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The Melting Snowball Effect: A Heuristic for Sustainable Arctic Governance Under Climate Change

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Climate change in the Arctic is occurring at a rapid rate. In Longyearbyen, Svalbard, the world's northernmost city, deadly avalanches and permafrost thaw-induced architectural destruction has disrupted local governance norms and responsibilities. In the North Atlantic, the warming ocean temperatures have contributed to a rapid expansion of the mackerel stock which has spurred both geo-political tensions but also tensions at the science-policy interface of fish quota setting. These local climate-induced changes have created a domino-like chain reaction that intensifies through time as a warming Arctic penetrates deeper into responsibilities of governing institutions and science institutions. In face with the increasing uncertain futures of climate-induced changes, policy choices also increase revealing a type of "snowballing" of possible futures facing decision-makers. We introduce a portmanteau-inspired concept called "The Melting Snowball Effect" that encompasses the chain reaction ("domino effect") that increases the number of plausible scenarios ("snowball effect") with climate change (melting snow, ice and thawing permafrost). We demonstrate the use of "The Melting Snowball Effect" as a heuristic within a Responsible Research and Innovation (RRI) framework of anticipation, engagement and reflection. To do this, we developed plausible scenarios based on participatory stakeholder workshops and narratives from in-depth interviews for deliberative discussions among academics, citizens and policymakers, designed for informed decision-making in response to climate change complexities. We observe generational differences in discussing future climate scenarios, particularly that the mixed group where three generations were represented had the most diverse and thorough deliberations.

Keywords: climate change, governance, geopolitics, Arctic, social sustainability, responsible research and innovation

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INTRODUCTION

How can the different social, economic, political and ecological aspects of climate change be useful for achieving sustainable governance of fisheries in the Arctic and beyond? Can the natural and social sciences integrate their methods to address inherent interdependencies and complexities of climate change? Is it possible for these insights to be discussed among the public, and do decision-makers have the capacity to be responsive to public deliberations about climate change? The inherent interrelations and complexities of climate-induced changes to fisheries pose huge challenges to the science—society dialogue. There is as such a knowledge gap in how to design a practical and digestible interdisciplinary framework to discuss plausible future scenarios with society and the implications of environmental change to human communities and political structures governing environmental issues globally.

This need is among others seen in the fishing industry, with the observed changes in the distribution trend of the Northeast Atlantic mackerel stock as a current example.

Specifically, the Northeast Atlantic mackerel stock has been growing since 2007 (Nøttestad et al., 2015; Nøttestad, 2016), often attributed to warming waters and increased available prey habitats because of climatic stressors (Gattuso et al., 2015). This increase of the stock has given great returns to the industry in the form of valuable catches. It has however, also led to quota allocation disputes between Norway, the European Union, the Faroes Islands on the one side and Iceland, Greenland and Russia on the other (Hotvedt, 2010; Spijkers and Boonstra, 2017). It has also led to an on-going disagreement between Norwegian pelagic fishers of the Pelagic Fishers' Association (Pelagisk Forening) and the scientific stock assessment teams of the Institute of Marine Research and the International Council for the Exploration of the Sea (ICES) in regard to the officially reported scientific assessment of the size of the stock. In addition, we a see that there are both possible and real geopolitical repercussions to changing fish stocks such as that of the herring as well (Tiller and Nyman, 2017; Harte et al., 2019; Tiller and Dankel, 2019; Tiller et al., 2019).

In this paper, we synthesize relevant insights from the Norwegian nationally funded project REGIMES and develop a portmanteau-inspired concept called "The Melting Snowball Effect." The Melting Snowball Effect encompasses the chain reaction ("domino effect") that increases the number of plausible scenarios ("snowball effect") associated with the possible effects of a number of climatic stressors, including snow melting, and thawing ice and permafrost in the Arctic. This concept emerged from the observations of the effects the warming Arctic climate have had on local governance situations for Longyearbyen, the largest settlement in the archipelago of Svalbard in the High North (**Figure 1**). In light of this, we look at heuristics, or practical but imperfect mental models for the purpose of decision-making, and how these can be helpful in arenas where interdependencies can be complex. As the Arctic warms, more plausible scenarios are revealed leading to more complexity and more uncertainty in decision-making. We hypothesize that the use of heuristics can be convenient and helpful for citizens and policy- and decision-makers who are faced with urgent decisions in highly uncertain scenarios in order to build capacity for inclusive democratic deliberation regarding climate plans at different levels of governance.

We already understand that marine fisheries are being affected by climate change, and it is projected that Arctic areas of the Ocean could be more productive in the future, thereby positively affecting the world's northernmost fisheries (Cheung et al., 2009; Gattuso et al., 2015; Lam et al., 2016a). We therefore begin our transdisciplinary analysis of Arctic climate change and how Arctic governance could respond by first applying the Dynamic Bioclimate Envelope Model (DBEM) to the Northeast Atlantic and areas around Svalbard under different IPCC climate scenarios (Cheung et al., 2009). We then couple these fisheries model projections with a fisheries economic model that incorporates costs and revenues of future fisheries scenarios. We then apply results from qualitative in-depth interviews of stakeholder perceptions from a selection of representative respondents living in Longyearbyen, Svalbard, about the economic potentials that they consider of interest under a changing climate. We finally make some conclusions as to how the Melting Snowball Effect can be used as an organizing heuristic to (1) demonstrate the additive effect of climate-induced complexity in decision-making, and (2) provide a space for deliberation of plausible scenarios among local citizens, academics and governing bodies. Taken together, we argue that these two points can contribute to reduce the inherent interrelations and complexities of climate-induced changes to fisheries that we see pose these substantial challenges to the science-society dialogue.

Social, Economic, Political, Ecological and Governance Aspects of Climate Change

Anthropogenic-induced climate change is altering the relationship humans and societies have with nature. Unsustainable practices of using non-renewable fossil fuels as the main source of energy for industries has become a causal agent of a warming climate and a warming Ocean for most parts of the world. According to the IPCC and other experts (IPCC, 2014), large-scale transitions to renewable, non-greenhouse gas emitting energy sources are needed as fast as possible to prevent CO_2 emissions into the atmosphere and further increases of global warming. These large-scale transitions, however, cannot occur without coordination of reliable renewable energy technologies and products, infrastructure investments, and regulations to guide climate-smart policies. There is little doubt that the regional and local scales will be critical areas for the success of climate mitigation and adaptation. But how can the regional and local levels of governance and policymaking in a given socio-geographical area have sustainable impacts?

Governance, and the related norms of societal structure and societal decision-making and control, is usually supported by institutions that are also shaped by society and politics by formal and informal processes (Krasner, 1983; Lawrence and Suddaby, 2006). Many societies have started to come to terms with climate change by incorporating climate plans in local, regional and national policies as measures to adapt to climate change. However, in certain parts of the world, like the Arctic, climate change has occurred so rapidly, that local governors and bureaucrats have already had to deal with dire consequences of a warming climate. In addition, the Arctic Council for the first time did not have a joint declaration signed at the end of

FIGURE 1 | Map of the Arctic Region. The Svalbard archipelago is outlined in the pink hashed circle, and Longyearbyen (Longyear City) indicated. Public domain source: https://commons.wikimedia.org/wiki/File:Arctic_circle.svg.

its 11th Ministerial Meeting – because of disagreements over climate change, with the United States wanting to remove all reference from the declaration if it were to sign the declaration (Tømmerbakke and Breum, 2019).

Svalbardi fundinn

In Longyearbyen, Svalbard, however, there is less discussion about whether there are effects of climate change – and more about how to adapt to it. This was the area in the High North where we explored the concepts of future fisheries and the role of institutional and community adaptive capacities. The case was chosen because it is located in an area where climate change is having an effect faster than most places in the world, but also because its governance structure is complex. This gave us the opportunity to assess the effects of institutional capacity on a case where governance is not straightforward, and where adapting to future scenarios involves not only institutional changes but also geopolitical considerations. This does not make it a representative area of the Arctic populations in general, given the diversity of its peoples and geographical realities, but it gives a snapshot of what one group of Arctic residents envision in terms of future scenarios around fishing. It also exemplifies some of the challenges to governance that the Arctic is faced with under a changing climate.

Svalbard is an administered territory of the Kingdom of Norway, though this is not without some controversy. Several nations, including Iceland, Norway, Russia and the United Kingdom, have all claimed that their people discovered Svalbard first with its first mention being from 1194 with *"Svalbardi fundinn"* written into the "Islandske Annaler." In a different text, dating from around 1230, geographical descriptions to this insert are given, upon which Fridtjof Nansen commented that the land found was likely what we do know as Svalbard and not Greenland, though the discoverer(s) remained unknown (Nansen, 1926). What is known for certain, though, is that in 1596, the Dutchman Willem Barents did discover the archipelago, and that in 1899, the first commercial exchange of coal from Svalbard took place in Tromsø as well as in Trondheim. It was not until the American John Munroe Longyear visited the archipelago in 1901 and 1903 and founded the Arctic Coal Company in 1906 that investments were made into coal extraction at a serious level. Longyear City (today known as Longyearbyen) as a community was as such founded by the Arctic Coal Company and was from its early beginning known as a "company town" where the only economic activity centered on coal extraction.

At this time, the Svalbard Treaty was not signed yet, and as such, Svalbard was still considered terra nullius, a de facto no-man's land owned by no-one. In 1918, however, the Norwegian government voted that it should attempt to take possession of Svalbard, and in a letter dated 10 April 1919, Norway relayed this request for sovereignty to the Supreme Council of the Peace Conference in Paris. This was re-emphasized by the Norwegian Ambassador in Paris, F. Wedel Jarlsberg under the peace negotiations. He claimed Svalbard for Norway, as war compensation for the losses of almost half the fleet tonnage of the Norwegian merchant fleet under WWI, as well as the lives of 2,000 sailors that were providing transport of supplies to the Entente nations (Ulfstein, 1995; Berg, 2012; Czarny, 2015; Rossi, 2016). The Svalbard Treaty was signed by the Treaty parties on February 9, 1920, and when Norway, under Article 1 of the Treaty, was granted territorial sovereignty, it effectively meant that it is free to regulate all activities on the islands, including fisheries and other non-coal related industries, current and future. After years of institutional adaptation to new realities, both socio-political and economic, in the autumn of 1993, political parties were allowed in Longyear City, and democratic elections were held for the 15 representatives of the city council (Utnes, 1999) and the town was no longer a coal company town.

A move toward new industries in Svalbard is important for the Norwegian population on Svalbard. Fisheries have not had a strong role as employment in Svalbard though. The cornerstone industry and de facto "district politics" tool, or "social contract" has consistently through the history of the community been the coal mining industry, which was decommissioned recently (Hagen et al., 2018). As such, there is a new horizon awaiting the community of Longyearbyen where new industry options must materialize sooner rather than later to ensure the sustainability of the community structure, and where fisheries and a fish processing industry is one of those options considered.

The Melting Snowball Effect in Light of Responsible Research and Innovation

The interconnectedness of natural phenomena like climate change and its relations to governance is critical for the management of the Arctic since this area is a literal hotspot for governance research, due to the warming Arctic climate and melting sea ice and permafrost (Tiller et al., 2019). The dynamics of the community of Longyearbyen is also changing, seen in the trend of the increase of non-permanent residents which reflects the shift of work from coal and hunting to research and tourism (Statistics Norway, 2017). This community has given us the opportunity to observe and assess the local governance challenges climate change has incurred on a specific Arctic group of people. In this paper, we explore this case study where the world's northernmost non-indigenous community is located. Although Svalbard is a world center for Arctic natural science research, there are significantly less efforts in linking the natural science research to social, economic and political science research and theories. We explored this interdisciplinary (linking different fields of research) and transdisciplinary (linking research to the social, economic and geopolitical realities of local communities) research in the 3-year project *REGIMES "An interdisciplinary investigation into scenarios of national and international conflicts of ecosystem services in the Svalbard zone under a changing climate in the Arctic."*

Climate change governance is a relatively new research front and the integration of ecological, social, economic and political insights are complex. Our overall methodological framework is "Responsible Research and Innovation" commonly known as

RRI (von Schomberg, 2013). von Schomberg (2013) lists two questions responsible research must attune to:

1. Can we define the right outcomes and impacts of research and innovation?
2. Can we subsequently be successful in directing innovation toward these outcomes if we would agree upon them?

The complexity of future climate change scenarios in the Arctic is confusing. Scientists use numerical models both to make predictions about climate change and to understand how climate change affects different sectors and society. But the underlying complexity and uncertainty of future climate-affected scenarios can be used as a stalling tactic for decision-makers and businessmen who prefer business as usual, and the need for anticipation, reflection and engagement. Participatory practices at the science-policy interface is a typical RRI tactic, and facilitated our use of plausible, interconnected future scenarios driven by climate. We have been most concerned with developing specific insights with pragmatic solutions, for example, heuristics.

MATERIALS AND METHODS

When applying RRI as a research frame, we induced the following four qualities of deliberation between science and society: *reflection/engagement (during workshops)*, *anticipation (scenarios)*, and *responsiveness (choices and decision-making under climate change)*.

As the basis for our anticipation intervention, we created a bio-social-economic-geopolitical plausible narrative of the future. To do this, we first applied the Dynamic Bioclimate Envelope Model (DBEM) to predict the ecological and economic effects of climate change in the Norwegian exclusive economic zones, with Atlantic cod as example. We then conducted in-depth interviews and participatory stakeholder driven workshops [see for example Tiller and Hansen (2013) for details on workshop methodology] as methods to elucidate current stakeholder perceptions and attitudes about climate change. These included in-person interviews in Longyearbyen (August 2017), as well as inter-generational pilot focus groups carried out in Bergen, Norway in November 2016 and September 2017 and the final workshop, on which we report here, in June 2019. The following subsections describe each of these methodologies in detail. The interviews were done in accordance with local regulations in terms of personal data through permits from NSD, Data Protection Services, Norway.

The next subsections describe the DBEM modeling and interviews conducted in Longyearbyen and workshops in Bergen.

Dynamic Bioclimate Envelope Model for the Northeast Atlantic and Svalbard Zone

The Dynamic Bioclimate Envelope Model (DBEM) is a simulation model that combines statistical and mechanistic approaches in projecting the changes in distribution, relative abundance and maximum catch potential (MCP) of the fishes, especially commercially important species such as Atlantic cod (*Gadus morhua*). DBEM has been applied at different scales and various regions globally (e.g., Fulton et al., 2005; Cheung et al., 2011; Lam et al., 2012; Jones et al., 2013; Leitão et al., 2018; Marushka et al., 2019). It (detailed description of DBEM, see Cheung et al., 2011). Here we use Atlantic cod as an example to project its population changes and its associated economic consequences. Based on the current distribution of Atlantic cod, the DBEM simulates changes in the distribution of abundance, biomass and MCP of Atlantic cod over time and space driven by projected changes in ocean conditions, with consideration of physiological and ecological effects of changes in ocean properties and density-dependent population growth and movement (Cheung et al., 2009, 2010).

To understand the impact of climate change on economics, DBEM has been built into economic models to examine the potential economic impact of climate change, and these studies focus on modeling the effects of climate change on the profits through changes in the catches (Lam et al., 2014, 2016b). We incorporate specific fishing effort dynamics into the DBEM. This model is a more holistic approach than the previous biological model such as DBEM and size spectrum model, which do not include how the change in socio-economic factors on the catch and biomass of marine species. Our model projects the future impact of climate change on economics of fisheries by incorporating the change in fishing effort, which is determined based on the change in catch, profit and fisheries regulations, into the biological model that projects the potential catch under climate scenarios.

The fishing effort dynamic model (EDM) simulates the change in fishing effort through the profit obtained from fishing in each year. The profitability is the driving force for fishing activity the following year. The fishers decide whether to go fishing, invest more on fishing activity, stay or exit fisheries. The potential fishing profits in each fishing year is projected using the bioeconomic model incorporating fish biology and economics of fishing operation (e.g., maximum carrying capacity, biomass, fishing cost, fish prices, subsidies, etc.). The resulting annual fishing effort in term of fishing mortality is integrated into the DBEM. Therefore, this entire model (DBEM-EDM-DBEM) (**Figure 2**) is an iterative process and allows us to investigate how the change in fish abundance and MCP may affect fishers' behavior and sequentially how fishers' action (i.e., change in fishing effort) may affect the fish abundance and MCP on top of the effect of climate change. The results from this simulation model will be used for formatting scenarios later for workshops conducted in Bergen with three generations.

In-Depth Interviews in Longyearbyen

We acknowledge that the use of case studies as a method in political science in the theory building process can help readers understand social problems in general (Stake, 1978; Eckstein, 2000), such as that of adaptive capacity to climatic stressors, including that of moving fish stocks. Following Stake's (1978) list of features of a case study in the social sciences, we emphasize that a given case study may include "*...descriptions that are complex, holistic, and involving a myriad of not highly isolated variables; data that are likely*

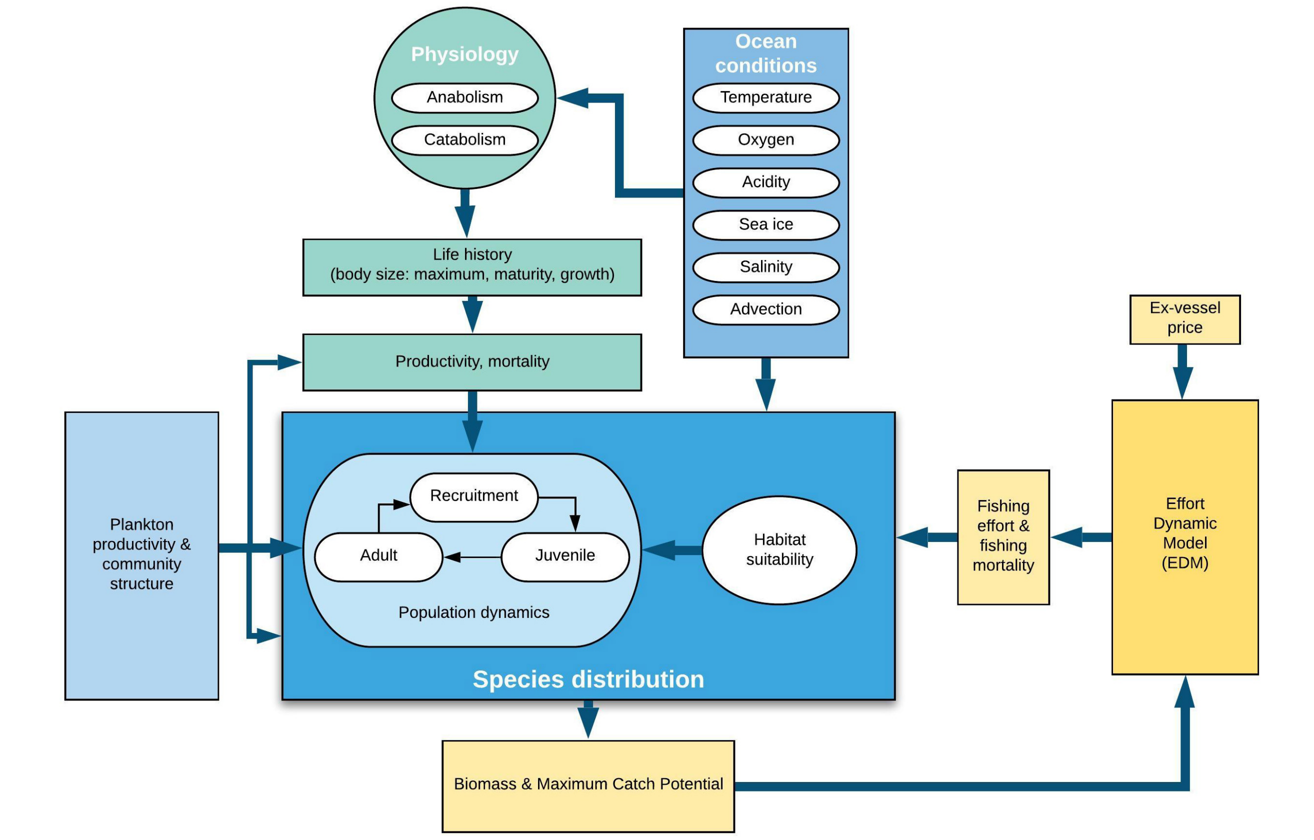

FIGURE 2 | Structure of the coupled Dynamic Bioclimate Envelope Model (DBEM) – Effort Dynamic Model (EDM) in this study.

to be gathered at least partly by personalistic observation; and a writing style that is informal, perhaps narrative, possibly with verbatim quotation, illustration and even allusion and metaphor."

On this note, our analysis therefore includes data gathered in August of 2017 from in-depth interviews of Longyearbyen residents. The interviews were semi-structured and in-depth, where the selected respondents were presented with a number of open-ended questions that were within the realm of the research question of the interviewer. The conceptual basis for the interview guide was based on literature studies, previous knowledge about the topic and the preliminary results from the DBEM. Based on this, and our research question, we formulated a first-draft interview guide (see **Supplementary Appendix** for Interview Guide) or list of questions, that would direct the interview with the informant. We wanted the questions to inspire the respondents to give frank, in-depth, and spontaneous answers and reflect their personal feelings – not just politically correct answers. We encouraged answers to be descriptive and thorough by leading with "who" or "where" or "what," and even "why" at times, for both the main questions and the follow-up questions, where the respondent would be asked to expand on the main topic. We then tested the interview guide on the research group to evaluate it in terms of its internal logic, lack of leading questions and interviewer bias, and that it gave us the answers we were looking to elicit. Though we used expert-testing, we could also have used in-field testing, having a potential interviewee test the guide. However, given our limited time of field work, we chose to test it within the research group itself. This exercise also helped determine the time frame of each interview.

The interviews lasted between 30 min and 1.5 h depending on the interest and needs of the respondents. To ensure that the interview respondents came from diverse backgrounds, we intentionally targeted participants that varied in their: years of residence in Svalbard, trade, family composition, gender, and age. We used the snowball method to contact individuals (Biernacki and Waldorf, 1981), and we had 17 interviews. Though this may seem like a small-N from a natural science and quantitative research perspective, samples in qualitative research tend to be smaller than one would expect in the more numerical sciences. This is to support the depth of case-oriented analysis that is fundamental to this mode of inquiry. The samples also tend to be purposive in that they were selected by virtue of the respondent's capacity to provide richly textured information, relevant to the phenomenon under investigation, in this case effects on fisheries potentials in the Arctic – specifically Longyearbyen. As such, this purposive sampling (as opposed to probability sampling that is customarily employed in quantitative research) selects "information-rich" cases or respondents, and the more useful the data sampled from each respondent is, the fewer respondents are needed. Research on this has shown for example that after 20 responses, there is seldom any new information to be gained that is analytically relevant (Green and Thorogood, 2004). We experienced this as well in our study and chose to end our inquiries after 17 responses.

These interviewees were represented by both men (6) and women (11), representing different sectors including tourism (6), research and education (5), public employees and governance (3), industry (2) and other (1). Five were in their 20s, four were in the bracket 30–40, two in the 40–50 age bracket, and six were more than 50 years old. They furthermore represented Norwegians (10), Europeans (5) and Russians (2). While the sample is small, we maintain that the sample size is relative to the information power a sample has and the value this presents for the advancement of the research toward a specific goal (Sandelowski, 1995; Malterud et al., 2015).

The emergent narratives from these interviews were later analyzed. Narratives are popularly described as "*discourses with a clear sequential order that connect events in a meaningful way for a definite audience and thus offer insights about the world and/or people's experiences of it*" (Hinchman and Hinchman, 1997). We interpreted the narratives and focused on pulling from the notes specific quotes that illustrate the emergent themes (Czarniawska, 2004), like that of a future of having Longyearbyen as a landing site for fish and other marine resources. The most important quality of the narrative in this case was the richness of the knowledge and experiences. This is in line with Elliott's (2005) account of narratives as being instrumental in that "*...internal validity is...thought to be improved by the use of narrative because participants are empowered to provide more concrete and specific details about the topics discussed and to use their own vocabulary and conceptual framework to describe life experiences*."

Workshops With Three Generations of People in Bergen, Norway (June 2019)

The focus groups were conducted over the span of 2 days, since the initial day only had 1 participant in the youngest category. This was remedied by recruiting young people in the local chapter of the activist group Natur og Ungdom (Nature and Youth) at their local meeting the following day. It is important to note that for both these workshops, we were not looking for a random sample of citizens, but instead people who were willing to discuss these issues. Therefore, many, but not all, of our workshop participants were currently well-versed in many aspects of climate politics and several considered themselves climate activists.

In order to demonstrate the "Melting Snowball Effect" to stimulate discussions in the workshops, we integrated plausible scenarios from four knowledge bases: (1) biology, climate and ecology, (2) economics, (3) political science (national and geopolitical), and (4) social science and community. Based on the DBEM and economic modeling and the community studies and interviews in Longyearbyen, we developed three scenarios, A, B, and C, that all take place in 2039, 20 years in the future. The scenarios in their entirety are in **Supplementary Appendix**. **Table 1** summarizes the excepts from each scenario related to fisheries and climate change.

TABLE 1 | The scenarios and questions used in the citizens' workshop in Bergen, Norway (June 2019).

Scenario	Excerpt related to climate change and fishing	Group question
A	Cod go to Russia Because of the warming Ocean, Norwegian cod seem to have stopped spawning in Lofoten, and now are exclusively located in the Russian zone. Russia has dropped out of the Joint Norwegian-Russian Fisheries Commission and does not let Norway fish any cod in their waters.	Should Norway do something to get back cod fishing?
B	Fish more popular It is more common to eat herring and mackerel, which have become more abundant along the coast of Norway. However, Norwegian fishermen has recently declined to follow the recommended scientific advice from the European fisheries scientists to reduce quota of these species, in order to meet the consumer demand for mackerel and herring. Environmentalists warn that this overfishing increases the risk that the fish stocks collapse.	Is it more important to provide healthy fish to reduce CO_2 emissions and increase public health, or to reduce fishing pressure to prevent overfishing? Why?

The scenarios are inspired by Round 1 of workshops with these three generations (each scenario topic is from specific areas of concern that came from the Bayesian Belief Networks conducted in November 2016 and September 2017). A first draft of the three scenarios that came out of the three generational groups' BBNs was peer-reviewed and discussed with two colleagues at the Centre for Climate and Energy Transformation (CET) in the Department of Geography at the University of Bergen. The second draft was reviewed by the REGIMES consortium. The third draft is what was used for the workshops (**Supplementary Appendix**).

The protocol is as follows:

1. Participants are welcomed and register their name, date of birth, education level and if they are currently active in any organizations (yes/no).
2. Participants split in generational groups in separate rooms (3).
3. Each generation gets a scenario/questions and 15 min to answer the questions as a group.
4. Refreshments break.
5. Random mixing of groups and repeat the scenarios/questions.
6. Plenary de-brief.

We audio recorded 15 min × 5 discussions (2 rounds of 2 discussions on Day 1 and 1 discussion the following day), transcribed each discussion and then performed a discourse analysis to analyze the discussion regarding future Arctic fisheries and their perceived strengths or vulnerabilities.

We demonstrate the use of "The Melting Snowball Effect" as a heuristic to create plausible scenarios (**Figure 3**) for deliberative discussions among academics, citizens and policy-makers and also a way to summarize these deliberative discussions.

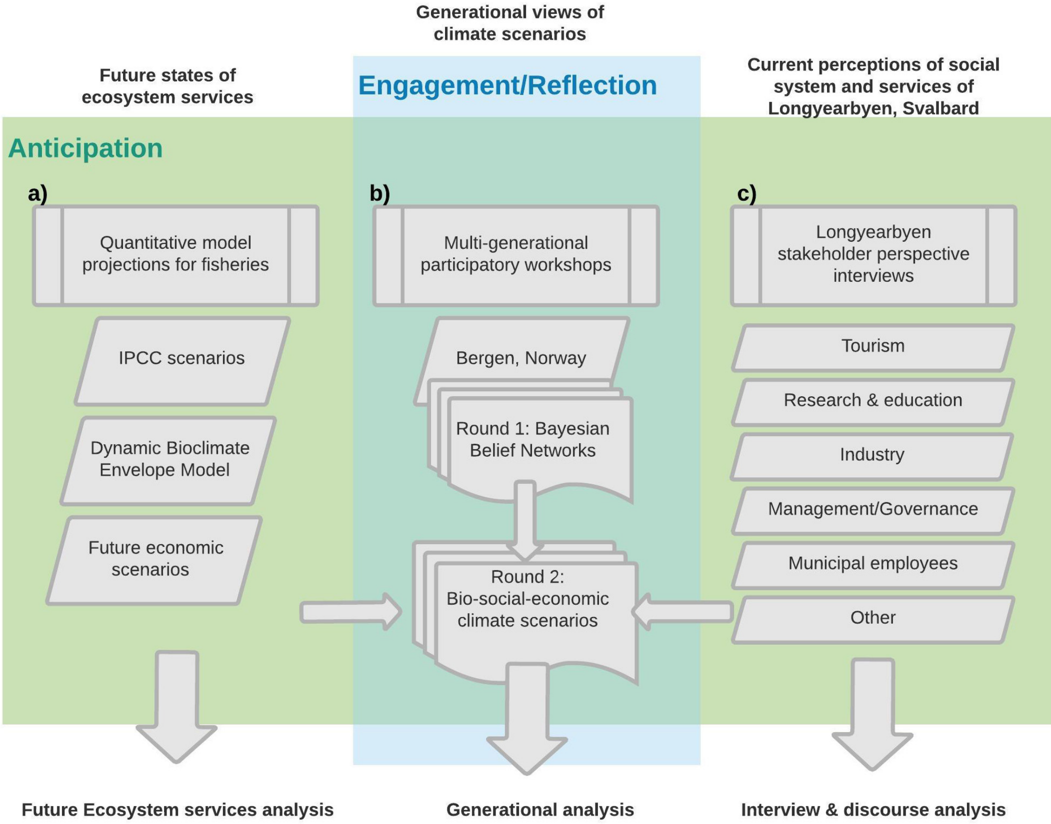

FIGURE 3 | A schematic of the interdisciplinary methodology developed for this paper. The three columns **(a,b,c)** represent the **(a)** modeling work, **(b)** workshops and **(c)** interviews. The arrows pointing to "Round 2" in **(b)** workshops show how the DBEM modeling and interviews were used to create the scenarios used in the second round of workshops.

RESULTS

In order to create plausible scenarios to use for our stakeholder workshops, we first analyzed our interviews from the different stakeholders in Longyearbyen. Then we applied the coupled *DBEM-EDM* and derived model projections of the future state of cod fisheries. Finally, as sketched in **Figure 3**, we created three plausible scenarios that we used as the basis for our stakeholder workshops in June 2019 (**Supplementary Appendix**). We now present the results as three parts: (1) Longyearbyen stakeholder interview results; (2) bio-physical-climate-economic model (*DBEM-EDM*) results; and (3) Bergen stakeholder workshop results.

Results 1/3 – Implications for Svalbard – Longyearbyen Interview Results (Excerpts Focus on Economic Opportunities and Fisheries)

Longyearbyen is in an international area, under Norwegian sovereignty. It follows some Norwegian rules and regulations, yet others cannot be implemented because of the international setting. You are not allowed to be born or to grow old in Svalbard, for example, and a popular phrase on tourist items is "Do not come here to die." This regulation has natural reasons, linking in on the institutional capacity of the area, in that social benefits from the mainland are not extended fully to Svalbard because of its international status. That is also the reason why women are not allowed to give birth on the archipelago but are sent to the mainland and their main address some weeks before the due date. Births still occasionally happen though, but that is usually with premature births, and they are rare (Dørmænen, 2007; Hansen, 2012). Nevertheless, as stated by another informant, "*there may one day be roots in the permafrost as well.*" Building resilience will be a requirement for these roots to gain traction, and more permanency of the population of Longyearbyen is a need. More work is therefore needed. However, in light of the geopolitically uncertainties around the Svalbard Treaty and the surrounding marine areas, climatic stressors, changes in fish distribution patterns and the closing of the coal mines in Longyearbyen in 2017 are still issues that may have a large effect in the future. One of the questions we asked the informants was whether – in their opinion – new industries could be able to attract a more stable population to the area, whereby social capital could build, and in turn enable the community to be more resilient to more climatic stressors. We also asked, more specific, what industries they considered as having future opportunities.

The sector which is seen as having the most potential for the future is the tourist sector, which is not surprising given the strong emphasis this industry has on the archipelago (**Figure 4**). However, there were multiple interviewees that mentioned the negative effects of tourism as well. They did see tourism as important to Svalbard, but said that it should not get too big, since this could cause more damage to the local environment and could affect the local community.

More than half the respondents, nine interviewees in total, discussed the topics of fish, fisheries and how these may become affected by climate change and affect Svalbard in turn. One respondent from the tourism industry, on this topic, said that *"The important thing with fish is that they are food for the seals. If climate change leads to warmer waters and more fish coming up here, that could also mean more seals come up here – which in turn means more food for the polar bear."* Another respondent, also from the tourism industry, expressed enthusiasm for the prospect of being able to land fish in Longyearbyen, but did not elaborate much beyond that, but a third tourism respondent was also enthusiastic, specifying how the community needed more industry legs to stand on, stating that *"This could definitely be a great opportunity to diversity the industries of Longyearbyen beyond tourism and research – and we hope it will be possible."*

A government employee furthermore emphasized that there already were new species of fish that had come up to Svalbard, but that only time could tell if they were there to stay or not. A researcher echoed this but specified it by stating that *"A lot of people like that the fish is coming up here now. Right now, they can't make any money off of it though since it is landed elsewhere. There is a possibility for a fishing industry here though."*

This was also reiterated by another researcher who said that "*They should be ready – the fish is coming – and maybe this will be the new Lofoten. Things will stabilize in about 50–100 years though, I think. There used to be a landing site in Ny Ålesund in the 1940s, you know. . .Maybe fisheries landing sites can happen again – but maybe only for a short while – there are no guarantees that the fisheries – if there is one in the future – will be stable."*

One of the respondents considered the issue more broadly though, bringing in the cost of investments for there to be a landing site for fish in Longyearbyen. In addition, he brought in the quota challenges because of the Svalbard Treaty, as opposed to Svalbard being considered Norway. He talked about how it would be a challenge if the quota for fish that were to be landed in Longyearbyen was considered part of the full Norwegian fish quota. *"It's a long way to go still, in other words"* he said somberly.

Results 2/3 – Arctic Change in Fish Abundance Under Climate Change Using the Bio-Physical-Climate-Economic Model (DBEM-EDM)

Our model showed that the total relative abundance of cod in the Northeast Atlantic is projected to increase under the high greenhouse gas emission scenario (RPC 8.5), however, the spatial distribution of cod is projected to shift from the southwestern coastal zone of the Norwegian EEZ to the Barents Sea by the 2100s (**Figure 5**). The increase in the biomass is because of the change in the suitability of the habitat such as the change in sea temperature and primary productivity under climate change (**Figure 6**), which leads to the shift in distribution of marine species. The model also predicts that other commercially important species, especially boreal species will be expanded northward (Manuscript in preparation). These results are consistent with findings from other research (e.g., Christiansen et al., 2014; Haug et al., 2017; Andrews et al., 2019).

Climate driven northward expansion of existing fish species may create potential opportunity for commercial fishing, especially the newly coming species for costal fishing vessels that can fish around the fjord of the Longyearbyen. However, the opportunities for feasible commercial fisheries are ambiguous, partially due to anticipated costs and benefits associated with Arctic ocean fishes (Christiansen, 2017). In the Svalbard Zone, the most important fisheries are Northeast Arctic cod, Northern shrimp, capelin and Northeast Arctic haddock, Iceland scallop and Greenland halibut (Misund et al., 2016; Statistics Norway), red king crab and snow crab have recently becoming important. The fishing cost in the Arctic zone is higher than in other fishing grounds due to its long transit time to the landing sites (Misund et al., 2016; Pettersson et al., 2020). Discussions of building a processing plant in the Longyearbyen for snow crab have been ongoing since 2016. Such a realization would boost employment and the local economy. However, a decision has not be made.

Results 3/3 – Scenario Workshop: Discussions Around the Melting Snowball Effect Scenarios

We now present how three different generations in our stakeholder workshops in Bergen in June 2019 discussed the scenarios. For this paper, we only present our analysis of scenarios A and C, which had themes related to fish and fishing. Scenario B contained topics that did not directly relate to those of A and C, so we omitted them from this analysis for brevity.

Youngest Generation

"We would have to have some compromises or something."

In Scenario A, NEA cod retreat more to the Russian zone and Russia pulls out of the quota sharing agreement with Norway. Should Norway do something to get cod back from Russia?

There were eight participants in this discussion who were all female. Their ages ranged from 16 to 19 years old. Each of these participants were members of the Norwegian Nature and Youth association (Natur og Ungdom).

The first aspect of the discussion was that Norway would become a poorer country if they lost the right to fish cod. These participants also discussed that it was very likely that Norway had stopped producing oil, thus making Norway even more vulnerable in the situation of losing cod. The main emphasis the youngest generation of participants was two-part: because Norway has become a poorer country due to loss of both oil and cod, a compromise with Russia to restore access to NEA cod was needed.

> *"So by reducing the cod I think we would be very poor, after a while. Because what should we base our economics on if we don't have the fish or the oil."*
>
> *"Yeah, and oil will be gone one day."*

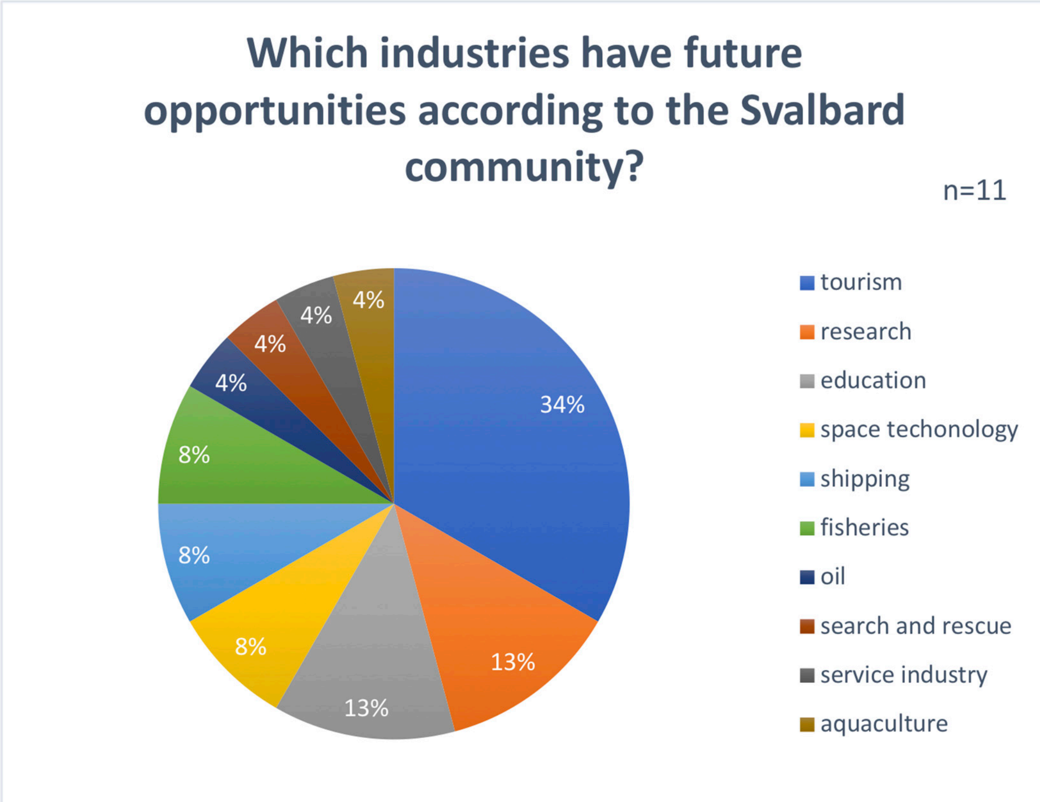

FIGURE 4 | Question posed to interviewees in Longyearbyen, Svalbard. Tourism was what was considered as having most potential, and fisheries only was discussed in 8% of the cases.

> *"And maybe it already is in this scenario."*

> *"What I believe is problematic with this is that Russia is a strong opponent. So, if Russia isn't willing to come back to us, it would be really dangerous for us to just demand Russia to give the fish to us. So, I don't quite know how we would do that. We would have to have some compromises or something."*

Oldest Generation

"We need limits on stocks but that might imply both fishing down and or reducing fishing based on what's needed for the total ecosystem."

In Scenario C, herring and mackerel are more abundant along the coast of Norway. We asked the participants if it is more important to increase fishing pressure to provide local, healthy fish to reduce CO_2 emissions (that would result from alternative imported protein sources) with the added benefit of increasing public health (due to Omega 3 that is abundant in herring and mackerel) or to reduce fishing pressure to prevent overfishing?

In this discussion, there were four participants between the ages of 47–71 years. All were male. The discussion revolved around the idea of an ecosystem approach to fisheries and an idea of considering the stocks as part of a protein system, and not as separate systems. Another point in this discussion was the migratory aspect of NEA mackerel, and that the sharing of this resource is currently problematic, and likely more so in the future.

One striking mention in this short discussion was that of the work of Johannes Hamre, and his theory, explained in the Introduction, that a large NEA mackerel stock is a threat to the Atlanto-Scandian herring:

> *"Right. (Johannes) Hamre is a person who is very into that theory. So his idea is that we should actually reduce the amount mackerel in order to get the balance on the other stocks."*

> *"This is also the theory that Jens Christian Holst[1] has come out in the media in the later years. Overgrazing."*

The mention of Hamre, and his protégé Jens Christian Holst, shows that theories about holistic views of the ecosystem are seen, by this group, as helpful and necessary to preserve fish stocks for the future.

Mixed Generations

Scenario A, was also discussed in a group that contained all three generations (N = 5, ages 19–66 years). The discussion commenced with an agreement that Norway didn't have a legal

[1]Jens Christian Holst is a former scientist who worked 23 years in the Pelagic Department at the Institute of Marine Research who now works as an independent scientific advisor.

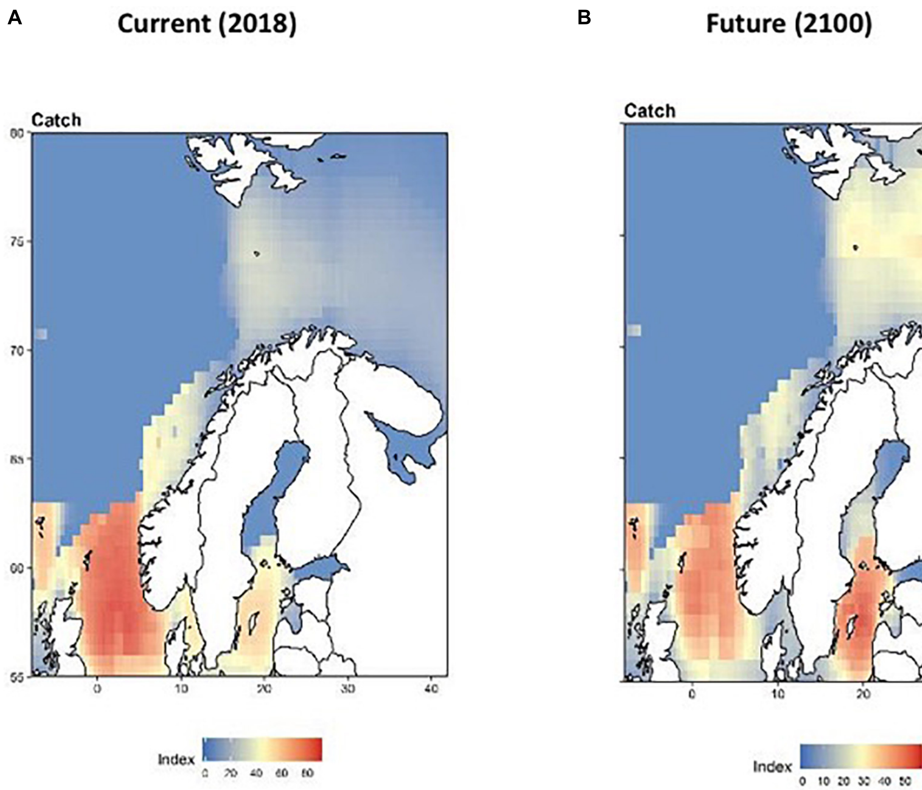

FIGURE 5 | The relative abundance of cod in the Northeast Atlantic region under **(A)** the current status **(B)** high greenhouse gas emission scenario (RCP8.5).

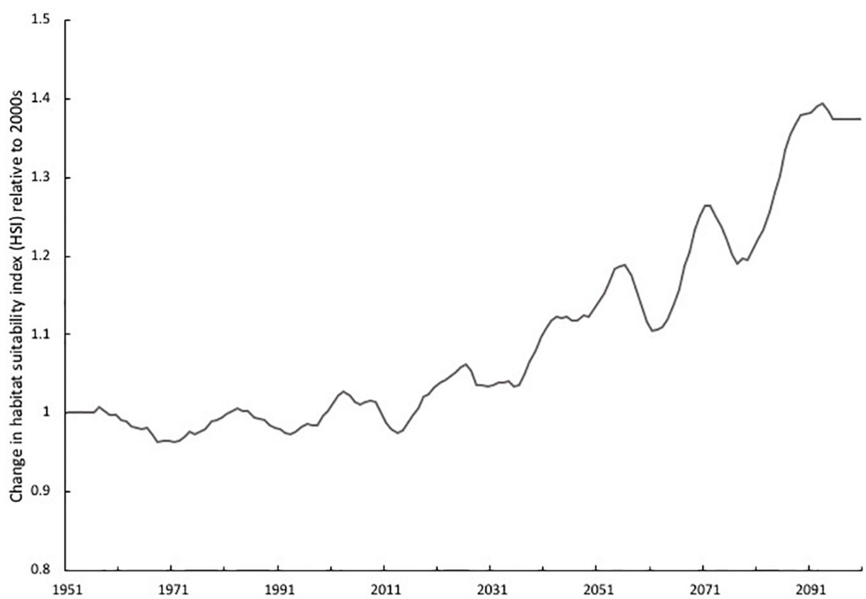

FIGURE 6 | Results from the DBEM-EDM model on the change in Habitat Suitability Index (HSI) in Norwegian EEZ.

right to fish in Russia's Economic Exclusive Zone, and that negotiations with Russia could be strained. One participant pointed out that Norway has "been lucky" with large fish stocks all these years, and if climate change leads to a major change in the location of the fish stocks to the Russian zone, then "that is not Russia's fault." The discussion then developed into an

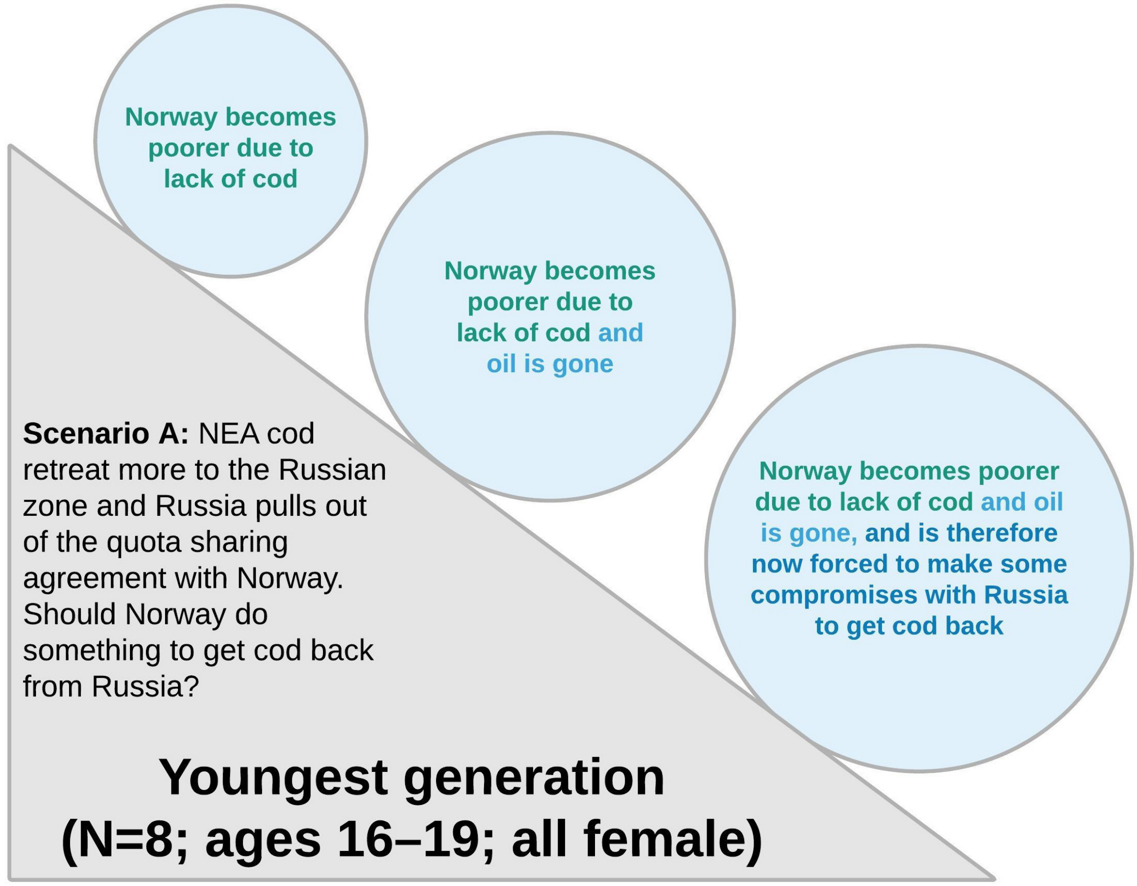

FIGURE 7 | A schematic summarizing the discussion among youths in Bergen, Norway in June 2019.

implicit argumentation for national food security. In the last part of the discussion, aquaculture was seen as a safer choice for fish production than wild caught fish shared with other countries. And finally, on the question "Should Norway do something to get cod back from Russia?" land-based aquaculture was mentioned as the safest and most reliable answer for producing fish protein, due to independence form uncertain geo-political and ecological Ocean states:

> *"Nah, that (negotiating with Russia to get more cod quota) will all be very hard, you know..."*
>
> *"We should increase fish farming."*
>
> *"On land."*
>
> *"That's the better way to grow fish."*

In summary, we illustrate the differences in the depth of dialogue that can occur when people of different generations are involved in discussions. This may be seen by the sheer amount of words needed to describe the discussions among three different groupings, where the mixed generational group (**Figure 9**) developed a future climate action narrative that was much more diverse than those of the youngest generation (**Figure 7**) and the oldest generation (**Figure 8**).

DISCUSSION: MELTING SNOWBALL EFFECT AND FUTURE FISHERIES IN THE ARCTIC

For centuries, we have observed that fisheries have an effect on ecology, social situations, local, regional and national economics and geopolitics. Depending on the severity of climate change, which in turn is dependent on how society mitigates future CO_2 emissions and adapts to the changing climate, the probable boost in Arctic fisheries due to a warming Ocean cold be negated by the Melting Snowball Effect if the geopolitical situation prevents an ecologically sustainable sharing of fish stocks.

In this sense, we see the vulnerability of fisheries to climate change in the Arctic around Svalbard as not a primary vulnerability, but a secondary or tertiary social, economic or geopolitical threat. This is because we see valuable fisheries like NEA mackerel and snow crab expanding, but the real tensions only precipitate when the expansions run into institutional deadlocks, such as the lack of the quota agreement with Iceland, Greenland for NEA mackerel (Spijkers and Boonstra, 2017; Harte et al., 2019), or the lack of precedent of sharing resources in the Svalbard Protection Zone (Tiller et al., 2019). The stock sharing regime and scientific collaborations between Norway and Russia

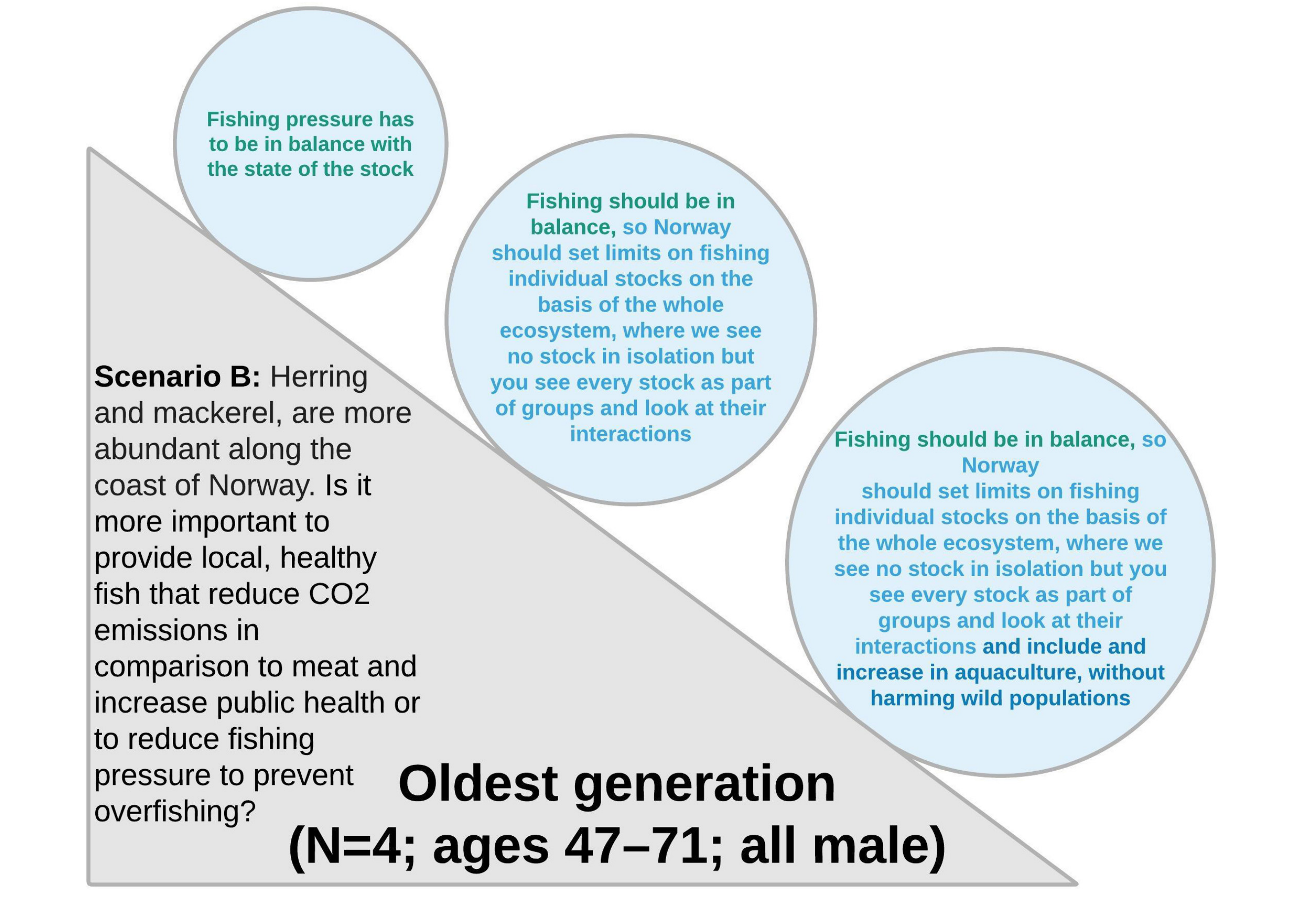

FIGURE 8 | A schematic summarizing the discussion among the group of the oldest participants in the workshop in Bergen, Norway, June 2019.

have been on-going for over 60 years, and is a very deserved celebration of successful sustainable management of the shared fish stocks (Hammer and Hoel, 2012). However, in the event of a shift in distribution or migration of NEA cod, for example, we postulate ripple effects that could strain this relationship as we illustrate in Scenario A. While the youngest generation focused on compromise, the mixed generation focus more on national security, turning to aquaculture rather than haggle with Russia to regain lost cod. It is obvious from the responses to Scenario A that there is a generational affect as to how to position the geopolitics between Russia and Norway. The Melting Snowball Effect heuristic makes these interdependencies and consequences an explicit part of model results.

And there are always unknowns. One of these is the ecological vulnerability of certain ecosystems to large increases in single stocks. Simple ecological theory says that if NEA mackerel population grows too big, the resulting predation on Atlanto-Scandian herring can be ecologically catastrophic. This theory was mentioned by the oldest generational group in section " Oldest generation."

The rapidly warming Ocean and Arctic regions is a game-changer for science-based policies and governance, due to the inherent complexities across disciplines, interdependencies across borders and uncertainties of predictions. Model projections help us understand the parameter space of aspects of ecosystem services and how these can change in the future, but we argue that these projections need to be put into plausible scenarios, or narratives, in order to be fully useful for society.

For those living in the High North, they general consensus of those that considered a local fishery and landing site a potential future industry for the archipelago of Svalbard, the future was bright, though complex. Many wanted population stability, and the chance to lay down roots in the Arctic. To do so, there had to be a shift in the employment pattern of especially Longyearbyen. In a city where the majority of the population is completely changed every 4 years, stability is rare, and goodbyes are plenty. For the small percentage of the population that is stable and that has been there for more than a decade, an opportunity for a stable employment sector that will ensure that more people choose to stay, longer, climate impacts pushing fisheries further north presents such an opportunity.

This methodological framework has provided an interactive platform or dialogue integrating inter- and intra-disciplinary sciences and various levels of stakeholders to discuss climate issues. We applied a RRI framework and designed a methodology based on anticipation, reflection and engagement in order to

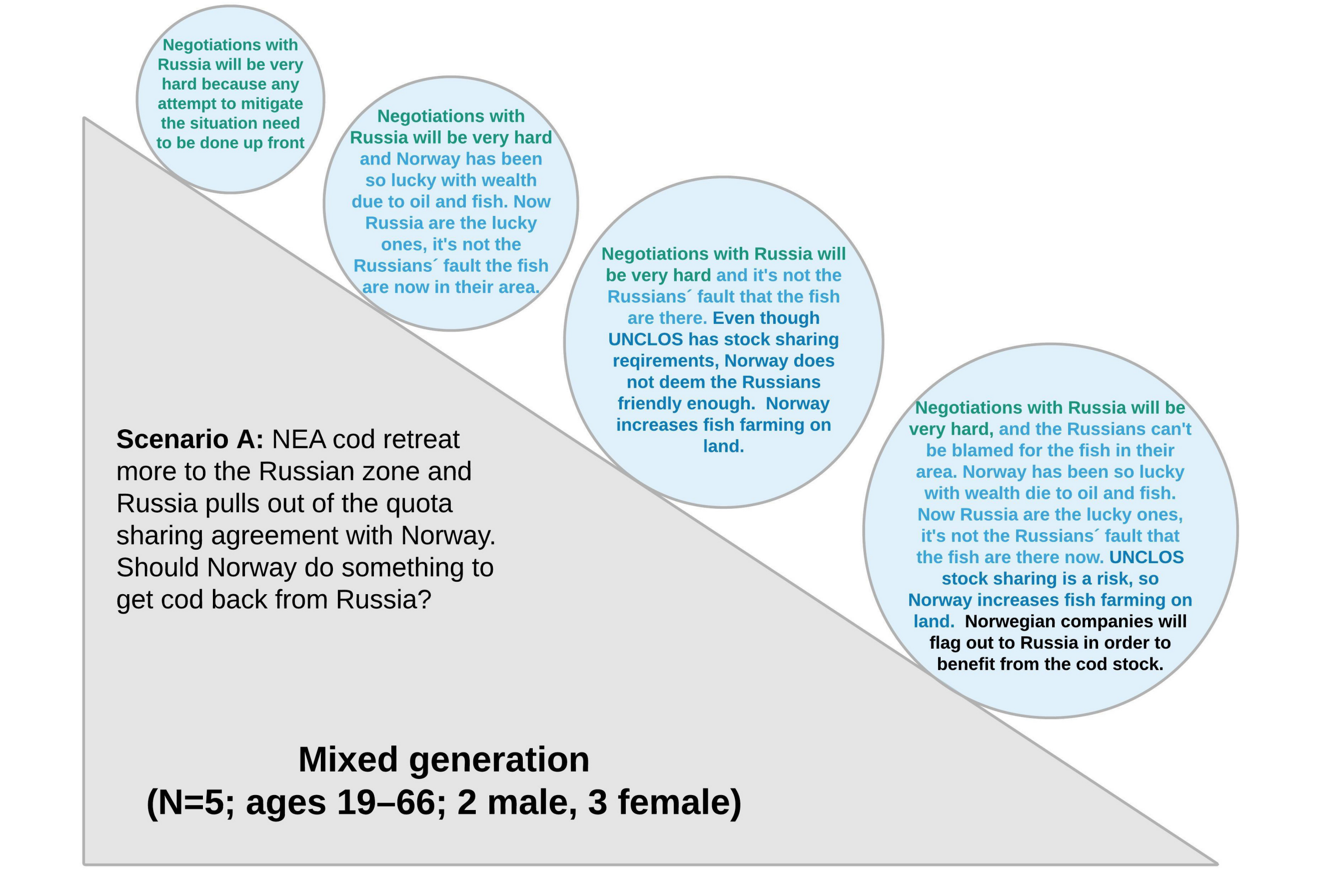

FIGURE 9 | A schematic of the results of a discussion among a mix of ages in Bergen, Norway, June 2019.

package the inherent complexity that we describe with the "Melting Snowball Effect" heuristic into plausible and realistic narratives of the future. We then designed an experimental set-up with three different generations in a workshop-setting to observe how publics responded to the narratives. There are two caveats we think are important to realize when interpreting the results of the Bergen workshop: (1) all participants were volunteers recruited from an unpaid advertisement on Facebook and flyers handed out at a climate strike in Bergen, and (2) all participants (except for two) all had been involved, or were currently involved in environmental NGOs. So, there is little doubt that the majority of our participants were concerned about climate change before their participation in the workshop. This being said, the discussions reflected the fact that the situations incorporated in our scenarios were unique narratives of the future that sometimes caught the participants off-guard. We feel this underscores the need for capacity-building in democratic deliberation, since even well-versed environmentalists were not used to being confronted with such dramatic, somewhat likely, vignettes.

Our goal was to design and test a heuristic that is able to encompass the complexity of cascading uncertainties that swell from the changing climate to the ecological and into the economic, social and geopolitical. Of course, we are not able to generate conclusions for decision-makers based on the views and discussions in the Bergen workshops, due to small example of participants and volunteer-based participation. Our focus in this paper is our approach, which we designed to be useful for different levels of decision-makers who are forced to related to the realities of climate change. Our approach can be used to map the interdependencies of climate-related effects on governance issues at the local, regional or even national, levels.

In this paper, we postulated that our workshops would aid in capacity-building for future climate plan discussions at a local level. But how could we measure this effect? We are encouraged that after the 15-min discussion for each scenario iteration, each group continued their discussions. In particular the oldest group who discussed for over 20 min and had to be reminded three times to please vacate the room in order to join the others for refreshments. In the de-briefing following the workshops, most of the participants continued to mingle, casually discussing with each other. At the very least, we feel that our workshops were an effective and lively way to disseminate interdisciplinary results that, in our opinion, are all too often hidden in distant and inaccessible reports.

Finally, the differences in the depth of dialogue that occurred in the mixed generational group (**Figure 9**) underscore a vital aspect of democratic deliberation: inclusive participation. We think that governance that includes perspectives from all generations in society is crucial for credible and salient future climate policies.

CONCLUSION

Climate change is affecting the Northeast Atlantic, one of the most studied parts of the Ocean, in different ways that affect different sectors and different ecosystem services. Scientists have attributed the increase in sea temperature as a contributor to the rapid expansion of the mackerel stock further north of the Arctic Circle and into the southern part of the Svalbard Fisheries Protection Zone. As a result, nations not originally included in the quota sharing scheme are now catching mackerel causing an on-going geopolitical havoc. This expansion of the distribution and increase in the biomass of the stock has made an already difficult scientific assessment of the stock even more difficult, leading to new benchmarks and revised quota advice (ICES, 2017, 2018, 2019a,b,c).

Many scholars agree that climate change has an effect on inherent synergies that encompass different parts of our societal interconnections with nature (Holtermann and Nandalal, 2015; Hoolohan et al., 2018). But interdisciplinary framings themselves, for example, the popular Water-Energy-Food Nexus scientific framing (Holtermann and Nandalal, 2015; Simpson and Jewitt, 2019) do not automatically produce good governance (Weitz et al., 2017). Scientists produce models to extrapolate climatic effects into the future, but it is not straight-forward how to translate these plausible futures into governance actions. This is why we designed and tested a conceptual modeling approach, based on a RRI framework, for deliberative democratic decision-making. We used our Melting Snowball Effect heuristic to bridge the complex coupled DBEM-economic model and its "snowball" effects on society into understandable narratives. We show through our results from the deliberations of different generations how society is able to grasp these narrative vignettes and make informed deliberations about the potential effects of climate change.

In 2019, the annual Arctic Frontiers science and policy conference in Tromsø, Norway had the theme "Smart Arctic." The theme was chosen as part of a pan-Arctic perspective "build new partnerships across nations, generations and ethnic groups." We agree to this perspective, but caution that these important process of inclusion and dialogue should be guided by credible and legitimate methods of engagement. In this paper, we demonstrated how our interdisciplinary team described the current climate and governance situation of Svalbard from the view of social science, ecosystem science, economics and political science. We created the heuristic, the "Melting Snowball Effect" to guide our scenario building and to examine the discussions and deliberations of different generations of citizens about futures affected by climate. We feel that the Melting Snowball Effect scenarios produced by an interdisciplinary team and deliberated on in by local citizens in our workshops present an example of filling a transdisciplinary void by engaging stakeholders across generations in ecological-social-economic-geopolitical moral narratives of a future Arctic. Only through these interdisciplinary and contextual scenarios can we come closer to a "Smart Arctic." Ultimately, though, it will be the local governors and citizens who will judge of the Melting Snowball Effect heuristic is helpful to design and implement appropriate responses for sustainable climate governance.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by NSD Norwegian Data Protection Services. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

DD initiated the manuscript idea, performed the analyses, wrote the first draft of the manuscript, and co-designed and co-conducted the workshops. RT held all the interviews, and presented results from these, reported on methodology as well as presented background on Svalbard and Longyearbyen for the article, and co-designed and co-conducted the workshops. EK transcribed the Longyearbyen interviews and summarized the results and co-conducted one workshop. YL and VL co-designed the manuscript, conducted model results, and wrote the methodology and results. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fmars.2020.00537/full#supplementary-material

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