Scenario Planning: An Introduction for Fishery Managers

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U.S. Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

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1.0 INTRODUCTION

The fisheries of the United States are facing unprecedented challenges due to changing ocean conditions and market forces. For example, a marine heat wave in the Gulf of Alaska from 2014 to 2016 resulted in a significant decline in the stock of Pacific cod, as well as a number of other ecosystem impacts. Even though scientists detected the decline in Pacific cod and were able to adjust catch limits accordingly, the new limits had negative effects on many Alaska fishing communities where cod is a vital resource (Townsend, et al., 2019). The same marine heat wave was also connected to a rise in whale entanglements in crab fishing gear along the U.S. west coast (Santora et al. 2020). Meanwhile, the crab fishery itself is at risk from ocean acidification (Bednaršek, et al., 2020).

Unpredictable events, combined with a changing climate and changes in global markets, form novel contexts in which fishery managers now have to work. Unlike scientific uncertainty, which is estimated and incorporated into management decisions, these large-scale changes often defy prediction. In the meantime, the fishery manager's mandate—to ensure that fisheries are both ecologically sustainable and economically profitable—has not changed. The challenge that fishery managers now face is planning to fulfill this mandate when the future holds multiple areas of uncertainty, and when these areas of uncertainty can affect one another. If future conditions are full of surprises, how can managers plan for effective fisheries management in five years, let alone twenty years?

The purpose of this paper is to introduce a tool known as scenario planning, which can help answer this question. Scenario planning is a method of identifying uncertainties and determining options that will meet management goals across multiple possible sets of future conditions (Peterson, Cumming, & Carpenter, 2003; Rowland, Cross, & Hartmann, 2014; National Park Service, 2013). In this document, we introduce scenario planning, provide examples of past scenario planning projects, and discuss some considerations for managers when developing a scenario planning exercise.

This document is intended as a resource for practitioners who are considering engaging in a scenario planning process by providing examples and analysis of previous scenario planning projects. Sections 2 and 3 introduce concepts and considerations key to scenario planning. Section 4 describes some commonalities of many scenario planning projects and lists common scenario planning steps. Section 5 describes how scenario planning projects were chosen for inclusion in this document. Section 6 encompasses seven summaries of diverse scenario planning projects. Section 7 provides a discussion of the lessons learned from the seven summaries. Appendix 1 lists published guides to scenario planning, and Appendix 2 is a table of published scenario planning projects.

2.0 WHAT IS SCENARIO PLANNING?

Scenario planning is a method of integrating uncertainty into planning for managing resources. Scenario planners look for areas of high uncertainty in a system and imagine 3-4 future situations, termed scenarios, that could occur given the uncertainties identified. Participants in scenario planning projects then look for management options or changes that would be useful across any of these plausible future scenarios. In this way, scenario planning can help managers and stakeholders understand where management strategies may need to change to prepare for the future. The end goals of scenario planning are to provide better policy or decision support and stimulate engagement in the process of change (Bizikova & Hatcher, 2010).

In natural resources management, scenario planning has most commonly been used to plan for adaptation to climate change, but it can be used to address many types of change or uncertainty, including uncertainties in regulations, markets, or the environment. Scenario planning offers the opportunity to integrate multiple forms of knowledge into multi-dimensional futures; quantitative data (for example, population change) can be combined with qualitative data (for example, political environment) to create plausible sets of future conditions under which resources will need to be managed.

Scenario planning was initially developed for military research, and transitioned into the corporate world in the 1970s. Shell Oil was an early adopter of scenario planning (Peterson, Cumming, & Carpenter, 2003), and the company's success with the method sparked interest from other private businesses, as well as the United States government. Scenario planning applications in natural resources management have increased quickly during the 21st century, spearheaded in the United States by the US National Park Service, which has carried out multiple scenario planning exercises for climate change using a standard protocol (Runyon, Carlson, Gross, Lawrence, & Schurmann, 2020). A few other organizations have adopted "standard" methodologies, but most scenario planning projects use methods that are adapted to fit the context of the individual project.

At its best, scenario planning is a collaborative process that includes input from multiple stakeholder groups, including resource managers, scientists, and resource users (Oteros-Rozas, Ravera, & Palomo, 2015). Broad participation expands the sources of information that are included in the project, and also promotes buy-in from groups that may be less active in the management process. Participatory scenario planning projects take months or years to complete, and often involve a trained facilitator. While every project is different, most use some form of the process described in Section 4. The participatory process allows a more comprehensive examination of uncertainties than simulation-driven processes, and provides the opportunity to include non-quantifiable drivers, such as stakeholder attitudes, in the scenarios. Thus, we believe that the scenarios generated by participatory processes can better reflect the true range of plausible future conditions for the study system. The participatory nature of these projects also generates additional benefits, such as increased trust in the planning process and communication among stakeholder groups. These less-tangible benefits can be critical to the success of a planning project.

Scenario planning is not a form of prediction (Weeks, Malone, & Welling, 2011). This makes it particularly useful in fields, including natural resources, where small changes in the system can drastically change future outcomes, and where tipping points and surprises are common (Peterson, Cumming, & Carpenter, 2003). If managers rely solely on scientific models that attempt to predict the most likely future in an uncertain and interconnected system, there is a strong chance that the current models will be incorrect and thus the managers will be unprepared for the actual outcomes. Anomalies like the 2014-2016 marine heat wave are not built into typical models, and thus managers may have little experience considering the impacts of similar surprises. In scenario planning, managers are encouraged to think about the unexpected and adopt strategies that are adaptable to unprecedented events.

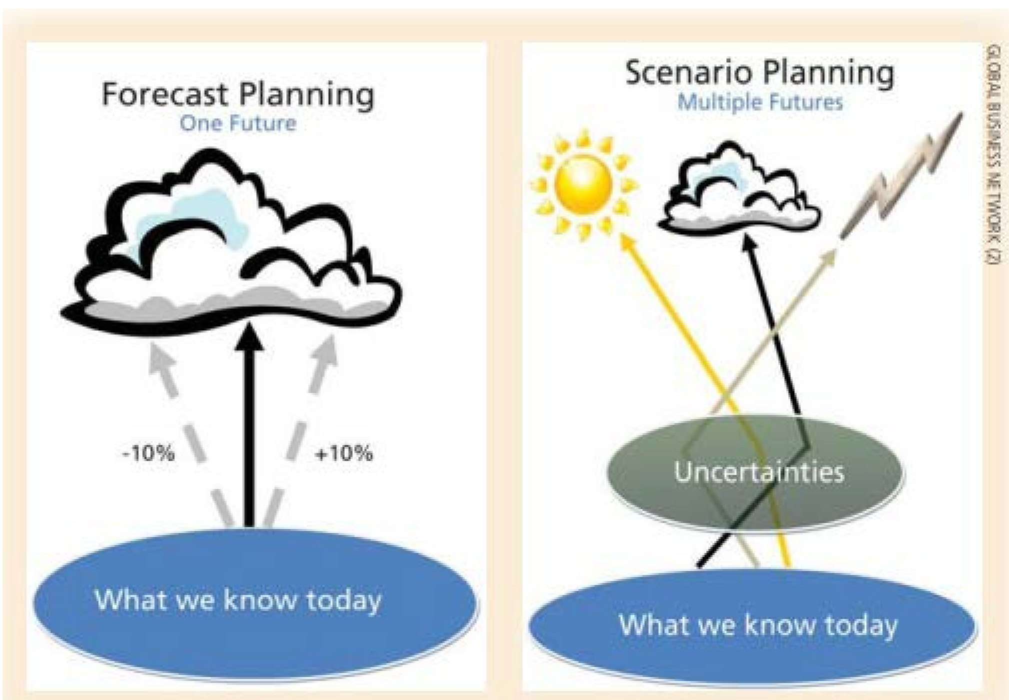

Figure 1: Scenario planning incorporates uncertainty and surprises to develop management strategies across multiple futures (Weeks et al 2011).

A broad range of project methods are termed "scenarios" in the scientific literature, but not all of these methods reflect the outside-the-box thinking and narrative focus that is the hallmark of scenario planning. For example, planning exercises based on the Intergovernmental Panel on Climate Change (IPCC) emissions scenarios are common. However, these emissions scenarios are more a series of related mathematical models than they are a set of multi-dimensional plausible futures. Scenario planning incorporates qualitative and quantitative data to build a set of divergent scenarios that allow managers to plan for surprises.

Management strategy evaluation (MSE), a current priority of NMFS Science Centers, has many attributes in common with scenario planning. Both methods have the goal of identifying management actions that are robust to uncertainty. However, MSE and scenario planning have different emphases which can complement one another. MSE typically uses simulations to compare how alternative management strategies meet pre-identified, quantitative goals such as landings or percentage of stocks not overfished. Scenario planning is generally more descriptive, combining local knowledge of the system with some quantitative data to describe multiple plausible future conditions. While scenario planning might make use of simulations in the vein of MSE, the narrative creativity facilitated by scenario planning provides space for participants to imagine entirely different futures from those that can be simulated.

3.0 WHEN COULD SCENARIO PLANNING BE MOST HELPFUL?

Scenario planning can be used to inform management in a wide variety of situations and systems. Whenever uncertainty is high and many aspects of the system are outside the control of managers, (a common combination in natural resources) scenario planning can be useful. What kind of process to use and which stakeholders to involve are decisions to be made on a case-by-case basis, based on project needs and resources (see Section 4).

Scenario planning has benefits that go beyond informing management. Situations in which different stakeholder groups have different knowledge bases, with little communication among groups, can benefit from the information exchange inherent in this process. Groups of users who have historically been less engaged in fisheries management can participate in the scenario planning process, empowering them to help clarify the value of the resource and increasing trust between managers and users. Even in situations of conflict, scenario planning can be used to identify commonalities in the futures participants hope to see or hope to avoid, and to develop a common language among participants.

Participatory scenario planning is not a panacea to all natural resource planning problems. It tends to be resource-intensive, often taking years to complete and requiring significant effort from the project team and facilitator. Power imbalances, including those of education and economics, among participants can affect the success of the project if they are not carefully considered (Reed, et al., 2013). Thus, if limited time or resources are available for the project, tools other than scenario planning may better fit the project needs. In addition, scenario planning may not be useful when current uncertainties are so overwhelming that the future seems irrelevant to stakeholders (J. Star, personal communication).

4.0 THE SCENARIO PLANNING PROCESS

While the general understanding of the scenario planning tool is clear (see section 2), the specific methods followed to implement a scenario planning project can vary. There are many scenario planning processes, each with its own strengths and weaknesses. We recommend that project teams adapt the processes as needed for their context and resources. Table 1 uses the National Park Service's five phases of a scenario planning project to detail the goals, steps, and outcomes of the process. These steps are flexible and are used in most scenario planning projects, regardless of specific approach. In the summaries in Section 6, you will find examples of how different organizations have approached this process.

The scenario planning process begins with an orientation to the problem and how scenario planning can help find management actions that address the problem. This phase is usually carried out by a small core team, which defines the purpose of the project and determines its goals and desired outcomes. The core team often includes a scenario planning expert and/or a facilitator who will help lead the process. During this phase, the team typically decides on the process they will use for the rest of the project.

The second phase involves further exploration into the focal problem. Exploration of the focal issue and identification of key drivers and uncertainties can be done by the core team, but often also includes interviews or workshops with stakeholders. This phase lays the groundwork for the scenario building, and can be an important time to build trust among and gain buy-in from stakeholders.

In Phase 3 of the process, the scenarios are constructed. Who constructs them varies from project to project: scenarios can be built collaboratively in workshops or by smaller stakeholder groups. Alternatively, the core team can build the scenarios and present them to stakeholders later in the process. Many methods of scenario building exist (see Section 6 for some examples), but all rely on the drivers and uncertainties identified in Phase 2 of the project.

The fourth phase, application, involves in-depth examination of the scenarios and evaluation of management actions under the conditions in the scenarios. This phase is typically carried out in a workshop or series of workshops in which stakeholders discuss the implications of the scenarios for the focal issue and look at the focal issue from multiple perspectives. A facilitator trained in scenario planning methods usually guides this process. This phase should produce recommendations of management actions that would be appropriate under more than one scenario.

The final phase of the project involves monitoring the environment for changes that indicate that the management recommendations should be implemented. Some projects pre-identify triggers, such as a certain amount of sea level rise, to signal to managers that it's time to implement a particular management action. If the scenario planning project has not been led by managers, this phase should also include communication between the project team and key managers, to ensure that the results of the scenario planning process can be applied.

While we have presented this process as a sequence of five phases, in practice the process should be more cyclical than linear. As understanding of the future improves, the scenario planning process could be repeated. Ideally, managers will adopt a scenario planning mindset in which they automatically consider uncertainties and multiple plausible scenarios when making any management decision; for example, they will always ask whether a proposed change in management will create a management system that is more or less responsive to plausible changes in the ecosystem.

The Scenario Planning Process

	Goal	Steps	Outcomes/Products
Phase 1: Orient	Set up project for success	• Establish purpose and scope of project • Determine type of desired outcomes • Specify focal issue (strategic challenge) to explore • Recruit core team	• An understanding of the purpose, desired outcomes, focal issue and scope of project
Phase 2: Explore	Identify and analyze drivers, variables, trends, and uncertainties	• Identify drivers, variables, and uncertainties • Identify potential impacts • Survey or interview stakeholders to improve understanding of issue (optional)	• Tables, conceptual models, charts, graphics, or maps that capture drivers, variables, or uncertainties
Phase 3: Synthesize & Create Scenarios	Produce small number of scenarios using critical forces and impacts identified in Phase 2	• Determine critical uncertainties (uncertainties with large impact on focal issue) • Build scenario frameworks and choose scenarios • Develop scenario narratives • Review scenarios for plausibility	• 3-5 plausible, relevant, challenging and divergent scenarios using critical uncertainties to inform, inspire and test actions/strategies
Phase 4: Apply	Answer "So what?" questions: What are the impacts of these plausible futures? What can we do about it?	• Identify scenario implications • Develop, test and prioritize management actions • Use scenarios to inform management strategies	• List of actions, strategies, or areas for additional research based on discussions initiated by scenarios
Phase 5: Monitor	Identify important indicators (trigger points) that can signal changes in the environment as future unfolds	• Select indicators to monitor • Monitor environment changes	• List of indicators and early warning signals for continued research and monitoring • A monitoring strategy

Table 1: Scenario planning process, adapted from National Park Service, 2013.

5.0 WHAT PROJECTS ARE INCLUDED IN THIS DOCUMENT?

We reviewed about 50 scenario planning projects, which were identified through literature searches on Google Scholar, a grey literature search conducted by researchers at NOAA Central Library, and using snowball search techniques. This number is not precise due to some ambiguity around the term "scenario planning" and possible duplication, such as when one project is used to pilot another project. We screened the identified projects for inclusion in this document based on the following criteria:

1. The project must be focused on scenario planning for natural resources management.
2. The project must include a participatory element involving stakeholders beyond those leading the project.
3. The project report must be publicly available or accessible electronically through the NOAA Library.

Together, these criteria ensure that the projects included in Section 6 and Appendix 2 of this document are both relevant and accessible to natural resources managers. Every project we could find that met all of the above criteria is included in Appendix 2, although there are almost certainly more scenario planning projects in existence.

Of the projects we screened, 30 met all three of the criteria above. Criterion 3 excluded several projects that are available only in academic journals or that have not been published. Criterion 2 excluded most projects that solely used quantitative data, since these projects tend to not be stakeholder-inclusive, as well as projects conducted by a small research team without outside input. While the projects included in this document leverage expert opinion and quantitative models in various ways, all of them include a phase in which knowledge is generated and/or evaluated by groups of stakeholders or experts from outside the project team, who have different areas of expertise.

Our definition of "stakeholders" was deliberately broad; in some cases, the stakeholders were all recognized experts on some aspect of the system being studied, while other projects included members of the general public or resource users. The intention was to include projects in which the project managers expanded their sources of knowledge to include information generated in a cooperative process, usually a workshop.

Appendix 2 provides basic information on all 30 scenario planning projects, and shows the range of participants and timeframes that projects have required. Section 6 of this document contains longer summaries of seven of the scenario planning projects found in Appendix 2. These summaries examine the processes and results of each project in detail. The case study projects were chosen to represent a broad range of scenario planning processes and goals, rather than to provide a representative picture of how participatory scenario planning is "typically" done.

While the majority of the projects highlighted in this document took place in the English-speaking world, participatory scenario planning has been used in multiple languages, countries, and cultures. Scenario planning exercises can be conducted by almost anyone and are often reported in the "gray literature," so it is difficult to ascertain how complete the list of projects is in Appendix 2. New studies are probably being published frequently. It is clear from our examples that innovation in scenario planning methods is common and that no two processes are exactly alike, and we encourage natural resources managers to adapt the method to their particular context and needs.

6.0 SCENARIO PLANNING PROJECT SUMMARIES

6.1 Tijuana National Estuarine Research Reserve

Project Title: Scenario planning: overcoming uncertainty and informing action

Location: Tijuana National Estuarine Research Reserve, California and Mexico

Year Completed: 2016

Agency/Institution: NOAA and NERRS Science Cooperative

Background: The Tijuana River National Estuarine Research Reserve is situated on the border between California, U.S.A, and Baja California, Mexico. The Reserve contains the largest intact coastal wetland system in Southern California, despite pressure from surrounding development. Managers began a climate vulnerability analysis to plan for the Reserve under future climate conditions, but soon realized uncertainty was extremely high in several areas relevant to the Reserve, including estuarine water levels, extreme events, and connection between the ocean and the estuary. In light of this uncertainty, they opted for a scenario planning project.

Objective: Inform the development of adaptation strategies addressing the impacts of climate change, specifically sea level rise and riverine flooding.

Time frame: about 2 years

Format: Project team chose scenario drivers and generated basic scenarios (Figure 1); 2 daylong in-person workshops discussed implications of scenarios for physical and biological environments, 1-on-1 interviews with local organizations discussed adaptation.

Participants: about 60

Outside facilitator used: Yes

Number of scenarios: 4

Project characteristics: This project uses a common scenario generation method, in which two primary variables or drivers are identified, then used as axes to define four scenarios. Two workshops, each with a different group of participants, created very in-depth narratives based on the scenarios.

Process: The project team chose two drivers of change—frequency of "extreme flow" events and tidal prism—and used them to create four scenarios. They first presented them at a workshop to an invited group of about 40 experts in various aspects of the physical environment in the Reserve. These participants built out implications of each scenario for environmental characteristics such as surface and groundwater salinity, sediment dynamics, and several other areas. A second workshop was comprised of 8-10 experts in the biological environment in the Reserve, who built out implications of each scenario for different ecological environments. This workshop also assessed the vulnerability of each ecosystem type under the different scenarios. Finally, the project team conducted a series of one-on-one interviews with local stakeholder groups to discuss the implications of the scenarios for people and infrastructure.

Project results: Conversations with stakeholders showed that scenarios in which the tidal prism increased and the river mouth stayed open were preferred to scenarios involving a decreased tidal prism. This scenario planning exercise supported the Reserve's tidal marsh restoration program by confirming that restoration to increase tidal prism would increase the system's overall resilience even with the sea level rising.

Reports and products: A partial project report is available at: http://trnerr.org/wp-content/uploads/2014/03/scenario-planning-guidebook_draft_Dec2016.pdf

Scenario excerpts (all excerpts are from the "Salt Flats" section of the scenarios):

From Scenario A (Increased extreme river flow events and decreased tidal prism): Mostly closed river mouth will lead to high salinity as water trapped behind the river mouth evaporates, increasing habitat area. Additionally, extreme events will increase sediment aggradation, as sediment is trapped behind the closed river mouth, helping to increase habitat area. However, increased extreme events will occasionally open the river mouth altering salinity and aggradation of sediment, keeping the increase in habitat area small.

From Scenario B (Increased extreme river flow events and increased tidal prism): Open river mouth and increased tidal prism, coupled with increased extreme events will lead to a small decrease in habitat area, due to increased freshwater inputs, increased coastal flooding and inundation (SLR outpaces aggradation in the lower valley).

From Scenario C (Decreased extreme river flow events and decreased tidal prism): Closed river mouth will lead to high salinity as water trapped behind the river mouth evaporates, increasing habitat area. Additionally, extreme events will increase sediment aggradation in the lower valley, as sediment is trapped behind the closed river mouth, making the increase in habitat area large.

From Scenario D (Decreased extreme river flow events and increased tidal prism): Mostly open river mouth and increased tidal prism will lead to a large decrease in habitat area, due to the increased of intertidal and saltmarsh habitats, and SLR outpacing aggradation in the lower valley.

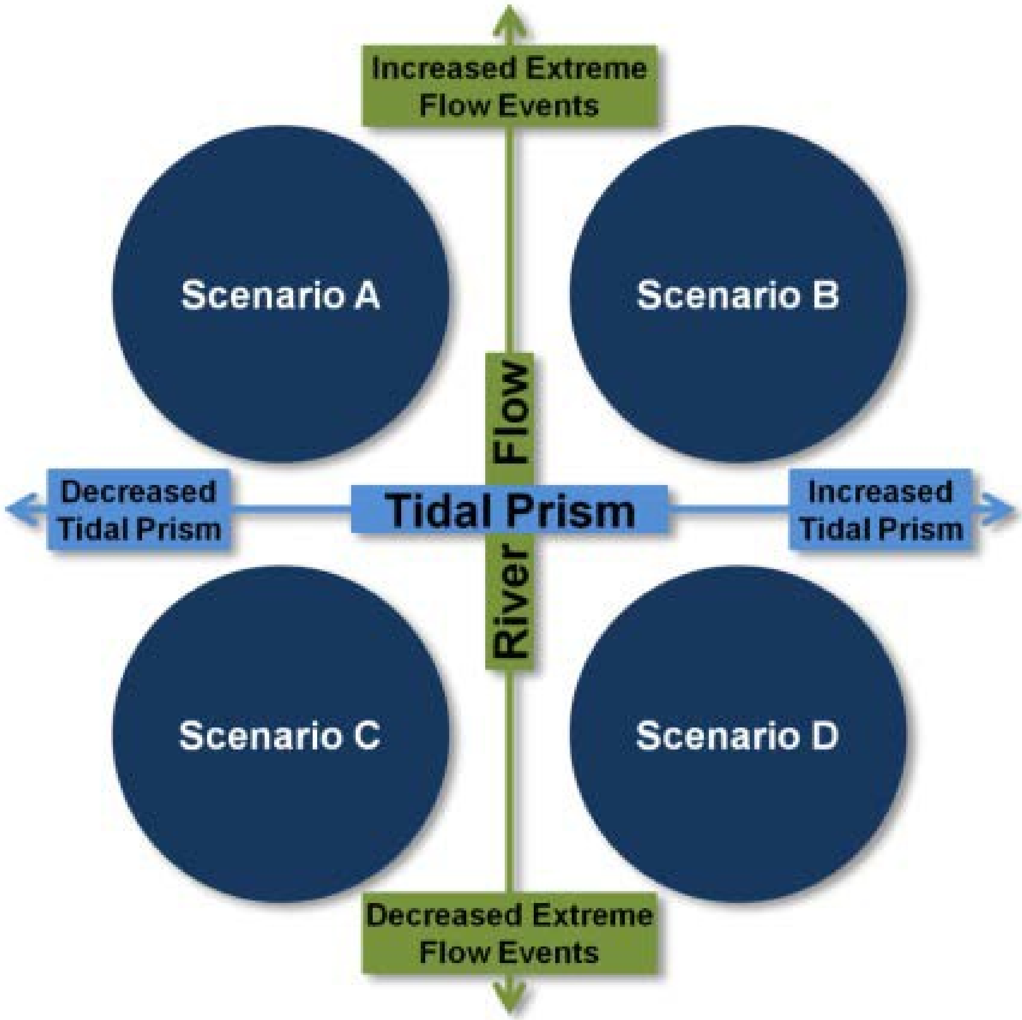

Figure 2: Two drivers generate four scenarios for Tijuana National Estuarine Research Reserve’s scenario planning project (Boudreau, Crooks, Goodrich, & Lorda, 2016).

6.2 Great Barrier Reef Catchment

Project Title: Future Scenarios for the Great Barrier Reef Catchment

Location: Queensland, Australia

Year completed: 2009

Agency/Institution: Commonwealth Scientific and Industrial Research Organization (CSIRO) Water for a Healthy Country

Background: The Great Barrier Reef catchment, located in northwest Australia, has experienced a significant decline in water quality in recent years, which has led to the degradation of ecosystems on the Great Barrier Reef. CSIRO partnered with the government of Australia and other stakeholder groups to attempt to reverse the decline in water quality and realize increased benefits from water in the catchment as a whole.

Objective: Work in collaboration with representatives from Australian and Queensland government, local government, regional Natural Resource Management (NRM) bodies, non-government organizations (NGOs), peak industry and research organizations to:

- Identify and analyze the key factors or variables likely to fundamentally influence the behavior of communities, industries and natural ecosystems in the Great Barrier Reef (GBR) catchment;
- Articulate and challenge expectations about the future;
- Develop four plausible scenarios that describe what the GBR catchment might be like for communities, industries and resource agencies in 2050; and
- Facilitate wide and ongoing communication and uptake of the findings to enhance the capacity of planners and policy-makers in strategic decision-making about the future of the GBR catchment.

Time frame: Unknown, preparation and reporting timelines not given

Format: Project team interviewed experts, identified drivers of change, and developed scenarios (Figure 2). 1-day in-person workshop evaluated the plausibility of scenarios, identified implications of the scenarios for different stakeholder groups, and discussed possible responses to each scenario.

Participants: 47 experts were interviewed about drivers of change in the region. An unknown number of stakeholders attended two briefing sessions on the project. 41 stakeholders attended the workshop, including 14 who had been involved in the interview or briefing stages.

Outside facilitator used: Yes

Number of scenarios: Four

Project characteristics: This project uses a common scenario generation method, in which in which two primary variables or drivers are identified, then used as axes to define four scenarios. In this case, the drivers were identified and the scenarios created ahead of the workshop; however, because this method does not necessitate use of quantitative data, stakeholders could choose drivers and create scenarios during the workshop as well.

Process: Researchers identified a pool of experts and high-level stakeholders from research, industry, government, and other sectors and sent letters requesting interviews with these individuals. The interviews focused on the interviewee's perspectives on possible futures and drivers of change in the GBR region. Researchers then synthesized the interviews into several categories of drivers and uncertainties. Of these, they identified two drivers that were important and highly uncertain, and crossed these two drivers (climate change and influences on governance) to yield four scenarios (Figure 2). They presented the four scenarios at the workshop. Workshop participants discussed each scenario's plausibility, assumptions, risks, and opportunities, then listed common themes that had emerged across multiple scenarios. They then discussed the implications of each scenario for a series of five issue areas: research and knowledge, regulation, infrastructure and land-use planning, industry and production, and traditional owners.

Project results: Specific future actions that are robust to more than one scenario were not identified. Broader categories of actions were discussed, including the need to engage in policy directions at a high level and the need for further community engagement. The researchers presented the results of this project in two public seminars and have met with several agencies and environmental organizations about the project.

Reports and products: The full text of the project summary is available at: http://www.clw.csiro.au/publications/waterforahealthycountry/2009/wfhc-future-scenarios-GBR-catchment.pdf

Scenario excerpts:
From "No Limits to Growth": "By 2050, land uses have intensified in the GBR catchment in response to increased economic growth. However, biodiversity in the Wet Tropics Rainforest and the GBR have been impacted by heat stress and habitat loss. Coastal erosion continues in places where coastlines are not actively managed and protected. In 2050, mining and farming are the backbones of the regional economy, while tourism is still a major contributor due to increased marketing efforts to attract visitors to the area."

From "Saving the Reef": "High transportation costs and environmental consciousness lead to a high degree of regional self-sufficiency and a boost in organic farming. In areas that are prone to flooding, cropland is reduced considerably. Many farms in the region have become unviable over time and are now managed for environmental outcomes, i.e. ecosystem services. Others are focusing on growing regional products and organic food. In 2050, tourism is the backbone of the regional Future Scenarios for the Great Barrier Reef Catchment Page 11 economy, despite reductions in international air travel. Climate friendly and nature-based tourism, such as hiking, biking and canoeing, is promoted."

From "Booming Sea-Change": "In 2050, a patchwork of highly intensive land uses interspersed with a network of protected areas cover the region. This is impacting terrestrial biodiversity, despite major conservation efforts at the global level. Concerns over the storage of nuclear waste that were initially outweighed by the ability of nuclear power to cut greenhouse gas emissions are slowly rising. Oil drilling is being re-considered in the GBR area due to global oil shortages. Prosperity in the region remains largely resource-based despite attempts to move towards a knowledge-and-services economy."

From "Revitalised Country Towns": "In 2050, land uses include agriculture, forestry, protected areas, mining, alternative energy, tourism, education, health and the arts. Farms are often community supported and act as social, cultural and educational places. Environmental impacts on water, biodiversity and landscape aesthetics are being mitigated through strict regulations supported by the community."

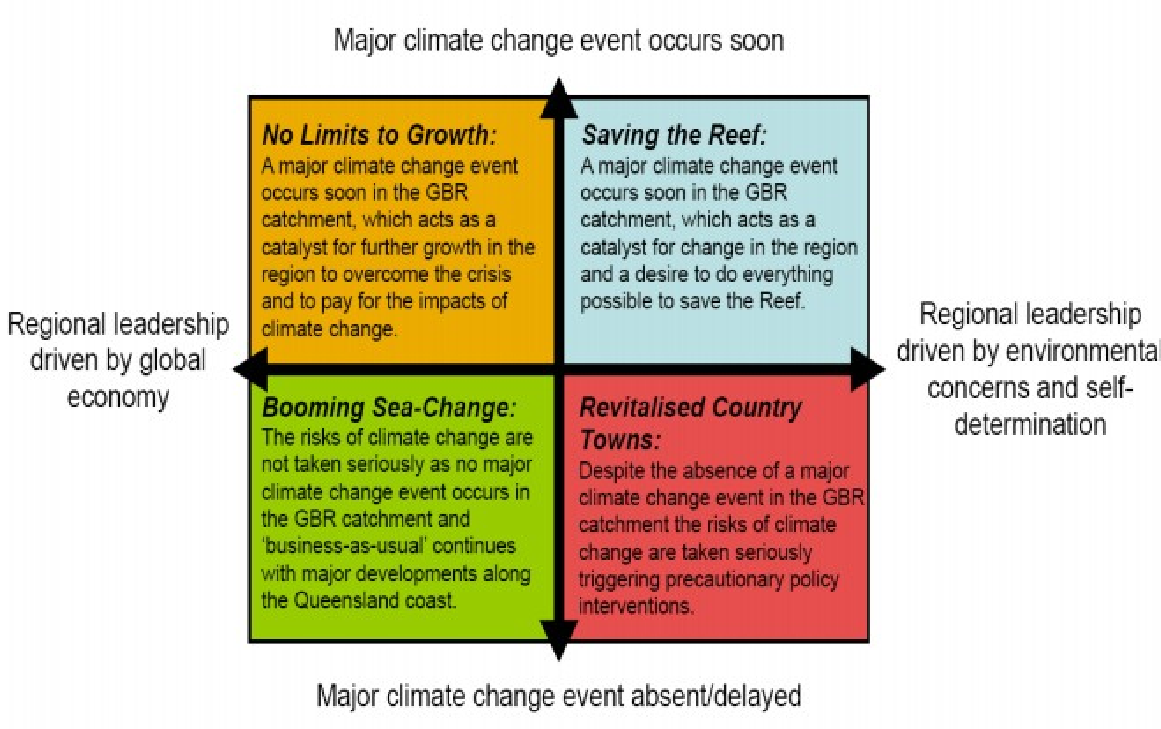

Figure 3: Two drivers combined to form four possible futures for the Great Barrier Reef catchment (Bohnet, Bohensky, Gambley, & Waterhouse, 2008).

6.3 Rhode Island Fisheries

Project Title: Resilient Fisheries RI

Location: Rhode Island, United States

Year completed: 2018

Agency/Institution: None; project website states "The Resilient Fisheries RI project is a decentralized, grassroots project belonging to the entire RI commercial fishing industry. The initial phase of the project was supported through a Saltonstall Kennedy grant from the National Oceanic and Atmospheric Administration awarded to the RI Natural History Survey, which acted as fiscal sponsor for the project from September 2015 - April 2018."

Background: Fishermen in Rhode Island, like many others in the northeastern United States, say they are facing increasing regulatory, economic, and environmental challenges in their work. This project began with the intention to identify and plan for key environmental challenges to the Rhode Island commercial fishing fleet. The fishermen that were interviewed as an early part of this project identified regulatory and economic challenges as being just as important as environmental issues, and so the project expanded to examine the Rhode Island fishing industry as a whole, identify positive future directions, and plan for how to get the future the fishermen envisioned for their industry.

Objective: None stated

Time frame: September 2015-May 2018

Format: Project team conducted 48 in-person stakeholder interviews. External issue experts led 10 2-hour seminars on topics that had been identified during the interviews. Project team developed scenarios. Participants in 1-day scenario planning workshop discussed implications of scenarios and possible management actions. This was followed by several month review and co-writing process and an implementation meeting.

Participants: 125 members of the commercial fishing industry participated in some way, including 48 interviewees and 45 scenario planning workshop participants.

Outside facilitator used: Yes

Number of scenarios: Four

Project characteristics: This project was an integrated, grassroots effort that evolved considerably based on stakeholder input. The project team invested a lot of time in reaching out to the community at large in different ways, ensuring that their scenario planning process would reflect stakeholder concerns accurately.

Process: A series of interviews with fishing industry stakeholders identified key changes and challenges in the Rhode Island commercial fishery. Subsequently, ten evening seminars were held over the course of three months on topics of interest identified during the interviews. The information collected in the interviews and from discussions during the seminars was used to help generate the scenarios used in the scenario planning workshop. At the workshop, participants were divided into four groups, and each group was given a unique environmental scenario and a unique sociopolitical scenario (Figure 3). Participants reflected on what it would be like to be involved in commercial fishing in the context generated by the combination of their scenarios. They then proposed strategies to achieve a healthy fishing industry in the years 2025-2030 under this alternative future. Finally, all groups came together and “stress-tested” one another’s strategies, scoring them based on how well they functioned under other alternative futures. This process produced seven key groups of strategies that emerged as useful under many different futures.

Project results: A launch event for the implementation of the project was held in May of 2018, which included breakout groups to discuss next steps for each of the seven strategies. No management outcomes have been reported to date.

Reports and products: The project report, “Blueprint for Resilience” was published in April 2018, with the goal of serving as a “platform for strategizing about the future of Rhode Island's fishing industry.” Individual reports on the interviews, the seminars, and the scenario planning workshop were also published. All project materials can be found at www.resilientfisheriesri.org.

Gold Group	*Natural Environment: "Global Weirding"* Manmade climate change and natural climate cycles are acting in opposite directions, creating a situation of climate chaos. Water temperatures vary greatly from year to year, with no apparent trend. Salinity goes up and down with rises and falls in temperature. Dissolved oxygen also varies, and anoxic events are more intense but less consistent and predictable. Incidences of acidified waters occur sporadically, but are intense and unpredictable. *Sociopolitical Environment: "Do It Yourself"* A short-lived period of chaotic politics 'for the people' has given way to 'small' government by a new third party, with policies influenced by the Silicon Valley high-tech industry. Business investment is up, but it's a harsh new working world and households are upended by the churn and pressures to compete in it.
Red Group	*Natural Environment: "Global Cooling & Eutrophication"* Natural cooling cycles are counteracting the global effects of manmade greenhouse gas emissions. Salinity is increasing, as more freshwater is trapped in expanding polar ice caps. At the same time, Narragansett Bay and other coastal areas are experiencing increasing eutrophication. This is causing greater intensity of anoxic events. Acidification (lower pH) is occurring as well, due to the increased amount of carbon in of coastal waters. *Sociopolitical Environment: "Second Wind"* The U.S. economy is growing – thanks to a new wave of technological innovation – led by artificial intelligence, micromanufacturing, and robotics. The pace of change is manageable, and there are much closer relations between government and industry, for good and bad.
Blue Group	*Natural Environment: "Anthropogenic Warming"* Water temperatures in Southern New England have continued to rise since the 1980s. Natural causes may play a role in some places, but the increase in temperature is primarily driven by manmade greenhouse gas emissions. Salinity is becoming lower due to the melting of glaciers and polar ice caps. Dissolved oxygen levels are going down, because warmer waters hold less oxygen. Anoxic events are more frequent. Ocean acidification (lower pH) is also occurring, mostly as a result of increasing carbon dioxide concentrations in the atmosphere. *Sociopolitical Environment: "The Long Plateau"* The U.S. has settled into a challenging and somewhat confusing period. The economy is sluggish and opportunities are limited. Inequality has fallen because there are fewer affluent households. Tough protectionism and government programs are keeping a lid on frustration. People wonder: is this as good as it gets?
Green Group	*Natural Environment: "Natural Warming"* Water temperatures in Southern New England have continued to rise since the 1980s. Man-made contribution to climate change appears to be negligible; instead, the warming that is occurring is due to natural cycles like the North Atlantic Oscillation. Salinity is becoming lower due to melting of glaciers and polar ice caps. Dissolved oxygen levels are also going down, because warmer waters hold less oxygen. Anoxic events are more frequent. Ocean pH has remained relatively constant. *Sociopolitical Environment: "The Next Big Thing"* A new economy is taking root, in anticipation of unprecedentedly cheap renewable energy. New Energy storage technology promises to solve renewables' intermittency problem. There are definite upsides for consumers. But in the near term, there are big adjustment problems and ongoing uncertainties are profound – for the U.S. and the rest of the world.

Figure 4: Four "natural environment" and four "sociopolitical environment" scenarios combined to form four alternative futures for Rhode Island fisheries (Schumann, 2017).

6.4 Barents Sea

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

Location: Barents Sea, Norway

Year Completed: 2018

Agency/Institution: Euromarine+ Program; Norwegian Institute of Marine Research

Background: The Barents Sea sits at the interface of the Arctic and Atlantic oceans, north of Norway and Russia. It supports large commercial fisheries and is likely to be highly impacted by climate change in the near future.

Objective: Produce a set of truly multi-perspective scenarios, which are developed in a participatory manner while preserving knowledge and practices specific to individual disciplines.

Time frame: Unknown

Format: 3-day workshop

Participants: 18 workshop participants included representatives of the fishing industry, fisheries policy, NGOs, and research in several disciplines.

Outside facilitator used: No

Number of scenarios: Three

Project characteristics: Unlike many scenario planning processes, which consider integrated scenarios from the start, the leaders of this project chose to first ask participants to develop scenarios from particular "perspectives" that had been identified prior to the workshop

Process: The research team identified four areas of interest in marine social-ecological systems: fisheries management, ecosystem, climate, and global governance. Participants identified trends in each area of interest (termed "perspectives,") then examined futures arising from a baseline, an improved, and a degraded management context for each perspective individually. The single perspectives were then combined (Figure 4). As a group, participants chose and developed three contrasting scenarios that included elements of each perspective. The three scenarios were A) the expected: all baselines, B) the wildcard: degraded fisheries management, healthy ecosystem, cold future, and declining governance, and C) other potential trajectories: improved fisheries management, unhealthy ecosystem, baseline ocean climate, and baseline governance. For each scenario, participants detailed the characteristics of the Barents Sea in 2050 and the trajectory over time that had resulted in those characteristics.

Project results: No management outcomes are listed in the paper.

Reports and products: The project leaders end the paper with a discussion of the limitations and possibilities of this method of scenario planning. It was published in the journal *Fish and Fisheries* and is available here: https://onlinelibrary.wiley.com/doi/full/10.1111/faf.12356

Scenario excerpts:

From "Scenario A: Baseline in all perspectives": "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 improved. This situation was made possible by the inertia in many processes relevant to all perspectives."

From "Scenario B: Cold future, decline of governance, degraded fisheries management, healthy ecosystem": "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."

From "Scenario C: Baseline ocean climate, baseline governance, improved fisheries management, poor ecosystem health": "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."

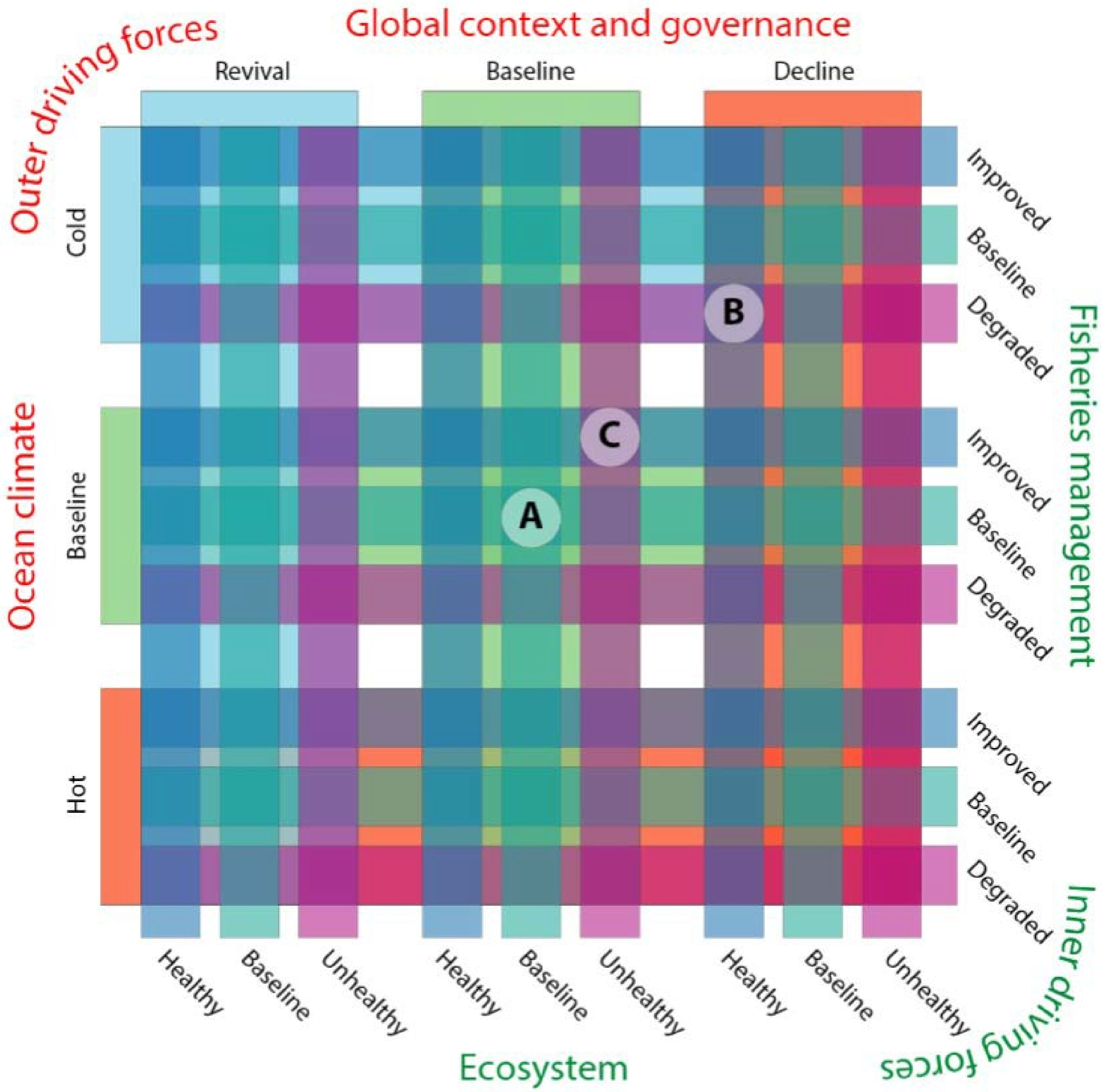

Figure 5: Single-perspective scenarios combined to form multi-perspective scenarios in the Barents Sea Circles marked “A”, “B”, and “C” represent scenarios selected for analysis (Planque, et al., 2019).

6.5 Yukon Territory

Project Title: Scenario Planning During Rapid Ecological Change

Location: Southern Yukon Territory, Canada

Year completed: 2013

Agency/Institution: University of Saskatchewan

Background: Within the past 50 years, wood bison were reintroduced to the Yukon Territory, in far northwestern Canada. Elk were introduced into the territory for the first time, and mule deer are moving northward from British Columbia. Strong traditions of subsistence hunting and trapping make these changes in the ecosystem highly impactful on local communities.

Objective: Identify wildlife management goals in a rapidly changing social-ecological system.

Time frame: January 2012-February 2013

Format: 3 workshops. The first lasted 1 day, during which participants identified drivers of change. The second lasted 2 days, during which participants developed scenario narratives. The third and final workshop ran for 1 day, during which participants considered management responses to each scenario.

Participants: 15 total; individual workshops ranged from 6-9 participants. All participants were natural resources managers in the region.

Outside facilitator used: No. The workshops were facilitated by one of the project leads, who had extensive existing relationships among stakeholders in the region.

Number of scenarios: Four

Project characteristics: This project used three workshops, which encompassed the entire scenario planning process, rather than having the project team conduct part of the process prior to the workshops. Different combinations of stakeholders attended each workshop. While using a "crossed drivers" system similar to several other projects, this project evaluated three drivers instead of the more typical two. The scenarios were expressed creatively, through illustration and narration.

Process: The first workshop focused on identifying drivers of change in the system. The participants identified 46 drivers of change, which they grouped into 3 axes: "Changing ecological-social interactions," "land use," and "the human factor." Each axis had two polar directions across which change might manifest. Combining the axes yielded eight scenarios, four of which participants identified as plausible (Figure 5). The second workshop focused on developing narratives for these four plausible scenarios for the year 2032 (20 years into the future.) Each scenario was narrated by an imaginary news article from 2032 and illustrated pictorially. Participants in the third workshop examined possible management responses to each scenario.

Project results: No management outcomes from the project were detailed in the report. The primary outcomes seem to have been lessons about how to conduct scenario planning exercises and other intangible outcomes, including improved communication and social learning.

Reports and products: The report was published in Ecology and Society in 2015 and can be accessed here: https://www.ecologyandsociety.org/vol20/iss1/art61/

Scenario excerpts:

From "Doom and Gloom (Scenario 1)": "The land-based economy of old dried up as prices and demand for land-based goods plummeted. Cabins rot as trappers continue to stay out of the bush. "I think the only ones of us still out here are the ones who are too old to know another way to live," says 65-yr-old Garret "Snare" Hill. Traps unset, berries unpicked and medicines uncollected. Old activities like these that once gave the Yukon a "last frontier" feel have disappeared, leaving those with the land at heart asking, "Do we have another Yukon to move to?""

From "Slow Boil (Scenario 2)": ""Outfitting has become a hard business," says Chris Masterson of Kluane Lake Outfitters. "We can no longer guide for caribou or sheep, which were huge economic drives." He adds that, "several of his clients mentioned crisscrossing ATV trails making the landscape look less wild." The wild, remote feeling of the landscape is a feature that has been a selling point of outfitting in the Yukon for generations but, as Masterson says, is disappearing."

From "A Confused State (Scenario 3)": "Initially decisions to shift management priorities were not popular with the public. But both Environment Yukon and First Nations governments in the southwest Yukon agree that management has to be directed where it can be effective. "Management has changed to focus more on resilience of the landscape," says Chang. "To achieve this we are promoting cooperation between departments." Rogers says, "Limiting nonclimate stressors is the best thing we can do for the Yukon's wildlife. We have worked with Energy, Mines, and Resources to reforest unused logging roads and looked at ways to reduce pollution and erosion from mining operations.""

From "Win-Win (Scenario 4)": "Farmer continues to say that, "there is a huge demand for people to try to eat locally and so hunting is extremely important, but when it comes to supplementing that meat with fruits and vegetables small farming that maintains the health of the soil is important." Dale Pepper of the Yukon Agriculture Association says, "There is a line between the kind of farming that is in harmony with the land and the kind that isn't. The scale of southwest Yukon agriculture and the sustainable practices keep that balance. Space is left for the wildlife and pesticides are kept out of the watersheds.""

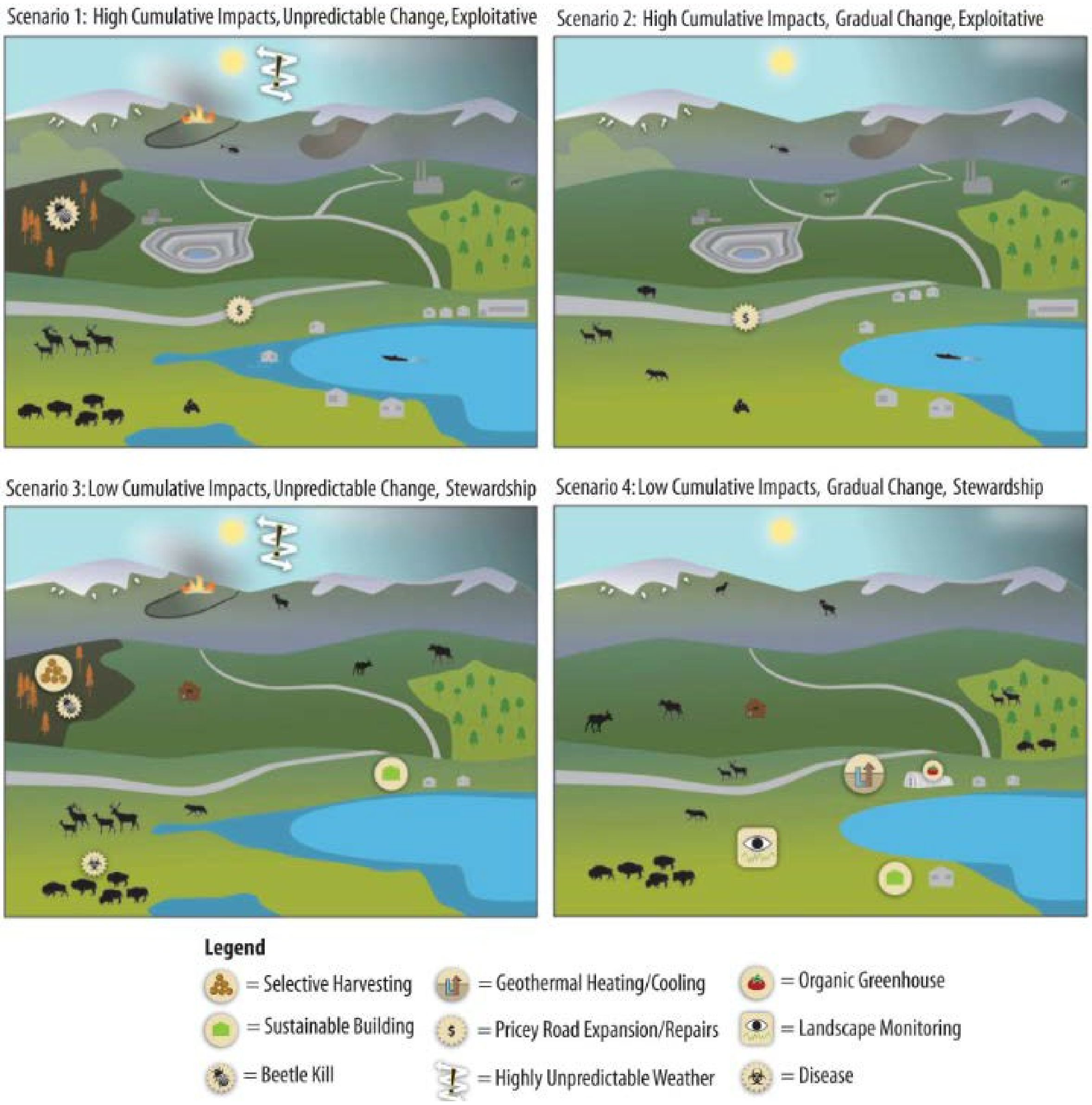

Figure 6: Scenarios of ecological change selected for analysis in the Yukon (Beach & Clark, 2015).

6.6 Gulf of Maine Salmon

Project Title: Atlantic Salmon Scenario Planning Pilot Report

Location: Gulf of Maine, United States

Year completed: 2019

Agency/Institution: National Oceanic and Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS)

Background: Atlantic salmon is a species that has been identified as being highly vulnerable to climate-related impacts across its life stages. This project was undertaken to explore how NOAA could improve resilience of Gulf of Maine Atlantic salmon population to climate change.

Objectives: 1) to better understand the challenges of managing Atlantic salmon in a changing climate; 2) to identify and discuss potential management actions and research activities that can be undertaken to increase our understanding of the drivers of salmon productivity and resilience; 3) to increase collaboration and coordination related to the species recovery; and 4) to explore how scenario planning can be used to support decisions.

Time frame: September 2016-October 2017

Format: 2 webinars followed by a 2-day workshop.

Participants: The 22 participants, all Federal employees, were invited based on their expertise in areas important to Atlantic salmon science and management.

Outside facilitator used: Yes

Number of scenarios: 4

Project characteristics: In this project, participants did significant work in advance of the workshop to define and develop scenarios, so that more workshop time could be focused on implementing management actions.

Process: The project began with a webinar in which participants identified and classified drivers critical to Atlantic salmon survival. A small subgroup was formed to determine which drivers were the most important and uncertain. The project team used the drivers selected by the subgroup to draft scenarios, which were presented to all participants in a second webinar. The project team incorporated feedback from the webinar and completed the scenario matrix prior to the workshop (Figure 6). At the workshop, participants were divided into four groups, and each group was given a scenario to develop. After discussing implications of each scenario for salmon in the future, each group generated a list of management and research actions that could be implemented under their scenario to improve Atlantic salmon resilience in a changing climate. Subsequently, participants were divided into two groups to identify high-priority actions that could be taken in the short term at two spatial scales (watershed and estuarian/marine.)

Project results: Several climate-related actions informed by this exercise were included in the 2019 NOAA/USGS Atlantic Salmon Recovery Plan. Some research needs identified through this exercise have been funded through NOAA and external partners, including a habitat analysis, a map of cold water salmon refugia, and a new tracking technology to monitor salmon migration.

Reports and products: The full project report is available at: https://www.greateratlantic.fisheries.noaa.gov/policyseries/index.php/GARPS/article/view/15/14

Scenario excerpts:

From "Free-flowing": "Winters experience less snow and when it does snow, it melts earlier. Winter precipitation occurs more frequently as rain. Combined, these conditions lead to higher winter and lower spring streamflow… Freshwater accessibility in the watersheds is high due to removal or modification of passage barriers. Atlantic salmon are primarily affected by the suitability of the marine habitat, the variability in streamflow, and increasing river temperature."

From "Hanging on by a stream": "River temperatures and the number of consecutive extreme hot days that exceed thermal thresholds for Atlantic salmon increase…Although freshwater accessibility in the watersheds is high due to removal or modification of passage barriers, the generally drier conditions lead to reduced streamflow year-round. Atlantic salmon are primarily affected by the suitability of the marine habitat, lower streamflow for extended periods, and higher river temperatures."

From "Soggy but hindered": "Winter precipitation occurs more frequently as rain. Combined, these conditions lead to higher winter and lower spring streamflow…Freshwater accessibility in watersheds is low because most passage barriers remain in place. Atlantic salmon are primarily affected by marine habitat suitability, streamflow variability, increasing river temperature, and the continued presence of barriers."

From "Hot and blocked": "River temperatures and the number of consecutive extreme hot days that exceed thermal Atlantic salmon thresholds increase…Freshwater accessibility in watersheds is low because most passage barriers remain in place. Atlantic salmon are primarily affected by marine habitat suitability, streamflow variability, increasing river temperature, and the continued presence of barriers."

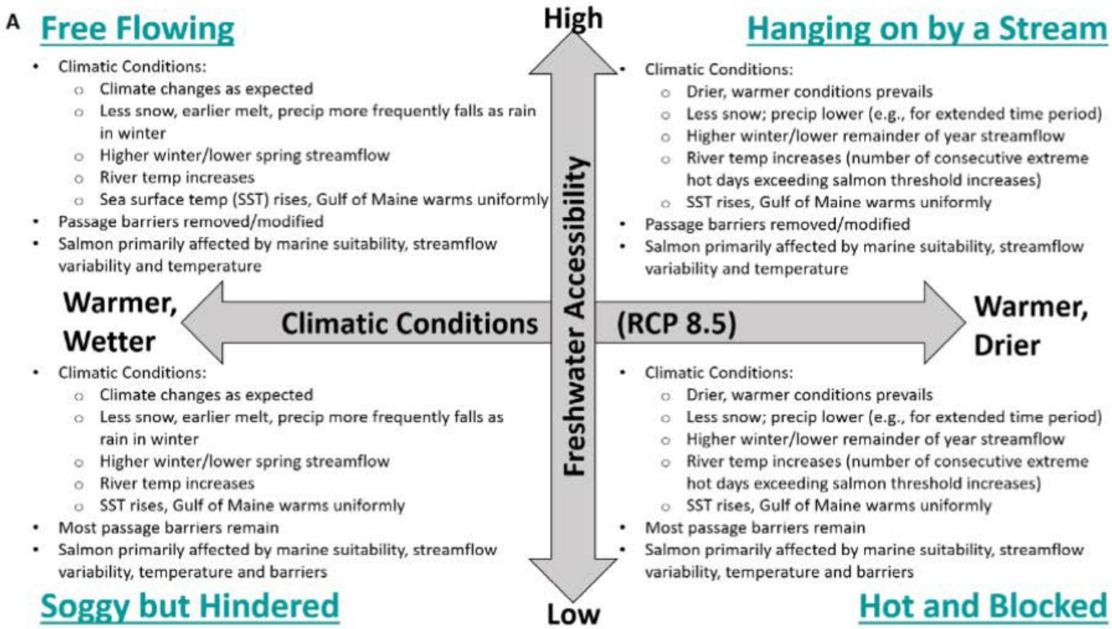

Figure 7: Climate conditions combined with freshwater accessibility produce four scenarios for Gulf of Maine salmon (Borgaard, et al., 2019).

6.7 Apostle Islands National Lakeshore

Project Title: Apostle Islands Climate Change Scenario Planning Workshop

Location: Apostle Islands National Lakeshore, Wisconsin, United States

Year Completed: 2015

Agency/Institution: US National Park Service

Background: The Apostle Islands National Lakeshore is located on Lake Superior at the northern tip of the state of Wisconsin. Recent and anticipated changes in climate have implications for infrastructure, visitor numbers and safety, staffing, ecosystem management, and other aspects of this National Park Service-managed system of islands and shoreline. The park superintendent began the project by asking participants to focus on how the park could prepare for the effects of climate change, particularly in the areas of dock design on Lake Superior, staffing levels in the winter and shoulder seasons, and altered wildlife and plant species distributions.

Objective: Help senior leadership make management and planning decisions based on up-to-date climate science and assessments of future uncertainty.

Time frame: March 2015-May 2015, including preparation by the project team.

Format: Project team developed climate futures (Figure 1); 1-day in-person workshop generated alternative future scenarios and discussed management implications.

Participants: The 38 workshop participants were almost all affiliated with universities and government agencies.

Outside facilitator used: Yes

Number of scenarios: Four, including a baseline that was not discussed in the workshop.

Project characteristics: This project exemplifies the approach the National Park Service uses for its scenario planning projects, in which climate scenarios are generated by experts using quantitative input, and are then expanded into qualitative scenarios and applied in a stakeholder workshop.

Process: Climate experts generated four climate futures (one baseline and three alternatives) prior to the workshop (Figure 7). These climate futures were developed by the Great Lakes Integrated Sciences and Assessment Center using quantitative data. The workshop began with several background presentations on the drivers and effects of climate change. Then, workshop participants were presented with the climate futures, and were asked to answer the question "what would happen in Apostle Islands if each of these three [alternative] scenarios played out over the next 25 years?" The discussion around this question resulted in more developed, qualitative scenarios that touched on visitor numbers, erosion, access, biodiversity, and safety, among other relevant topics (excerpts below). The participants then evaluated proposed management decisions under each of the three alternative scenarios.

Project results: While each qualitative alternative scenario involved many issues, participants were asked to evaluate management approaches to three focal areas: dock design, staffing, and changes in species distribution. Changing the design of docks to be more flexible to different water levels, and to include rails and "flow-through" design was identified as an adaptation that would be suitable for all scenarios. The other two focal areas did not have management actions identified that were robust across scenarios, although two of the alternative scenarios would benefit from more flexibility in staffing. The new docks, designed with features suggested during the workshop, were installed in the winter of 2015.

Reports and products: Full report available at: https://www.nps.gov/subjects/climatechange/upload/Scenario-Workshop-APIS-508compliant.pdf Scenarios were updated based on more specific climate information here: http://www.glisaclimate.org/projects/2125/page/2566

Scenario excerpts:

From "Soggy": "A wetter climate leads to greater erosion of cliffscapes and sandscapes. Access to smaller beaches becomes limited as lake levels rise – loss of beach area causes increased trampling of sensitive dune vegetation. Trails are flooded and water quality suffers from increased run-off. High lake levels cause damage to docks and lakeshore infrastructure. Search and rescue services are stretched as storms become more common."

From "Yo-yo": "However, this increase in attractiveness and attention results in more management challenges. Visitor amenities - campsites and docks - are at a premium, and unpredictable conditions are on the increase. Many island trips get cancelled due to dangerous weather, and search and rescue services are kept busy and often stretched."

From "Hot and Bothered": "The warmer, drier conditions cause changes in land use in the region: more land is converted to agriculture as the growing season lengthens. Water quality declines in the lake as nutrient-laden runoff and sedimentation rises. Beaches get bigger as lake levels fall. Docks are left high and dry in many instances, even as docks are in greater demand from more summer visitors and activities."

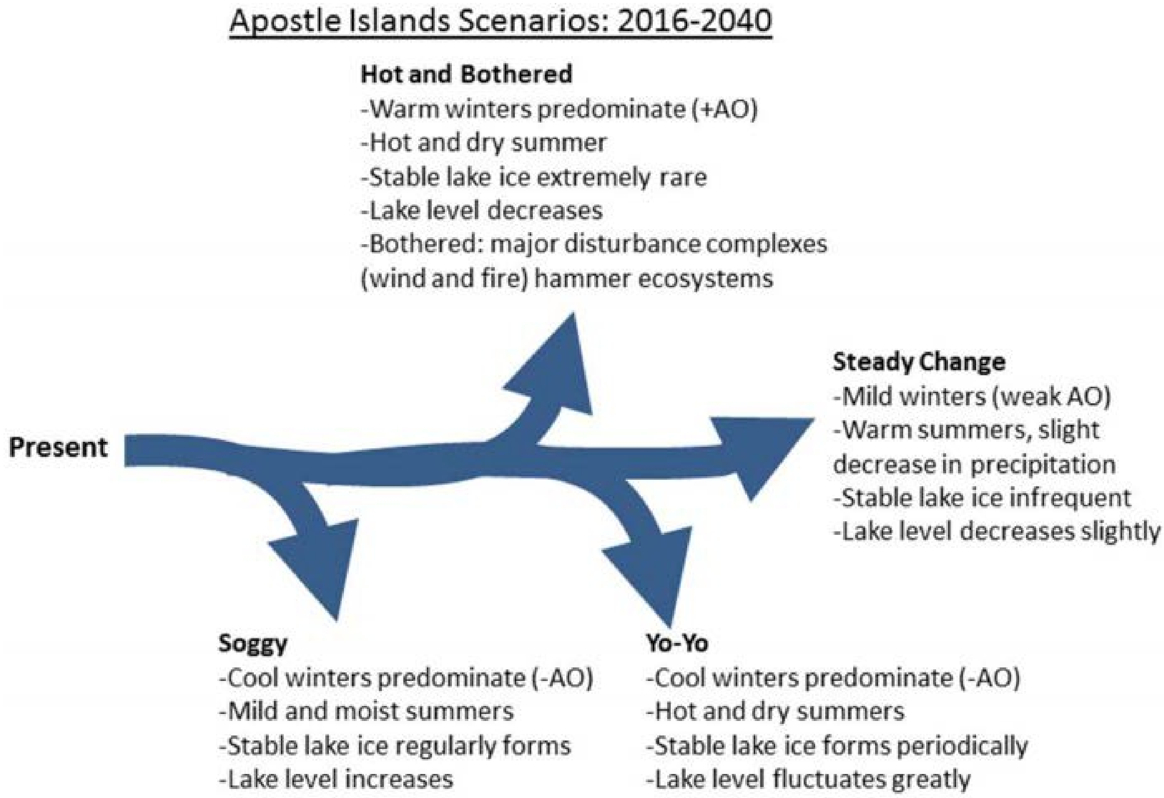

Figure 8: Expert-generated climate scenarios used in the Apostle Island Climate Change Scenario Planning Workshop (Star, et al., 2015).

7.0 CONCLUSIONS

Scenario planning is a flexible tool for planning for the future when there is a lot of uncertainty. As the summaries in the previous section show, scenario planning can be adapted for many systems and purposes. Because of this flexibility, it is important to carefully consider the purpose, scope, and desired outcomes of a scenario planning project from the beginning. There is no one-size-fits-all approach to conducting scenario planning; each process must be adapted to its specific context.

Stakeholder engagement is at the core of scenario planning, and confers benefits that transcend the planning process. Inclusion of a diverse group of stakeholders contributes a broad knowledge base to the project and helps open lines of communication to various groups in the community. However, larger groups, especially those in which responsibility is somewhat diffuse, can have a harder time coming to conclusions. The goal of the project and its context should help project leaders determine the appropriate level of stakeholder involvement. The project team should facilitate interactions among stakeholders so that power imbalances are evened out to the extent practicable and all voices are heard, so that creativity is encouraged, and so that relationships are strengthened in the process. If the project team members do not themselves come from the fishing community, it is important to engage community leaders to identify dynamics that could help or hinder an open and successful process.

Implementation of a scenario planning project is a long-term activity; many of the managers we spoke with for this review indicated that implementation of their project outcomes was ongoing several years after the planning workshop was completed. Scenario planning can also be iterative, with a new planning process initiated when conditions have changed significantly from the original conditions. Implementation is more likely to be effective when managers commit to an implementation phase prior to the beginning of the project, and when managers with decision-making authority over implementation resources are involved. We expect that strong engagement from Fishery Management Councils will be key to implementing most fishery management scenario planning projects in U.S. fisheries.

Scenario planning projects can identify suggested management actions at a variety of different levels, ranging from government-wide to individual and from regulatory actions to voluntary actions. For example, increased dedication to civic engagement was one result of the Resilient Fisheries RI project. In addition, there may not be management options that are applicable under all future conditions, so managers will need to weigh the costs and benefits of each option given the uncertainties that are present. There may be solutions that are applicable to some, but not all, of the plausible futures, or actions that work to spread risk more evenly across futures. The ongoing nature of implementation means that all the results of a scenario planning project may not be realized for a long time. Scenario planning should be viewed as a long-term investment in resources management.

Scenario planning is a flexible tool that has potential to help fisheries managers plan for a future that is full of uncertainty by working with the uncertainty rather than attempting to reduce it. Participatory scenario planning also takes advantage of the already-strong connections between fishery managers and stakeholders, making it a promising tool for NOAA Fisheries to use in planning for sustainable fisheries management in all kinds of futures.

REFERENCES

Beach, D. M., & Clark, D. A. (2015). Scenario planning during rapid ecological change: lessons and perspectives from workshops with southwest Yukon wildlife managers. *Ecology and Society*, 61.

Bednaršek, N., Feely, R. A., Beck, M. W., Alin, S. R., Siedlecki, S. A., Calosi, P., . . . Spicer, J. I. (2020). Exoskeleton dissolution with mechanoreceptor damage in larval Dungeness crab related to severity of present-day ocean acidification vertical gradients. *Science of the Total Environment*, In press.

Bizikova, L., & Hatcher, B. G. (2010). *Scenario-Based Planning for a Changing Climate in the Bras d'Or Ecosystem.* Winnipeg: International Institute for Sustainable Development.

Bohnet, I., Bohensky, E., Gambley, C., & Waterhouse, J. (2008). *Future Scenarios for the Great Barrier Reef Catchment.* Canberra, Australia: CSIRO .

Borgaard, D., Dick, D., Star, J., Alexander, M., Bernier, M., Collins, M., . . . Staudinger, M. (2019). *Atlantic Salmon (Salmo salar) Climate Scenario Planning Pilot Report.* Gloucester, MA: Greater Atlantic Region Policy Series [19-05] NOAA Fisheries Greater Atlantic Fisheries Regional Office.

Boudreau, D., Crooks, J., Goodrich, K., & Lorda, J. (2016). *Scenario planning: overcoming uncertainty and informing Action.* Imperial Beach, CA: Tijuana River National Estuarine Research Reserve.

National Park Service. (2013). *Using Scenarios to Explore Climate Change: A Handbook for Practitioners.* Fort Collins, CO: National Park Service Climate Change Response Program.

Oteros-Rozas, E., Ravera, F., & Palomo, I. (2015). Participatory scenario planning in place-based social-ecological research: insights and experiences from 23 case studies. *Ecology and Society*, 32-49.

Peterson, G., Cumming, G. S., & Carpenter, S. R. (2003). Scenario Planning: a Tool for Conservation in an Uncertain World. *Conservation Biology,* 358-366.

Planque, B., Mullon, C., Arneberg, P., Eide, A., Fromentin, J.-M., Heymans, J. J., . . . Thorvik, T. (2019). A participatory scenario method to explore the future of marine social-ecological systems. *Fish and Fisheries*.

Reed, M., Kenter, J., Bonn, A., Broad, K., Burt, T., Fazey, I., . . . Ravera, F. (2013). Participatory scenario development for environmental management: A methodological framework illustrated with experience from the UK uplands. *Journal of Environmental Management*, 345-362.

Rowland, E. L., Cross, M. S., & Hartmann, H. (2014). *Considering multiple futures: Scenario planning to address uncertainty in natural resource conservation.* US FIsh and Wildlife Service.

Runyon, A., Carlson, A., Gross, J., Lawrence, D., & Schurmann, G. (2020). Using scenarios to explore climate change: a handbook for practitioners. *Parks Stewardship Forum*.

Santora, J. A., Mantua, N. J., Schroeder, I. D., Field, J. C., Hazen, E. L., Bograd, S. J., . . . Forney, K. A. (2020). Habitat compression and ecosystem shifts as potential links between marine heatwave and record whale entanglements. *Nature Communications*, 1-12.

Schumann, S. (2017). *Report of the workshop "Future-proofing Rhode Island's Commercial Fisheries".* South Kingstown, RI: Resilient Fisheries RI.

Star, J., Fischelli, N., Schuurman, G., Welling, L., Rood, R., & Briley, L. (2015). *Apostle Islands National Lakeshore Climate Change Scenario Planning Workshop Summary.* National Park Service.

Townsend, H., Harvey, C. J., deReynier, Y., Davis, D., Zador, S. G., Gaichas, S., . . . Kaplan, I. C. (2019). Progress on Implementing Ecosystem-Based Fisheries Management in the United States Through the Use of Ecosystem Models and Analysis. *Frontiers in Marine Science*.

Weeks, D., Malone, P., & Welling, L. (2011). Climate change scenario planning: A tool for managing parks into uncertain futures. *Park Science*, 26-33.

APPENDIX 1: SCENARIO PLANNING GUIDES AND HANDBOOKS

Title	Organization	URL
Using Scenarios to Explore Climate Change: A Handbook for Practitioners	US National Park Service	https://www.nps.gov/parkhistory/online_books/climate/CCScenariosHandbookJuly2013.pdf
Scenario planning for climate change adaptation: A guidance for resource managers	Point Blue Conservation Science and the California Coastal Conservancy	http://www.prbo.org/refs/files/12263_Moore2013.pdf
Considering multiple futures: Scenario planning to address uncertainty in natural resource conservation	US Fish and Wildlife Service	https://www.fws.gov/home/feature/2014/pdf/Final%20Scenario%20Planning%20Document.pdf
Scenario planning: a tool for conservation in an uncertain world	*Conservation Biology*	https://www.researchgate.net/publication/227600228_Scenario_Planning_a_Tool_for_Conservation_in_an_Uncertain_World
Oregon Scenario Planning Guidelines	Oregon Sustainable Transportation Initiative	https://www.oregon.gov/ODOT/Planning/Documents/Oregon-Scenario-Planning-Guidelines.pdf

APPENDIX 2: SCENARIO PLANNING PROJECTS

Title	Lead author	Year Published	Location	Total project time	# Workshop Participants	# Scenarios	Scenario method	Scenario type
A holistic approach to studying social-ecological systems and its application to southern Transylvania	Hanspach, J	2014	central Romania	unknown	unknown	4	matrix	semi-quantitative
A participatory scenario method to explore the future of marine social-ecological systems	Planque, B	2019	Barents Sea	unknown	18	81 generated, 3 examined	combined matrices	qualitative
Acadia National Park Climate Change Scenario Planning Workshop*	Star, J	2016	Maine, USA	unknown	44	4	baseline with alternatives	semi-quantitative
Apostle Island Climate Change Scenario Planning Workshop*	Star, J	2015	Wisconsin, USA	3 months	38	3	baseline with alternatives	semi-quantitative
Atlantic Salmon Scenario Planning Pilot Report	Borggaard, D	2019	Northeastern USA	1 year	22	4	matrix	semi-quantitative
Climate Futures and Rural Livelihood Adaptation Strategies in Nusa Tenggara Barat Province, Indonesia†	Butler, JRA	2011	Nusa Tenggara Barat, Indonesia	3 years	32	4	matrix	qualitative
Climate Futures, Ecosystem Services and Livelihood Adaptation Strategies in West New Britain Province, Papua New Guinea†	Butler, JRA	2012	West New Britain, Papua New Guinea	2 years	17	4	matrix	qualitative
Current and Future Challenges in the Great Limpopo Transfrontier Conservation Area	Murphree, M	2010	Mozambique, South Africa, and Zimbabwe	3.5 years	unknown	4	matrix	qualitative
Erub Yesterday, Today and Tomorrow: Community Future Scenarios and Adaptation Strategies†	Bohensky, E	2014	Torres Strait Islands, Australia	3.5 years	30	4	matrix	qualitative
Evaluating taboo trade-offs in ecosystems services and human well-being	Daw, T	2015	Mombasa, Kenya	unknown	12-14	4	narrative	qualitative
Exploring Futures of Ecosystem Services in Cultural Landscapes through Participatory Scenario Development in the Swabian Alb, Germany	Plieninger, T	2013	Germany	more than 1 year	7-14	2 each in 2 locations	matrix	qualitative
Future Ecosystem Services in a Southern African River Basin: a Scenario Planning Approach to Uncertainty	Bohensky, E	2006	Gariep River Basin, Lesotho and South Africa	unknown	unknown	4	adaptation of MEA scenarios	qualitative
Future Scenarios for the Great Barrier Reef Catchment†	Bohnet, I	2008	Queensland, Australia	unknown	41	4	matrix	qualitative
Integrating Climate Change in Transportation and Land Use Scenario Planning	Rasmussen, B	2015	New Mexico, USA	unknown	unknown	3	baseline with alternatives	semi-quantitative
InVEST Scenarios Case Study: Oregon, USA	Nelson, E	2012	Oregon, USA	2.5 years	20	3	adaptation of InVEST scenarios	semi-quantitative
North-central California Coast and Ocean Climate-Smart Adaptation Project	Hutto, S	2016	Greater Farallones National Marine Sanctuary, California, USA	1.5 years	24	4	matrix	qualitative
Participatory Scenario Planning for Protected Areas Management under the Ecosystem Services Framework: the Donana Social-Ecological System in Southwestern Spain	Palomo, I	2011	southern Spain	unknown	32-34	4	adaptation of MedAction scenarios	qualitative

Title	Lead author	Year Published	Location	Total project time	# Workshop Participants	# Scenarios	Scenario method	Scenario type
Puget Sound Future Scenarios	Puget Sound Nearshore Partnership	2008	Washington, USA	2 years	38	6	combined narrative scenarios	qualitative
Resilient Fisheries RI	none	2018	Rhode Island, USA	2.5 years	45	4	combined narrative scenarios	qualitative
Resource Management and Operations in Central North Dakota*	Fisichelli, N	2016	North Dakota, USA	unknown	unknown	4	baseline with alternatives	semi-quantitative
Salmon 2050	Trammell, EJ	2016	Kenai Peninsula, Alaska	~1 year	unknown	5	narrative	qualitative
Scenario Planning During Rapid Ecological Change	Beach, D	2015	Yukon Territory, Canada	1 year	6-9	4	matrix	qualitative
Scenario Planning in the Great Basin Region	Wall, T	2015	western USA	about 8 months	10-15	4	combined matrices	qualitative
Scenario Planning: Overcoming Uncertainty and Informing Action	Boudreau, D	2016	Tijuana River Estuary, USA and Mexico	about 2 years	10-40	4	matrix	qualitative
Scenario-based planning for a changing climate in the Bras d'Or Ecosystem	Bizikova, L	2010	Nova Scotia, Canada	unknown	at least 21	3	baseline/best/worst	qualitative
Scenario-based stakeholder engagement: Incorporating stakeholders preferences into coastal planning for climate change	Tompkins, E	2008	Christchurch Bay and Orkney Islands, UK	unknown	13-20	4	matrix	qualitative
Social-Ecological Scenarios for the Eastern Cape	Hamann, M	2012	Eastern Cape Province, South Africa	unknown	19	4	matrix	qualitative
Using Climate Change Scenarios to Explore Management at Isle Royale National Park*	Fisichelli, N	2013	Michigan, USA	unknown	22	4	baseline with alternatives	semi-quantitative
Using Scenarios to Assess Possible Future Impacts of Invasive Species in the Laurentian Great Lakes	Lauber, T	2016	north central USA	15 months	10	15 total, across 5 species	expert opinion narrative	quantitative

* These projects were done by the US National Park Service following the NPS scenario planning protocol.

† These projects were done by Commonwealth Scientific and Industrial Research Organisation of Australia and all follow similar processes.