1. Introduction

Around the end of the 18th century, with the design of the steam engine by James Watt, the geological age of the Anthropocene started [1] which has led to unprecedented changes in the natural environment, the most serious of which is climate change. The Ocean has felt the impact of the Anthropocene as well, including a 26% increase in acidity caused by the ocean absorption, and natural sinking, of about 30% of anthropogenic emissions of CO_2 [2]. The combined effects of climate change on the marine environment are still uncertain in magnitude and relative to its actual effects on human coastal communities. Research shows that the world is steadfastly moving towards any of a number of future scenarios as depicted by the Intergovernmental Panel on Climate Change (IPCC) [2] based on the collaborative efforts of hundreds of scientists. In all these future scenarios, the surface waters of global oceans will continue to get warmer, especially in tropical and northern hemisphere sub-tropical areas [2]. Even the IPCC's low-emissions scenario of RCP2.6, which stipulates the UNFCCC target of staying below and increase in 2 degrees Celsius, research has shown that ocean temperatures will rise 1.2 degrees Celsius and sea levels will rise by 0.60 meters [3, 4]. In terms of fisheries, research suggests that if the 'business as usual' scenario continues (RCP8.5), more than 800 species of marine fish and invertebrates will shift towards the poles 65% faster than if the low-emission scenario of 2 degrees Celsius is achieved.

There have been attempts at changing this path towards global warming from the 1990 launch of negotiations leading to the UN Framework Convention on Climate Change by regulating the anthropogenic emissions of CO_2. The UNFCCC was signed at the Rio Earth Summit (UN Conference on Environment and Development) in June of 1992, and entered into force just two years later, on March 21st 1994 [5]. The Kyoto Protocol was adopted in 1997, and for the first time, strict requirements for emission reduction plans were included in the text. At that time, policy makers still expected that most effects from climate change were avoidable through strict regulations and mitigation efforts. However, it did not enter into force until 2005 and then without the ratification of the United States of America. The Kyoto Protocol was due to expire in 2012 and the then anticipated successor agreement was scheduled for Copenhagen in 2009. Negotiators understood that mitigation would not be enough and that adaptation to effects of climate change would have to be discussed. However, the Copenhagen Accord was never formally adopted, since a number of countries blocked the proceedings, with the then European Union (EU) leader proclaiming his disappointment in declaring that '...the document falls far short of our expectations' [6].

The political success of the Paris Agreement in 2015 brings new hope to global negotiations on emissions reductions and climate change adaptation. In this agreement, "...185 countries representing 94% of current global greenhouse gas (GHG) emissions and 97% of the world population..." ambitiously "...established the goal of holding the global mean atmospheric temperature rise by the end of this century to well below 2 °C, if not 1.5 °C, above pre-industrial levels." [4]. Notably, 186 countries had declared, or pledged, their national plans for these reductions of GHG emissions prior to the start of the conference [7]. The Paris Agreement entered into force in November 2016 and lays the plans for transitioning the global economy from hydrocarbon- to green by 2050. As of February 2017, 131 of 197 had ratified the Paris Agreement.

Considering the projections of changes in sea surface temperature and ocean acidification, under even a stringent climate change reduction scheme, changes are inevitable in coastal areas and beyond. Commercial activities and human populations in general will have to adapt in response to changes and their effects, in order to mitigate the damage of it to their system, or to exploit potentially beneficial opportunities deriving thereof. In light of this, this paper explores the extent to which stakeholders in

Northern Norway are willing to accept, or expect to be able to adapt to, these new realities. This article investigates this using participatory modeling workshops with stakeholders from three key industries in Norway, namely commercial fisheries, aquaculture and tourism. In the first section, the theoretical framework around adaptive capacity and vulnerability both in general and for marine sectors specifically, is discussed. This is followed by a methodology section, where the setup of the participatory stakeholder workshops and the selection process is explained. The results of the workshops and the discussion and conclusions on the adaptive capacity of coastal communities and industries in Norway are then presented.

2. Adapting to the effects of climate change

The discussion around the concept of vulnerability and adaptive capacity of human communities is framed by the policy implications of understanding how groups of key stakeholders in important industries perceive potential changes will affect them. Authors have emphasized that it is essential for policy makers to be able to assess perceptions from a wide range of stakeholders so that they are better able to understand their constituents' needs under climate stress [8]. The focus during the workshops in Northern Norway was therefore to determine to what degree a sample of stakeholders from fisheries, aquaculture and tourism perceived their industry's adaptive capacity to changing marine environments, and to what degree this adaptive capacity could be challenged under different circumstance resulting from climate change. Adaptive capacity in Arctic societies for some of these groups specifically has been treated in depth by researchers previously [9, 10], and this study will build on these findings and its applicability will be reflected upon in the discussion.

The term "vulnerability" has also been extensively studied [11], but there is no coherent interdisciplinary definition of it. However, vulnerability always relates to a specific disturbance to a state of equilibrium and about the potential for transformation when confronted with external or internal stressors. Social vulnerability of a given stakeholder group can be defined as "…those characteristics of the population that influence the capacity of the community to prepare for, respond to, and recover from hazards and disasters." [12]. Another popularly-used definition of vulnerability is "…the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard." [13].

Adaptive capacity can similarly be framed in a number of ways [14], 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*." [15]. It has also been conceptualized as the sum of objective and subjective dimensions, where the adaptive capacity is latent under the former and activated under the latter. The objective dimension includes external aspects such as the availability of marine resources in question, the governance structure in place, and income within the given sector. These are aspects that latently determine to what degree a given group is vulnerable or able to adapt to climate change effects. The subjective dimension on the other hand taps into that which is covered in this article, with relation to the perceptions of risk associated with different climatic stressors, and to what degree the individual or group perceives the feasibility of adapting to these within the objective dimensions available to them [9].

The IPCC emphasizes that a given area´s 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 partially due to the cost of adaptation and the ability a given nation or individual has to pay for these costs [16]. Norway is especially in a good position. It has a population of 5.084 million inhabitants, and the GDP in 2013 was USD 512 billion, which when converted to GNI[1] per capita is the highest in the world at USD 102,610 [17][2]. Besides wealth, Norway also offers its homeowner citizens the mandatory Norwegian National Perish Pool ("Norsk naturskadepool"). This fund 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 with the goal of providing 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 [20]. As such, even if a given municipality has low income and much of it is tied up, the insurance law protection of the Norwegian people makes them less vulnerable to effects of climate change. This is particularly relevant in the cases of sea level rise and extreme weather since the inhabitants are able to rebuild their homes and work places in the event of a natural disaster. This makes the population less vulnerable overall, at least at the personal level especially since almost 80% of Norwegian households live in homes that they own. This fund therefore offers substantial protection to the vast majority of the inhabitants relative to personal security [21]. This is important since the suggested consequences of climate change are related to coastal areas, and a total of 276 out of 428 Norwegian municipalities (64 percent) border directly on the coastal waters **[22]**. This leaves as many as 80 percent of the Norwegian population living within less than 10 km of the coastline **[23]**. It is important to note, however, that this does not apply to public organizations such as municipalities, counties or national agencies. These organizations are usually not covered by insurance and as such can be considered financially vulnerable to the impact of a potential natural disaster brought forth by climate change, especially when it is the buildings or the roads that are owned by the municipality that are impacted.

Sectors, such as fisheries, aquaculture and tourism are also not equally protected by insurance schemes since their vulnerabilities lie with the (in)stability of the marine physical environment. Commercial fisheries in the "High North" may actually be the climate change "winners" under the IPCC projection scenarios as it will benefit from increased primary production, which in turn will attract more commercially valuable fish species that have been displaced from areas where the sea surface temperature has become too high [24]. For the aquaculture industry, the effects of increased sea surface temperature may bring both joy and perils. In this article the term aquaculture refers to the farming of Atlantic Salmon within the framework of the production process of placing produced smolts in sea cages for saltwater and growing them out until the fish reaches the size that is suitable for market purposes. In Norway, the marine temperature and salinity along the coast are generally stable, making these areas very suitable for cold-water fish farming. In addition, pollution and eutrophication are restricted to only a few areas, and the water quality is good. All of these lay the groundwork for the comparative advantage that the aquaculture industry experiences relative to environmental factors **[25]**. Warmer waters may open up new areas suitable for aquaculture further north, although many of these areas may not have the public support to allow the industry to move [26]. Finally, for tourism, the IPCC [16] projects that this sector is expected to increase in Northern

[1] 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.

[2] Within the framework of climate change, the primary driver of this wealth is coincidentally the petroleum sector, the largest industry and value creator in the country. Norway is also the third largest exporter of natural gas globally and the largest oil producer in Western Europe [18] U.S. Energy Information Administration, Norway, 2014. http://www.eia.gov/countries/cab.cfm?fips=NO. 2014).. The export of crude oil, natural gas, and pipeline transport services accounted for 52% of the Norwegian export revenues in 2012 [19] Norwegian Petroleum Directorate, The petroleum sector - Norway's largest industry, 2013. http://npd.no/en/Publications/Facts/Facts-2013/Chapter-3/. (Accessed 17. October 2014)..

Europe by 2050, which would be beneficial to the sector. However, climate change may also affect and damage cultural heritage sites, which in turn could affect tourism.

3. Materials and Methods

By looking at the vulnerability of the selected case area, the research group undertook a qualitative study of four preselected municipalities on the island of Senja in northern Norway. To add socio-geographical context, the application ViewExposed [27] was also used. This program identifies the vulnerability of a given municipality in terms of how exposed it is to physical exposure and threats in combination with its capability of resisting the threat (social vulnerability). This is important for assessing where the socially and economically vulnerabilities are highest in order for policy makers to focus their mitigation efforts to where they are most needed. In this case it validated the qualitative background for selecting the case area. The viewExposed program assesses the vulnerability of the given community looking at an Exposure Index (EI) and a Social Vulnerability Index (SocVI). The EI combines the exposure indicators for floods, storms and landslides into one. The SocVI includes 25 socioeconomic variables (SeVI) and 8 built environment vulnerability index (BEVI). Together, these formed the Integrated Vulnerability Index (IntVI) [27]. An indepth explanation of the methodological framework has been published and the reader is invited to explore these for more information [28]. viewExposed was used in this study as an informative and validation tool to contextualize the case areas from which the pool of workshop participants were drawn.

There are four municipalities on the island of Senja, namely Berg (915 people), Torsken (913 people), Tranøy (1,543 people) and Lenvik (11,618 people). The total population of these four municipalities is 14,989, which includes the on shore municipal center of Lenvik, namely Finnsnes. In Tromsø, the major city in the region of Troms, had 73,480 people 2016, which represented a steady growth since 2006, when the population was 63,546. Considering that the entire region consisted of 164,330 people, it was found that 45% of the entire region population of Troms lived in the city of Tromsø [41]. The most vulnerable areas were found to include northern Norway, where the pre-determined case municipalities are located, validating them as case areas of interest for management consideration of perceptions of adaptive capacity. Of the 40 most vulnerable municipalities in Norway, 39 were located in the four northernmost regions of Nord Trøndelag, Nordland, Troms and Finmark [28]. The municipality of Berg on Senja was the 16th most vulnerable municipality in Norway, and Torsken was the 19th most vulnerable. The city of Tromsø itself is ranked low in vulnerability at 34.9% on the integrated index. It is the only municipality in the four northernmost regions to rank lower than the national average of vulnerability. With regards to exposure, the findings for Tromsø are in line with the country average with exposure to storms approximately 50% and floods and landslides near 0%. [28]. Similarly, viewExposed results showed that the two municpalities on Senja that are "inward-facing" are less vulnerable. These municipalities also have higher populations than the two most vulnerable ones in the sample.

Table 1 approximately here

The analysis was complemented with stakeholder driven participatory workshops, both in Tromsø and in Finnsnes, one of the larger cities in the Senja region. There is a strong motive for engaging with stakeholders in policy matters, since it enables a policy maker to access the expertise that they possess (i.e. 'knowledge-base' data). The fields of climate change adaptation and resource management have strong human dimensions and therefore draw heavily upon this knowledge-base. Participatory stakeholder workshops were therefore at the center of the study in assessing the adaptive capacity of the area around Senja.

A stakeholder in general has been defined by the literature as "…any group or individual who can affect, or is affected by, the achievement of the organization's objectives" [29]. 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 stakeholders chosen for the purposes of this paper were Fishers, Aquaculture industry, and Tourism sector.

The fisher workshop was held at the end of June 2015 in a fishing community on the island of Senja. Four fishers attended the workshop. They were selected using the snowball method [30], with the main representative of the Norwegian Fishermen's Association requiring their attendance at the meeting. Fishers were placed in a separate workshop group, since their affiliation with coastal or long-distance fishing is not separated in the Directorate of Fisheries list of full-time (B-list) and part-time fishermen (A-list). It was also considered natural to do this for both the purposes of recruitment and for the end game of each group being the same. There are 12 landing sites for fish in the Tromsø municipal region in 2014, according to the Norwegian Fishermen's Sales Organization, which is an organization whose goal it is to safeguard the income of the fishers and ensure growth in the industry in a sustainable way. This means that fishers from all along the coast can deliver their fish in this region.

The aquaculture industry workshop was held around the same time in June 2015. This workshop was also centered on user groups in the area around Senja based on the same reasons as used for the workshop involving the fishers. The workshop was held in the city of Finnsnes, the municipal center of Lenvik municipality. Stakeholders were represented by both large and small scale aquaculture operations. Also participating in the aquaculture workshop was a representative of the Norwegian Seafood Federation (Sjømat Norge), an industry that represents the interests of approximately 500 member companies that cover the entire value chain from fjord to dinner table for both the aquaculture industry as well as commercial fishers. Norwegian Seafood Federation were representing the aquaculture interests for the purposes of this workshop. In the four municipalities of the island of Senja, there are 25 aquacutlure licenses that are in use by 10 different companies [31]. These licences are distributed as follows: Berg Municipality has 5 localities, Tranøy has 7 localities and both Lenvikand Torsken each have 11 [32]. It is the locality that is at the root of the problem with regards to coastal zone conflicts in Norway.

The aquaculture industry was treated separately from the commercial fishers mainly because they are dealing with a resource that is not migratory. They also have different challenges than faced by the fishing industry. In 2013, for example, the municipality of Tromsø alone had 111 sites in sea water for grow out production of salmon, rainbow trout and trout, down from 117 in 2012 [33]. With projections of warmer water further north, more sites may become more suitable for aquaculture. Here too, the industry from the area around Senja, near Tromsø, was selected instead of those from the city primarily because it was easier to engage the stakeholders in the smaller communities with closer ties to the local municipalities. Also, the delegation of coastal zone areas for production purposes has to follow an application path where the authority to make decision is placed on the regional government rather than local communities. Therefore, it was decided that for the purposes of this study, the aquaculture industry would be considered a regional group rather than one belonging specifically to a given area. Furthermore, there is no requirement to have your headquarters where your localities are, and as such, those that attended the meeting in Finnsnes were equally likely to have localities in city of Tromsø as on the island of Senja.

The tourism sector workshop, finally, was held in the beginning of August 2015. This sector is a major employer in Tromsø, directly and indirectly employing 7,200 persons in 2011 [34]. The workshop participants were chosen from the membership based of the Norwegian Hospitality Association (NHO Reiseliv) local chapter in Tromsø. NHO Reiseliv is a member organization consisting of hotels and other accommodation, restaurants, catering and other food service businesses. Members also include campsites, family amusement parks, alpine facilities and other attractions. Therefore, the workshop participants represented all aspects of tourism and were as such the most representative group, despite being the one with the least participants (3).

Prior to doing the specific intra-stakeholder workshops with the selected stakeholder groups, an expert workshop was arranged to develop the initial drivers to be used in the later workshops. The participants consisted of experts in biology, micro-biology, environmental modeling, oceanography and political science. 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** . This was then presented to a pre-selected intra-stakeholder group from all three case-sectors as well as research and management for feedback. These representatives considered the drivers too vague and removed from the actual stakeholder realities. Therefore, they suggested a change 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 were related to aquaculture and to coastal planning, both of which mirror the ocean-space zero-sum game between fisheries and aquaculture. The drivers that were considered too vague or academic for the stakeholders and were therefore removed were 1) Food web; 2) Biological Pump function; and 3) Ocean Acidification.

Based on the recommendations from this initial workshop, stakeholders were recruited for all three participatory modeling workshops using the snowball method [30], using project contacts and establishing contact through interest organizations for the different industries. 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 towards a specific goal [35]. 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 of 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 not obligated to participate and free to leave the workshop at any time.

3.1. Systems Thinking

The facilitator initiated the system conceptualization process by presenting the stakeholder representatives with the seven ‘drivers’ established earlier. Systems thinking is a methodology that develops shared mental models of a given ‘system’ as the stakeholders perceive it. This group model building process facilitates the development of 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 influence or are 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 [36]. This facilitates the exploration of the focus system (i.e. commercial 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 during the workshops that the drivers were variables that had the ability to influence other variables, though were not typically affected by other variables themselves. Furthermore, the drivers list was not exhaustive and the facilitator emphasized that the stakeholders could change it during the workshop. That stakeholders can change these drivers or put in new ones is one of the benefits of this methodology.

The process started with the facilitator writing the drivers on the board and the stakeholders 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. For example, this could 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 approximately two hours. The result was a group mental model, or system conceptualization, that represented how this particular stakeholder group collectively considered the causal pathways between variables. It also demonstrated where possible conflict lines were between other user groups.

3.2. Bayesian Belief Networks

The researchers used an integrated approach of combining systems thinking with Bayesian Belief Network (BBN) modeling in order to gain critical insight into the adaptive capacity of the local stakeholder group. Quantifying narrative-rich and inherently qualitative knowledge for the purpose of making management decisions (e.g. adaptive management scenario testing) is difficult. On these grounds, BBN modeling was selected as the methodological framework for further exploration of the issue the stakeholders to be of the highest priority to them as developed during the Systems Thinking process. In addition, it was chosen because it facilitates participatory modeling and is well–suited to representing causal relationships between variables in the context of variability, uncertainty and subjectivity. Furthermore, BBN modeling is a method that is extremely well suited for coalescing knowledge, even if this knowledge comes from a variety of sources (e.g. stakeholders) and is of a variety of completeness, into a single modeling framework [37]. It is particularly effective in eliciting stakeholder opinion through participatory engagement because of the following two reasons:

1) **Firstly**, the visual aspect of developing the causal maps that characterize Bayesian network models are easily understood and readily accomplished (as confirmed by experience) by the stakeholders. The impact of this should not be understated, as this fosters trust during the stakeholder engagement process.

2) **Secondly**, the robust mathematical framework of Bayes theory underpins these models. This aspect, whilst not necessarily obvious to the stakeholders, provides a mathematical basis for incorporating the beliefs of the stakeholders into the model, something that traditional statistical approaches (e.g. null hypothesis testing) does not allow. They have also demonstrated ability in utilizing subjective expert opinions to both derive the structure of, and variables within, a BBN [38].

The methodological process of developing BBNs through stakeholder engagement is outlined in detail elsewhere [38, 39]. Briefly, however, the structure of a BBN is a network of nodes that are connected by arcs. Each node is treated as a variable and therefore must have more than one state (e.g. if 'car color' is the variable, then the states could include 'white', 'red', 'blue' etc). Furthermore, these states must be mutually exclusive (a variable can only have one state at a time), exhaustive (the states cover all possibilities e.g. for car, the variable color would entail that all possible colors must be assigned as individual states, or alternatively, the states defined in a way that covers all possibilities e.g. 'white cars', 'not white cars') and consistent (i.e. the states must relate to the same variable). Arcs connect variables and show the direction of causality through the direction of the arrow at the end of the arc – this direct connection between variables represents conditional dependence, which is a fundamental tenet of Bayes theory upon which BBNs are based.

Feedback pathways are not allowed in Bayesian networks and therefore the entire network must be acyclical (i.e. one direction of causality). The implications for this constraint include the inability to model the influence of reinforcing (positive feedback) or balancing (negative feedback) pathways on the system being modeled. Such feedback pathways are important for understanding the temporal evolution of a system (i.e. how it changes overtime) and how it might respond to 'perturbations' [40]. Whilst there are techniques that can enable feedback pathways in BBNs these can quickly lead to cumbersome models with a large amount nodes, even for very simple feedbacks [41]. If the purpose of a model is to explore the role of feedback pathways in governing temporal dynamics then other modeling methodologies such as systems dynamics [40] would be more appropriate to use than Bayesian statistical modeling. However, the research interest centered on employing a modeling methodology that allowed straightforward integration of multi-disciplinary (environmental, social and economic) variables, accommodated 'expert opinion' as a data source and enable models to be developed even when data is relatively scarce.

In this research, the focus was on **scenario analysis** (i.e. what if situations?) where changes in conditions deriving from a changing climate may be used to update the prior understanding of the research group of an event (e.g. the priority issue in the model) to posterior understandings. These ideals are well-matched by the attributes of BBNs. The other main component of the BBN is the set of conditional probability tables (CPTs) that quantitatively define the conditional dependence between linked nodes. In the workshop setting outlined in this paper, the perceptions of the stakeholders are used to populate these CPTs with probabilities, quantifying their beliefs about the relative importance of different variables within the network. The underlying probabilistic framework (i.e. Bayes theory) provides a mechanism of directly integrating social, economic and environmental variables within a single model [41]. During the workshops used in this study and elsewhere [38, 39] development of the structure of the BBNs is a group-level exercise. That is, it represents the group-level belief about which variables are included and how arcs connect them. Therefore, this process typically requires negotiation between the stakeholders. Conversely, each stakeholder populates the CPTs with their own probabilities providing individual-level parameterization. The individually-parameterized BBNs can then be combined into a single model as they share the same structure but have different CPTs. This is achieved here by using an auxiliary variable[41], which weights each of the individual stakeholder CPTs so that the beliefs of one stakeholder can be given more or less weighting in the model than others. Noe that for this study the stakeholders were weighted evenly. Finally, the BBN-development process facilitates the capture of further information through the discussions that accompanied the development of these networks with this narrative providing important context to the importance of different variables during the workshops.

4. Results and Discussion

4.1. Commercial Fishers

During the participatory stakeholder workshop with the commercial fishers, the research facilitator asked them to talk about the drivers and what variables in their system were affected by these drivers in light of a changing climate in their region. Their discussion focused a lot on mackerel, and how they, the fishers, were observing that this fish were moving northwards. The problem was not that this new and lucrative species was moving in their direction, however, but that they were not allowed to catch it – it would be an illegal bycatch since they did not have a quota for it. In addition to that, they experienced that the fish they did have a quota for, the saithe, was 'driven crazy' by the presence of the mackerel, making them harder to catch. The saithe, were also affected by algae blooms, which the fishers highlighted were occurring more often, resulting in the sea being white and grey much longer than before.

Figure 1 approximately here

The general thoughts of the fishers, however, was that the smaller coastal vessels would be the losers in a changing climate. With new species moving northwards, the ships would have to get larger, and access to quotas would be too expensive. In addition, they felt that the municipality greatly favored aquaculture, and that coastal zone planning did not favor the coastal fishermen. What worried them a lot was not that these new fish were coming, but that there would be no access to quotas for them. They had observed that the saithe was being displaced by the mackerel, however they were not able to fish the mackerel. Consequently, they felt that their priority issue in a changing climate would be to have actual access to these new species such as mackeral and named their priority issue 'New Species or Migratory Paths'. In the BBN initially developed for the fishers group perception combined indicated that only 30.3% of the fishers believed that this would be likely in any future scenario. In other words, they perceived that the likelihood of their stakeholder group gaining access to new quotas for the fish that could be migrating to their area under a changing climate was at less than 1/3. This mirrored their belief that their group would be the climate change loser.

A sensitivity analysis was then conducted on the BBN and developed around the priority issue 'New Species or Migratory Paths'. The results of this sensitivity analysis is highlighted in Figure 2 (color coded) and Table 2. For the parent nodes of the priority issue, *Capital* is clearly the most influential node on the priority issue. Its variance of beliefs value (0.08) is approximately six times higher than the next influential node (Stakeholder auxiliary node). This reflected their belief that without capital, they would not be able to buy themselves into the quota market. *Management* is the next most influential (discounting the *Stakeholder* node for the moment) followed by *Market*. At the secondary-level (i.e. nodes that are 'Grandparents' for the priority node), *Competence* is the most influential – its influence is such that it has the same level of influence as the primary-level node *Market*. The next most influential is *Ability to Communicate Well* - both of these are parent nodes of *Capital*. This entails that the most influential pathways on the priority issue are:

- Competence → Capital → New Species or Migratory Paths
- Ability to Communicate Well → Capital → New Species or Migratory Paths

This reflects their perception that they, as a group, need to be able to communicate well, primarily with lender institutions, and that they also need to have the competence to be able to head of this new possible scenario with new species in their waters.

The auxiliary node representing the individual Stakeholder beliefs (the green node in Figure 2) was observed to have the second greatest influence on the priority node (the yellow node in Figure 2). This indicates some variability and/or divergence in the conditional probabilities assigned to the BBN by the individual stakeholders. However, this variability is likely introduced at the secondary-level because it is clear that the Stakeholders perceive *Capital* as the greatest influence on the priority node both as a group and as individuals.

Figure 2 approximately here

Table 2 approximately here

4.2. Aquaculture

The systems thinking conceptual model shows what was expected, to a degree. The industry was frustrated that their contribution to the local community in terms of ripple effects were not acknowledge. They were also frustrated because of the lack of flexibility associated with area planning, and they were worried about the management of areas moving towards more and more what they named "stamp-sized areas", indicating that they were very small areas with very clear borders, lacking flexibility. What they needed, both now and in terms of the future in a changing climate, was flexibility. They needed this for pollution purposes, illnesses, algae blooms and all other issues that could happen rapidly. They were not worried about the area though. They stated that the north only used about 1/4th of what they used in the western part of the country today, so that there was plenty of areas available for take over for the production failures of the west in a future where it was too hot for salmon in the south but perfect in the north. Adapting to new futures and new circumstances was something they had always had to do in Norway when doing business along the coast, they said, so their adaptability to this was not considered insurmountable. They said that they could even move further off shore if it was a necessity. They spoke with some frustration about the city of Harstad and what they considered the power of stakeholders. They explained that in their opinion, this city had "…a lot of oil workers who had a lot of time off…", with reference to common work shifts often associated with workers on Norwegian oil platforms of two weeks work followed by four weeks off. They claimed that these groups had a lot of power in Harstad and in they believed that they were behind the lobbying for no aquaculture, presumably since they used the coast so much for leisure. This perception of power in this city was interesting, and something that should be followed up by stakeholder power researchers.

Figure 3 approximately here

The focus on area was not surprising, given that it is part of the general discourse that is highlighted by the aquaculture industry in Norway. The priority issue agreed on by the workshop participants was the ability for the industry to gain access to flexible and accessible areas for aquaculture in a future where the climate was changing. This included the presumption set forth at the beginning of the workshop that there would be an increased need for this area in the two northernmost regions in Norway because of increasingly warmer waters further south in Norway. This warming in the south would require that a projected five-fold increase in production volume of the industry that would have to be met in the northern parts of Norway as reemphasized in political and industry speeches. This emphasis on area was a methodological choice in this workshop, and was based on the report by SINTEF where this potential in growth increase was first suggested [42]. This need is difficult to fill, since the licenses to practice aquaculture are granted by the national government, but applications for the location in which to place the facility must take into account the area plans of the municipalities in which they wish to establish new aquaculture localities as well. The application is subject to rigorous municipal hearings with affected stakeholders, such as commercial fishers and the tourism sector. Furthermore, special dispensations from the municipal planners have to be administered if the actual area plans are to be sidestepped or changed from the original planned purpose of the area. However, there is much negative media attention towards the aquaculture industry in Norway [43], and the public has an agenda-setting role in governance as well [44].

A sensitivity analysis of the results was conducted on the BBN developed around the priority issue of 'Area for Aquaculture'. The results of this sensitivity analysis is highlighted in Figure 4 (color coded) and Table 3 below.

The auxiliary node representing the individual Stakeholder beliefs (the green node in Figure 4) was observed to have the greatest influence on the priority node (the yellow node in Figure 4). This indicates strong variability and/or divergence in the conditional probabilities assigned to the BBN by the individual stakeholders; in other words, the stakeholders did not share similar perceptions about the scenarios they were asked to give weights to. For the parent nodes of the priority issue, *Management* is the most influential node on the priority issue (*Area for Aquaculture*), which reflects their discourse about the necessity of the local politicians to have the political will for the industry to grow in order for areas to be made available to them. *Local Population* is the next most influential followed by *Communication of Knowledge*. At the secondary-level (i.e. nodes that are 'Grandparents' for the priority node), *Stakeholder Conflicts* is the most influential amongst the secondary-level nodes. They stated that if these conflicts are not minimized through cooperation, the chance of gaining access to areas is limited, The next most influential is *Stakeholder Prioritization* , meaning that the managers had to prioritize the industry over other uses in the coastal zone, and then *Competence*, reflecting the industry belief that management in general needed to have updated and good competence about the industry. Note that all three of these secondary level nodes are parents of *Management*. They felt, in other words, that management was what would weigh their chances of gaining flexible and accessible coastal areas for use in the aquaculture industry – more so than any other variables. However, they also gave some weight to the local population and their attitudes towards aquaculture.

This entails that the most influential pathways on the priority issue are:

- Stakeholder Conflicts → Management → Area for Aquaculture
- Stakeholder Prioritization → Management → Area for Aquaculture
- Management → Management → Area for Aquaculture

Figure 4 approximately here

Table 3 approximately here

4.3. Tourism

The stakeholders for the workshop strongly disagreed with the initial drivers suggested for the conceptual modeling, as opposed to the other two stakeholder groups. They argued that the number one and most critically important business magnets of them all for Northern Norway was the Northern Lights. The Northern lights in combination with snow set the city of Tromsø apart from other areas in Norway. They also changed two of the drivers shortly after the workshop commenced. They did not choose to focus on Sea Surface Temperatures (SST), but wanted rather to look at temperatures in general. Temperature was important for the tourism sector because snow was scenic and special, although they also acknowledged that snow was not a requirement for seeing the Northern Lights. Also, they wanted to talk about "Aquaculture" instead of Aquaculture management laws.

Fishing in any form or shape did not come up as something that was important for the tourism sector, at least not in comparison with the northern lights. They emphasized the importance of putting together packages for the tourists, and that today, what was important was dog sled trips and snow mobile trips to see the Northern Lights. They agreed however, that if the snow was to disappear, they would have to be adaptive and start employing ATVs instead, or bikes. "Product Development", they named it. With regards to aquaculture, they did not have strong emotions pro or con, probably related to their not finding marine activities to be the most important ecosystem service in terms of their industry. However, they did express the opportunity that aquaculture demonstration sites could become a new product for them, although the "apparent lack of control" with regards to coastal zone planning was something negative. They also reiterated the common conceptions of salmon escapees and negative effects that this had on the wild salmon. This was bad because the wild salmon, according to the participants, was another variable that contributed to the all-important image of the region being clean, wild and natural.

Figure 5 approximately here

Temperature, although important, was an issue that the participants were not in agreement with at all times. However, in the end they settled on temperature being an important driver but that they also highlighted that it would always be colder in Tromsø than anywhere else, even if the temperatures significantly increased over the next decades. The area would always be cooler than further south, although they worried they would lose their comparative advantage over other areas where there was Northern Lights if they did not offer the snow as an alternative as well. They also highlighted cloud cover as another element of weather variability that was a concern to the sector. Specifically if there was increased cloud cover as well as warmer weather then this was an ever larger worry to the sector. Their reasoning was that under this scenario the northern lights would not be visible. Temperature was also a worry with regards to logistics, and the skepticism they worried the tourists would adopt, should the weather be too unpredictable, or even dangerous, so that flights would be a negative mode of transportation.

The priority issue for their BBN therefore exclusively centered on communications, and that under a changing climate, the most important issue for the tourism industry was actually ensuring that the tourists were able to come there – and even wanted to despite the travel distance from Europe to the far high north. The participants were concerned that there would be more cancellations of flights and that it could become unsafe to fly in a changing climate. In this case, they argued, there needed to be existing supplements available with regards to transportation, or else, the industry would fail completely given its geographical location. The BBN therefore centered on the availability of alternate modes of communications having to be made available as a supplement to flights, focusing primarily on long-distance fast trains, possible routed through Sweden, as well as the opportunity of having more fast boats (Hurtigbåt) that would take the tourists from areas in Norway farther south in a very short time period. However, they emphasized, that the most important mode of transportation would nevertheless still have to be flights – but there needed to be a political priority, as well as available funding and a willingness to research the technological possibility of these new modes of transportation to northern Norway.

A sensitivity analysis was conducted on the BBN developed around the priority issue 'Communication'. The results of this sensitivity analysis is highlighted in Figure 6 (color coded) and Table 4 below.

Figure 6 approximately here

The sensitivity analysis demonstrated that *Political will to act* (blue) emerged as the most sensitive node acting on *Communication*. Its variance of beliefs (the measure of sensitivity) is double that of the next most sensitive variable (*Long distance fast train to Tromso*). The third most sensitive (or influential) node is *Fast boat to Tromso*, which has the lowest variance of belief out of the three parent nodes for *Communication*. This indicates that the participants at the meeting perceived that the political will was important to ensuring that there would be no instability in tourism traffic in the future. The pattern of influence at the secondary level, however, does not reflect the pattern of influence observed at the primary level. *Technological development* emerges with the highest influence, even though it is acting through *Fast boat to Tromso* (which had the lowest influence out of the three primary level nodes). This is followed by *Market for Train communications* acting through *Long distance fast train to Tromso*. The most influential node acting through *Political will to act* (which was the most influential at the primary level) is *Tourists*. The reversal in influence at the secondary level is probably due to how the conditional probability weighting is distributed amongst the secondary nodes by the stakeholders. In other words, the influence of a secondary node will likely have a greater influence on *Communication* if all stakeholders have a shared belief about which is the most influential.

In general, the analysis demonstrated that the conditional probabilities of the three stakeholders were similar, if not in actual value (e.g. one might have said 95% and another said 80% for some particular conditional scenario) but in their general patterns (i.e. each stakeholder generally ranked the importance of variables the same based on their conditional probabilities). In fact, the auxiliary node was less influential than all three primary level nodes, indicating that there is general agreement amongst the stakeholders about the relative importance and influence of these. This also extends to the secondary node *Technological Development*, which also was more influential than the auxiliary node – this indicates that the chain of influence of *Technological Influence* → *Fast boat to Tromso* → *Communication* is shared by the stakeholders (at least based on this method of elicitation of their mental model).

Table 4 approximately here

5. Conclusions

With the projected increase in sea surface temperature, whether under a "business-as-usual" or a 1.5 degree increase scenario as per the Paris Agreement aims[2, 45], stakeholders and stakeholder groups will have to adapt to different levels of change. This is especially relevant in the Arctic where the changes are happening faster and are more visible than elsewhere [46, 47]. These changes will happen in, but not be limited to, the marine food web, coastal communities, marine ecosystem goods and services, global fisheries, tourism and aquaculture. This article has explored stakeholder perceptions within this context in different municipalities in Norway. The stakeholder groups targeted for assessment of their perceptions of adaptive capacity in light of a changing climate were commercial fishers, the tourism industry and the aquaculture industry. The focus was on determining the degree stakeholders perceived their industry's adaptive capacity to be in response to changing marine environments brought about as a result of climate change. Their adaptive capacity was addressed qualitatively based on how they perceived their *ability to adapt to a certain range of environmental contingencies*. For the purposes of this study, stakeholder adaptive capacity was assessed relative to self-perceptions of levels of exposure to climate change**,** or the extent to which the stakeholders perceived *the goods and environmental services that are important for a given coastal community is affected by climate change*. This was assessed within the framework of objective- and subjective-dimension measures of adaptive capacity, referring to external factors (objective) and perceptions of vulnerability (subjective). The conceptual model suggests that adaptive capacity is latent under the former and activated under the latter aspects [9]. This was confirmed during the workshops. The stakeholders all confirmed that they were seeing the signs of what they interpreted as changes to the ecosystem, including the change in distribution patterns of both mackerel and whale. The former was a nuisance to the fishing industry at the time of the workshop, and seriously affected their fishery. Their emphasis was that if they were to survive as coastal fishers in the future, where a number of different fish species changed their distribution patterns and became "local" in their area, they would be dependent on access to quotas for these new species. They did not expect that this would be inexpensive and were negative as to the adaptive capacity of especially the smaller coastal fleet, which was unable to travel far or follow the fish to new areas. They were also concerned about the power of the aquaculture industry. This concern centered on the areas set aside in municipal area planning, and whether these plans would favor the aquaculture industry or the commercial fishers when both needed the same area for their trade. As such, the narratives from the workshop confirmed the conceptual framework, in that the commercial fishers perceived themselves as more vulnerable and less able to adapt because of the governance structure benefiting the larger fleets and the aquaculture industry, and that their feasibility of adapting was low because of this.

The aquaculture industry was similarly concerned about the municipal area planning. This concern was stronger given the premise of the workshops stipulating that sea level rise would increase in the future. In such a future, that would entail that the sea surface temperature would also be higher further south, where the majority of aquaculture farms are located today. Given that the suggestion of a possibility of a five-fold increase in aquaculture production by 2050 [48], this production increase would need new areas in the municipal plans. They argued that with warmer waters further south, these farms would need areas further north, in their area, where the process of gaining acceptance was already difficult. Their perception, however, was that if managers identified that they were an asset, and learned more about the industry, this would not be a problem. They argued that they had adapted to changing conditions always, and that was part of the game of working in the coastal zone. This also confirms the narratives of "we face whatever comes", which was originally coined for the commercial fishers in the Arctic and their adaptive capacity, but provides a better fit for the narratives of the aquaculture industry [10]. They also emphasized that there was plenty of area in northern Norway that could easily absorb the coming needs when the south and west became too hot – if only the industry was prioritized by the objective element of the governance structure. This was naturally in line with what the commercial fishers also said, although they already feared that the tides were turning against them and for the aquaculture industry. The tourism sector, however, did not so much fear the other two coastal industries, rather they saw potential in exploiting changes in both and using their industries as additional tourism packages, such as demonstration sites for aquaculture or tourist fishing, or even whale safaris with boat owners. What they did fear was changing weather conditions, and most importantly, they feared increased cloud covers as that would take away their number one attraction, which is the northern lights. They also feared that air stability would change, making it more dangerous to fly, and thereby, decreasing the number of tourists that wanted to fly all the way up north. They did not fear adapting to less snow, as they emphasized that the tourist came for the northern lights and the northern lights only.

The adaptive capacity of these three industries were in line with expectations, although the emphasis on northern lights was unexpected. Clean oceans, water activities, and sea food availability was expected to be the most important ecosystem goods and services that the tourism industry needed to excel. Learning that Tromsø as a city was dependent on the northern lights was surprising – and it also makes this industry very vulnerable given IPCC scenarios with high confidence that project extreme precipitation in northern Europe both in near term (2030-2040) and long term (2080-2100), which naturally brings cloud cover [2]. For management purposes, an emphasis on continuous stakeholder perception studies with relation to their perceptions of adaptive capacity would be of utmost importance in the future. Although in many instances Norway is already highly inclusive with regards to stakeholder engagement [49], this is not equally so with all cases and seldom iteratively, as a study in changes in stakeholder perceptions within a time-series perspective that also takes into account both objective and subjective aspects of adaptive capacity. There is still an institutional ignorance as to how best to initiate, engage and reap the full benefits of stakeholder engagement of management of resources, especially under a changing climate, and especially in the Arctic where this is happening so much faster than elsewhere.

Acknowledgement: This work was supported partially by the European Commission (OCEAN-CERTAIN, FP7-ENV-2013-6.1-1; no: 603773) and the Norwegian Research Council project REGIMES 257628.

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