Introduction

This document outlines four draft scenarios that describe different possible futures for east coast fisheries in an era of climate change. The scenario framework is based on initial conversations held at a scenario creation workshop on June 21-23, 2022, attended by approximately 75 east coast fishery stakeholders and support staff. The draft scenarios were subsequently refined, based on comments received at two 'scenario deepening' webinars attended by over 100 fishery stakeholders.

Two core questions about the future - critical uncertainties - form the basis for the scenario framework:

1. What happens to stock production/species productivity by 2040 as climate change continues? Does it result in declining productivity (alongside worsening habitat, and low rates of species replacement), or is productivity mostly maintained (with adequate habitat and sufficient levels of species replacement)?
2. How unpredictable are ocean conditions, and how well is science able to assess and predict stock levels and locations by 2040? Do conditions become far more unpredictable, where existing science is clearly unable to provide much useful information, or are conditions sufficiently predictable to allow science to provide mostly accurate information about stocks and location?

Combining these uncertainties results in a 2x2 matrix that creates four distinct quadrants. None of these quadrants are predictions of what will happen in the next 20 years. Instead, they merely outline what might happen to ocean conditions, stocks and other changes to coastal communities. The scenarios also contain storylines and suggestions as to how fishing industry participants, managers, other ocean use sectors, and seafood consumers might adapt, react to and prepare for such conditions. We have often used specific examples as devices to add detail and color to the scenarios. These are meant as illustrations and not as specific suggestions for what will happen to a particular species, region or management action.

While the scenarios are designed to be divergent from each other, it is also important to acknowledge that there are some aspects that are broadly predictable over the next 20 years, so these elements will be reflected in all of the scenarios.

Across the scenarios, we can assume that ocean temperatures will increase in the next 20 years which will affect marine species biology and distribution. Regions are likely to exhibit differences in seasonal temperatures, and primary production will vary across different regions. We can expect that sea levels will rise. In terms of economic and social changes, it is likely that the coastal population will grow, and new and changing ocean

uses will create more competition - for space and labor - for fisheries. These factors are features of each of the scenarios, but their impact might be different across quadrants.

How to Read and Use these Scenarios

The scenarios are intended to be used as a platform from which we can imagine whether and how fishery management and governance might need to change in future. Below, we pose four categories of questions to consider while reviewing the scenarios.

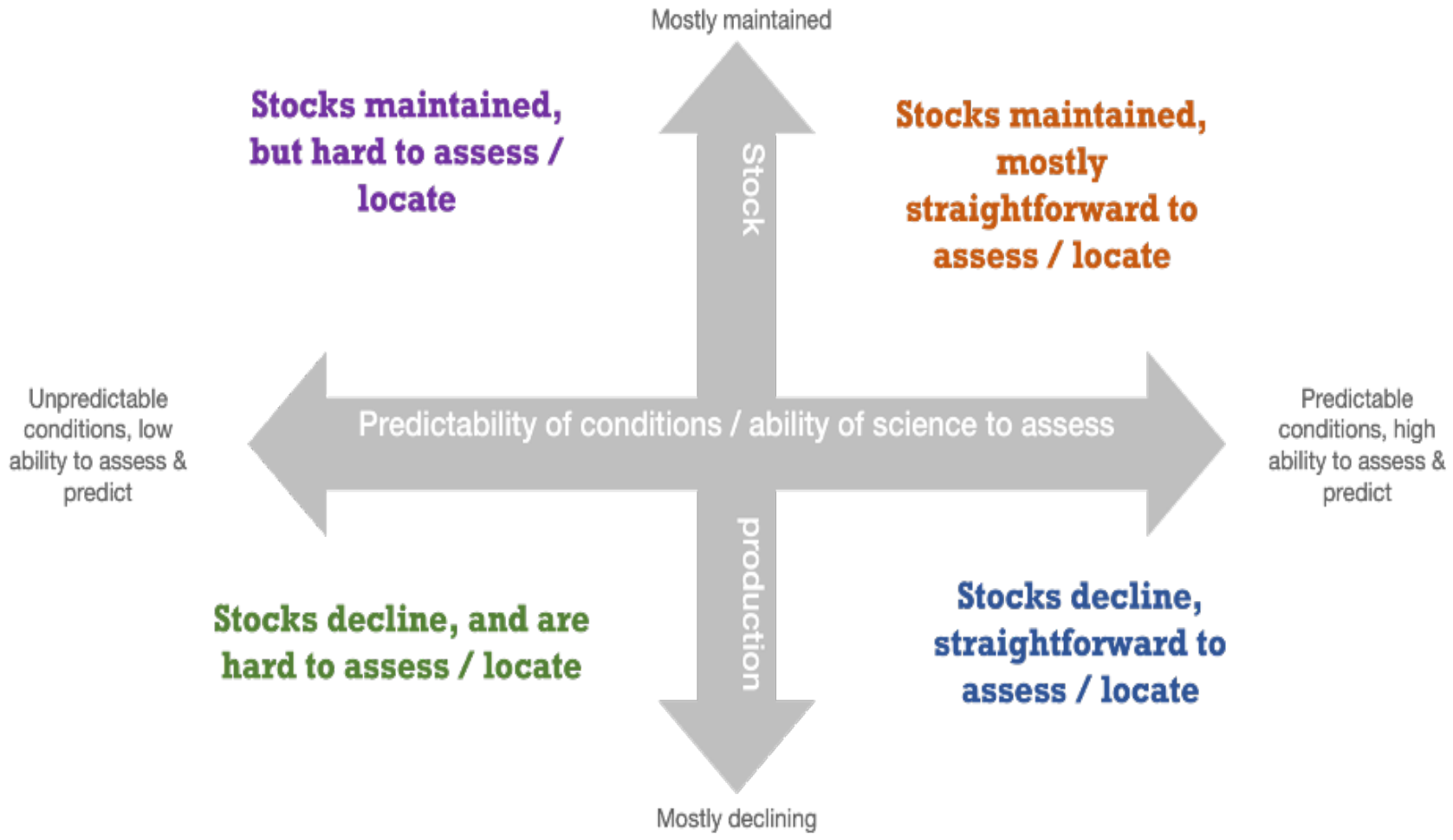
1) Management and Industry Adaptability / Flexibility / Nimbleness
   a) What does successful adaptability/nimbleness look like in this scenario for managers? For industry?
   b) What are the main barriers to effective adaptability in this scenario?
   c) If you knew this scenario was going to play out, what actions would you propose now, so that operators, communities and managers could adapt to cope with conditions in this scenario?

2) Data & Science
   a) What are the biggest data & science challenges facing fishery managers in this scenario?
   b) What new data & science opportunities emerge in this scenario?
   c) If you know this scenario was the future, what actions should fishery managers take now to ensure that data & science contribute to fisheries' success (data collection, coordination of existing streams, data usage, data sharing)?

3) Alternative Ocean Uses
   a) What are the most significant challenges for fishery managers posed by new ocean uses (aquaculture, offshore wind, shipping, tourism) in this scenario?
   b) What opportunities are presented by new ocean uses in this scenario?
   c) If you knew this scenario was going to play out, what would you do now to ensure that alternative ocean uses resulted in a positive or minimal impact on fisheries?

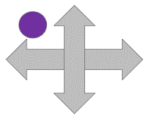
4) Cross-Jurisdictional Management & Governance
   a) What major stresses would be placed on existing cross-jurisdictional (Council/Commission/State) governance arrangements in this scenario?
   b) Would current approaches for updating management authority over a fishery work well? Here, management authority refers to the entity (Council(s), Commission, or NOAA) responsible for developing the management plan.
   c) What mechanisms for changing management authority need to be considered? For example, automatic triggers based on changes in stock distribution?
   d) What management challenges are present for species that move across jurisdictional boundaries?
   e) What actions/changes are needed to better manage species that move across jurisdictional boundaries?

Final Scenario Framework



Main Themes of Each Scenario

OCEAN PIONEERS "Weird weather and crazy conditions." That's what fishing operators and fishery managers are facing in 2040. Life on the ocean is remarkably different compared to 20 years ago. Climate change has prompted more investment in alternative energy and aquaculture. Seasons and locations of fisheries change unpredictably, and traditional science is unable to make accurate assessments. Despite this, fishermen report they are encountering plenty of seemingly healthy stocks. Ocean pioneers thrive in these turbulent conditions. Success doesn't come easy - it requires taking risks (such as investments in new data-gathering technology), deep pockets and an ability to ride out the storms of uncertainty. There are shifts in social and cultural connections and those who are able to work together and adapt can often improve their economic outcomes.	**CHECKS AND BALANCE** Good science, smart collaboration and tolerable conditions allow East Coast fisheries to cope with the challenge of climate change in 2040. But nothing is easy: stocks shift and expand their ranges, while busier coasts and new offshore activity create accessibility challenges for both commercial and recreational fishermen. Investments in habitat protection and restoration begin to reverse decades of damage and loss. Science capacity is boosted, delivering improved ocean monitoring, real-time catch reporting and population monitoring. A prosperous ocean economy leads to competition (e.g., between fisheries and aquaculture) but also collaboration (e.g., as fisheries science is boosted by data-gathering sensors on wind energy installations). Changing management approaches help usher in more extensive opportunities and economic benefits for fisheries.
COMPOUND STRESS FRACTURES Several sources of stress have led East Coast fisheries to breaking point by 2040. Shifts in ocean currents and extreme weather events have tipped ecosystems out of balance. Major storms lead to more pollution and degraded habitats. Healthy stocks are scarce. Low abundance leads to reduced harvests and protected species regulations close several fishing grounds. Science is unable to help, as stock assessment data cannot cope with such a changeable and volatile ecosystem. Even fishermen's local ecological knowledge is unreliable or irrelevant. Trust between stakeholders is in short supply, illustrated by fractious debates over the siting of offshore wind installations. Operators are forced to shift to lower trophic level species, and government support is needed to save a few selected fisheries.	**SWEET & SOUR SEAFOOD** "The science is good, but the news is bad." In 2040, climate change is affecting ocean and stock conditions in ways long predicted by scientists. Stocks have shifted their range while productivity and abundance have declined for most relevant species. Better forecasting techniques help fishermen prepare for marine heatwaves and localized die-offs. Aquaculture provides a much-needed alternative as wild-caught seafood declines, and better science ensures that any pollution dangers are minimized. There are signs of a few smart management decisions (such as limits on newly arriving species) and adaptation from fishing operators, but most management approaches have not adapted to the tougher conditions of today, and those on the horizon.



Scenario Narratives

Ocean Pioneers

"Weird weather and crazy conditions." That's what fishing operators and fishery managers are facing in 2040. Life on the ocean is remarkably different compared to 20 years ago. Climate change has prompted more investment in alternative energy and aquaculture. Seasons and locations of fisheries change unpredictably, and traditional science is unable to make accurate assessments. Despite this, fishermen report they are encountering plenty of seemingly healthy stocks. Ocean pioneers thrive in these turbulent conditions. Success doesn't come easy - it requires taking risks (such as investments in new data-gathering technology), deep pockets and an ability to ride out the storms of uncertainty. There are shifts in social and cultural connections and those who are able to work together and adapt can often improve their economic outcomes.

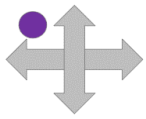
Ocean Conditions and Stock Productivity

In this scenario, ocean waters continue to warm, but rates of warming vary across regions. Environmental conditions and climate drivers are largely unpredictable, complex, and full of shocks and wild card events. Weather patterns and events become increasingly abnormal and harder to predict, including storms, heatwaves, localized warming, and severe weather events. Environmental change is not consistent, and there are spatial and temporal differences in the direction of climate drivers. Seasonal patterns and timing are changing, but with limited interannual predictability. Annual variability in currents and the cold pool contributes to the unpredictability of conditions.

Primary production is high due to increased upwelling and storms. Habitat generally remains of sufficient quality and quantity to support productive stocks. For some stocks, habitat is enhanced by the addition of more structure from wind farms on the continental shelf. Overall, fish stocks are doing well and the food web structure remains robust. Many species distributions have shifted, but species leaving an area are largely replaced by new species of similar economic value moving in. Most areas along the coast see changing and sometimes fluctuating species composition, but fishermen report that they are still encountering seemingly healthy stocks.

Science and Stock Assessments

The volatility in environmental conditions increases seasonal variability which makes it difficult to assess and forecast the health of specific marine resources in the current manner as stock availability and distributions are impacted. While overall productivity remains high, individual stock productivity is variable, with many species experiencing boom and bust years and frequent pendulum swings. Increased alternative energy and other ocean uses contribute to difficulties with stock assessments, as associated structures restrict traditional trawl survey areas. Seasonal management regulations



become more difficult to set and less successful as it becomes harder to predict where fish will be at a given time of year.

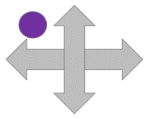
Mismatches arise between how data is collected and where the fish are, both spatially and temporally. Assessments have a difficult time keeping up, and eventually it becomes difficult to assume that stock assessments are robust. It is also difficult to determine "sustainable" biomass and fishing levels given changing distributions and fluctuating productivity of species. Because there is little baseline information about how stocks may fare under new ranges and conditions, it is often unclear what targets are appropriate. Managers suspect that for some species, changes in productivity and stock size are not being captured adequately by traditional assessments; in other cases, assessments indicate large fluctuations in biomass that may not be occurring in reality. Overall productivity seems to be high yet the concerns about the accuracy of assessments leads some to consider if scientific uncertainty buffers should be reevaluated. A new paradigm for determining sustainable fishing parameters emerges, with many 'historic' stock assessments being replaced with more 'pragmatic' methods for setting catch limits. It is also difficult for scientists to predict species range changes, as it seems to vary by species and region, and there are few consistent trends across years.

In general, scientists and managers struggle to keep up with changing conditions and increasing management needs. In many situations the traditional scientific process is too slow to provide advice on management-relevant time scales. Technology helps address some issues arising under this scenario, but isn't able to solve all problems. Increased use of transparent technology such as electronic monitoring and transmission of real time fishing data are able to give managers more information when traditional scientific methods and surveys struggle to keep up. While fishing industry and citizen science data are seen as increasingly critical, managers are still grappling with the best ways to use it, and tackling complicated questions around ownership of data. New data streams can also change conclusions about stock health, compounding uncertain and fluctuating estimates of biomass.

Fishing Practices and Pressures

Local ecological knowledge and innovative technological expertise is at a premium as fishermen adapt. Their data provides critical on-the-water observations and catch information. Management begins to rely more on the data and information collected and transmitted from fishermen on the water, as well as shoreside data collection at docks. Industry participants continue to push for this data to be used to its full potential.

Variations and unpredictability in environmental conditions and fish distributions lead to variable fishing success from year to year, creating "boom" and "bust" years for commercial and recreational fishing communities. In addition, sometimes harvesters must work around dangerous fishing conditions created by unexpected and extreme



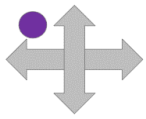
weather events. In the commercial sector, this creates market swings that cause frustration in the industry - it is hard to create stable seafood markets under these conditions. However, this is partially offset by increased public demand and willingness to pay a premium for sustainable seafood. Some smaller niche businesses succeed in adapting to fluctuating markets and new supply chain dynamics, but that requires courage, risk-taking, and a good amount of luck. The fishing industry faces a constant struggle to bring in new players given so much variability and uncertainty about future income potential. The next generation generally pulls back on investing in fishing industry businesses, aside from a few players who try to take advantage of new opportunities in a markedly different fisheries world.

Recreational for-hire businesses suffer in many areas as demand for trips drops: it is difficult to keep clients coming back with inconsistent catch and less familiar target species as local availability changes. However, a few recreational for-hire communities positioned in an area with an influx of popular for-hire target species are doing well. Private anglers are more adaptable as information about locally abundant fish populations travels through the angling community quickly enough to provide quality fishing opportunities for anglers with access to private boats or productive shore fishing sites.

Winners and Losers

Patterns of who is catching what have changed quickly. Inequity issues are prominent as differences in adaptability, largely driven by access to capital, have become clearer. For both commercial and recreational fisheries, those with access to more capital are able to ride out difficult times and take advantage of good stock conditions. Many others - often with fewer resources - struggle to cope with such uncertainty. There is a trend toward consolidation in the industry.

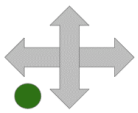
Winners are those who participate in highly mobile fleets as well as those who are able to invest in fleet and gear technology to adjust to fishing in deeper waters and/or to traveling further distances. But the longer travel times come at a cost for fishermen and their families, especially those with children. Investing in more fuel-efficient vessels contributes to success, given fluctuations in the cost of fuel. But such new technology is more expensive, even if over time it pays for itself. More complex business models adapt better to a different species composition, changing environmental conditions and weather patterns, and market conditions. Operators that are less able to diversify their target species and/or less able to travel to find fish are struggling. Those who cannot fish further offshore or by traveling longer distances along the coast find their local ecological knowledge, gathered in some cases over multiple generations, has become less useful as the ocean and the stocks change. For some gear types, smaller, more nimble vessels are at an advantage.



Extreme weather also creates winners and losers at the shoreside community level. Depending on local resources and wealth, some communities struggle to reinvest after major storms, while others use these events as an opportunity to invest in improved infrastructure. Ports that have already invested early in the protection of the coastline, driven by sea level rise and previous storms, are benefitting. Regional factors also influence vulnerability to sea level rise and extreme weather events. For example, ports in Virginia are subsiding which accelerates sea level rise impacts while the rocky shoreline of Maine is rebounding and less vulnerable to erosion from storms. On the other hand, coastal areas off of the Chesapeake Bay, Delaware Bay, and Hudson Bay are more vulnerable to water quality changes due to freshwater and storm runoff. Meanwhile, smaller fishing communities, especially those that had become dependent on a small range of climate-at-risk species, are having trouble adapting. Some suffer a loss of cultural identity, social bonds, and sense of place. However, some of these communities find ways to work together to adapt and thus strengthen their social and cultural connections.

Alternative Ocean Uses

While stocks are overall productive, many players have lost access to historically important fishing grounds due to space competition with new ocean uses, compounding industry struggles to maintain consistent access to shifting stocks and making it difficult to use accumulated local ecological knowledge. Extensive offshore wind and other ocean energy uses are changing access to traditional fishing grounds, so many fleets have shifted effort to less productive fishing grounds or expanded into previously un-fished areas. Shifts in the location of fishing effort combined with shifts in the range of marine species leads to changes in patterns of interactions with protected resources, which are now more difficult to predict. In some cases, increased interactions with whales and other protected species place further constraints on where fishing can occur. In addition, reduced available fishing area leads to increased user conflicts, between and among different gear types and between the fishing industry and adjacent uses. These changes have excluded participants who were unable or unwilling to modify their fishing practices.



Compound Stress Fractures

Several sources of stress have led East Coast fisheries to breaking point by 2040. Shifts in ocean currents and extreme weather events have tipped ecosystems out of balance. Major storms lead to more pollution and degraded habitats. Healthy stocks are scarce. Low abundance leads to reduced harvests and protected species regulations close several fishing grounds. Science is unable to help, as stock assessment data cannot cope with such a changeable and volatile ecosystem. Even fishermen's local ecological knowledge is unreliable or irrelevant. Trust between stakeholders is in short supply, illustrated by fractious debates over the siting of offshore wind installations. Operators are forced to shift to lower trophic level species, and government support is needed to save a few selected fisheries.

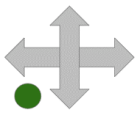
Ocean Conditions and Stock Productivity

This is a world in which ocean temperatures are increasing, sea levels are rising, currents are unpredictable, and marine heatwaves have increased in frequency and duration. There is a climate tipping point where the Atlantic Meridional Overturning Current, AMOC, becomes unstable. Severe storms have increased in frequency, which creates brown water and temporary dead zones nearshore, which in turn disrupts spawning events. Despite targeted restoration efforts, coverage of submerged aquatic vegetation, a climate-vulnerable coastal habitat upon which many species depend, is reduced. Temperature and pH changes vary, with some areas warming and/or acidifying more rapidly than others. Unpredictability is a hallmark.

Under these conditions, fisheries production and habitat quality has declined. Species distributions are shifting, and for some regions, there is little replacement of important commercial and recreational species that have moved into other areas or declined in abundance. Generally, species diversity has declined, while range expansion and contraction are extremely variable. Overall, the fish community looks quite different from today. Undesirable or low dollar value species that have traditionally been discarded (e.g., sculpins and searobins) are common. Abundance of lower trophic level species increases as top predators decline. Generalist species that occupy a range of habitats and do not rely on particular prey are more successful.

Many fishermen need to change stocks and/or traditional fishing grounds and find their decades-long or even intergenerational local ecological knowledge is unreliable or irrelevant. Even for those traditional species that remain, fishermen switching to a traditional species they had not previously fished need to learn new local ecological knowledge. Fishermen already fishing those species do not easily share knowledge and the newcomers' catches (and income) suffer during that learning period.

Estuaries, which are important fish nursery grounds, are experiencing declines in productivity due to habitat degradation. This is caused by several factors, including sea level rise and changes in salinity due to alterations of freshwater outflows. There is less



larval dispersal and increased larval mortality. Saltmarsh areas are reduced due to droughts, and coastal population growth leads to increased demands for coastal armoring to protect infrastructure, which prevents natural landward migration of these habitats. Coral habitats, which support some southeastern species, decline in quality.

Changes in the distribution and abundance of plankton lead to shifts in where large whales occur. Efforts to conserve listed fish species, such as Atlantic sturgeon and Atlantic salmon, continue, but populations remain depleted.

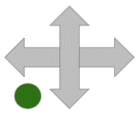
Science and Stock Assessments

Science is not able to predict the changes occurring in this complex and unpredictable ocean - and partly as a result, funding does not keep pace with ever-increasing demands. Stock assessment and status determination suffer. For most stocks, data streams and assessments lag behind current conditions, and are not useful for predicting dynamics. Scientists' assessments often clash with the experience of fishermen, leading to a lack of trust in the data. New fisheries emerge, targeting species lower on the food web, but a lack of knowledge of these stocks often leads to overexploitation. In some cases there is limited ability to obtain permits to target locally available and abundant species. Many stocks experiencing range shifts are incorrectly classified as overfished, and these false flags undermine trust in the management process. Over time, there is less funding for science and fishery management in general.

In a few fisheries, scientists and managers eventually learn to use novel, real-time data streams from some stocks to conduct more frequent management track assessments. Through advances in electronic monitoring (EM) some fleets have adopted 100% monitoring coverage. These fleets are able to provide more real-time data to managers and scientists, allowing for more nimble management of stocks, both in-season and annually. While many fishery management plans and regulations remain inflexible and are slow to change, those with enhanced monitoring have started to develop new approaches to better suit the needs of the changing fisheries.

Social and Economic Conditions

The costs of harvesting fish continue to rise and profit margins shrink. Fuel prices are volatile, and costs for other items such as ice, fishing gear, and other provisions increase regularly. Vessels are more transient, chasing fish northward and offshore, which increases transit times from home ports. This places stress on crew members and their families and leads to higher fuel consumption. Commercial harvesters find it difficult to retain and recruit crew. Current crew are aging and retiring fishermen are not replaced - fishing is not an attractive industry for most, especially young people. Some young people from fishing families still want to enter the industry, and manage to leverage family vessels and social capital to stay in the industry. But overall, the employment picture is grim. Processors are also having trouble retaining workers, given that cutters



often specialize in certain species and the species landed are changing, often unpredictably.

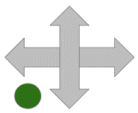
There are other stresses facing fishing operators. Precautionary management of protected species (including large whales) constrains fixed gear fisheries. Discards of diseased fish are problematic. Significant atrophy occurs within some fleets. Damage from more frequent and extreme weather events has a compounding negative impact on some coastal communities, including fishing ports. As it becomes harder to succeed within existing fishery laws and regulations, trust and open communication between the fishing and management communities erodes.

More people move to the coast to gain relief from higher inland temperatures, exacerbating pre-existing gentrification problems. This causes ever-growing development-related stresses on nearshore habitats. Climate impacts on agriculture lead to rises in food prices, and ultimately, this leads to higher demand for seafood protein. While this provides opportunities for fisheries, consumers are primarily concerned with price and taste and are willing to buy imported or tissue cultured products so long as they are inexpensive and enjoyable to eat. There is limited broadscale emphasis on locally caught seafood, though some consumer-supported fisheries and other direct marketing businesses retain sufficient customer base to stay afloat or even prosper. Further complicating matters, there are international tensions which also affect seafood trade. Faced with such multiple and mounting pressures, the industry experiences significant consolidation, with marginal players often forced to sell up and move out. This has a damaging effect on fishing communities, with traditional activity shrinking or disappearing. Cultural identity, sense of place, and social bonds deteriorate in some fishing communities, especially those with significant influxes of population from further inland.

Recreational fishing by boat becomes very expensive and is usually only available to the wealthy. Some of the more sought-after species move further offshore and occur at lower densities, making them harder to target. As a result, new community groups form to lobby for government support to maintain access for lower-income recreational fishermen. The profile of shoreside angling changes in many areas of the Southeast, where reductions in fish habitat and water quality render coastal waters unsuitable for species that were previously common there. This has ripple effects for bait and tackle shops and other recreational fishing infrastructure. It especially impacts those fishing for food, as the lower value species they had traditionally depended on are less common or being landed by more purely recreational fishermen in place of their traditional recreational species that are not as available.

Alternative Ocean Uses

As fishing activity declines due to uncertainty and stock changes, fishing is no longer the dominant activity in the ocean. Offshore energy and shipping now take up more



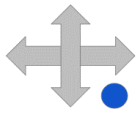
space and, despite good intentions, these industries don't need to rely on a healthy ocean ecosystem. Wind installations and shipping create damaging effects on nearshore and offshore fish and fisheries.

More funding is directed to these new ocean uses, with managers and scientists focusing their attention towards these new opportunities sometimes at the expense of researching changes in fisheries. Atrophy in the fishing industry allows ports to expand and change to accommodate offshore wind and shipping, but this does little to support fishing operations. Smaller fishing ports are lost without targeted interventions. Such interventions are successful where the right mix of resources come together, and a few ports experience a renaissance, where hub ports with diverse fishery support services remain accessible and the number of fishing vessels increases for the first time in decades. But many other fishing communities lose local waterfront space, leading fishing families to struggle to remain in fishing. In some cases, fishing families are pushed even further inland than they had been by previous gentrification issues. Fishing families from a single community end up scattered across several communities, losing their sense of place and sometimes their cultural identity as fishing families. This leads to social disruption as former fishermen struggle to find other work that is as fulfilling as fishing.

Responses to Difficult Conditions

As a short-term response to these extreme harvesting and marketing stresses, the Federal government acknowledges fisheries disasters and increases support for selected domestic fisheries. It supports the development of domestic markets for fish and reduces imports through tariffs. This includes market development, advertising, science, technology, and workforce training. Workforce training is especially valuable when it builds on and expands existing programs with proven track records. Given limited resources, specific fisheries are targeted for these interventions because they likely have staying power under new environmental conditions. In fisheries that receive these interventions, there are successes around reduced operational costs, new markets, and innovative science programs. Some fisheries and fleets do not survive the cataclysm. Some fishing communities lose vessels that depended on those fisheries and fleets, and eventually fishing infrastructure and population. This frays the social bonds, cultural identity and sense of place in those towns.

Despite these fractures, there are some bright spots on the horizon for the industry. Battery technology improves to allow some vessels to switch to more efficient electric vessels and improvements in radar systems allow for safer navigation. Offshore aquaculture expands to both supplement and enhance wild capture fisheries. Because both wild capture fisheries and aquaculture require processing infrastructure, aquaculture-related enhancements benefit wild capture fisheries as well. Shellfish aquaculture mitigates coastal water quality concerns in some specific areas, improving habitat for many species.



Sweet and Sour

"The science is good, but the news is bad." In 2040, climate change is affecting ocean and stock conditions in ways long predicted by scientists. Stocks have shifted their range while productivity and abundance have declined for most relevant species. Better forecasting techniques help fishermen prepare for marine heatwaves and localized die-offs. Aquaculture provides a much-needed alternative as wild-caught seafood declines, and better science ensures that any pollution dangers are minimized. There are signs of a few smart management decisions (such as limits on newly arriving species) and adaptation from fishing operators, but most management approaches have not adapted to the tougher conditions of today, and those on the horizon.

Ocean Conditions and Stock Productivity

The earth and oceans continue to warm, particularly in the Gulf of Maine, where the average temperature has risen by ~1.5 degrees since 2022. The Gulf Stream has continued to become more prominent, bringing warmer water along the east coast, and edging out the cooler waters from the north. The cold pool historically present off of the mid-Atlantic is now a rare occurrence. New primary production varies with latitude, but generally, across all areas, we are seeing larger plankton being replaced by smaller species, resulting in lower fish productivity.

There is an increase in stronger and more frequent storms that impact coastal communities most acutely. While predictive capabilities for these storms are good, impacts to fish habitat and infrastructure are high due to the lack of time between storms to repair and restore. Along with storms, increased pollution plus continued warming have impacted habitat type and function, resulting in decreased abundance and a comprehensive shift in available fish stocks in each region. Some towns are faring well, despite these changes, because of the efforts made to develop living shorelines, while providing incentives to private marina owners for ensuring a proportion of the marina is available for commercial and for-hire vessel access.

Despite similar climatic influences, the biological impacts vary between regions due in a large part to local adaptation efforts. Stock distributions have continued to shift, sizes of individual fish are smaller, and productivity of most stocks has decreased. Continued degradation of estuaries and other habitats has contributed to impacts to spawning areas and decreased recruitment.

Science and Stock Assessments

In this scenario, scientific understanding of the oceanographic and biological conditions is very strong, even if the news is not good. Researchers are able to closely track changes in water temperature and stock distribution using a variety of methodologies. These include enhancements to the Federal trawl survey, cooperative research with the fishing, offshore energy, and aquaculture industries, and new

techniques to better model and predict future changes. Marine heat waves continue to be important, but scientists are able to predict them in enough time for fishermen to prepare. Scientists track changes in the environment and share them with management using robust indicators within ecosystem status reports. Their findings indicate declining stocks and worsening habitat, but at least the accuracy of the information provides opportunities for managers to address such problems. Generally, effective management is able to keep pace with new information and identify how to use it to inform timely decisions. But some management is constrained by slow decision-making processes and incongruent approaches along the East Coast.

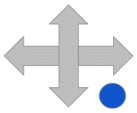
Management Responses

Unregulated access to species in new areas before the broader management program can respond is problematic. This leads to distrust across fishing communities, as groups who have the permits are unable to benefit from expanded stock availability due to complex regulations. However, proactive efforts by one of the region's fishing industry groups resulted in healthy and productive fisheries despite these changes. For example, their actions to limit fishing on the few newly arriving species allowed the establishment of reproducing populations that have generally replaced the cod, Atlantic mackerel, and lobster that have moved north into Canada. However, no trans-boundary agreements were forged to allow New England fishermen to follow the stocks into Canada; this, in addition to a continued market focus on these historical species, led to increased imports of these species rather than focusing on new species in the area. For example, tourists still insist on lobster rolls along the coast of Maine, rather than adjusting to eating the black sea bass that local fishermen are harvesting now.

Adapting to New Conditions

Aquaculture has seen significant growth in the area, driven by demand for protein as the abundance of wild caught seafood declines. Advances in science and technology have led to less pollution from net pens and less reliance on wild caught fish for aquaculture feed. Streamlining of the regulatory process has allowed for aquaculture businesses, including offshore finfish farms and sea ranching, to expand, yet their small ocean footprint does not impact wild fishing to the same extent as other alternative ocean uses.

Fish stock distributions have changed what is available for day-boat fishermen, but their ability to catch those species has stalled the shifts, with a few exceptions. Some fishermen have been able to adjust to fishing for different species, despite the expense associated with acquiring the gear necessary to make those changes. For example, one group has been able to capitalize on turning previously low value, bycatch species into animal feed and fertilizer. Importantly, a shift toward "boutique fisheries" allowed some small-scale fishermen to adapt to the reduced catch limits and new stocks yet still remain economically viable. This occurred because an Alternative Ocean Use area reopened to commercial and for-hire hook and line fishing, primarily targeting highly migratory

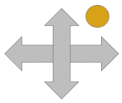


species such as Atlantic cobia. The previous closure of this area had allowed for this previously southern stock to establish a strong sub-population without exploitation. The management body added this species to an existing FMP, with provisions limiting access to previously permitted small vessels only.

Unfortunately, similar efforts were not implemented throughout the region, leading to varying levels of protection for newly arriving stocks, and limited establishment of new populations. This has been especially problematic as the loss of forage fish biomass has impacted all levels of the food web in these areas. Continuation of historical fishing methods and sales, along with poor articulation of priorities or values, has led to the loss of many small-scale fishermen in some areas because they are being replaced by large corporations able to focus on quantity over quality. In such areas, changes in the management process have been far behind the timetable necessary to allow smarter and more cost-efficient permitting changes. This has resulted in an industrialization of the fleet, edging out owner operators with less capital. The variable management response between regions has also led to increased conflict between regions and sectors. Fishermen have also struggled to establish solid marketing of locally sourced fish because consumers are still able to access the historically popular stocks through imports.

Access to fishing areas and stocks by commercial and recreational fishermen is not just impacted by the availability of permits and gear. Privatization of marinas, docks, and other ocean access sites has made it difficult for low and average income commercial and recreational fishermen to take advantage of new opportunities. These access restrictions have also led to substantial and disproportionate impacts on subsistence (food/cultural heritage) fishing, greatly limiting the ability of poorer communities to supplement food sources and of some groups from acquiring specialty species for religious/cultural practices.

As the ocean gets busier, commercial and recreational fishing participation is limited by the physical space available to fish in. New offshore energy and aquaculture structures have narrowed the fishable areas in ways that are not aligned with shifting habitat preferences of target species. Some participants in recreational fisheries have enjoyed an increased access to previously unavailable stocks closer to home, but most struggle to afford the ability to fish in deeper, colder waters. Many recreational fishermen have also been impacted by the loss or diminishing of longtime or even generational family traditions associated with annual or seasonal trips to the shore.



Checks & Balance

Good science, smart collaboration and tolerable conditions allow East Coast fisheries to cope with the challenge of climate change in 2040. But nothing is easy: stocks shift and expand their ranges, while busier coasts and new offshore activity create accessibility challenges for both commercial and recreational fishermen. Investments in habitat protection and restoration begin to reverse decades of damage and loss. Science capacity is boosted, delivering improved ocean monitoring, real-time catch reporting and population monitoring. A prosperous ocean economy leads to competition (e.g., between fisheries and aquaculture) but also collaboration (e.g., as fisheries science is boosted by data-gathering sensors on wind energy installations). Changing management approaches help usher in more extensive opportunities and economic benefits for fisheries.

Ocean Conditions and Stock Productivity

This is a world where societal and policy choices are firmly focused on emissions reduction. This has not yet had noticeable impacts on ocean conditions (temperatures continue to warm and sea levels rise), but more investment and attention is now placed on addressing climate change and environmental concerns. This has resulted in increased funding for science and innovations in data that have improved the ability to predict and assess the impacts of climate change.

Ocean temperatures have increased, leading to extensive shifting stocks and range expansions. Science has been able to accurately predict the changing location of abundant stocks, which is critical to the ability of commercial and recreational fishermen to plan for adaptation.

Public and private investments in estuarine conservation, restoration, and enhancement have created a more robust, foundational support for the ecosystem, food web, and forage and estuarine-dependent managed species. Habitats have improved, enhancing the production of many stocks. Storms are more frequent and intense, but science is able to better forecast and understand the impact of such events, increasing safety in what has historically been one of the highest risk occupations in the U.S.

Fishing Practices and Pressures

Despite advancements in science, commercial fisheries still struggle to thrive, faced with high operational costs and a decrease in product prices. Fishermen travel long distances for their catch, increasing their fuel costs and placing increasing burdens on fishermen and fishing families due to longer absences from home. Meanwhile, some fishermen have further diversified their employment across the seasons, with some adding aquaculture to their seasonal rotations and others periodically driving boats servicing offshore wind platforms. Some fishery participants have adapted well to changing conditions by reconfiguring their vessels, moving to the new locations of their traditional species, utilizing new technologies to find fish more effectively and/or using

less fuel and other resources. But this is a significant amount of work at a time when fishermen are already spread thin trying to keep track of changing oceans, changing ocean infrastructure, and changing management.

Despite a broad abundance of stocks, some commercial fishery participants have decided that the fishing activity is not worth the effort. Many of these fishermen have sold their interest in fishing to corporations and are no longer involved in the industry or have gone to work as captains or crew for corporate fleets where their income is more secure and they no longer have the sole responsibility of responding to the changing fishery conditions. The result has been a general loss of small-scale commercial operators and an increase in corporate interests and aquaculture. Corporations have had better flexibility to sustain larger operations over a wider geographic area.

The recreational sector is strong thanks to abundant production and relatively predictable ocean conditions. Wealth has increased along the coastlines, encouraging expansion of recreational fishing. However, the accessibility to recreational fishing has diminished as the effects of sea level rise, coastal development and gentrification have reduced public access to the ocean via piers, docks, and beaches. Many recreational fishermen must have the income to either fish on for-hire vessels or travel offshore on personal vessels. Those unable to do this are losing access to fish for food, cultural practices, and/or fishing as a family tradition. The for-hire sector adapts to new species and continues to expand, creating an increase in overall recreational fishing. Fishermen in the Southeast have transitioned to different species such as harvesting yellowtail snapper off the reefs of Georgia or conch in North Florida. In the Northeast, recreational trips target black sea bass and spotted sea trout.

As society becomes more concerned with climate change impacts, science is well funded, and its efficiency has improved. Effective ocean monitoring, real time fisheries reporting, and food web and population monitoring are all regular sources of information for fishery participants. Smarter surveys are able to identify changes in species compositions, the habitats both new and traditional species are utilizing, and oceanographic characteristics, all of which lead to a better understanding of the changes in the food web. With proactive and increasingly effective science, species productivity is better assessed, distribution shifts and range expansions are forecast and tracked, and interactions with protected species and bycatch fall to historically low levels. Interactions with protected species and bycatch are further reduced by advances in gear technology developed in both corporate and cooperative research fleets.

As science improved, stock production increased and management evolved. Fishing operators and communities have started to successfully adapt to a range of changing conditions. New markets have been developed, helping to sustain more commercial fisheries and increased recreational opportunities. White and brown shrimp now compete with Maryland crab cakes in popularity and the grouper sandwich has now

become a tourist draw in New Jersey. But the successful evolution of commercial and recreational fisheries was only possible because of changes in management approaches. When effective, such changes provided for a full and flexible balanced use of available stocks, leading to a more diverse array of marketable species along the coast. Without changes to management, extensive opportunities and economic benefits for the commercial and recreational fisheries may not have been realized and there would have been greater impacts to fishing communities and fishing as a way of life.

Alternative Ocean Uses

East Coast waters are now being used for multiple purposes, including extensive wind energy areas and aquaculture. These competing uses have created significant tensions related to fishing rights, opportunities, working waterfronts, and equity. Zoning issues on land combined with impacts of sea level rise create user conflicts. For example, the expansion of wind power has led to a decrease of commercial spaces in working waterfronts, causing commercial fishermen to have issues finding dock space and local dealers. This also exacerbates an already ongoing consolidation of dockside services in hub ports rather than being scattered along the coast.

Gentrification continues to create concerns over accessibility for both recreational and commercial fishermen. Where commercial fishing access is lost, some fishing community members end up moving to other towns, losing their unique sense of place and some of their cultural identity. These communities then lose any remaining commercial fishing infrastructure. Local businesses such as ice vendors and grocery stores lose revenue. Where recreational fishing access is lost, local businesses such as bait & tackle shops have to close, as do some local restaurants and businesses catering to tourists. Some fishing communities, though, find ways to push back against gentrification through new town, county, or state laws that preserve their unique heritage.

More alternative energy activity has resulted in less political leverage for fishermen as energy users become more powerful. However, many fishery and coastal stakeholders have benefited from this new influx of attention and investment. Ocean research and monitoring activity is improved by using offshore wind platforms. Aquaculture and offshore wind drive more infrastructure spending in coastal towns. More generally, fisheries benefit from improved coordination with alternative energy operations, assisted by effective regulatory and management approaches. In addition, aquaculture has expanded and is included in the suite of marketable seafood products.

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Scenarios As Platforms for Thinking About Adaptability

The scenarios above represent four different futures influenced by varying levels of stock productivity/abundance and the level or predictability of ocean conditions. Within each of these four stories, the success of players in the system varied according to whether they (and the system in general) were adaptable to the new and different sets of conditions.

Different degrees of adaptability were in evidence in the scenarios. Sometimes, the stories explained how some regions were more adaptable than others. Sometimes players in the system learned over time, so adaptability was higher in later years compared to earlier. In other storylines, adaptability was determined by the level of capital investment, or sometimes by the willingness to use technology.

It seems clear that the secret to success (for most players) in an era of climate change is an ability to adapt to changing conditions. But what does adaptability mean? Across the scenarios, ideas about adaptability were discussed across several dimensions.

- Many of the scenario stories recognize that fishing operators are inherently adaptable, as they have reacted to changing conditions over many years. Stock availability has varied, fish have changed their ranges, economic challenges have emerged from unexpected sources (like the pandemic). But a future of climate change will put even more pressure on the ability of operators to adapt. The optimistic see no reason why operators won't continue to adapt. The pessimists see that climate change alters conditions so much that it could get more difficult to do so.

- Elements of the scenarios also reflect the fact that operators have only so much influence over their ability to adapt. They might be constrained by external factors, such as "too much change," a lack of resources, technology, or politics. They might also be constrained by more internal factors such as existing skills and conventional attitudes.

- The scenarios also raise questions about who adapts. In some situations, new players come into the market for ocean resources. Energy and aquaculture companies might innovate and become more powerful players, creating a highly adaptable environment that poses real challenges for fishing operators. This links back to the question of the resources and attitudes available for adaptation.

- During scenario creation conversations, fishing operators saw their ability to adapt being constrained by existing fishery management and governance approaches. In a future of climate change, where stocks might move, ranges might expand, and new challenges could emerge from year to year, it is imperative that governance and management recognize the need for their own

approaches to adapt. There is a major concern that current arrangements will limit success, given the need for operators to travel further, catch different stocks, etc., etc.

- Adaptability was also referenced in terms of the legal and regulatory apparatus (mostly the MSA, but also including other federal and state regulatory constraints). At this stage, the scenarios have been written in a way that assumes that the legal and regulatory apparatus remains broadly intact. However, this should not constrain the next stages of the process from generating ideas based on possible changes in the legal and regulatory environment.

To sum up, these scenarios describe ways in which various players and places might adapt (or fail to adapt) to a range of new and different conditions in an era of climate change. The descriptions outline some of the broad contours of possible changes - to fishing practices, use of technology, governance and management etc. -- but they stop short of suggesting specific actions. That is the purpose of the next stage in the overall process. These scenarios should be used merely as platforms, containing hints and provocations to help stakeholders discuss the actions to come.