = index for dependent variable,
j = index for influencing variable,
λ = squashing parameter (set at 2)
μ = average state value of the variable (generally 0, 5)

This procedure is repeated for a number of steps until an equilibrium or semi-equilibrium (periodic behavior) is reached for all variables. The presence of so-called "transmitter" variables (Kontogianni et al., 2012) with a one-way impact on one or more other variables are those that actually drive the system. Their development over time in turn define the scenario. This means that we have to predetermine what we would like these transmitters to "do" in a given scenario. For instance, if Sea Surface Temperature (SST) is a transmitter, one scenario could be to explore the effect an increase from 0 to 1 would have over 50 years. Another scenario could be to see what 0,5–0 would do to the system, relative to the stakeholders perceptions. The scenarios are as such not "real" numbers, but fall within the definition of scenarios as a series of hypothetical events or potential futures, in this case in the commercial future of the aquaculture industry in light of different understandings of the efficacy of accountability (Kahn and Wiener, 1968). The original purpose of the scenarios was to draw management attention to relationships that existed between actual developments and

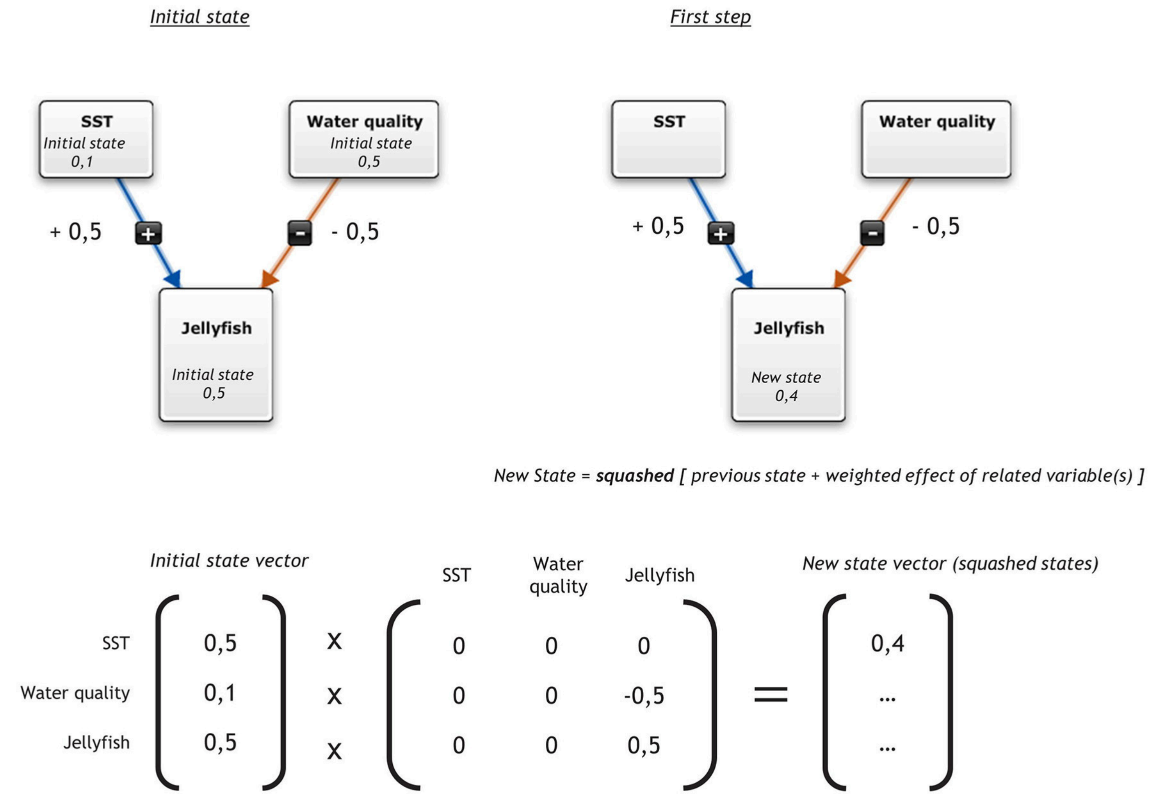

FIGURE 4 | Illustration of example FCM with three variables and the computation of the first step based on state vector.

the possible interventions that could be prepared were a given scenario to be actualized (Botterhuis et al., 2010). We examined the outcomes and compared the different scenarios using a simple MatLab script.

The advantage of FCMs is that the behavior of key variables under different scenarios can be compared in a more consistent manner. This is important, since, in our work we focus on **scenario analysis** (i.e., what if?) where changes in conditions (for instance increased sea surface temperature in Northern Norway) may be used to update our prior understanding of an event (e.g., the priority issue in our model) to posterior understandings. These requirements are well-matched by the functionalities of FCMs. "Scenario" is increasingly popularized. The term "Scenario" comes from the Latin word *scaenarium.* Scaenarium, which in term is based on the latin word *scaena,* signifies a location where one erects stages (Merriam-Webster, 2012). For the current article, we will use the academic definition of scenario that covers our aim: "S*cenarios are consistent and coherent descriptions of alternative hypothetical futures that reflect different perspectives on past, present, and future developments, which can serve as a basis for action"* (van Notten, 2006). Herman Kahn founded the Scenario method. He described scenarios as a set of hypothetical events that define images of potentials in the future. Scenario storylines, also known as visualizations of different futures envisioned, were according to Kahn supposed to be: "*... lively but realistic and attempt to draw attention to causal relationships between developments and the possible interventions policy makers or businesses can prepare for in the event of an actualization of a given scenario"* (Botterhuis et al., 2010; Tiller et al., 2013). The literature on scenarios generally highlight that we cannot treat scenarios as predictions (Schnaars, 1987; Hugues, 2000; Kristóf, 2006; Lena et al., 2006). Furthermore, scenarios can be proposed and they can be explored, but are not possible to validate until it is observed (or not) at a future time.

RESULTS AND DISCUSSION

The following **Figure 5** visualizes the Systems Thinking conceptual model of their first session, when the commercial fishers were asked to talk about the drivers and what in their system this affected, and would affect in light of a changing climate in their region. Their discussion focused much on mackerell, and observations that the species was moving northwards. The problem was not that this new and lucrative species was moving in their direction, however, but that they did not have quota to catch it—it would therefore be considered an illegal bycatch if they targeted it.

In addition, they experienced that the fish they did have a quota for, the saithe, "*... goes crazy around the mackerell ...*", in other words, behaves differently and erratically compared to the normal situation. The saithe, in turn, was also affected by algae

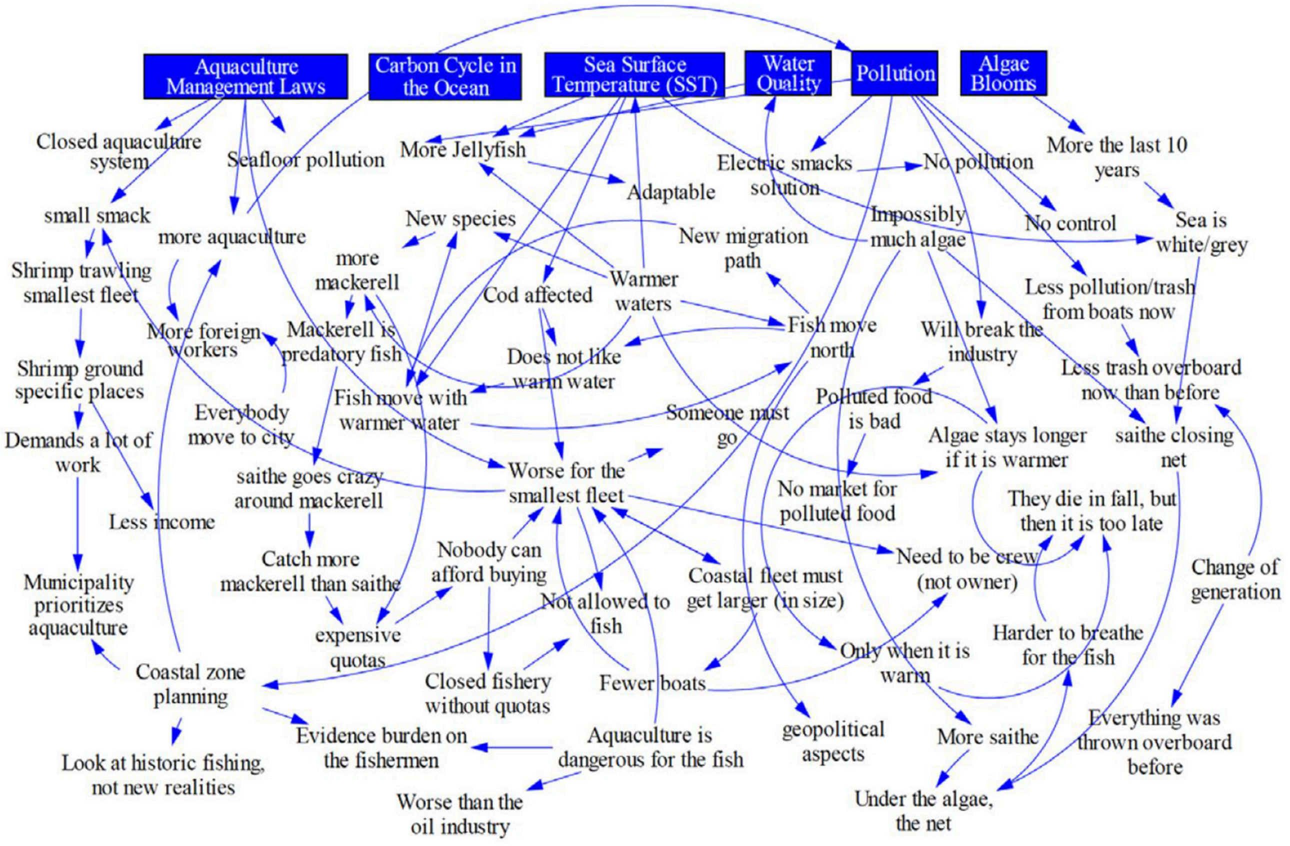

FIGURE 5 | Vensim conceptual model of the Commercial Fishers in Senja, Troms.

blooms, which they also were experiencing more of in the last ten years, they said, with the sea being "... *white and gray much longer than before* ...". Their general concerns, though, was that the smaller coastal vessels had the lowest adaptive capacity, and would be the losers in a changing climate. With new species moving northwards, the ships would have to get larger, and access to quota would be too expensive. In addition, they felt that the municipality greatly favored aquaculture, and that coastal zone planning did not favor the coastal small-scale fishers. What worried them a lot was not that these new fish were coming, but that there would be no access to quota for them. As they already saw that the saithe was being displaced by the mackerell, but that they could not fish the predator, they felt that their priority issue in a changing climate would be to have actual access to harvesting rights to these new species.

The narratives from this workshop along with the Vensim diagram (**Figure 5**) were translated into a Fuzzy Cognitive Map (**Figure 6**) of their perceptions, in order to facilitate the development of future scenarios. Though there are many similarities between systems thinking and FCM in terms of the conceptual map, and the latter builds on the former—the FCM is a simplification that has weights added to it (**Table 2**).

The scenarios run in ExtendSim centered on the two transmitters driving the system: SST (Sea Surface Temperature) and the "Power of aquaculture industry in municipality" (marked with red dotted line in **Figure 6** and the first and last variables marked with double lines in the matrix in **Table 2**).

We chose to run different scenarios for each of the transmitter variables for the purposes of this study. For SST we chose to first run a scenario where SST was initially at a 0 value, indicating that it was "normal" for the season (**Figure 7**). This scenario ended with 0,5 indicating that it would only reach half of the worst case scenario. For the purposes of these scenarios, we will not add "real" degrees to these numbers, since this information was not obtained from the workshops. While these two scenarios were run, the other variables all started with a 0,5 value (methodological choice corresponding to a neutral medium value) and used to analyze how the fishers system would change over a 50 year period based on a gradual increase in SST and the conceptual model obtained from the workshop. The other transmitter—"*Power of the aquaculture industry in the municipality,*" was held constant at 0,5, representing the fact that the fishers already considered that this stakeholder groups was relatively powerful in the area. We chose not to let this vary in the first phase, because it would make it difficult to separate the effect of the two transmitters on the variations in the other variables.

The majority of the variations take place in the first 10 years of the simulation (the "transition" phase). The most immediately

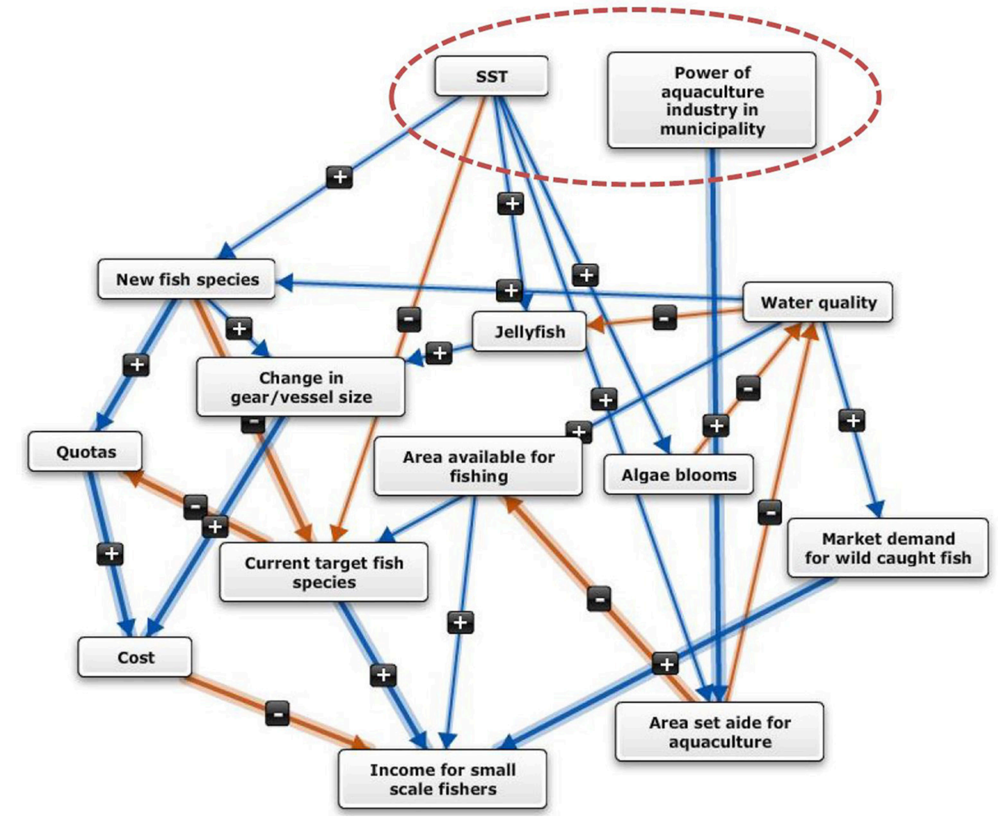

FIGURE 6 | Fuzzy cognitive map for fishers in the Troms region (done in Mentalmodeler).

visible change in variables comes with an increase in perceptions of costs for the fishers, which from the narratives we know were related to new species leading to a need for new quota, which in turn would increase the fishers' costs. Also, the FCM (**Figure 6**) specified that change in gear/vessel size because of both new fish species and jellyfish (for harvesting it—and for increased CPUE when cleaning) would also increase cost. The Matrix (**Table 2**) further informs us that these are strong effects, based on the perceptions of the fishers, with the highest value (1). It is therefore not surprising that this shows an immediate effect in the figure and that it stabilizes at a continous high level of 0,99 approximately.

Another variable that shows an immediate sharp incline is actually "Income for small scale fisheries". The three variables that have an effect on their income according to **Table 2** are "Current targeted fish species," "Market demand for wild caught fish," and "area available for fishing." However, all these variables have sharp declines, though, and as such, the initial increase can only be because "Quota" declines sharply in the same period—and once this starts to increase, the income for the fishers decrease immediately. If they can fish without needing new quota, in other words, their income will increase because of the influx of new fish species (the mackerell specifically, as they mentioned during the workshop). With SST increasing, however, we see that their income will continue to drop if their fishing necessitates new quota for new target fish species for the entire period and it never stabilizes, indicating that in an even longer run, their income would eventually no longer be profitable. Bear in mind also, that in this scenario, the "Power of the aquaculture industry in the municipality" is held at 0,5 for the entire period, which is fairly high.

In the second scenario run for SST, we changed this latter "Power" variable to a constant 0,2 instead (relatively little power of the aquaculture industry) and chose to start SST at 0,5 with a gradual increase to 1 over a 50 year period—indicating the highest perceivable SST in this period. In this scenario, we wanted to see if the perceived effects if we lowered the power of the aquaculture industry in the area. This is because a large part of the narrative centered on their industry being powerful and that with increased SST, it would be necessary to move the industry up north in order to fulfill the ambitions of the industry and the national government of increasing export volumes up to five times as high by 2030. This date would be almost within this 10-year zoom range for the second scenario (**Figure 8**).

Under this scenario, we see that similar to the first one, there is an immediate increase in both income and costs of the fishers, even more dramatic, perhaps because the drop in "Targeted fish species" was more sharp in this case than it was in the first scenario where the SST started much lower. Also, we understand

TABLE 2 | Adjacency Matrix with weight of variables, from –1 to 1.

	SST	**New fish species**	**Current target fish species**	**Algae blooms**	**Area set aide for aquaculture**	**Jellyfish**	**Quotas**	**Change in gear/ vessel size**	**Cost**	**Income for small scale fishers**	**Water quality**	**Market demand for wild caught fish**	**Area available for fishing**	**Power of aquaculture industry in municipality**
SST	0	0,5	–0,5	0,5	0,5	0,5	0	0	0	0	0	0	0	0
New fish species	0	0	–1	0	0	0	1	0,5	0	0	0	0	0	0
Current target fish species	0	0	0	0	0	0	–1	0	0	1	0	0	0	0
Algae blooms	0	0	0	0	0	0	0	0	0	0	–0,5	0	0	0
Area set aide for aquaculture	0	0	0	0	0	0	0	0	0	0	–0,5	0	–1	0
Jellyfish	0	0	0	0	0	0	0	0,5	0	0	0	0	0	0
Quotas	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Change in gear/vessel size	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Cost	0	0	0	0	0	0	0	0	0	–1	0	0	0	0
Income for small scale fishers	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Water quality	0	0,5	0,5	0	0	–0,5	0	0	0	0	0	0,5	0	0
Market demand for wild caught fish	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Area available for fishing	0	0	0	0	0	0	0	0	0	0,5	0	0	0	0
Power of aquaculture industry in municipality	0	0	0	0	1	0	0	0	0	0	0	0	0	0

The columns and variables marked with double lines are the transmitters and how other variables only have 0 values on them, illustrating how they only affect other variables and are not in turn affected by them.

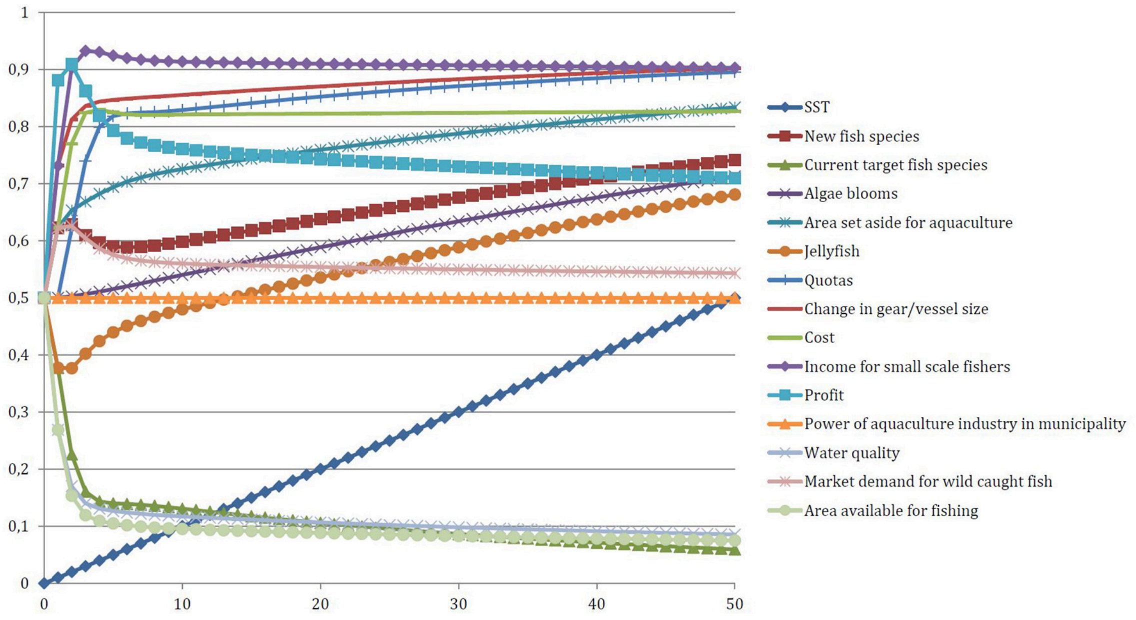

FIGURE 7 | 50 year development of variables with a 0–0,5 increase in SST. Notice that most dramatic changes in variables happen at the start of the period.

the increase in "Cost" better in this scenario, since it coincides with a sharp incline in "Jellyfish," which we know has an effect on costs in terms of changing the vessels and gears, as well as cleaning (Gjelsvik Tiller et al., 2014). In addition, there are more urgent quota needs under this scenario, which also explains the increasing costs, which are higher under this scenario where the water is consistently warmer than in the first one. The increased costs could also be because, under this scenario there are even more new fish species, which also demand more costs in terms of quota and changing of gear.

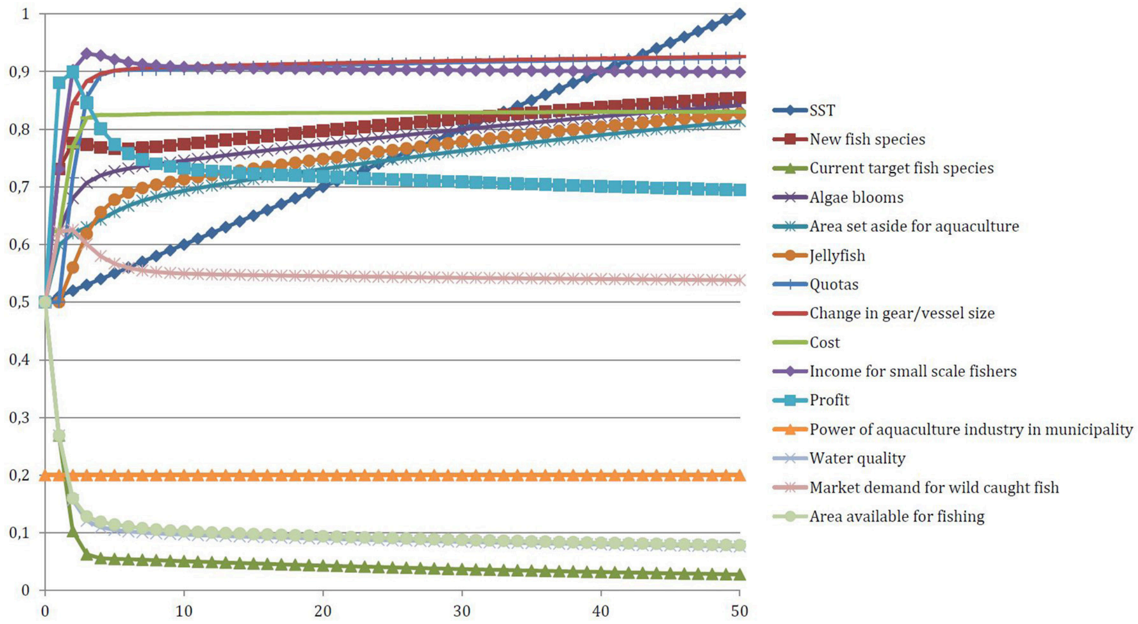

FIGURE 8 | Scenario 2 where SST increases from 0,5 to 1 (from fairly high to the highest possible/conceivable) over 50 years and Power is held constant at 0,2 (relatively low).

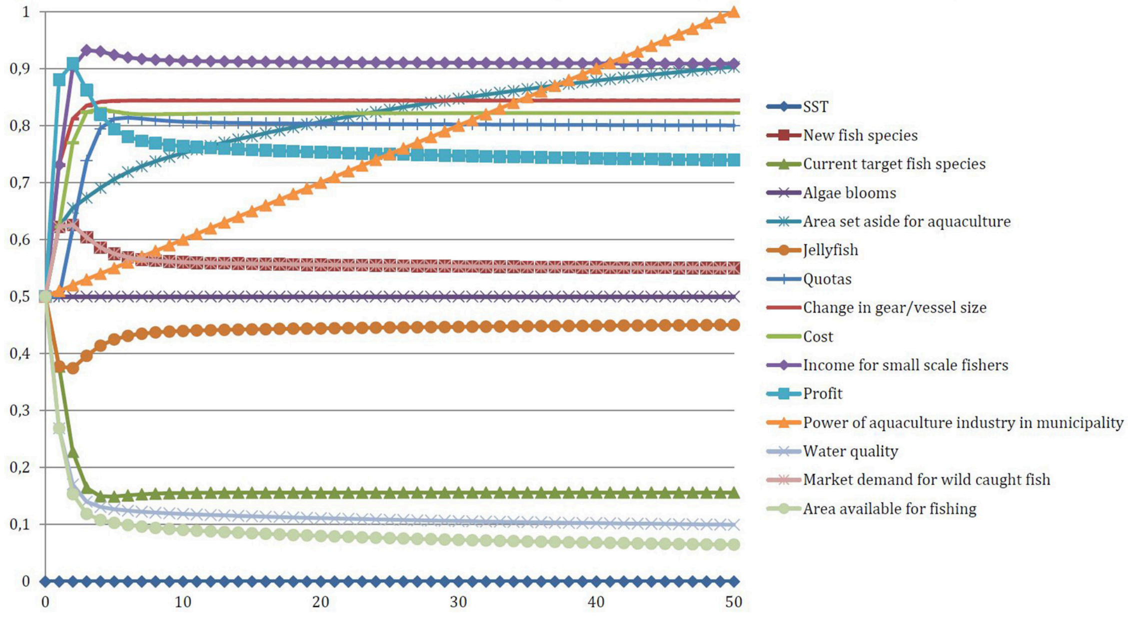

FIGURE 9 | Scenario 3 where SST was held constant and "Power of Aquaculture Industry" rose from 0,5 to 1 over 50 years.

What we also wanted to explore, though, was whether the stakeholders perceptions relative to their own adaptive capacity was different if we held SST stable at a very low rate (0) and instead increased the "Power of the Aquaculture Industry" (**Figure 9**). This is because the topic of aquaculture vs. fisheries is a more "current" topic of interest and close to the heart of many fishers (Tiller et al., 2012, 2015). Under this third scenario, we held SST constant at 0—meaning it had no perceived effect on the marine environment at any point during the scenario run for 50 years. The "Power of the Aquaculture industry in the Municipality" however, went from 0,5 to 1 during the same period (from relatively high to the highest possible/conceivable). In doing this scenario run, it was interesting to see that the "Area set aside for aquaculture" increased much more dramatically than when we considered increased SST. Also, there was an increased in costs under this scenario too, which we believe is because under a 0 scenario, there would still be less space available for fishing since more would be set aside for aquaculture. This would force the fishers to adapt to new species, or get quotas for other commercial species, both of which would require refitting the boat or purchasing new boats. Contrary to the SST scenarios though, in this case, many more variables stabilized despite increasing power, including "Quota," "Change in gear," "Target species," "Market demand for Wild Fish," and in fact, their "Income," though it was much lower than the original scenario. This can be expected because their "Target Species" also stabilized under this scenario. In other words, the fishers' scenario model does not imply that the stakeholders perceive aquaculture to be more threatening to their adaptability than an increasing SST.

CONCLUSIONS

The IPCC has stated that a given areas ability to adapt to the consequences of climate change are different from region to region, and in Europe, this capacity is high as compared to other areas in the world. This is among others because of the cost of adaptation and the ability to pay for the effects (Intergovernmental Panel on Climate Change IPCC, 2013). Norway, the case in point in this study, has a population of 5.084 million inhabitants, and the GDP was in 2013 USD 512 billion, which when converted to GNI[2] per capita is the highest in the world at USD 102.610 (World Bank, 2014). In addition, Norway has a Norwegian National Fund for Natural Damage Assistance ("Statens Naturskadefond") that provides *natural disaster insurance* as a mandatory part of all fire insurance of property and personal items. This fund was created by the Act on Natural Damage of June 9th 1961, which goal was to provide compensation for damages caused by natural perils. Damages from natural perils are understood as damages that can be directly blamed on natural disasters such as landslides, storms, floods, earthquakes and volcanoes to name a few (Norsk Naturskadepool, 2014). Many of these perils are possible consequences of climate change. As such, even if the natural municipality has low income and much of it is tied up, the insurance law protection of the Norwegian people makes the less vulnerable. Especially in the cases of (1) Sea Level Rise and (2) Extreme weather, since they are able to rebuild homes and work places in the event of a natural disaster is available to all, making them less vulnerable overall, at least at the personal level.

Sectors, however, such as fisheries, aquaculture and tourism, are not equally protected by insurance schemes, since their vulnerabilities lie with the (in)stability of the marine physical environment. Social forces in the form of users of marine eco-system goods and services are key drivers of ocean stressors, and its many consequences such as ocean acidification, change in sea surface temperature (SST), pollution and nutrient loading, but also an overharvesting of marine species. Human responses to changes in oceans (and to other factors), and the effects this has on eco-system goods and services, produce feedbacks to natural systems as well, making it important to include stakeholder perceptions in the planning options for policy makers. This is especially true, as much scholarship has centered on the short term perspectives of stakeholders relative to climate change legislation (Lazarus, 2008; Levin et al., 2012). Perceptions of adaptive capacity to climate change and future scenarios relative to this capacity can inform policy makers of the potential reactions a given stakeholder group may exhibit given different outcomes.

When stakeholder driven scenarios are used as a method of policy planning, managers get presented with several fundamentally different future perspectives to consider when planning for the future (Postma and Liebl, 2005). One of the reasons why scenario analysis is increasingly being raised as a method of choice in decision support, especially in the social sciences, is because it is considered a decision-making aid. This is because it is based on possible future scenarios, within the framework of the perceptions of those stakeholders who will be most affected. However, scenario analysis suggests a development of alternative visualizations of the future events relative to a given issue area. In doing so, it both reveals and brings emphasis to uncertainties. Dator's Laws of the Future (Dator, 1996) emphasizes that it is impossible to study the future since it doesn't yet exist. However, developing stakeholder driven scenarios as a method of decision support emphasizes that its limitations lies in the fact that it indeed only represents ideas or possible images of the future, and not the actual future. Alternative and preferred or even impossible futures can, and should, be forecasted, envisioned, invented, considered and evaluated on similar turns.

As we saw from the scenarios we produced, which are only three of many possible scenarios a policy maker can run using the data from this one specific workshop, we noticed among others the perceptions of negative effects on the fishers if quota for new species were to be the norm, within the perspective of increasing SST. This is likely not only the case for Norwegian fishers, but also for fishers in other nations that fish in many of the same waters. The challenges of regional and local fishers in the future is therefore to consider the effects on the ecosystem not only in terms of actual biological responses, but also the responses of the current, and future users. Another important take-home message from the workshop was that the stakeholders were not by far as near-sighted as may have been expected. They were keenly aware of changes taking place, and they were clear that a changing climate was the cause of this change, and that it was indeed affecting their livelihoods—and would continue to do so in the future. A valuable next step in this research will be to bring these results back to the stakeholders for validation of results, and explore what their willingness to mitigate in order to avoid some of these negative effects is.

---

[2] GNI (formerly GDP per capita) is an index developed by the World Bank and signifies the Gross National Income using the Atlas method, and dividing it by the given country's population at mid-year.

ETHICS STATEMENT

NSD - The Norwegian Social Science Data Services—exempted the project. This exemption was because the data was anonymous and there is no way for readers to be able to identify the participants. There are no name lists that correspond to the workshops, and the name of the community is not mentioned, only the island—which consists of four municipalities.

AUTHOR CONTRIBUTIONS

RT contributed with the data on the workshop and the theoretical framework. JD and KV contributed with the data analysis and the scenario development. RR contributed with climate data and information, and MV contribute with overarching information and quality assurance relative to the scientific part of the project. JB is lead supervisor for the work package on the workshops and contributed with quality assurance and feedback on this part of the work and ensured that it was all within the work package framework.

FUNDING

Financial aid from the European Commission (OCEAN-CERTAIN, FP7-ENV-2013-6.1-1; no: 603773) is gratefully acknowledged.

REFERENCES

Abdallah, P. R., and Sumaila, U. R. (2007). An historical account of Brazilian public policy on fisheries subsidies. *Mar. Policy* 31, 444–450. doi: 10.1016/j.marpol.2007.01.002

Anderies, J. M., Janssen, M. A., and Ostrom, E. (2004). A framework to analyze the robustness of social-ecological systems from an institutional perspective. *Ecol. Soc.* 9:18. doi: 10.5751/es-00610-090118

Barkin, J. S., and DeSombre, E. R. (2013). *Saving Global Fisheries: Reducing Fishing Capacity to Promote Sustainability*. Cambridge, MA: MIT Press.

Barnard, A. (1983). Contemporary hunter-gatherers: current theoretical issues in ecology and social organization. *Annu. Rev. Anthropol.* 12, 193–214. doi: 10.2307/2155646

Biernacki, P., and Waldorf, D. (1981). Snowball sampling: problems and techniques of chain referral sampling. *Sociol. Methods Res.* 10, 141–163. doi: 10.1177/004912418101000205

Botterhuis, L., van der Duin, P., de Ruijter, P., and van Wijck, P. (2010). Monitoring the future. *Building an early warning system for the dutch ministry of justice. Futures* 42, 454–465. doi: 10.1016/j.futures.2009.11.030

Chilvers, J., Lorenzoni, I., Terry, G., Buckley, P., Pinnegar, J. K., and Gelcich, S. (2014). Public engagement with marine climate change issues:(Re) framings, understandings and responses. *Glob. Environ. Change* 29, 165–179. doi: 10.1016/j.gloenvcha.2014.09.006

Chiu, A., Li, L., Guo, S., Bai, J., Fedor, C., and Lee Naylor, R. (2013). Feed and fishmeal use in the production of carp and tilapia in China. *Aquaculture* 414–415, 127–134. doi: 10.1016/j.aquaculture.2013.07.049

Dator, J. (1996). "Foreword," in *The Knowledge Base of Futures Studies*, ed R. Slaughter (Hawthorne, QLD: DDM Media Group), xix–xx.

Davidson, K., Pan, M., Hu, W., and Poerwanto, D. (2012). Consumers' willingness to pay for aquaculture fish products vs. Wild-caught seafood – a case study in hawaii. *Aquaculture Econ. Manag.* 16, 136–154. doi: 10.1080/13657305.2012.678554

De Kok, J.-L., Kofalk, S., Berlekamp, J., Hahn, B., and Wind, H. (2009). From design to application of a decision-support system for integrated river-basin management. *Water Resour. Manag.* 23, 1781–1811. doi: 10.1007/s11269-008-9352-7

Dickerson, J. A., and Kosko, B. (1994). Virtual worlds as fuzzy cognitive maps. *Presence* 3, 173–189.

Directorate of Fisheries (2016). *Fishermen, Fishing Vessels and Licenses*. Available online at: http://www.fiskeridir.no/English/Fisheries/Statistics/Fishermen-fishing-vessels-and-licenses

FAO Fisheries and Aquaculture Department (2010). *The State of World Fisheries and Aquaculture 2010, in Rome: Food and Agriculture Organization of the United Nations*. Available online at: http://www.fao.org/docrep/013/i1820e/i1820e00.htm

Freeman, R. E. (2010). *Strategic Management: A Stakeholder Approach*. New York, NY: Cambridge University Press.

Gallopín, G. C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. *Glob. Environ. Change* 16, 93–303. doi: 10.1016/j.gloenvcha.2006.02.004

Gallopin, G. C., Gutman, P., and Maletta, H. (1989). Global impoverishment, sustainable development and the environment: a conceptual approach. *Int. Soc. Sci. J.* 41, 375–397.

Garcia, S. M., and Rosenberg, A. A. (2010). Food security and marine capture fisheries: characteristics, trends, drivers and future perspectives. *Philos. Trans. R. Soc. B Biol. Sci.* 365, 2869–2880. doi: 10.1098/rstb.2010.0171

Gjelsvik Tiller, R., Mork, J., Richards, R., Eisenhauer, L., Liu, Y., Nakken, J.-F., et al. (2014). Something fishy: assessing stakeholder resilience to increasing jellyfish (*Periphylla periphylla*) in Trondheimsfjord, Norway. *Mar. Policy* 46, 72–83. doi: 10.1016/j.marpol.2013.12.006.

Gopnik, M., Fieseler, C., Cantral, L., McClellan, K., Pendleton, L., and Crowder, L. (2012). Coming to the table: early stakeholder engagement in marine spatial planning. *Mar. Policy* 36, 39–1149. doi: 10.1016/j.marpol.2012.02.012

Gray, S. A., Gray, S., De Kok, J. L., Helfgott, A. E. R., O'Dwyer, B., Jordan, R., et al. (2015). Using fuzzy cognitive mapping as a participatory approach to analyze change, preferred states, and perceived resilience of social-ecological systems. *Ecol. Soc.* 20:11. doi: 10.5751/ES-07396-200211

Hasenclever, A., Peter, M., and Rittberger, V. (2000). Integrating theories of international regimes. *Rev. Int. Stud.* 26, 3–33. doi: 10.1017/s0260210500000036

Holmyard, N. (2014). *Climate Change: Implications for Fisheries* & *Aquaculture. Key Findings from the Intergovernmental Panel on Cliamte Change Fifth Assessment Report*. ed J. Benn. Available online at: http://cmsdevelopment.sustainablefish.org.s3.amazonaws.com/2014/05/27/IPCC_AR5_Fisheries_Summary_FINAL_Web-1001a188.pdf: European Climate Foundation (ECF), The Sustainable Fisheries Partnership (SFP), University of Cambridge's Judge Business School (CJBS) and Institute for Sustainability Leadership (CISL).

Hughes, K. M., Dransfeld, L., and Johnson, M. P. (2015). Climate and stock influences on the spread and locations of catches in the northeast Atlantic mackerel fishery. *Fish. Oceanogr.* 24, 540–552. doi: 10.1111/fog.12128

Hugues, D. J. (2000). A brief methodological guide to scenario building. *Technol. Forecast. Soc. Change* 65, 37–48. doi: 10.1016/s0040-1625(99)00123-7.

ICES (2013). *Report of the Ad hoc Group on the Distribution and Migration of Northeast Atlantic Mackerel (AGDMM).* Available online at: http://www.ices.dk/sites/pub/Publication%20Reports/Expert%20Group%20Report/acom/2013/AGDMM/AGDMM%202013.pdf

Impson, S. (2011). The blue food revolution. *Sci. Am.* 304, 54–61. doi: 10.1038/scientificamerican0211-54

IPCC (2013). *Climate Change 2014: Impacts, Adaptation, and Vulnerability. In IPCC Fifth Assessment Report (WGII AR5),* ed IPCC Working Group II Contribution to AR5. Available online at: http://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap23_FINAL.pdf

Intergovernmental Panel on Climate Change IPCC (2014). *Climate Change 2014–Impacts, Adaptation and Vulnerability: Regional Aspects: Part B: Regional Aspects*. eds C. B. Field and V. R Barros New York, NY: Cambridge University Press.

Islam, M. S. (2014). *Confronting the Blue Revolution: Industrial Aquaculture and Sustainability in the Global South*. Toronto, ON: University of Toronto Press.

Jensen, F., Frost, H., Thøgersen, T., Andersen, P., and Andersen, J. L. (2015). Game theory and fish wars: the case of the Northeast Atlantic mackerel fishery. *Fish. Res.* 172, 7–16. doi: 10.1016/j.fishres.2015.06.022

Kahn, H., and Wiener, A. J. (1968). *The Year 2000: a Framework for Speculation on the Next Thirty-Three Years*. New York, NY: Macmillan.

Kok, K. (2009). The potential of Fuzzy Cognitive Maps for semi-quantitative scenario development, with an example from Brazil. *Glob. Environ. Change* 19, 122–133. doi: 10.1007/s11269-008-9352-7

Kontogianni, A. D., Papageorgiou, E. I., and Tourkolias, C. (2012). How do you perceive environmental change? Fuzzy Cognitive Mapping informing stakeholder analysis for environmental policy making and non-market valuation. *Appl. Soft Comput.* 12, 3725–3735. doi: 10.1016/j.asoc.2012.05.003

Kosko, B. (1986). Fuzzy cognitive maps. *Int. J. Man Mach. Stud.* 24, 65–75.

Krasner, S. D. (1983). "Structural causes and regime consequences. regimes as intervening variables." in *Internatioanl Regimes*, ed S. Krasner (Ithaca, NY: Cornell University Press), 1–21.

Kristóf, T. (2006). Is it possible to make scientific forecasts in social sciences? *Futures* 38, 561–574. doi: 10.1016/j.futures.2005.09.004

Lazarus, R. J. (2008). Super wicked problems and climate change: restraining the present to liberate the future. *Cornell Law Rev.* 94:1153.

Lehmbruch, G. (2003). "Concertation and the structure of corporatist networks," in *Verhandlungsdemokratie: Beiträge zur vergleichenden Regierungslehre* (Wiesbaden: VS Verlag für Sozialwissenschaften), 103–128.

Lena, B., Höjer, M., Dreborg, K.-H., Ekvall, T., and Finnveden, G. (2006). Scenario types and techniques: towards a user's guide. *Futures* 38, 723–739. doi: 10.1016/j.futures.2005.12.002

Lester, S. E., McLeod, K. L., Tallis, H., Ruckelshaus, M., Halpern, B. S., Levin, P. S., et al. (2010). Science in support of ecosystem-based management for the US West Coast and beyond. *Biol. Conserv.* 143, 576–587. doi: 10.1016/j.biocon.2009.11.021

Levin, K., Cashore, B., Bernstein, S., and Auld, G. (2012). Overcoming the tragedy of super wicked problems: constraining our future selves to ameliorate global climate change. *Policy Sci.* 45, 123–152. doi: 10.1007/s11077-012-9151-0

Lijphart, A. (1999). *Patterns of Democracy: Government Forms and Performance in Thirty-Six Countries*. London: Yale University Press.

Lubchenco, J., and Sutley, N. (2010). Proposed U.S. Policy for Ocean, Coast, and Great Lakes Stewardship. *Science* 328, 1485–1486. doi: 10.1126/science.1190041

Maani, K. E., and Cavana, R. Y. (2007). *Systems Thinking, System Dynamics: Managing Change and Complexity*. Auckland: Pearson Education.

Mazmanian, D. A., Jurewitz, J., and Nelson, H. T. (2013). A governing framework for climate change adaptation in the built environment. *Ecol. Soc.* 18:56. doi: 10.5751/ES-05976-180456

MentalModeler (2015). *What is Mental Modeler?* Available online at: http://www.mentalmodeler.org/

Merriam-Webster (2012). "Scenario," in *Merriam-Webster.* Available online at: http://mw3.merriam-webster.com/dictionary/scenario

Ministry of Fisheries and Coastal Affairs (2011). 3 "Dei ulike fiskeriavtalane for 2011," in *Fiskeriavtalane Noreg Har Inngått Med Andre Land for 2011 og Fisket Etter Avtalane i 2009 og 2010*: *Regjeringa Stoltenberg II*.

Ministry of Trade Industry and Fisheries (2013). *Meld. Stg. 22: Verdens Fremste Matnasjon*. ed Det Kongelige Fiskeri- og Kystdepartement. Available online at: http://www.regjeringen.no/pages/38271196/PDFS/STM201220130022000DDDPDFS.pdf

Mitchell, R. K., Agle, B. R., and Wood, D. J. (1997). Toward a theory of stakeholder identification and salience: defining the principle of who and what really counts. *Acad. Manag. Rev.* 22, 853–886.

Morgan, I. G., Ohno-Matsui, K., and Saw, S.-M. (2012). Myopia. *Lancet* 379, 1739–1748. doi: 10.1016/S0140-6736(12)60272-4

Norsk Naturskadepool, (2014). *Insurance Compensation for Natural Damages (in Norwegian: Erstatningsordningene Ved Naturskade).* Available online at: http://www.naturskade.no/no/Hoved/Forside/ (Accessed October 17).

Pauly, D. (2007). The sea around us project: documenting and communicating global fisheries impacts on marine ecosystems. *AMBIO: A J. Hum. Environ.* 36, 290–295. doi: 2.0.co;2]10.1579/0044-7447(2007)36[290:tsaupd]2.0.co;2

Pauly, D. (2008). Global fisheries: a brief review. *J. Biol. Res.Thessaloniki* 9, 3–9. Available online at: http://www.jbr.gr/papers20081/01-Pauly%20et%20al.pdf

Pauly, D., Christensen, V., Guénette, S., Pitcher, T. J., Sumaila, U. R., Walters, C. J., et al. (2002). Towards sustainability in world fisheries. *Nature* 418, 689–695. doi: 10.1038/nature01017

Postma, T. J. B. M., and Liebl, F. (2005). How to improve scenario analysis as a strategic management tool? *Technol. Forecast. Soc. Change* 72, 161–173. doi: 10.1016/j.techfore.2003.11.005

Sandelowski, M. (1995). Sample size in qualitative research. *Res. Nurs. Health* 18,179–183. doi: 10.1002/nur.4770180211

Senjavandrer.no (2016). *Info About the Senja Municipalities* (*in English: "Info om Senjakommunene"*). Available online at: http://www.senjavandrer.no/InfoOmSenja.html

Smit, B., and Wandel, J. (2006). Adaptation, adaptive capacity and vulnerability. *Glob. Environ. Chang.* 16, 282–292. doi: 10.1016/j.gloenvcha.2006.03.008

Sterman, J. D. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*, Vol. 19, Irwin/McGraw-Hill Boston.

Schnaars, P. S. (1987). How to develop and use scenarios. *Long Range Plann.* 20, 105–114. doi: 10.1016/0024-6301(87)90038-0.

Stokke, O. S. (2007). *Examining the Consequences of Arctic Institutions. Edited by Olav Schram Stokke and Geir Hønneland, International Cooperation and Arctic Governance: Regime effectiveness and Northern region building*. London: Routledge.

Stone, C. D. (1997). Too many fishing boats, too few fish: can trade laws trim subsidies and restory the balance in global fisheries. *Ecology* 24:505.

Tiller, R., Brekken, T., and Bailey, J. (2012). Norwegian aquaculture expansion and Integrated Coastal Zone Management (ICZM): simmering conflicts and competing claims. *Mar. Policy* 36, 1086–1095. doi: 10.1016/j.marpol.2012.02.023

Tiller, R. G. (2008). The Norwegian system and the distribution of claims to redfeed. *Mar. Policy* 32, 928–940. doi: 10.1016/j.marpol.2008.01.008

Tiller, R., Gentry, R., and Richards, R. (2013). Stakeholder driven future scenarios as an element of interdisciplinary management tools; the case of future offshore aquaculture development and the potential effects on fishermen in Santa Barbara, California. *Ocean Coast. Manag.* 73, 127–135. doi: 10.1016/j.ocecoaman.2012.12.011

Tiller, R. G., Svalestuen, Y., Öztürk, P., and Tidemann, A. (2015). Simulating stakeholder behavior in a marine setting: integrated coastal zone planning and the influential power of selected stakeholders in Frøya, Norway. *Front. Mar. Sci.* 2:90. doi: 10.3389/fmars.2015.00090

UNCLOS. (1982). *Part V: Exclusive Economic Zones*. ed United Nations.

Vanhonacker, F., Pieniak, Z., and Verbeke, W. (2013). European consumer image of farmed fish, wild fish, seabass and seabream. *Aquaculture Int.* 21, 1017–1033. doi: 10.1007/s10499-012-9609-2

van Notten, P. (2006). "Scenario development: a typology of approaches," in *Think Scenarios, Rethink Education*, ed OECD (Paris: OECD Publishing), 69–92.

van Vliet, M., Kok, K., and Veldkamp, T. (2010). Linking stakeholders and modellers in scenario studies: the use of Fuzzy Cognitive Maps as a communication and learning tool. *Futures* 42, 1–14. doi: 10.1016/j.futures.2009.08.005

Vensim (2015). *Vensim Software.* Available online at: http://vensim.com/vensim-software/. http://www.mentalmodeler.org/

World Bank (2013). "Fish to 2030: prospects for fisheries and aquaculture (English), "in *Agriculture and Environmental Services Discussion Paper* (Washington DC World Bank Group.)

World Bank (2014). *GNI Per Capita, Atlas Method (Current US$)*. ed World Bank. Available online at: http://data.worldbank.org/indicator/NY.GNP.PCAP.CD/countries/NO--XS-CL-TR?display=graph

Worm, B., Barbier, E. B., Beaumont, N., Duffy, J. E., Folke, C., Halpern, B. S., et al. (2006). Impacts of biodiversity loss on ocean ecosystem services. *Science* 314, 787–790. doi: 10.1126/science.1132294

Young, O. R., Osherenko, G., Ekstrom, J., Crowder, L. B., Ogden, J., Wilson, J. A., et al. (2007). Solving the crisis in ocean governance: place-based management of marine ecosystems. *Environ.Sci. Policy Sustain. Dev.* 49, 20–32. doi: 10.3200/ENVT.49.4.20-33

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.