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A participatory scenario method to explore the future of marine social-ecological systems

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Abstract

Anticipating future changes in marine social-ecological systems (MSES) several decades into the future is essential in the context of accelerating global change. This is challenging in situations where actors do not share common understandings, practices, or visions about the future. We introduce a dedicated scenario method for the development of MSES scenarios in a participatory context. The objective is to allow different actors to jointly develop scenarios which contain their multiple visions of the future. The method starts from four perspectives: "fisheries management," "ecosystem," "ocean climate," and "global context and governance" for which current status and recent trends are summarized. Contrasted scenarios about possible futures are elaborated for each of the four single perspectives before being integrated into multiple-perspective scenarios. Selected scenarios are then developed into storylines. Focusing on individual perspectives until near the end allows actors with diverse cultures, interests and horizons to confront their own notions of the future. We illustrate the method with the exploration of the futures of the Barents Sea MSES by 2050. We emphasize the following lessons learned: first, many actors are not familiar with scenario building and attention must be paid to explaining the purpose, methodology, and benefits of scenarios exercises. Second, although the Barents Sea MSES is relatively well understood, uncertainties about its future are significant. Third, it is important to focus on unlikely events. Fourth, all perspectives should be treated equally. Fifth, as MSES are continuously changing, we can only be prepared for future changes if we collectively keep preparing.

KEYWORDS

Barents Sea, future studies, multiple perspectives, participatory fisheries management, storylines, uncertainty

1 | INTRODUCTION

The combined effects of climate change, rapid population growth and technological, economic and political changes have the potential to bring about large changes in Social-Ecological Systems (SES, Watson et al., 2015). These changes are happening at an accelerating pace with significant anticipated consequences at a multidecadal time scale (Steffen, Broadgate, Deutsch, Gaffney, & Ludwig, 2015). To prepare for this, we need to carefully explore what these changes might be and our capacity to mitigate or adapt to such changes. There is thus a pressing need to increase our efforts to explore the possible futures of SES (Österblom et al., 2013). This must be achieved in a participatory framework that can cope with the diversity of perspectives that need to be considered simultaneously for systems undergoing change in many dimensions. As highlighted by Rigg and Mason (2018), the dominant reductionist scientific approach, in which natural and human sciences are poorly integrated, is detrimental to participatory building of creative solutions to global problems.

Developing scenarios for the future has been an integral part of the framework of "future studies" or "futurology" for more than 50 years (Bradfield, Wright, Burt, Cairns, & Van Der Heijden, 2005). The golden age of futurology, in the 1970s, was marked by the report from the Club of Rome (Meadows, Meadows, Randers, & Behrens, 1972) and far-reaching books (Fowles, 1978; Schwartz, 1996). A multiplicity of scenario methods emerged, for example Delphi (Linstone & Turoff, 1975), and their typology is summarized in several works (Bishop, Hines, & Collins, 2007; Börjeson, Höjer, Dreborg, Ekvall, & Finnveden, 2006; Van Notten, Rotmans, Van Asselt, & Rothman, 2003; Wilkinson & Eidinow, 2008). Contemporary future studies incorporate new modelling (Batty & Torrens, 2005) and communication tools (Vervoort, Kok, van Lammeren, & Veldkamp, 2010), they make use of social networks (Cachia, Compañó, & Da Costa, 2007) and of dedicated serious games (Dannenberg & Fisher, 2017). In recent years, "participatory scenario planning" or PSP has been emphasized as a promising way forward for future studies (Chakraborty, 2011). The idea of "scenario planning" (Amer, Daim, & Jetter, 2013; Schoemaker, 1995; Schwartz, 1996), rather than simply working on "scenarios," explicitly states the existence of a management objective, local or regional, while the term "participatory" entails the involvement of different actors (Gray, 2005).

Outside the framework of future studies, scenarios for future world climate developed by the Intergovernmental Panel on Climate Change (IPCC) (Moss et al., 2010; Rogelj, Meinshausen, & Knutti, 2012) have set a milestone. The IPCC identified four Representative Concentration Pathways (RCPs: +2.6, +4.5, +6.0, and +8.5 W/m^2, respectively) and five global Shared Socioeconomic Pathways (SSPs: sustainability, middle of the road, regional rivalry, inequality, fossil-fuelled development) which are used to build scenarios of future earth systems. The work of the IPPC has stimulated the intensive development of numerical models to simulate future trajectories of the global earth system in general and of marine systems in particular (Cheung et al., 2009; Gattuso et al., 2015). In this context, scientists, and numerical modellers in particular, have played an important role in building conceptual representations of marine SESs (MSES), simulating their dynamics several decades into the future and alerting other actors about possible undesirable outcomes or dangers (Heymans, Skogen, Schrum, & Solidoro, 2018). This particular approach to explore the future is, however, only one among many. At a regional scale, there is a need for tools that support actors of regional fisheries management in co-developing their own visions of the future in a participatory way. These tools can incorporate, but do not need to be limited to, IPCC pathways (RCP and SSP); they can rely upon scenarios and participatory scenarios methods (Röckmann et al., 2012).

This situation is gradually changing. There have been recent attempts to go beyond the type of scenario approaches used by the IPCC and to develop more comprehensive scenarios by, for

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example, explicitly accounting for cross-sectorial interactions when investigating climate change impacts (Harrison, Dunford, Holman, & Rounsevell, 2016). More generally, there has been a number of developments in scenario methods used for environmental science, such as highlighted by Rounsevell and Metzger (2010), Van Vuuren, Kok, Girod, Lucas, and de Vries (2012), the special issue of *Futures*, "The Politics of Anticipation: On knowing and governing environmental futures" (September 2017) and the special issue of *Ecology and Society*, "Scenarios of global ecosystem services" (2016).

It is noteworthy that MSES are not considered in the Global Biodiversity scenarios for 2100 (Sala et al., 2000), nor are they explicitly identified in the first round of International Platform on Biodiversity and Ecosystem Services (IPBES) regional assessments, although scenario-based methodologies are included in the chapter on scenarios and models (Acosta et al., 2016). When developing scenarios for marine systems, most attempts are focused on a single perspective or single process, such as the effects of climate change (expressed according to the IPCC framework) on commercial species (Cheung, Dunne, Sarmiento, & Pauly, 2011), or of an increase in the demand for fish (Béné et al., 2015). A notable exception is the recent attempt by Maury et al. (2017) to use a conventional scenario method to explore future tuna fisheries along several perspectives that include economy, fisheries management and global governance.

Participatory fisheries management was developed in the late 1980s and the initial project (Jentoft, 1989; Stephenson & Lane, 1995) was followed by experiments (Mackinson, Wilson, Galiay, & Deas, 2011), the results of which were evaluated (Jentoft, 2000). Today, participatory management is a necessity of fisheries policies (Gray & Hatchard, 2003; Symes, 2007), but many studies point to the difficulty of effectively engaging actors in participatory marine resource management operations (Gopnik et al., 2012; Gray & Hatchard, 2003, 2008; Kraan, Hendriksen, Van Hoof, Van Leeuwen, & Jouanneau, 2014; Pita, Pierce, & Theodossiou, 2010). This difficulty can result from lack of belief in the need for planning, divergent objectives, difficult dialogue (Bailey, Liu, & Davidsen, 2016), mutual misunderstanding (Johannes, Freeman, & Hamilton, 2000), or mistrust between natural scientists and other actors (De Vos & Van Tatenhove, 2011; Eggert, Kataria, & Lampi, 2016; Glenn et al., 2012).

Building participatory scenario methods for MSES requires prior recognition that different actors have different perceptions and approaches towards the future. These reflect different opinions of what constitute relevant future time horizons and spatial scales of concern, as well as different levels of engagement, responsibility and experience with scenario development; all of which must be jointly considered in marine management. Therefore, the challenge for participatory scenario planning is to establish a constructive dialogue while acknowledging and accounting for the distinctive positions of all actors involved. This challenge in participatory management was already identified 50 years ago by Arnstein (1969) who suggested and analysed a variety of citizen participation approaches ranging from citizen control (best) to manipulation (worst).

In this paper, we describe how scenario building can constitute a participatory tool with which different actors, with diverse background and positions, can jointly envisage their actions in the face of possible future changes. The challenge is to create favourable conditions for continuous deliberation, which entails that distinct conceptions of the future from different actors must be recognized and integrated. Building on existing scenario approaches, and taking into account the above remarks, we describe a scenario method for MSES that is a first step to addressing this challenge. We illustrate the method with an application to the Barents Sea MSES.

2 | PERSPECTIVES ABOUT MARINE SOCIAL-ECOLOGICAL SYSTEMS

The notion of perspective is a central concept to the method proposed here. A perspective synthesizes the views and understanding that particular actors have of a MSES. Perspectives are sometimes termed axes, themes, domains or dimensions. In this section, we provide a list of perspectives on MSES, summarize their principal characteristics and briefly analyse their inter-relationships. Four perspectives are considered: Fisheries management, Ecosystem, Ocean climate, and Global context and governance.

2.1 | Fisheries management

Fishing is a human activity driven by needs and opportunities (food supply, economic revenue, recreation, cultural identity). It is constrained by nature (accessible fish resources), technology (vessels and fishing methods), markets and institutional frameworks. Fisheries management is concerned with the regulation of fishing activities, from local to global scales, in order to ensure economically, environmentally and socially viable fisheries (Botsford, Castilla, & Peterson, 1997). The key actors include fishers, fishing industries, administrators in national and international organizations, scientists in public or private research organizations, enforcement bodies (e.g. coast guards) and other groups representing specific interests (for example non-governmental organizations, NGOs). Fisheries management principles are based on institutions, practices, experiences and cooperative arrangements (legally binding or not) ruling the interactions between different actors and organizations, as well as historical developments in fisheries, research and management organizations. These have resulted in a fisheries management culture with its own set of paradigms and an endemic vocabulary. This perspective is shared by fisheries managers, fisheries scientists and fishers.

2.2 | Ecosystem

The Ecosystem perspective focuses on the key components of marine ecosystems and on their interactions: primary production, and trophic and other ecological interactions. Key components are typically primary producers such as phytoplankton and other algae,

secondary producers such as zooplankton and benthic invertebrates, and higher predators such as fish, seabirds and marine mammals. A key process is how energy and biomass flow from low to high trophic levels through structured food webs. Trophic processes are dependent on the seasonality of production, and on its articulation with life history events (feeding, somatic growth, reproduction). This is particularly important in high latitudes where seasonal variations in light are extreme, and where phenological changes explain the match or mismatch between prey production and predator feeding needs and the possible success or failure of recruitment in commercially exploited species. Ecological processes can be affected by human perturbations, whether these are chronic or exceptional, physical, biological or chemical. Such perturbations typically include fishing, pollution (e.g. oil, plastic, noise, eutrophication) or habitat degradation. Climate driven changes can lead to variations in the productivity and biogeography of populations and communities. Natural or human induced invasions of alien species, diseases or parasites can also greatly impact community structure and ecosystem dynamics. This perspective is mainly shared by scientists (ecologists, fisheries scientists) and environmental NGOs.

2.3 | Ocean climate

The ocean climate perspective covers the main physical features of the atmosphere-ocean system (Griffies, 2004). The focus is on ocean climate and the coupling of the ocean to the atmosphere through the exchange of heat, water, and momentum. The ocean stores vast amounts of energy in the form of heat. It receives energy from solar radiation and the gravitational pull from the sun and moon. The amount of sunlight absorbed at the surface varies strongly with latitude, which causes currents that influence climate by transporting heat from the equator towards the poles. Ocean surface currents are largely wind-driven and can vary from year-to-year as a response to large scale atmospheric oscillations. Contrarily, deep ocean flows are driven by water density differences. In addition, the rotation of the Earth, the geographical arrangement of continents, and the oceans' internal dynamics also have a strong influence on ocean currents. Density-driven currents significantly contribute to heat redistribution across the globe and, although these vary slowly, they can have a major impact on the Earth climate. Climate variations on decadal time scales are often related to the coupling between the ocean and atmosphere through persistent changes in heat transfer, deep water formation and deep ocean circulation. The ocean climate perspective is mainly shared by scientists (climatologists, oceanographers) and environmental NGOs.

2.4 | Global context and governance

The perspective on global context and governance focuses on how regional fisheries management is integrated in the global framework for the governance of the oceans and on how it is influenced by global economic, legal and political forces (Allison, 2001). This perspective considers global political and economic developments such as the trends in global fish markets in the context of economic globalization, and it includes other aspects of MSES than fisheries such as shipping, oil and mineral extraction, and cultural and recreational values. Through the establishment and recognition of Exclusive Economic Zones (EEZs), the United Nation Convention on the Law of the Sea (UNCLOS) and its implementation agreement for fisheries (the 1995 UN Fish Stocks Agreement) had major influence on the regulation of world global, regional and national fisheries. Organisations that primarily focus on international commercial trade rules (e.g. the World Trade Organization) and international agreements that primarily work towards nature conservation or poverty alleviation (e.g. UN Sustainable Development Goals) are relevant to this perspective. An important dimension is also the influence of global and regional political situations on regional and national fisheries management. How will future fisheries management be structured in a world where political uncertainties are increasing? Such tensions generate uncertainties that are important to consider for understanding the dynamics of a given MSES and envisaging its possible futures. Environmental NGOs and the recent emergence of large social networks that are concerned about ocean protection or eco-labelling schemes which guide consumers are increasingly influencing markets for specific fish and shellfish resources, both regionally and globally. In summary, this perspective is concerned with the dynamics of political, economic, institutional, and social features on a wide or global scale, which impact fisheries management regionally and nationally. This perspective is shared by diplomats, lawyers, fisheries managers and environmental NGOs.

A summary of the key actors, objects, key concepts, time scales, practices and vocabularies for each of the above four perspectives is provided in Table 1.

2.5 | Interactions between perspectives

A single perspective often contains the drivers or the consequences of changes in other perspectives. Therefore, it is useful to describe how different perspectives are connected. Two perspectives can interact in a uni-directional fashion, for example ocean climate acts as an external driver for ecosystems, or in a bi-directional fashion, for example the dynamics of fisheries management and ecosystems are interrelated. Describing interactions between pairs of perspectives constitutes an important step in developing a fruitful dialogue within an interdisciplinary group. It results in specific questioning about the future of the system, for example: how fisheries management may respond to changes in ecosystem health; how climate driven policies (e.g. reduction of carbon emission) may trickle down to fisheries management; by which mechanisms changes in global governance may influence ecosystem health; how global governance may impact global and local climate trends and how global climate trends may significantly impact global governance in return; and so on.

Explicit enunciation of dual interactions leads to a representation of the ensemble of interactions between perspectives as illustrated in Figure 1. Ocean climate and Global context and governance appear as "outer" driving forces, which primarily affect other perspectives

TABLE 1 The four selected perspectives (rows) and their characteristics (columns)

	Actors	Involvement	Objects	Key concepts	Practices	Time scale	Spatial scale	Vocabulary
Fisheries management	Fisheries managers, fishing industry, fishermen, scientists, governments, RFMO	Explicit responsibilities towards governments	Fish stocks, fishing firms and fishermen	Recruitment, fishing effort, yield, economic returns, employment	Assessment, regulation	Short time perspective (the next few years)	National or regional systems	Discards, compliance, TACs, MSY, stock assessment, ecosystem approach manage, maximum sustainability, reference points
Ecosystem	Scientists, environmental NGOs	Scientific ethos, responsibility towards ocean environment, need to alert	Fish populations, other marine species and their habitats	Population dynamics, community ecology, foodwebs, habitats, biodiversity, ecosystem services	Surveys at-sea, remote observations, numerical models	A range of time scales to integrate (from season to decades)	A range of space scales to integrate	Biodiversity, animal populations, primary and secondary production, food web, phenology, invasive species, habitats, pollution, diseases, species interactions, perturbations
Ocean climate	Scientists, multilateral organizations, environmental NGOs	Scientific ethos, responsibility towards planet environment, need to alert	Global and local climate	Coupled physics of oceans and atmosphere	Observation networks, projection models, global/local integration	A rather deterministic view of the next century	World, oceans, seas	Currents, thermohaline circulation, atmosphere-ocean coupling, water masses, heat content, temperature, salinity, density
Global context and governance	Diplomats, lawyers, experts	Explicit responsibilities towards governments	Treaties, world institutions	Negotiation, international law	International negotiation	Half century. Inertia of the UN and other international governance bodies	World, countries	United Nations, UNCLOS, international law, global fish trade, food security, multilateral agreements, technological development, civil society, offshore oil industry, maritime roads

Note. MSY: Maximum Sustainable Yield; NGO: Non-Governmental Organisation; RFMO: Regional Fisheries Management Organization; TAC: Total Allowable Catch; UNCLOS: United Nations Convention on the Law of the Sea.

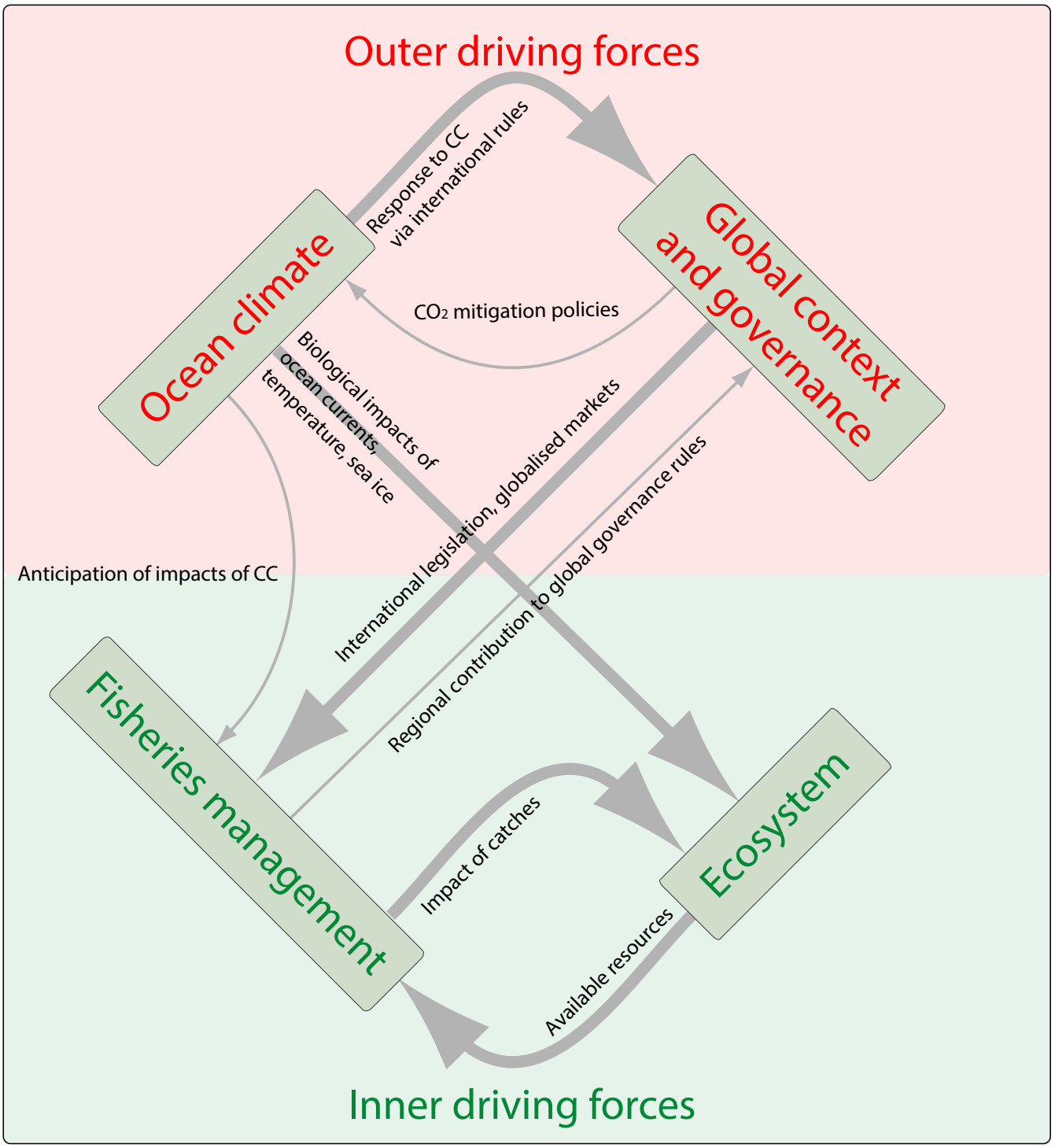

FIGURE 1 Key perspectives (boxes) and causalities (arrows) in a Marine Social-Ecological System [Colour figure can be viewed at wileyonlinelibrary.com]

but are little influenced in return. In contrast, Fisheries Management and Ecosystems constitute "inner" driving forces which interact with each other and are influenced by the outer drivers. While exploring dual interactions between perspectives enunciates interesting questions, it is not sufficient to develop full narratives for MSES scenarios. Developing full narratives requires the joint consideration of the four perspectives. The proposed approach for full narrative development is presented below.

3 | A METHOD FOR PARTICIPATORY SCENARIO DEVELOPMENT

The seminal work of Schwartz (1996) influenced most current scenario development methods or participatory scenario planning. These methods include a succession of steps: in the first steps (integration steps), the actors jointly identify key processes and uncertainties and set common objectives. The following steps (projection

steps) are concerned with the building of narratives or models that follow from the jointly identified processes and uncertainties. Because integration steps can be more easily achieved when actors are members of a community and share common objectives, concepts, vocabularies and practices, participatory scenario planning makes the implicit assumption that various actors share a common perspective before engaging with scenario development.

In the context of MSES, we have seen that actors can have distinct perspectives so that objectives, concepts, vocabularies and methods are usually not shared in advance or during a scenario development exercise. Different actors might have been involved in earlier scenario exercises and may start with different conceptions of what the future might be. Many are often not ready to engage in terminology exercises, which are quite common in academia, but less common in the administrative or business world. As a result, it is difficult to integrate knowledge from several perspectives early in the process of scenario development.

To ease integration between actors who have diverse perspectives, we advocate reversing the process and postponing integration to the end. The method we suggest involves three major steps: (a) identify current state and recent trends in each perspective, (b) project contrasted futures according to each perspective (single-perspective scenarios), and then (c) build a set of comprehensive future scenarios by integrating projections (multiple-perspective scenarios). Proceeding in this order avoids complex semantic debates at the start of the process and maintains a broad multi-perspective outlook throughout the development of scenarios. By carrying through individual perspectives until near the end, it allows actors and experts with diverse cultures, interests and horizons to confront their own conceptions of the future.

The approach is explorative. Its goal is the production of a broad range of contrasted futures. The result is a set of truly multi-perspective scenarios, which are developed in a participatory manner while preserving knowledge and practices specific to individual disciplines. This framework allows actors to collectively explore plausible futures beyond the most likely extrapolations of current trends.

3.1 | Step 1: identify current state and recent trends

During the first step, participants describe the current state and trends in the MSES for each individual perspective considered separately (i.e. ecosystem, fisheries management, ocean and climate, or global governance). These descriptions express the current understanding of the MSES functioning and its recent history. A concrete example of these descriptions is provided in the Barents Sea case study presented below. The time scale considered for historical trends has to be compatible with the time horizon of the future scenarios, several decades in the present case.

3.2 | Step 2: single-perspective scenarios

During the second step, participants produce multiple narratives about the possible futures of the MSES, separately for each individual perspective.

- The narratives are termed “single perspective scenarios.”
- They are elaborated following a few contrasted storylines, typically “baseline,” “positive,” and “negative.” This allows for the exploration of a wide range of futures while limiting the number of single-perspective scenarios developed.
    - o Baseline scenarios consist primarily of the extrapolation of recent trends into the future.
    - o In positive/negative scenarios, recent trends are bent towards evolutions considered to be more positive/negative for most processes relevant to the perspective.

3.3 | Step 3: multiple-perspective scenarios

The third step is dedicated to integration, when actors are ready to explore complex and multi-faceted futures and bring together their views about the current status, trends and futures of the system.

- Participants analyse the interactions between perspectives (as in Figure 1) together and then explore how to combine single-perspective scenarios into multiple-perspective ones.
- In the present case, there are three explorative scenarios for each of the 4 perspectives, which results in possibly $3^4 = 81$ multi-perspective scenarios. Exploring all scenarios is an overwhelming task for an expert group working with limited time and resources. Therefore, from this ensemble of scenarios, participants select and develop a small set of possible narratives based on their perceived plausibility or on the group's specific interests. The selection of the scenarios that will be elaborated is context dependent and left to the deliberation of the actors.
- The resulting scenarios explicitly combine all perspectives in order to envisage how individual elements of the systems (parts of the ecosystem, individual fishers, management institution) could be affected. Cartoons or animations can be used to illustrate some salient points of these multiple-perspective scenarios or storylines.

4 | AN ILLUSTRATIVE CASE STUDY: THE BARENTS SEA

The Barents Sea (Figure 2) was used as a case study to illustrate the multiple-perspective scenario method. The Barents Sea is a shelf sea located north of Norway and Russia, covering 1.4 million km^2. It is the largest and deepest of the continental shelf seas surrounding the Arctic Ocean, situated at the interface between Atlantic and Arctic waters, and supports large commercial fisheries (Jakobsen & Ozhigin, 2011). The development of the scenario method and its application to the Barents Sea MSES were conducted during a workshop hosted in Sommarøy, Tromsø, Norway in June 2016. The participants in this workshop were diverse: representatives of the fishing industry, of fisheries policy, NGOs, and research in several disciplines.

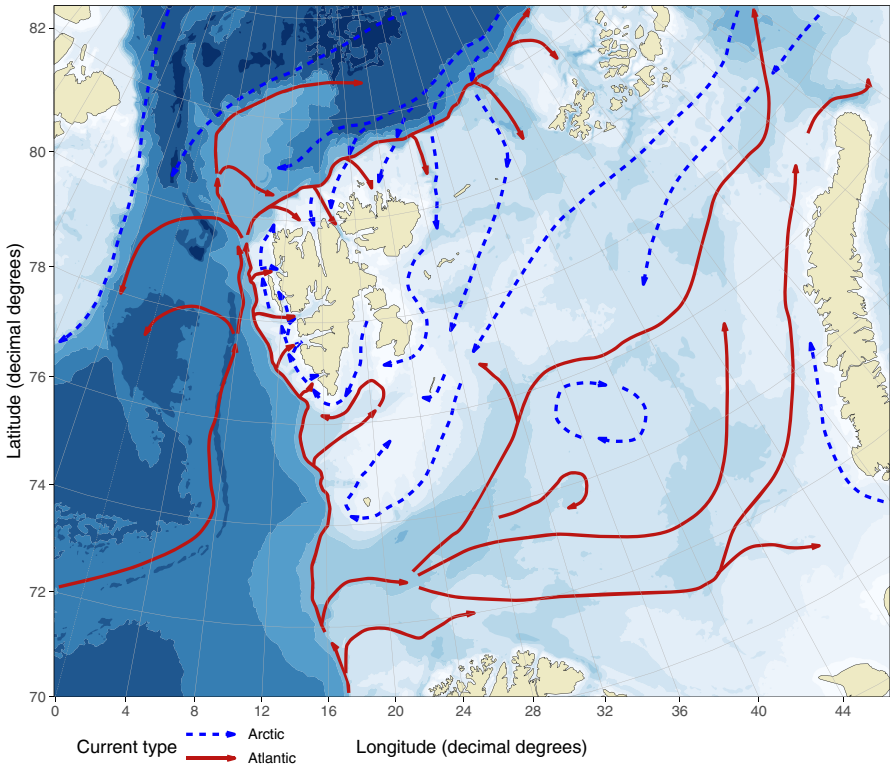

FIGURE 2 The Barents Sea shelf and surrounding waters with indication of bathymetry (the darker the deeper) and main surface ocean currents (arrows). Redrawn from Vihtakari, Sundfjord, and Steur (2019) [Colour figure can be viewed at wileyonlinelibrary.com]

4.1 | State, trends and single-perspective scenarios

Workshop participants first synthesized current state and trends of the Barents Sea according to the four identified perspectives (Table 2, Supporting Information Appendix S1).

They then elaborated 12 single-perspective scenarios: one for each perspective (fisheries management, ecosystem, climate and global governance) and for each trend (baseline, positive, negative; Table 3, Supporting Information Appendix S1). For each scenario, key processes, time line, wild cards and uncertainties were examined. The year 2050 was chosen as the common time horizon for the scenario development. How much the succession of events in a single-perspective scenario depended on events that pertain to other perspectives was also considered. This led to the next and final step of the MSES scenario building process: a transdisciplinary integration of scenarios across perspectives.

4.2 | Multiple-perspective scenarios

From the full combination of single-perspective scenarios (Figure 3), workshop participants jointly selected and developed three contrasting storylines. A: all baselines, B: degraded fisheries management, healthy ecosystem, cold future and declining governance, and C: improved fisheries management, unhealthy ecosystem, baseline ocean climate and baseline governance. The selection of these three storylines followed the explorative approach proposed here, from the expected (scenario A) to the wildcard (scenario B) and other potential trajectories of marine ecosystems (scenario C).

4.2.1 | Scenario A: Baseline in all perspectives

Characteristics of the Barents Sea in 2050 (Figure 4)

In 2050, Barents Sea fisheries are still managed according to strict regulation and enforcement, in an international context of persistent economic globalization. Management decisions are supported by scientific advice from the International Council for the Exploration of the Sea (ICES). The Barents Sea ecosystem is healthy, productive and eco-tourism is developed. Sea water temperature is rising and sea ice cover in the northern Barents Sea is decreasing. There is a strong contrast between the good ecological and fisheries status of the Barents Sea ecosystem and the uncertain state of many MSES in other parts of the world. Norway and Russia are under pressure to give access to foreign fishing fleets. The fisheries in the Barents Sea generate significant profit for fleets operating in the region. A small number of fishing companies concentrate an increasing share of the fishing capacity and catches, while local fishing communities get an increasing part of their income from eco-tourism and recreational fishing.

How has the system evolved to get there?

A sustained economic context of financial globalization combined with continued climate change has resulted in high economic profits from a more productive ecosystem. There is a high level of wealth concentration, that is fewer vessel owners, while local fishing communities are more economically dependent on inter alia eco-tourism and recreational fishing. Despite global warming and a stressed global economic and governance context, ecosystem health and fisheries management in the Barents Sea have

TABLE 2 General features of the Barents Sea, current states and trends in each perspective

Fisheries management	Total annual catch of about 1.4 million tonnes
	Main exploited species include cod, capelin, saithe, haddock, redfish, Greenland halibut, shrimps, red king and snow crabs
	A bilateral cooperation between Norway and Russia with a scientific foundation (cooperation between research institutes, IMR in Norway and PINRO in Russia)
	An ecosystem approach to ocean management and adopted integrated management plans for the Barents, Norwegian and North Seas
	Present fisheries management in the Barents Seas considered to be successful
Ecosystem	Annual net primary production estimated at about 59 million tonnes of carbon
	Strongly seasonal (light and ice conditions)
	Primary production: phytoplankton in ice-free areas, algae in ice-covered regions. Importance of influx of nutrients from the Norwegian Sea
	Secondary production highly variable (geographically, seasonal, interannual)
	Fish production highly variable (geographically, seasonal, interannual)
	'Borealization" (geographical extension of boreal species) as an effect of warming
	Presently high level of fish stocks
Ocean climate	A transition zone between the warm and saline water flowing from the Atlantic Ocean via the Norwegian Sea into the central Arctic Ocean, and the cold and less saline water flowing from the Arctic Ocean to the Atlantic Ocean
	Extreme environmental conditions with strong geographical gradients. A large year-to-year variability in the Barents Sea climate
	A prominent trend: increasing sea temperatures and decreasing ice coverage
Global context and governance	Extension of the global market for fish
	Increase in fish consumption
	Development of aquaculture
	In developed countries, the decreasing number of fishermen and development of more efficient capture techniques
	UNCLOS as a global institutional context
	Global trends in the global context: (a) increasing ecosystems considerations in fisheries management implementation, (b) growing concerns for global food security and biodiversity, (c) consideration of mining, oil extraction and shipping, (d) raising public awareness on Arctic issues and concerns about possible threats, and (e) geopolitical developments in the high North (e.g. Arctic Council)

Note. IMR: Institute of Marine Research (Norway); PINRO: Knipovich Polar Research Institute of Marine Fisheries and Oceanography (Russia); UNCLOS: United Nations Convention on the Law of the Sea.

improved. This situation was made possible by the inertia in many processes relevant to all perspectives. Fisheries policy successfully resisted economic pressures, maintaining strong regulation even under positive ecosystem state. It also resisted financial pressures to downscale the costly monitoring of a healthy ecosystem. The biomasses of most exploited stocks stabilized, with low natural variability. Limited jellyfish invasions and invasive species, such as snow (*Chionoecetes opilio*, Oregoniidae) and red king (*Paralithodes camtschaticus*, Lithodidae) crabs, still provide economic profits without noticeable damage to the ecosystem. World climate has developed following the IPCC RCP2.6 scenario, with limitation of emissions and a 2°C increase in global temperature resulting in sustained biological productivity in the Barents Sea. Inertia is a well-known characteristic of global governance. Countries have agreed that an international agreement on biodiversity and marine genetic resources beyond national jurisdiction is required to adapt to new modes of ocean exploitation, and a new implementing agreement to UNCLOS entered into force in the 2030s.

4.2.2 | Scenario B: Cold future, decline of governance, degraded fisheries management, healthy ecosystem

Characteristics of the Barents Sea in 2050 (Figure 5)

By 2050, the Barents Sea MSES is characterized by a colder ocean climate than in the early 2000s. Biological productivity has declined but the Barents Sea ecosystem is healthy and provides valuable fisheries resources. At the same time, fisheries are not well managed, with low efficiency and lack of trust in management decisions. The increasing global need for food resources is paralleled by an increase in economic protectionism, preferential trade agreements and a decrease in the efficiency of multilateral treaties. The Barents Sea MSES is described as a high benefit-high risk system.

TABLE 3 Single-perspective scenarios for the Barents Sea

Fisheries management	*Improved: participatory and ecologically responsible management*	*Baseline: things are still going well*	*Degraded: poor management practices and short-sighted views*
	Ecosystem-level regulations (multi-species TACs)	No major changes in fisheries management	Fisheries management focussed on selected single species approaches
	Increased participation of actors other than fisheries	No major changes in the economic situation of the fisheries	Too high TACs above recommended safe levels
	Technological advances incorporated in regulations	Maintenance of the market value of commercial fish and shelfish stocks	Artificial maintainance of market prices
	Increasing prices for seafood (relatively to the general level of income and costs)	Concentration of fishing capacity	Technological advances overlooked in regulations
	High trust between scientists, managers, fishermen and civil society	Priority to cod management	Low trust between scientists, managers, fishermen and civil society
	High compliance with regulations	HCR-based management	Low compliance with regulations
		Harvesting close to or below MSY	Degradation of international agreements for fisheries management
		No major changes in fishing costs	
Ecosystem	*Optimistic: increase of biological production, ecosystem health and harvesting potential*	*Baseline: increase then stabilization of biological production*	*Pessimistic: collapse of fish stocks, degradation of ecosystem health*
	Increase in biological production	Increase first then stabilization in biological production	Stocks of demersal fish species below safe levels
	Increase in production of demersal and pelagic fish species and in their geographical expansion	A similar pattern in the production of commercial demersal fish	Large fluctuations of pelagic species on decadal time scales
	New species with high commercial potential	Fluctuations of pelagic species on decadal time scales	Decline of populations of top predators
	Abundant top predator populations	Geographical expansion of Atlantic/boreal species	Important changes in ecosystem functioning due to a combination of factors, including climate, fishing, pollution (noise, persistent organic pollutants, heavy metals, plastics, oil) and invasive species
		New species and opportunities for new fisheries	
Ocean climate	*Hot future: faster warming and ice melting*	*Baseline: Continued warming*	*Cold future: import of fresh water and AMOC shutdown*
	Increase in warming and acidification (RCP8.2 scenario). Increase in sea ice extent	Ocean warming (RCP2.6 or RCP4.5 scenarios)	First, accelerated ice melting and increase in sea level from 2 to 17 m
	More frequent extreme weather events	A continuous retreat of the ice towards the northeast. The polar front is pushed further northeast	Then, a lid of fresh and cold water on the polar ocean. Limited heat loss to the atmosphere and space, and thereby a warming of the ocean at the depth of ice shelves. Increased stratification. A shutdown of the AMOC, and thereby a reduced poleward heat transport
	Less impact of natural climate oscillations	Importance of natural climate oscillations	Colder waters and increase of sea ice extent
	Decrease of the temperature gradient between lower and higher latitudes near the surface. Increase of this gradient at higher levels in the atmosphere	Longer biological production season	
		Weakening of the AMOC (starting around 2050)	

(Continues)

TABLE 3 (Continued)

Global context and governance	*Optimistic: strengthening of multilateral governance*	*Baseline: ongoing trends of multilateral governance and globalization continue*	*Pessimistic: decline of multilateral governance and increase in protectionism*
	A return to the original principles of multilateralism	Importance of UN organization related to the marine environment	Decline of concerns towards poverty alleviation, human development and global ocean governance
	A strengthening of the UNCLOS-based legal framework and implementation of the SDGs	Ongoing international efforts to address the SDGs	Halting the development of the global framework based on UNCLOS
	An explicit consideration of food security, ecosystem conservation, equity and economics through a new implementing agreement of UNCLOS	Targets of SDG-14 (Oceans) met to different degrees	Importance of protectionism in trade relations. Bilateral treaties, based on political and economic considerations. Generalization of arbitration as a tool for solving international conflicts, even between states and private investors
	An improved and expanded dialogue between Norway and Russia	Overfishing still considered as a problem globally	Degradation of northeast Atlantic fisheries agreements, including the Russian-Norwegian dialogue
		International conservation NGOs as important actors	
		Implementation of the UNCLOS and the UN Fish Stocks Agreement by a growing number of states	
		Importance of free trade principles in trade relations	

Note. AMOC: Atlantic Meridional Overturning Circulation; HCR: Harvest Control Rule; ICES: International Council for the Exploitation of the Sea; MSY: Maximum Sustainable Yield; NGO: Non-Governmental Organisation; RFMO: Regional Fisheries Management Organization; RCP: Representative Concentration Pathway (of greenhouse gases); SDGs: Sustainable Development Goals (of the United Nations); TAC: Total Allowable Catch; UNCLOS: United Nations Convention on the Law of the Sea.

How has the system evolved to get there?

International failure to meet the CO_2 emission targets has led to increased melting of the Greenland ice cap. Ice cap hydro-fracturing, which had been overlooked in early ocean climate studies, accelerated at an unprecedented rate which led to a lid of fresh and cold water on the polar ocean. The increased stratification resulted in a slowdown of the Atlantic Meridional Overturning Circulation (AMOC), which in turn led to lower surface atmospheric temperature and ultimately a colder and icier Barents Sea. Because most scientific studies had predicted ocean warming, a major consequence of this unexpected situation was a growing distrust in scientific expertise to guide regional and global environmental policies. The return of colder and icier conditions favoured growing populations of species that were earlier considered to be endangered or in strong decline such as charismatic ice-dependent megafauna (polar bears and seals) and ice associated and lipid-rich zooplankton. Biological diversity in the Barents Sea increased with the presence of boreal, arctic and ice-fringe species at all trophic levels. While the production of fisheries resources did not significantly change, the economic value of these resources increased. This situation resulted from increased technological performance of fishing practices, a higher demand for seafood products, degraded fisheries in many other areas of the world ocean, and increased demand in markets overseas. Simultaneously, fishing rights, capacity and economic benefits concentrated into few large firms. The socio-economic system in Norway, with a relatively even distribution of wealth, started to crack and the general trust between people and public organizations slowly eroded to the extent that finding common and future-oriented solutions became difficult. Good ecosystem health combined with the increasing demand for seafood, high economic rent, increasing negotiating power of fishing firms, degradation of the political climate and declining faith in scientific predictions led to a reduction in governments' power to regulate fisheries. Communication and trust between scientists, fishing firms and managers slowly declined. A situation of laissez-faire management emerged, in which ecological and societal concerns received little attention. Ultimately, the resilience of the Barents Sea MSES has become impaired and, although high economic benefits are achieved, the risk is high that minor changes in the climate, ecological, economic or political context will have strong consequences on natural and human systems.

4.2.3 | Scenario C: baseline ocean climate, baseline governance, improved fisheries management, poor ecosystem health

Characteristics of the Barents Sea in 2050 (Figure 6)

By 2050, the Barents Sea MSES is characterized by a warmer ocean climate than in the early 2000s and a degraded ecosystem state. Regional fisheries management has developed to become more transparent, participatory and responsive. The world demand for

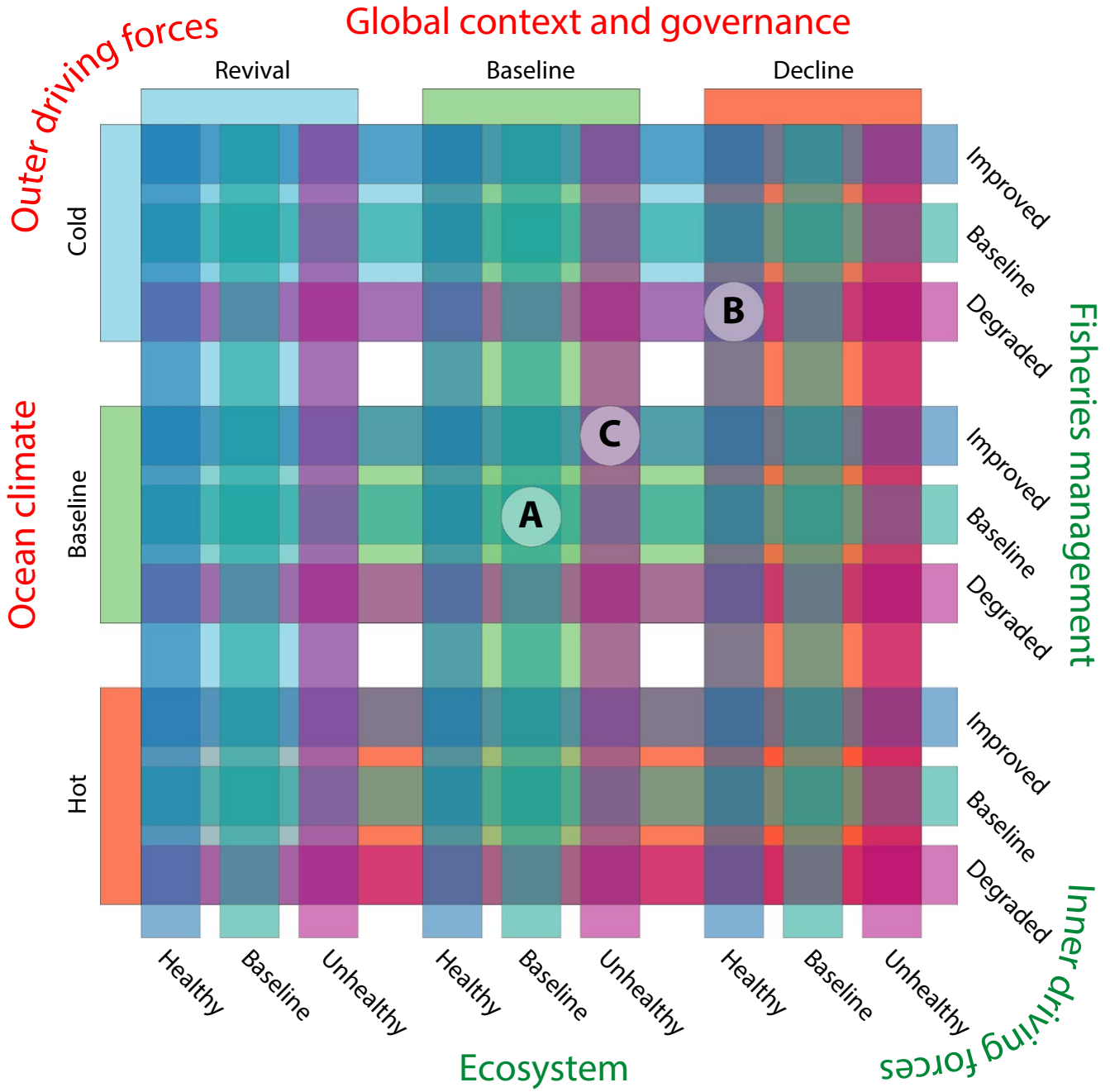

FIGURE 3 Map showing the combination of single-perspective scenarios into 81 multi-perspective scenarios. Each square is a scenario at the intersection of four perspectives. Scenarios marked with the letters A, B and C are those that have been selected to be developed into short stories. The all-baseline scenario is located in the centre of the map (A) [Colour figure can be viewed at wileyonlinelibrary.com]

seafood has significantly increased while shipping, tourism and oil exploitation have continued to develop regionally. The global context for marine governance and trade of seafood worldwide is not significantly different from the beginning of the century. The Barents Sea MSES is described as a well-managed, poor health system.

How has the system evolved to get there?

As anticipated by the climate science community (IPCC), the continuous rise in CO_2 emissions and a number of feedback mechanisms, including polar amplification (Screen & Simmonds, 2010), has led to significant increase in sea temperatures and loss of sea ice in the Barents Sea. As expected, the ecosystem response has been a continued borealization with an increase in Atlantic species and decline in Arctic species (Fossheim et al., 2015). Populations of charismatic Arctic megafauna, such as polar bears, have drastically declined and severe changes in zooplankton composition have altered the Barents Sea food web structure and dynamics. Development of shipping, Arctic tourism and oil exploitation has led to an increase in noise pollution. Monitoring programmes of water and sediment have revealed increasing trends in persistent

FIGURE 4 Scenario A: (a) A small number of fishing companies own more and more powerful fishing vessels while local fishing communities get a significant part of their income from tourism and recreational fishing; (b) Sea water temperature is rising and ice cover is decreasing, the biomass of most exploited stocks stabilized, with a low natural variability; (c) An international context of persistent economic globalization. (illustration: Juliette Planque) [Colour figure can be viewed at wileyonlinelibrary.com]

organic pollutants, heavy metals, microplastics and oil residues. The stocks of the main fish populations have substantially declined and fisheries have had to deal with highly fluctuating and economically less valuable species (e.g. capelin, *Mallotus villosus*, Osmeridae). Global increase in demand for seafood, oil and transport has maintained the good economic status of the Barents Sea MSES. Simultaneously, the general public has acquired a better understanding of the importance of living marine resources, including their long term and sustainable management; fishers and the industry have adopted a decadal perspective on every aspect of management of marine living resources, including the resolution of conflicts with other industries (oil, tourism, fisheries, shipping). Comprehensive management plans have been developed for several types of marine resources other than fish stocks. This has stimulated new approaches to regional management. The Norwegian regional management plans initiated in the early 2000s have been further developed to include fisheries, and the new Marine Resource Act has propelled fisheries management into a new organization in which codified arrangements give a much larger role to public participation, transparency, accountability and the resilience of the Barents Sea MSES.

4.3 | A short appraisal of the experience

From this experimentation of the scenario development method for the Barents Sea, we take the following points:

- The use of scenarios is currently not well developed in marine research and management. Many participants had not worked with scenario methods in the past, had little background knowledge about these methods and usually had more experience with, and preference for, model-based projections than explorative scenarios. As a result, a significant effort was required to inform and educate participants in scenario approaches, their rationale, usefulness and the variety of methods available. It proved important to emphasize that being prepared for the future does not entail a capacity to predict the future, but rather the ability to set oneself in a situation that is sufficiently plausible, or which might have sufficiently dramatic consequences to be worth including in a forward-looking analysis. This information had to be restated throughout the duration of the workshop. The IPCC approach to scenarios has been widely and efficiently communicated and is therefore a dominant paradigm. However, while the RCPs or SSPs implicitly contain normative values (e.g. RCP8.5 and SSP inequality are bad outcomes), the co-development of multi-perspective scenarios proposed here offers a way to get prepared for possible future situations without this normative load. In addition, this open and regionally focused approach favours participatory scenario planning even in situations where not all actors adhere to the pathways proposed by the IPCC.
- The methodological principle "first: scenarios, second: integration" was easily grasped by the participants.
  The choice to develop single-perspective storylines as a starting point proved to be efficient. The elaboration of single-perspective storylines was relatively easy and already gave rise to discussions and interactions. Because of the interactions between perspectives and the high levels of uncertainty, it is not possible to rank individual perspectives by level of importance for the elaboration of future scenarios. For this reason, all of the individual perspectives should be considered at the same level of importance.
- The preparation work and the discussions that formed the basis of the present study confirmed that engaging multiple-perspective discussions is a time consuming and difficult task which requires preparation, engagement and trust.
- An advantage of setting the time horizon of the scenarios to 2050 is that it offered a way to engage into a less personalized debate in which different actors could envisage their respective positions in the future rather than focus on shorter term conflict resolution.
- Communication between actors is a key issue. Keeping a level of simplicity in the scenarios and writing them in a language easily understood by all actors was important. Illustrating these scenarios with cartoons (Figures 4–6) or animations provides a further

FIGURE 5 Scenario B: (a) While the production of fisheries resources did not significantly change, the economic value of these resources did; (b) The return of colder and icier conditions favoured growing populations of species that were earlier considered to be endangered or in strong decline such as charismatic ice-dependent megafauna; (c) Communication and trust between scientists, fishing firms and managers has slowly declined. A situation of management laissez-faire has emerged, in which ecological and societal concerns receive little attention. (illustration: Juliette Planque) [Colour figure can be viewed at wileyonlinelibrary.com]

step to communicate the narratives to a wider audience, in an even simpler format.

- Identifying uncertainties is important. Many aspects of the Barents Sea SES are relatively well understood and various actors shared common conceptions of the interactions between climate, ecosystem, fisheries and governance. Despite this promising starting point, we found that uncertainties about the possible state of the Barents Sea in 2050—more than 30 years ahead—are immense. This is the case when perspectives are considered individually and even more so when they are considered collectively. The contrasted scenarios exposed the interdependence between ocean climate, ecosystem, fisheries management and global context and governance perspectives, and stressed that the response of one component of the MSES to another is hard to anticipate. For example, improved fisheries management does not automatically result from, or imply, good ecological status (Heymans & Tomczak, 2016) (e.g. scenario C); specific changes in global governance or economic context on fisheries at the regional level can result in a wide range of consequences. Most uncertainties are hard to quantify as they are primarily qualitative (i.e. which process or interaction might or might not occur).
- Due to the high level of uncertainty, it is as important to focus on unlikely events and wildcards as it is to work on more likely baseline scenarios. Having several perspectives may contribute to this need. This last point can be best illustrated with the following anecdote. In June 2016, when the workshop in which this work is based took place, meeting participants based their reflections on the political situation at the time. There was much discussion about the possible exit of United Kingdom (UK) from European Union (EU), which was feared but appeared quite unrealistic, and much less discussion about the upcoming presidential election in the United States of America (USA). No one in the group seriously envisaged Donald Trump's election. A few weeks later, on the 23 June 2016, the referendum results led the UK to exit the EU. Five months later, on the 8 November 2016, Trump was elected 58th president of the United States. Both events, which could be considered as wildcards, have the potential to change the global context within which international political, diplomatic, legal, and commercial interactions operate.
- In addition, the authors felt that it could be useful to institutionalize or repeat these exchanges on a regular basis. In the specific case of the Barents Sea, there are several ongoing efforts and research programmes that include perennial workshops. It was felt that these could be dedicated to future anticipations.

5 | DISCUSSION

Anticipating the future of MSES has become essential in an era of climate change, population growth, and rapid technological advances. Such anticipation should be part of a participatory management process and therefore call for multiple actors to interact and share visions of the future. Attempts to anticipate MSES futures based on simulation models are often perceived as black-box by non-experts and can restrict the involvement of various actors in the anticipation process (Heymans et al., 2018). Other attempts are based on scenario building, following the approach of "Future Studies." Conventional scenario methods address the complexity of MSES processes and dynamics and are useful for anticipation, that is they provide explorative scenarios which produce a broad range of contrasted storylines but they generally assume that different actors share common expectations and understanding of the key processes or the critical uncertainties of the system and thereby underestimate the difficulty of an early integration of the positions of different actors which is common in multi-perspective contexts.

The method suggested here arises from the need to think about the future from different perspectives. In contrast to conventional scenario methods, instead of first integrating knowledge from different perspectives (integration) and then building narratives (projection), it starts from the building of single-perspective narratives, maintains a broad multi-perspective approach throughout the

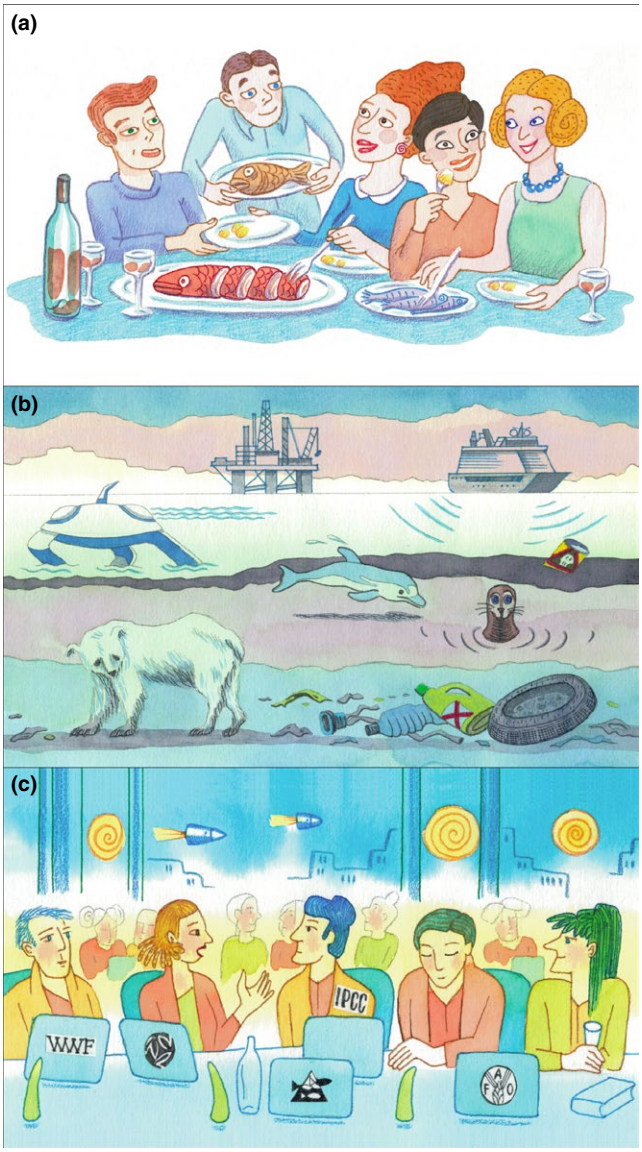

FIGURE 6 Scenario C: (a) The international demand for seafood is growing; (b) Development of shipping, Arctic tourism and oil exploitation has led to an increase in noise pollution. Monitoring programs of water and sediment have revealed increasing trends in persistent organic pollutants, heavy metals, microplastics and oil residues; (c) Stakeholder participation, transparency, and accountability play essential roles in the new marine resource management. (illustration: Juliette Planque) [Colour figure can be viewed at wileyonlinelibrary.com]

development of scenarios and ends with the multi-perspective integration. It takes account of the fact that all actors start from their own experiences and anticipations.

During the scenario exercise on the future of the Barents Sea, the approach taken respected the diversity of participants, and, instead of being directive, participants were left to imagine the possible futures according to their own perspective, before confronting and trying to synthesize what they had produced. Participatory scenario building was preceded by: (a) the definition of four contrasted perspectives about this MSES (ecosystem, fisheries management, ocean climate, global context and governance), (b) the analysis of the dual interactions between these perspectives, and (c) the choice of three single-perspective narrative lines: continuity, improvement or degradation. We found that these steps, performed in advance of the workshop, were useful to initiate constructive discussions between actors, and provided a simple, yet diverse, set of plausible projections that contributed to the group dynamics. This allowed actors to concentrate on combining perspectives into multi-perspective scenarios, which was the most engaging part of the process. It was also important to identify a small, rather than large, number of multi-perspective scenarios. The relevance, usefulness or plausibility of different scenarios was debated, and these discussions contributed to the efficiency of the participatory approach. This allowed participants, when confronted with specific events in a scenario, to envisage their reaction and anticipate the reactions of other participants. On these occasions, it appeared to us that our approach helps to avoid some of the pitfalls of participatory management.

There are limitations to the method proposed here. First, scenario building is not about predicting, but about helping to confront the different points of view of actors concerned about the future of a marine SES. It is not about managing but about helping to manage. There is often confusion between scenario and prediction, between anticipation and management. This problem is not specific to the present method. Despite presenting the objectives of the exercise in an explicit manner, we found that such confusion often took place, indicating that it was not well resolved and still needs to be better addressed. Second, the suggested method intends to be non-prescriptive, but some steps were completed before the workshop could take place, for the sake of efficiency: this was the case for the identification of perspectives, the description of trends and states, and the choice of three contrasted lines for the single-perspective scenarios. This strategy was efficient, but it also meant that these choices could be challenged in later steps of the process. Third, the choice of multi-perspective scenarios to develop is context dependent. It is the most important part of the participatory work, but it can be biased if the participation of actors is unbalanced (some try to dominate while others do not get their point of view through to the group) or if some ways of expressing ideas and concepts are preferred to other (for example quantitative figures over qualitative descriptions). Dealing with such difficulties was beyond the scope of the study presented here.

The utility of a scenario approach is often questioned or compared to end-to-end (or whole of ecosystem) modelling approaches that have become common tools within the marine research community (Fulton, 2010; Heymans et al., 2018). However, rather than being in conflict, storylines and numerical simulations are complementary approaches that can inform each other or ultimately be combined (Alcamo, 2008; Houet et al., 2016). Storylines, such as the ones elaborated in this study, can form the basis for the development of numerical models that can illustrate in greater details and in a quantitative manner the paths that a MSES could take several decades into the future, as well as possible key thresholds leading to bifurcations in the different perspectives. These storylines can also expose where numerical modelling tools require further development, that

is which processes and concepts are not well captured by existing models and how to integrate multi perspectives within a common modelling framework. Projections from models that only consider one or two disciplines and assume that other parts of the MSES remain unchanged (*ceteris paribus*) may cover only a narrow range of the system's plausible futures. In these cases, model projections can be biased or result in a sense of overconfidence and thus do a disservice to actors who are engaged in preparing for the future (Harrison et al., 2016). Exploratory scenarios can provide a broader outlook of a MSES future and serve as a basis for further model developments. These can also help to scope the range of so-called structural or epistemic uncertainty which should be included in applications of management strategy evaluations supporting the regulation of particular activities such as commercial fisheries.

Thinking about the future is both universal (everyone thinks about the future) and personal (everyone thinks about it in their own way). It is difficult to rationalize a common approach to the future, in any domain. We propose a method where each actor, who enters the exercise with some idea about the future, can exit the exercise with a better understanding of the complexity of the situation, the associated uncertainties, and other actors' points of view. This provides tools for actors to revise their vision of the future and to be better prepared for various plausible future situations.

6 | CONCLUSION

We have adapted a scenario method in order to allow researchers, managers and other actors to jointly anticipate MSES futures. A key element of the proposed method is to preserve individual perspectives until the final integration step. A lesson learned from the Barents Sea case study is the realization by participants of the irreducible uncertainties when projecting MSES into the future, as many scenario exercises have already shown. Multiple-perspective discussions can be conducted in efficient ways as revealed by the group dynamics experienced during the workshop. This shows that scenario developments could be pursued in a perennial framework to support MSES participatory management. The approach proposed here to jointly construct multiple-perspective scenarios is sufficiently general to be applied to MSES in many regions of the world's oceans.

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SUPPORTING INFORMATION

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