



August 2022

FEDERAL FISHERIES MANAGEMENT

Opportunities Exist to Enhance Climate Resilience

GAO Highlights

Highlights of [GAO-22-105132](#), a report to congressional committees

Why GAO Did This Study

Commercial and recreational marine fisheries managed by NMFS and regional fisheries managers are critical to the nation's economy. These fisheries contributed nearly \$118 billion to the U.S. gross domestic product and 1.8 million jobs in 2019. The increasing effects of climate change can alter the number and location of fisheries and have negative economic consequences on fishing-reliant industries and coastal communities.

House Report 116-455 includes a provision for GAO to examine federal efforts to prepare and adapt federal or jointly managed fisheries for the impacts of climate change. This GAO report examines, among other things, (1) the extent to which fisheries managers have used climate information and (2) challenges to enhancing the climate resilience of federal fisheries and opportunities to address challenges. GAO reviewed laws, regulations, NMFS documents, and relevant literature. GAO interviewed representatives from all five NMFS regions; NMFS' HMS Division; all eight Councils; and all three interstate commissions, as well as 15 relevant stakeholders, selected based on geographic diversity and other factors.

What GAO Recommends

GAO is recommending that NMFS (1) regularly collect and share information on fishery management activities for enhancing climate resilience and (2) work with federal fisheries managers to identify and prioritize climate resilience opportunities and develop a plan to implement them. The agency agreed with GAO's recommendations.

View [GAO-22-105132](#). For more information, contact Cardell Johnson at (202) 512-3841 or johnsoncd1@gao.gov.

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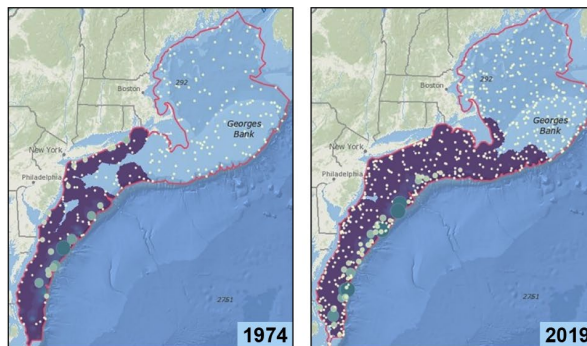
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What GAO Found

Fisheries managers comprised of eight Regional Fishery Management Councils (Councils) and the National Marine Fisheries Service's (NMFS) Atlantic Highly Migratory Species Division (HMS Division) have generally used climate information to a limited extent in fisheries management activities. For example, GAO identified 12 out of 46 fishery management plans and amendments that considered climate-related information. However, many fisheries managers are leading initiatives that could advance the use of climate information in management, such as addressing distributional shifts in species, pictured below. Initiatives include the creation of a special task force to identify actions and tools to better incorporate climate information in fisheries management. Six of nine fisheries managers told GAO that they were not aware of climate-related fisheries management activities taking place in other regions. According to a few stakeholders, fisheries managers could benefit from learning about such actions, but NMFS does not regularly collect or share this information. According to GAO's *Disaster Resilience Framework*, federal efforts can help decision makers better identify and select actions to enhance climate resilience. An effort by NMFS to regularly collect and publicly share information on climate-related activities taken by fisheries managers could help decision makers identify and prioritize resilience measures.

Map from the National Marine Fisheries Service's Distribution Mapping and Analysis Portal Showing Changes in Black Sea Bass Distribution from 1974 to 2019



Source: National Oceanic and Atmospheric Administration. | GAO-22-105132

NMFS and fisheries managers face challenges to enhancing the climate resilience of federal fisheries, including limited data and modeling information, and resource constraints. However, opportunities exist to help address these challenges based on GAO's review of relevant literature and a 2018 NMFS guidance document on fisheries management and climate change. For example, one potential opportunity to help address limited fisheries data involves NMFS partnering with the fishing industry to collect data through equipment on commercial vessels. Most NMFS regions (three of five) have taken some related actions and shared the 2018 guidance document with the Councils. However, GAO found that one Council was not familiar with the document and that NMFS is not actively working with Councils on implementing opportunities that it identifies. According to the principles outlined in the *Disaster Resilience Framework*, NMFS could help address climate-related challenges facing the Councils by collaborating with them to identify, prioritize, and plan to implement opportunities to enhance the climate resilience of federal fisheries.

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Abbreviations

Atlantic Commission	Atlantic States Marine Fisheries Commission
BOEM	Bureau of Ocean Energy Management
CEFI	Climate, Ecosystems, and Fisheries Initiative
Council	Regional Fishery Management Council
DisMAP	Distribution Mapping and Analysis Portal
HMS Division	NMFS' Atlantic Highly Migratory Species Division
J-SCOPE	JISAO's Seasonal Coastal Ocean Prediction of the Ecosystem
Magnuson-Stevens Act	Fishery Conservation and Management Act of 1976, as amended
MSE	management strategy evaluation
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OAR	Office of Oceanic and Atmospheric Research
PRiSM	Predictive Spatial Modeling tool
TOTAL	Temperature Observations To Avoid Loggerhead tool

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August 18, 2022

Congressional Committees

Commercial and recreational marine fisheries are critical to our nation's economy, contributing nearly \$118 billion to the U.S. gross domestic product and supporting approximately 1.8 million jobs in 2019.¹ However, fisheries are increasingly vulnerable to changes in ocean waters associated with the effects of climate change—including physical changes, such as warmer water temperatures, and chemical changes, such as increased ocean acidity. The 2018 *Fourth National Climate Assessment* concluded that physical and chemical changes in the ocean are affecting the productivity and distribution of fisheries.² Changes in the productivity and distribution of certain fisheries could have economic consequences for the industries and communities that depend on harvesting the affected species.

Climate change also may contribute to future fishery disasters, which include sudden large decreases in the abundance of a fishery that result in significant economic losses.³ In certain circumstances, the federal government can provide assistance in response to fishery disasters. Between 1990 and 2019, Congress appropriated over \$1 billion in federal

¹U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service, *Fisheries Economics of the United States, 2019*, NOAA Technical Memorandum NMFS-F/SPO-229 (Silver Spring, MD: Mar. 29, 2022). For the purposes of this report, the terms “fisheries” and “fisheries management” refer to marine fisheries that are at least in part federally managed and include fish and invertebrate species, such as shellfish.

²U.S. Global Change Research Program, *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*, vol. 2 (Washington, D.C.: 2018).

³Various factors can cause sudden or unexpected losses in a fishery or significant loss of access to a fishery that lead to economic losses for fishers and communities. For example, harmful algal blooms, oil spills, hurricanes, typhoons, and other disasters can harm a commercial fishery or cause it to fail. When this occurs, a state's governor, or a duly appointed representative of an affected fishing community, can request a determination by the Secretary of Commerce that there is a commercial fishery failure because of a fishery resource disaster.

assistance in response to 72 fisheries disaster declarations.⁴ In 2013, we included *Limiting the Federal Government's Fiscal Exposure by Better Managing Climate Change Risks* on our High Risk list, in part because of the federal government's increasing fiscal exposure from costs related to federal disaster response and recovery assistance.

Under the Fishery Conservation and Management Act of 1976, as amended, generally referred to as the Magnuson-Stevens Act,⁵ the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) and eight Regional Fishery Management Councils (Council)⁶ are responsible for fisheries management and conservation in federal waters.⁷ NMFS generally serves as the lead agency for developing scientific information and management advice for federally managed fish stocks,⁸ of which there are

⁴Congressional Research Service, *Fishery Disaster Assistance*, RL34209 (Washington, D.C.: Apr. 7, 2020). In addition, in 2020, Congress appropriated a total of \$600 million to the Secretary of Commerce to provide assistance to eligible fisheries participants (including, among others, tribes, fishing communities, and certain fishery-related businesses) affected by COVID-19 through the CARES Act and the Consolidated Appropriations Act, 2021. For more information, see GAO, *COVID-19: Additional Actions Needed to Improve Accountability and Program Effectiveness of Federal Response*, [GAO-22-105051](#) (Washington, D.C.: Oct. 27, 2021).

⁵Pub. L. No. 94-265, 90 Stat. 331 (1976) (codified as amended at 16 U.S.C. § 1801 et seq.).

⁶Established under the Magnuson-Stevens Act, the Councils are supported by federal funds, and each Council generally comprises, as voting members, the NMFS Regional Director for the geographic area concerned, the principal state official with marine fishery management responsibility and expertise in each state within a Council's region, and individuals nominated by state governors and appointed by the Secretary who are knowledgeable regarding the conservation and management, or the commercial or recreational harvest, of fishery resources within the Councils' geographic areas. The Councils also include nonvoting members, such as officials from other federal agencies, and have staff members who administer finances, conduct meetings, and prepare analytical documents used to inform decision-making. NMFS provides support during the Council member appointments process, and supports the Councils by training new members and providing guidance on how Councils are to implement their responsibilities.

⁷Federal waters generally extend from 3 to 200 nautical miles off the coast of the United States. Coastal states generally maintain responsibility for managing fisheries in waters that extend approximately out to 3 geographic miles from their coastlines.

⁸A stock of fish, or fish stock, means a species, subspecies, geographical grouping, or other category of fish capable of management as a unit. According to NMFS officials, NMFS uses fish biology factors (e.g., age, growth, and reproduction), when possible, to help identify a stock's geographic boundaries. In some cases, individual species are managed as multiple stocks based on their geographic location.

approximately 460, including developing stock assessments, which measure the population of specific fish stocks. Fisheries managers, including the Councils, work with NMFS to use this scientific information to develop and implement fishery management plans that establish rules, such as annual catch limits, for the management of individual fish stocks.⁹

In 2016, we reviewed federal efforts to address the effects of climate change on federally managed fisheries.¹⁰ At that time, NMFS was in the early stages of implementing its *Climate Science Strategy* to increase the production, delivery, and use of climate information in managing fisheries and other living marine resources.¹¹ In our 2016 report, we recommended that NMFS (1) develop guidance to support the implementation of its *Climate Science Strategy* and (2) improve performance measures to help track its implementation. NOAA agreed with both recommendations and has taken some actions to address them.

In implementing its *Climate Science Strategy*, NMFS is seeking to enhance the climate resilience of federal fisheries. In the context of fisheries, enhancing climate resilience means taking actions to reduce potential future impacts on fisheries by preparing and adapting for potential climate hazards, such as extreme storm events, sea level rise, and warming ocean temperatures. This can include tracking fish productivity and distribution changes, adjusting management practices as

⁹For the purposes of this report, we define “fisheries managers” as all eight Councils and NMFS’ Atlantic Highly Migratory Species Division (HMS Division), which are the entities with responsibilities for managing fish stocks in federal waters. NMFS’ HMS Division is responsible for managing highly migratory fish species in certain federal waters, from Maine to Texas, as well as Atlantic tunas in all states to the shore, except Connecticut and Mississippi. The Councils develop and submit to NMFS fishery management plans for specified geographic areas. NMFS reviews the plans for consistency with the Magnuson-Stevens Act and other applicable law and, for approved plans, promulgates regulations. In addition, three interstate marine fisheries commissions were established to better use and protect fisheries across states’ jurisdictions. One of these commissions—the Atlantic States Marine Fisheries Commission (Atlantic Commission)—has the authority to manage certain fish stocks in interstate waters. Where a fishery occurs in both federal and Atlantic interstate waters, the Atlantic Commission works collaboratively with NMFS and the Councils to jointly manage those fisheries.

¹⁰GAO, *Federal Fisheries Management: Additional Actions Could Advance Efforts to Incorporate Climate Information into Management Decisions*, [GAO-16-827](#) (Washington, D.C.: Sept. 28, 2016).

¹¹U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *NOAA Fisheries Climate Science Strategy*, NOAA Technical Memorandum NMFS-F/SPO-155 (Silver Spring, MD: August 2015).

conditions change (e.g., changing catch levels or the dates of fishing seasons), and managing fisheries across Council boundaries as fish species move.

House Report 116-455 includes a provision for GAO to examine federal efforts to prepare and adapt federal or jointly managed fisheries to the impacts of climate change.¹² Our report examines (1) the actions NMFS has taken to enhance the climate resilience of federal fisheries since GAO's 2016 report; (2) the extent to which fisheries managers have used climate information provided by NMFS and others in fisheries management activities; and (3) the challenges NMFS and fisheries managers face in enhancing the climate resilience of federal fisheries, and opportunities that exist to address these challenges.

To identify actions taken by NMFS to enhance the climate resilience of federal fisheries since GAO's 2016 report, we reviewed NMFS' *Climate Science Strategy* and corresponding regional action plans, as well as policies and guidance developed to support implementation of the strategy. We also reviewed available documents and tools that incorporate climate information developed by NMFS, such as climate vulnerability assessments and ecosystem status reports. In addition, for this and the other two objectives, we reviewed our prior work on climate change and climate resilience and reviewed NMFS' actions for consistency with relevant principles in GAO's *Disaster Assistance Framework*.¹³ We interviewed officials from NMFS about the agency's progress in implementing its *Climate Science Strategy* and other actions to make fisheries more resilient to climate change. Specifically we interviewed officials from NMFS headquarters and all five NMFS regions (including officials from the five regional offices and six corresponding fisheries science centers).¹⁴ We also interviewed officials in NOAA's Office of Oceanic and Atmospheric Research (OAR) and NOAA's

¹²H. Rept. 116-455, accompanying H.R. 7667, Commerce, Justice, Science, and Related Agencies Appropriations Bill, 2021.

¹³GAO, *Disaster Resilience Framework: Principles for Analyzing Federal Efforts to Facilitate and Promote Resilience to Natural Disasters*, [GAO-20-100SP](#) (Washington, D.C.: Oct. 23, 2019);

¹⁴Where possible, we jointly interviewed NMFS' regional offices and regional fisheries science centers—which conduct research and provide scientific advice. We compiled information collected from these interviews on a regional basis for each of the five NMFS regions where individual interviews were conducted.

National Ocean Service about their collaboration with NMFS on these activities.

To examine the extent to which fisheries managers have used climate-related information provided by NMFS and others in fisheries management activities, we reviewed websites and documentation from the eight Councils and from NMFS' Atlantic Highly Migratory Species Division (HMS Division) on their fisheries management activities. We also interviewed the eight Councils and NMFS' HMS Division about their use of climate-related information in fisheries management and other efforts to enhance the climate resilience of federal fisheries. In addition, we interviewed officials from NMFS headquarters and regions; the three interstate marine fisheries commissions representing states in the Atlantic, Gulf, and Pacific that support both state and federal fisheries management; and 15 selected stakeholders about their perspectives on the use of climate information in fisheries management activities. We selected a nongeneralizable sample of stakeholders representing groups from commercial and recreational fishery organizations and conservation organizations, as well as researchers from academic institutions conducting work in this area. Our selection of stakeholders was intended to gather a range of views and was based on factors such as familiarity with different aspects of the fisheries management process and geographic diversity.¹⁵

To identify challenges to enhancing the climate resilience of fisheries facing NMFS and fisheries managers, and opportunities to address these challenges, we interviewed officials from NMFS and the eight Councils. We also interviewed officials from all three interstate marine fisheries commissions and the 15 selected stakeholders about their perspectives on climate resilience challenges and opportunities. In addition, we conducted a literature search and reviewed 34 articles from 2016 through 2021 that discuss approaches to increasing the climate resilience of fisheries to help identify opportunities for addressing challenges identified in the interviews. Appendix I presents a more detailed description of our objectives, scope, and methodology.

We conducted this performance audit from April 2021 to August 2022, in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain

¹⁵For the purposes of this report, we use the term "stakeholders" when referring to views of both researchers and stakeholder organizations.

sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

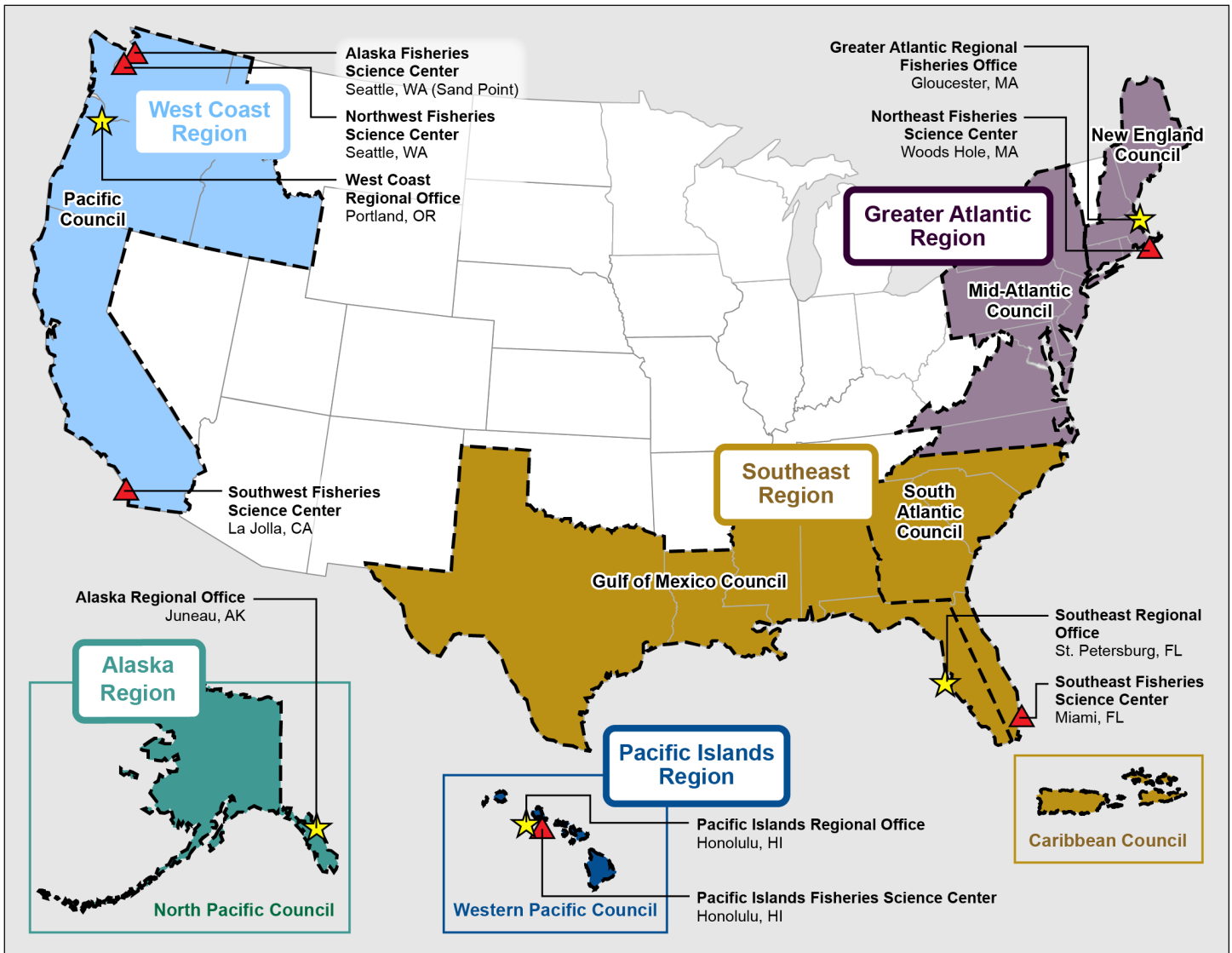
Background

Federal Fisheries Management

NMFS and the eight Councils are responsible for managing approximately 460 fish stocks in federal waters across five geographic regions of the country. Federal waters generally extend from 3 to 200 nautical miles off the coast of the United States. NMFS operates through its headquarters, five regional offices, and six regional fisheries science centers to partner with the Councils to manage federal fisheries, as shown in figure 1. Under this structure, NMFS provides scientific information and management advice. The Councils use this information to make management decisions that they submit to NMFS for approval. In addition, NMFS' HMS Division manages highly migratory fish species in certain federal waters.¹⁶ For the purposes of this report, we define "fisheries managers" as the eight Councils and NMFS' HMS Division.

¹⁶Specifically, the HMS Division is responsible for managing billfish, shark, and swordfish in federal waters, from Maine to Texas, as well as in Puerto Rico and the U.S. Virgin Islands. NMFS' Atlantic HMS Division is also responsible for managing Atlantic tuna stocks from federal waters to the shore in all states except Connecticut and Mississippi.

Figure 1: National Marine Fisheries Service (NMFS) Regional Offices, Fisheries Science Centers, and Regional Fishery Management Councils (Council)



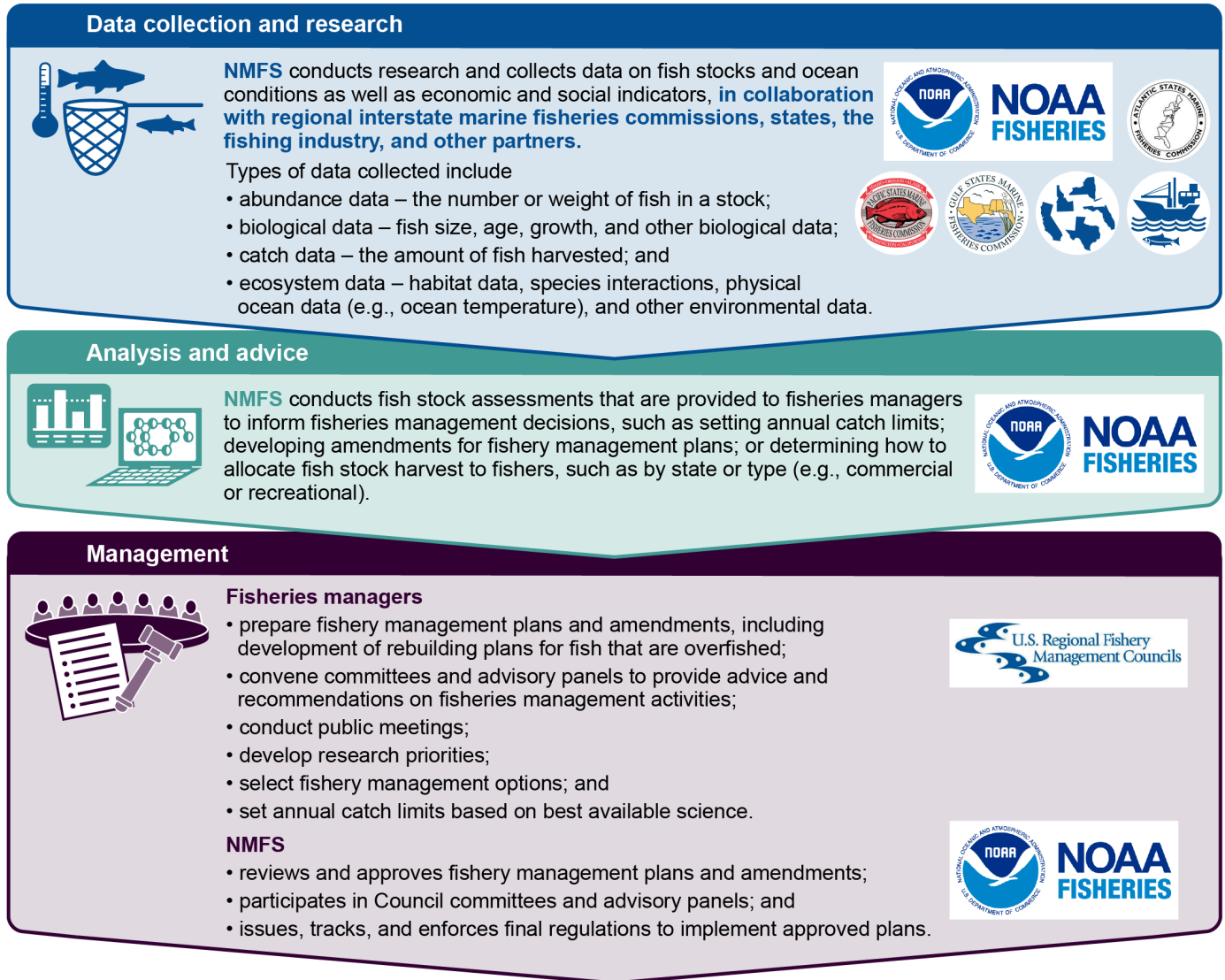
Sources: NMFS; Map Resources (map). | GAO-22-105132

Note: The Western Pacific Fishery Management Council also includes the Mariana Islands archipelago, American Samoa, and a range of remote island areas in the central and western Pacific not depicted on this map. In addition, NMFS' fisheries science centers have other laboratory facilities, and its West Coast Regional Office has satellite offices that are not depicted on this map.

In addition, three interstate marine fisheries commissions, representing states in the Atlantic, Gulf, and Pacific regions, support both state and federal fisheries management. One commission, the Atlantic States Marine Fisheries Commission (Atlantic Commission), has the authority to manage certain fisheries in interstate waters and is directly involved in managing more than 25 fish stocks in state waters, including nine stocks that are jointly managed by NMFS and the Councils in federal waters.

NMFS, the Councils, interstate marine fisheries commissions, and other partners have varying roles in the federal fisheries management process, which generally involves data collection and research, analyzing this information to develop management advice, and taking management actions (including enforcement), as shown in figure 2.

Figure 2: Roles and Responsibilities of the National Marine Fisheries Service (NMFS) and Fisheries Managers in the Federal Fisheries Management Process



Source: GAO analysis of NMFS documents. | GAO-22-105132

Note: The term “fisheries managers” refers to entities with responsibilities for managing fish stocks in federal waters, including all eight Regional Fishery Management Councils and NMFS’ Atlantic Highly Migratory Species Division. NMFS is also referred to as NOAA [National Oceanic and Atmospheric Administration] Fisheries, and the agency uses that name in its logo.

NMFS has overall responsibility for collecting data on fish stocks and ecosystem conditions and for conducting scientific research and analysis necessary for the conservation, management, and use of marine resources, including fisheries. NMFS' six regional fisheries science centers are primarily responsible for collecting fisheries data, and they also collaborate with partners on this effort, including the interstate marine fisheries commissions, coastal states, academics, and members of the fishing industry. Data are collected on fish stocks and ecosystem conditions on an ongoing basis to support scientific analyses, including fish stock assessments that are used to inform fisheries management decisions.

These assessments consider information such as fish biology, abundance, and distribution to evaluate the health and size of a fish stock and to predict future trends to the extent possible. NMFS provides the results of its stock assessments to the Councils and the HMS Division, who use the information to set annual catch limits and implement other aspects of the Councils' and HMS Division's management responsibilities.

The Councils and the HMS Division develop and implement fishery management plans and plan amendments, using guidelines developed by NMFS. These plans, and any amendments to them, include fishery conservation and management measures, such as permitting policies and restrictions on the timing or location of permissible fishing, as well as the use of certain fishing equipment.

When developing or amending a fishery management plan, the Councils and the HMS Division convene committees and advisory panels, as well as solicit stakeholder input through public meetings or written comments. After considering this input, the Councils submit the proposed plan or plan amendment to the NMFS regional office, which determines whether it is consistent with the national standards and other provisions of the Magnuson-Stevens Act and any other applicable law.¹⁷ The plan is then submitted to the NOAA Assistant Administrator for Fisheries for

¹⁷The HMS Division conducts this review of fishery management plans or plan amendments that it develops for highly migratory species.

approval.¹⁸ NMFS issues and enforces final regulations to implement approved plans. In developing fishery management plans and amendments, and on a continuing basis, the Councils and the HMS Division are to, among other things, assess and specify the maximum sustainable yield and optimum yield for each fishery.¹⁹ Maximum sustainable yield is the basis for setting annual catch limits for each fish stock, which is the amount of fish that can be harvested in the year.

For fiscal year 2022, Congress directed nearly \$655 million to go to NMFS' fisheries science and management activities, such as conducting stock surveys, stock assessments, and developing fisheries management guidance. This includes approximately \$28.8 million and nearly \$7.3 million, respectively, for fishery management activities by the Councils and the three interstate marine fisheries commissions.

Climate Change Effects on Fisheries

According to the *Fourth National Climate Assessment*, marine fisheries and fishing communities are at high risk from climate-driven changes to ocean ecosystems, such as ocean warming and acidification.²⁰ Climate-driven impacts to fisheries include changes in species productivity and the distribution of fish stocks. Climate change is also impacting the timing and magnitude of seasonal biological events, such as plankton blooms, which juvenile fish depend on for food, which can alter the food web structure. Further, climate change is contributing to the increasing frequency and severity of extreme events in many U.S. marine ecosystems, such as very high water temperatures, very low oxygen levels, or very acidified oceans.

The *Fourth National Climate Assessment* also stated that climate-change-related effects on ocean ecosystems are likely to increase, thereby creating additional challenges to effectively managing marine fisheries. For example, increasing water temperatures in the Gulf of Maine

¹⁸The Magnuson-Stevens Act provides that the Secretary of Commerce shall approve, disapprove, or partially approve a fishery management plan or plan amendment submitted by the Councils after a public comment period. 16 U.S.C. § 1854(a)(1)(A). The Secretary has subsequently delegated this responsibility to the NOAA Assistant Administrator for Fisheries.

¹⁹The Councils do this in consultation with their scientific and statistical committees, advisory bodies comprised of federal and state employees, academics, and independent experts who are required to have strong scientific or technical credentials and experience and are appointed by the Councils.

²⁰U.S. Global Change Research Program, *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment*, vol. 2 (Washington, D.C.: 2018).

contributed to a decline in productivity for Gulf of Maine cod. In response, the New England Fishery Management Council reduced the amount of cod that can be caught, which has resulted in negative economic impacts on the fishing industry in New England. Recent extreme marine heat events have also had significant impacts on species in the Pacific Ocean and other areas.

In addition, according to the *Fourth National Climate Assessment*, projected impacts to fisheries will likely vary between regions. Fishing communities in warmer regions like Hawaii and the Pacific Islands are particularly vulnerable to a decline in fish species from climate impacts because there are few species to replace those that shift to cooler waters. In contrast, certain fish populations in cooler regions like Alaska are projected to increase as species shift northward.

Relevant Laws, Regulations, and Directives

The Magnuson-Stevens Act governs the conservation and management of federal fisheries. Among other things, the act establishes 10 national standards for fishery conservation and management and provides that fishery management plans are to be consistent with those standards.²¹ NMFS has established guidelines, based on the national standards, to assist in the development and review of fishery management plans, amendments, and regulations. According to NMFS officials, all of the standards are pertinent to managing fisheries in a changing climate; they identified three standards as the most directly relevant to managing fisheries in a changing climate because the guidelines for these standards reference environmental and climate-related factors (see table 1).

Table 1: Magnuson-Stevens Act National Standards and Guidelines Identified by the National Marine Fisheries Service (NMFS) as Most Relevant to Managing Fisheries in a Changing Climate

National standard	Guidelines
<p>National standard 1: Optimum Yield <i>Conservation and management measures shall prevent overfishing while achieving, on a continuing basis, the optimum yield from each fishery for the United States fishing industry.</i></p>	<p>The guidelines for national standard 1 provide that fishery managers are to, when specifying limits and accountability measures, take an approach that considers uncertainties related to scientific information and management control of the fishery. The guidelines note that scientific uncertainty includes longer-term uncertainties because of potential ecosystem and environmental effects.</p>

²¹The 10 national standards relate to (1) Optimum Yield, (2) Scientific Information, (3) Management Units, (4) Allocation, (5) Efficiency, (6) Variations and Contingencies, (7) Costs and Benefits, (8) Communities, (9) Bycatch, and (10) Safety of Life at Sea. 16 U.S.C. § 1851(a).

National standard	Guidelines
<p>National standard 2: Scientific Information <i>Conservation and management measures shall be based upon the best scientific information available.</i></p>	<p>The guidelines for national standard 2 provide that fishery conservation and management require high-quality and timely biological, ecological, environmental, economic, and sociological information to effectively conserve and manage living marine resources. The guidelines also call for reports, referred to as stock assessment and fishery evaluation reports, that, among other things, summarize the best scientific information available concerning the past, present, and possible future condition of stocks, essential fish habitat, marine ecosystems, and fisheries being managed under federal regulation.</p>
<p>National standard 6: Variations and Contingencies <i>Conservation and management measures shall take into account and allow for variations among, and contingencies in, fisheries, fishery resources, and catches.</i></p>	<p>The guidelines, in describing how national standard 6 intersects with national standard 1, state that Regional Fishery Management Councils must build into the reference points and control rules appropriate consideration of risk, taking into account uncertainties in estimating harvest, stock conditions, life history parameters, or the effects of environmental factors. The guidelines for national standard 6 note that unpredictable events, including climatic conditions or environmental catastrophes, are best handled by establishing a flexible management regime.</p>

Source: GAO analysis of Magnuson-Stevens Act National Standards and NMFS guidelines identified by NMFS officials as most relevant to managing fisheries in a changing climate. | GAO-22-105132

In addition, Executive Order 14008 directs federal agencies to enhance their climate resilience efforts. In particular, Executive Order 14008 directs each federal agency to develop and submit a plan to the National Climate Task Force and the Federal Chief Sustainability Officer that describes steps that the agency can take to bolster adaptation and increase the resilience of their operations and facilities to the impacts of climate change.²² In response, the Department of Commerce issued a plan that identified five priority actions.²³ The plan’s first priority action states that NOAA will help decision makers prioritize adaptation measures by developing information and tools and executing climate-related research grant programs.

Executive Order 14008 also directs the Secretary of Commerce, through the Administrator of NOAA, to initiate efforts to collect input from various stakeholders on how to make fisheries and protected resources more resilient to climate change, including changes in management and conservation measures, and improvements in science, monitoring, and cooperative research.²⁴ In response, NOAA hosted three national listening sessions in March and April 2021 and collected written

²²Exec. Order No. 14008, § 211(a), 86 Fed. Reg. 7619, 7625 (Feb. 1, 2021).

²³U.S. Department of Commerce, Secretary of Commerce, *2021 Climate Action Plan for Adaptation and Resilience* (Washington, D.C.: Aug. 27, 2021).

²⁴Exec. Order No. 14008, § 216(c), 86 Fed. Reg. at 7627.

comments from stakeholders on how to make fisheries more resilient to climate change.²⁵

Key NMFS Actions through 2016

In 2016, we reviewed federal efforts to address the effects of climate change on federal fisheries, and we reported on efforts that NMFS had undertaken.²⁶ In August 2015, NMFS had issued its *Climate Science Strategy*, which describes plans to increase the production, delivery, and use of climate-related information as part of its fisheries management and marine resources stewardship responsibilities.²⁷ The strategy identified seven corresponding objectives to be implemented through regional action plans developed by NMFS for each of its five regions.

In addition, in 2016 NMFS issued its Ecosystem-Based Fisheries Management Policy and corresponding roadmap.²⁸ Ecosystem-based fisheries management is an approach that recognizes interactions within an ecosystem—physical, biological, economic, and social—rather than considering a single species or issue in isolation. In its roadmap, NMFS recognized its *Climate Science Strategy* and supporting regional action plans as part of the process of implementing ecosystem-based fisheries management.

In our 2016 report, we found that NMFS was in the early stages of implementing its *Climate Science Strategy*.²⁹ At that time, we recommended that NMFS (1) develop guidance to support the implementation of its strategy and (2) improve performance measures to

²⁵NOAA summarized these comments in a final report. See U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *Synthesis of Public Comments to NOAA on Executive Order 14008, Tackling the Climate Crisis at Home and Abroad, Section 216(c): Recommendations on How to Make Fisheries and Protected Resources, Including Aquaculture, More Resilient to Climate Change*, NOAA Technical Memorandum NMFS-F/SPO-218 (Silver Spring, MD: October 2021).

²⁶[GAO-16-827](#).

²⁷National Marine Fisheries Service, *NOAA Fisheries Climate Science Strategy*.

²⁸U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *Ecosystem-Based Fisheries Management Policy of the National Marine Fisheries Service*, National Marine Fisheries Service Policy 01-120 (Silver Spring, MD: Renewed in September 2018. Initial directive effective on May 23, 2016); and *Ecosystem-Based Fisheries Management Road Map*, National Marine Fisheries Service Procedure 01-120-01 (Silver Spring, MD: Renewed in November 2018. Initial procedure effective on Nov. 17, 2016).

²⁹[GAO-16-827](#).

help track implementation of the strategy. NMFS agreed with both recommendations and has taken steps to address the recommendations, as we describe in the next section of this report.

NMFS Has a Range of Efforts Underway to Help Fisheries Managers Enhance the Climate Resilience of Federal Fisheries

Since 2016, NMFS' regional offices and fisheries science centers have developed regional action plans and new climate information and tools, such as climate vulnerability assessments for fish stocks. In addition, NMFS is collaborating with other NOAA offices on activities and efforts, such as the Climate, Ecosystems, and Fisheries Initiative (CEFI), which could provide fisheries managers with additional climate-related information to help enhance the climate resilience of federal fisheries.

NMFS Developed Regional Action Plans, New Information, and Tools to Help Fisheries Managers

As part of implementing its *Climate Science Strategy*, NMFS fisheries science centers and regional offices developed initial and draft updated regional action plans that cover all eight Councils and the NMFS HMS Division.³⁰ All of the plans (initial plans and draft updated plans) identified specific actions to develop climate-related information and tools for the next 3 to 5 years. Actions identified in the plans help to support the overarching goal of the *Climate Science Strategy* to increase the production, delivery, and use of climate-related information in fisheries management.

All of the initial plans and updated draft plans, for example, include actions related to increasing NMFS' capacity for carrying out climate-related efforts (e.g., through staffing or funding). They also all include actions to develop certain climate-related tools and information, such as climate vulnerability assessments for fish stocks and integrated ecosystem models. All of the updated plans included actions to improve collaboration with others, such as conducting meetings or workshops to share information across NMFS regions or with stakeholders within a region. In addition, most of the draft updated plans contained regional

³⁰NMFS regions developed some regional action plans that cover more than one Council or multiple plans for different areas managed by a single Council within the region. The initial regional action plans completed between 2016 and 2020 covered all Councils, except for the Caribbean Council. The updated draft plans were made available for public comment in April 2022 and cover all eight Councils.

performance metrics to help track implementation of the strategy in response to GAO's recommendation made in 2016.³¹

According to NMFS' December 2021 progress report on the implementation of its *Climate Science Strategy*, the majority of progress that has been made is related to two objectives. First, the report stated that progress has been made on an objective related to maintaining infrastructure. This includes improving staffing and partnerships. The report also noted progress on an objective to help with tracking change to provide early warnings. This includes developing scientific information such as ecosystem status reports with physical, biological, and community indicators.³² The report also described progress on conducting climate vulnerability assessments, which supports another objective on understanding the mechanisms of fisheries' vulnerability and adaptive capacity.

In its progress report, NMFS also flagged some areas where actions recommended in its strategy were not yet completed and were in need of additional focus. For example, the progress report identified the need to improve science infrastructure, such as rebuilding and expanding ecosystem surveys to track and anticipate changes in species distribution and dedicating adequate resources for research. In addition, the report identified the need for actions related to supporting climate-informed management. For instance, the report stated the need for additional actions to work with Councils to use the climate modeling and other tools being developed to evaluate fisheries management options for changing ocean conditions.

Consistent with the findings of NMFS' progress report, our review found that most of the actions that NMFS has taken to implement its *Climate Science Strategy* since 2016 have primarily involved producing and delivering climate science information and tools (see table 2 below). For

³¹[GAO-16-827](#). In July 2022, NMFS officials told us that the agency plans to further revise the draft performance metrics as it finalizes the new regional action plans. Once the plans are finalized, we will evaluate them to assess whether the agency has fully addressed our recommendation.

³²U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *NOAA Fisheries Climate Science Strategy Five Year Progress Report*, NOAA Technical Memorandum NMFS-F/SPO-228 (Silver Spring, MD: December 2021).

example, NMFS developed region-specific information and tools for use by fisheries managers, such as:

- **Climate vulnerability assessments.** NMFS has prepared climate vulnerability assessments for fish stocks, protected species,³³ fishing communities, and related habitats. These assessments identify which species may be most vulnerable to climate change based on their exposure to projected environmental changes and their sensitivity to such changes. As of May 2022, NMFS had completed three fish stock climate vulnerability assessments and was in the process of developing four more assessments (see app. II for a summary of climate vulnerability assessments).³⁴ Fisheries managers are using these assessments to identify at-risk species and areas where additional research and action are needed to reduce the risks to fish stocks posed by climate change effects, according to NMFS officials.
- **Ecosystem status reports.** NMFS periodically provides regional ecosystem status reports on the status and trends of ecosystem conditions. These reports include information on physical (e.g., ocean temperature), biological (e.g., fish species abundance, habitats) and socioeconomic (e.g., fishing communities) factors. According to the agency's website, NMFS provides these reports to fisheries managers and stakeholders to better facilitate ecosystem-based fisheries management. As of May 2022, NMFS had produced at least one ecosystem status report targeted for use by six of the eight Councils and had a report for one Council under development, as shown in table 2 and described in more detail in appendix III.³⁵
- **Regional management strategy evaluations (MSE).** NMFS supports the development of regional MSEs that can help fisheries managers evaluate the potential short- and long-term outcomes of

³³This includes certain marine mammals and sea turtles protected under the Marine Mammal Protection Act or Endangered Species Act.

³⁴As of May 2022, in addition to the three completed fish stock climate vulnerability assessments, the agency had also completed one fishing community assessment for the U.S. Eastern and Gulf Coasts and one habitat assessment for the Northeast U.S.. In addition, according to NMFS officials, as of May 2022, three assessments for protected species (e.g., certain mammals and sea turtles) were in progress.

³⁵According to information on NOAA's website, NMFS' Alaska Fisheries Science Center has developed four ecosystem status reports for Alaska, including for the Eastern Bering Sea, Gulf of Alaska, Aleutian Islands, and the Arctic. In addition, the NMFS' Pacific Islands Fisheries Science Center has developed an ecosystem status report targeted for use by state fisheries managers in that region, but has not developed one for the Western Pacific Council.

management actions. Regional MSEs use models to simulate marine ecosystem and fisheries conditions under various climate change scenarios. The MSEs can then be used to analyze the potential effects of various management actions (such as revising catch limits for specific fish stocks or closing certain areas to fishing) on ecosystems, fisheries, and fishing-dependent communities. Overall, MSEs can help fisheries managers determine what strategies could be most effective for achieving specific management objectives under likely future conditions. For example, the NMFS Alaska Climate Integrated Modeling project was launched in 2018 to provide the North Pacific Council with information on the best near- and longer-term management strategies for crab and other stocks in the Bering Sea, considering projections of future climate, marine ecosystem, and fish stock conditions.³⁶ NMFS is also involved in similar pilot projects to develop regional MSEs for the Greater Atlantic and West Coast Regions and supports the development of MSEs for some species managed by the HMS Division, as noted in table 2 and further described in appendix IV. In addition, according to NMFS officials, NMFS has hired MSE experts in each fisheries science center.

- **Regional real-time mapping tools:** NMFS also helps develop regional real-time mapping tools that incorporate climate-related information to support fisheries management. For example, NMFS' West Coast region helped to develop EcoCast and Whalewatch. These web-based tools use regularly updated satellite mapping data to help identify locations for fishing that minimize the bycatch of protected species, such as certain whales and turtles.³⁷ Similar tools have been developed by the NMFS Pacific Islands fisheries science center to help reduce inadvertent interactions between loggerhead sea turtles and Hawaii-based longline fishing vessels. The HMS Division is also working on developing a tool using satellite mapping data to support monitoring of open and closed fishing areas. For more information on these tools, see appendix V.

³⁶As of January 2022, NMFS' Alaska Region was beginning to develop a similar MSE project for the Gulf of Alaska—the Gulf of Alaska Climate Integrated Modeling project. The model will evaluate fisheries management actions in the Gulf of Alaska and consider the effects of climate change. The model is intended to help fisheries managers consider alternative management options in response to potential issues (e.g., changing productivity levels; shifting baselines or reference points; and governance flexibility at the federal, state, and international levels).

³⁷Bycatch are fish that are harvested in a fishery but that are not sold or kept for personal use. Shifting distribution of fish can result in increased bycatch, which may include protected species.

Table 2: Status of National Marine Fisheries Service (NMFS) Regions' Actions to Implement the Agency's *Climate Science Strategy*, as of May 2022

NMFS region	Regional Fishery Management Council	Regional action plans ^a	Climate vulnerability assessments ^b				Ecosystem status reports ^c	Regional management strategy evaluations ^d	Regional real-time mapping tools ^e
			Fish stock	Protected species	Habitat	Fishing community			
Alaska	North Pacific	●	●	◐	○	○	●	◐	○
Greater Atlantic	New England	●	●	◐	●	●	●	◐	○
	Mid-Atlantic	●	●	◐	●	●	●	◐	○
Pacific Islands	Western Pacific	●	◐	○	○	○	○	○	●
Southeast	Caribbean	●	○	○	○	○	◐	○	○
	Gulf of Mexico	●	◐	○	○	●	●	○	○
	South Atlantic	●	◐	◐	○	●	●	○	○
West Coast	Pacific	●	●	◐	○	◐	●	●	●
Other entities									
Multiple	NMFS Atlantic Highly Migratory Species Division ^f	●	◐	—	—	—	●	◐	◐

Legend:

- = Completed
- ◐ = In progress
- = Not completed, in progress, planned, or scheduled
- = Not applicable

Source: GAO analysis of NMFS documents and interviews. | GAO-22-105132

Note: The table indicates whether a plan or assessment covers a specific Regional Fishery Management Council (Council) and is not a tally of the total number of plans or assessments. In some instances, a NMFS region may have developed a plan that covers more than one Council or may include multiple assessments for different areas managed by a single Council within the region. For example, a single regional action plan for the northeast U.S. covers fisheries resources managed by the New England and Mid-Atlantic Councils. Three separate regional action plans are developed for the Eastern Bering Sea, Gulf of Alaska, and Arctic managed by the North Pacific Council.

^aRegional action plans are plans developed by NMFS regional fisheries science centers and regional offices to support implementation of NMFS' *Climate Science Strategy* over a 3- to 5-year period. Initial plans completed from 2016 through 2020 cover all Councils except for the Caribbean Council and the NMFS Atlantic Highly Migratory Species Division. Updated draft plans for 2022 through 2024 covering all eight Councils and the NMFS Atlantic Highly Migratory Species Division were made available for public comment in April 2022.

^bClimate vulnerability assessments being conducted by NMFS and other scientists are intended to help develop an understanding of which fish stocks, protected species (including certain marine mammals and sea turtles), fishing communities, and habitats may be most vulnerable to climate change based on their exposure to projected changes in the environment and their sensitivity or adaptability to handle those changes. Fishing community climate vulnerability assessments identified in this table build on the fish stock vulnerability assessments and reflect efforts that NMFS is planning under the climate vulnerability assessment methodology. Other fishing community climate vulnerability assessments using different methodologies exist and are not noted here.

^cEcosystem status reports are periodic regional reports developed by NMFS regional fisheries science centers for use by fisheries managers and other stakeholders to provide an overview of the status and trends of ecosystem components, such as fish species, communities, and habitats.

^dRegional management strategy evaluations are regional models developed to help fisheries managers evaluate the potential outcomes and tradeoffs of alternative management actions—such as impacts of changes to catch limits for certain fish stocks or closing areas to fishing—on fish ecosystems and fishing-dependent communities.

^eRegional real-time mapping tools, or dynamic ocean management tools, incorporate climate-related information for use by NMFS staff, the Councils, and other relevant stakeholders to support fisheries management. Specifically, these web-based tools contain regularly updated real-time or near-real-time satellite mapping data, ocean monitoring data, and data from models to support fisheries and ocean management objectives, such as helping identify locations for fishing that minimize bycatch of protected species (e.g., whales, turtles).

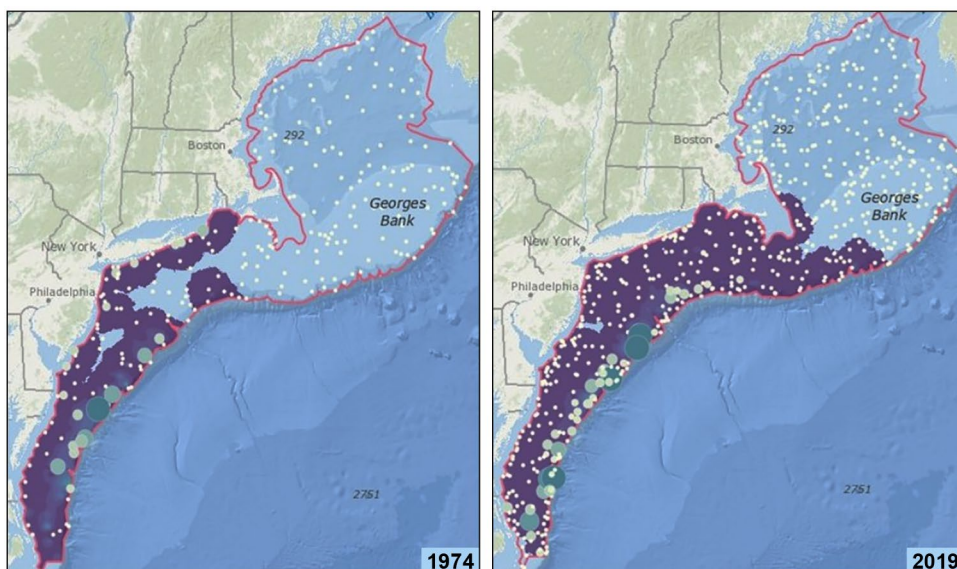
^fStatus of activities for NMFS' Atlantic Highly Migratory Species Division considers information and tools developed for NMFS' Greater Atlantic and Southeast Regions that are applicable to some fisheries managed by the NMFS Atlantic Highly Migratory Species Division, according to NMFS officials.

- **National web-based mapping tools.** Nationally, NMFS has developed web-based mapping tools that provide information on climate-related impacts on fisheries and fishing communities for use by NMFS staff, fisheries managers, and the general public (see app. V for a further description of these tools). For example, in April 2022 NMFS launched the Distribution Mapping and Analysis Portal (DisMAP)—a new web portal that is designed to provide information about past, current, and possible future distribution of fish stocks under projected climate and ocean scenarios.³⁸ According to NMFS' website, DisMAP was developed to provide species distributions information for use by fisheries managers, scientists, and NMFS to help inform decision-making and support science across regions. This first version of DisMAP provides access to past and current distribution information for more than 800 marine species in U.S. marine areas over the past more than 40 years (see fig. 3 for an example of output). NMFS plans to provide information on projected future species distributions in future versions of DisMAP. In addition, NMFS has developed a web-based mapping tool with community social vulnerability indicators for more than 4,600 coastal communities in 24 states. Indicators include those related to sea level rise and storm surge, as well as indicators on social vulnerability, such as poverty. According to NMFS officials, NMFS fisheries science centers

³⁸NMFS developed DisMAP in collaboration with the Global Change Ecology and Evolution Lab at Rutgers University. The site uses bottom trawl survey data collected by NMFS and will be expanded to include additional data types in the future. Users can select a species of interest and visually examine changes in the distribution over time by viewing maps and graphs of key indicators of a species distribution, such as changes in species latitude, depth, and range limits. The user can also choose to view changes in distributions at the regional level as an indicator of broader community-level changes. See <https://apps-st.fisheries.noaa.gov/dismap/>.

in all regions have used these indicators to assess the potential economic impacts of proposed fishery management plan amendments on affected fishing communities.

Figure 3: Map from National Marine Fisheries Services' Distribution Mapping and Analysis Portal Showing Changes in Black Sea Bass Distribution from 1974 to 2019



Black sea bass expanded approximately 140 miles north over this period.

Source: National Oceanic and Atmospheric Administration. | GAO-22-105132

Since 2016, NMFS has issued multiple policies and guidance documents on how to incorporate climate information in the fisheries management process. For example, in 2018, partly in response to a recommendation that we made in 2016,³⁹ NMFS issued a guidance document that identified six steps and associated actions for how NMFS and fisheries managers can address changes related to climate change.⁴⁰ The technical memorandum offered recommendations on how to improve the science for detecting and understanding climate impacts on fisheries distribution and productivity, as well as how to improve the communication and use of this information by fisheries managers. Also in

³⁹[GAO-16-827](#).

⁴⁰U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *Accounting for Shifting Distributions and Changing Productivity in the Fishery Management Process: From Detection to Management Action*, NOAA Technical Memorandum NMFS-F/SPO-188 (Silver Spring, MD: November 2018).

2018, NMFS issued a guidance document to improve the development of fish stock assessments.⁴¹ A primary goal of the guidance document is to increase the use of ecosystem and socioeconomic data in the fish stock assessment process. Among other things, the guidance document outlines new steps for incorporating the results of national efforts, including incorporating climate vulnerability assessments results into the national prioritization process for scheduling fish stock assessments.⁴²

NMFS Is Collaborating with Other NOAA Offices to Develop Additional Information and Tools to Help Fisheries Managers

NMFS is collaborating with other NOAA offices, including with OAR on research and development of new information and tools related to fisheries and climate change. In particular, NMFS is collaborating with OAR's Climate Program Office on leading the Climate, Ecosystems, and Fisheries Initiative (CEFI)—a NOAA-wide effort to build a national integrated ocean modeling and decision support system to enhance the climate resilience of marine resources, including fisheries.⁴³ As described in a NOAA factsheet on the initiative, the CEFI system will include enhanced ocean modeling and an information hub to disseminate CEFI-generated analyses and tools, such as ocean forecasts and projections at time and spatial scales for use by fisheries managers. NMFS officials identified CEFI as a critical effort for enhancing climate-informed fisheries management and the climate resilience of marine resources, including fisheries and other living marine resources. Also noted in the NOAA factsheet, the modeling and decision support system will provide fisheries managers with essential information and capacity needed to prepare for

⁴¹U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *Implementing the Next Generation Stock Assessment Enterprise: An Update to the NOAA Fisheries Stock Assessment Improvement Plan*, NOAA Technical Memorandum NMFS-F/SPO-183 (Silver Spring, MD: June 2018).

⁴²The national prioritization process was developed in 2015 to provide a consistent framework to help guide regional decisions about how often to assess stocks and what type of assessments should be conducted (more in-depth research assessments versus less-intensive operational assessments). NMFS officials told us that they have been considering whether to incorporate a climate vulnerability factor into the stock assessment prioritization process, but there is currently no schedule for updating the process to add this information. As of March 2022, NMFS was assessing how NMFS regions have implemented the 2015 stock assessment prioritization process before it will issue revised criteria to prioritize stock assessments. NMFS expects to update the stock assessment prioritization process after the current stock assessment process is fully implemented in each region.

⁴³U.S. Department of Commerce, National Oceanic and Atmospheric Administration, *NOAA Climate, Ecosystems, and Fisheries Initiative Fact Sheet* (Silver Spring, MD: July 23, 2021), accessed June 1, 2022.
<https://www.fisheries.noaa.gov/resource/document/noaa-climate-ecosystems-and-fisheries-initiative-fact-sheet>.

and respond to changing conditions in short- and long-term time frames. For example, CEFI is expected to accelerate the production of climate-informed fish stock assessments and sharing of information on species distribution and ecosystem changes.

NOAA's Science Advisory Board reviewed a draft implementation approach for CEFI in September 2021. The board commended NOAA for recognizing the lack of an integrated decision support system for delivering climate information and identified areas for improvement, including the need for an implementation plan to identify roles, responsibilities, and a time line to implement the plan. In addition, the board recommended that NMFS develop approaches to facilitate stakeholder engagement to ensure that the system provides usable information and tools for decision-making and to enhance trust in NOAA products and processes. In response, NMFS has formed working groups to develop plans for implementing specific aspects of CEFI, according to NMFS officials. Although NMFS has not received specific funding for CEFI, NMFS officials told us that work on ocean modeling that is fundamental to the development of the decision support system will continue as part of their ongoing work.⁴⁴

NMFS has also collaborated with OAR's Climate Program Office to fund specific projects to help enhance the climate resilience of fisheries. For example, in 2014, the two offices developed the Climate and Fisheries Adaptation Program to advance the understanding of climate-related impacts on economically important fish stocks and fishing communities. Since fiscal year 2015, the program has provided \$15.6 million to support 24 research projects. Other OAR programs also have provided funding for climate-related fisheries research. For instance, in fiscal year 2020, OAR funded 13 projects to help integrate climate predictions in modeling efforts.⁴⁵ These included projects to develop short-term climate projections from several months to several years at a regional scale.

⁴⁴The fiscal year 2022 NOAA budget included a request for \$30 million to begin building the CEFI integrated modeling and decision support system. The explanatory statement accompanying the Consolidated Appropriations Act, 2022, included language encouraging NMFS to continue to adapt its fishery management practices to the reality of the changing climate and to deliver the climate-informed advice needed for effective marine resource management in rapidly changing oceans; however, NOAA did not receive any fiscal year 2022 funding specifically for the initiative. According to NMFS officials, NOAA also included a request for funding for CEFI in its fiscal year 2023 budget.

⁴⁵These 13 projects were funded through OAR's Climate Program Offices' Modeling Analysis Predictions Program.

Fisheries Managers Generally Have Not Used Climate Information in Fisheries Management Activities, and NMFS Could Better Share Information

Fisheries managers' use of climate information to develop and conduct management activities is limited. However, we found that many fisheries managers are leading initiatives that could help advance the use of climate change information in managing federal fisheries. NMFS does not regularly collect or share information about actions that fisheries managers are taking to enhance the climate resilience of federal fisheries and could better share information across regions.

Fisheries Managers Use Climate Information to a Limited Extent

According to our review of documents and interviews, we found that fisheries managers' use of climate information is limited, and few fishery management activities incorporate climate information. However, many fisheries managers are leading initiatives to help develop approaches to advance the use of climate change information in managing federal fisheries.

Overall, we found that fisheries managers consider climate-related factors to a limited extent when developing or amending fishery management plans. Using our review of documents and interviews with NMFS and fisheries managers, we identified 12 fishery management plans and amendments that considered climate-related information out of 46 fishery management plans in place (see app. VI for a list of examples of these fishery management plans and amendments). For instance, the fishery management plan that covers sardines managed by the Pacific Council includes a harvest control rule for adjusting harvest guidelines or acceptable targets based on ocean temperature trends. In another example, the Atlantic Commission and the Mid-Atlantic Council approved a joint management plan amendment for black sea bass that increased state commercial quota allocations in some northern states to account for stock expansion and shift in the distribution of black sea bass related to warming ocean temperatures.

NMFS officials and federal fisheries managers we interviewed cited several reasons why their use of climate information has been limited. NMFS officials told us that developing climate-informed fishery management plans or amendments is a time-consuming and resource-intensive process that requires significant stakeholder engagement and

buy-in. In addition, all fisheries managers pointed to shortcomings in the available scientific information regarding the effects of climate change on fisheries, such as the availability of short-term projections of the climate impacts on specific stocks.

Three of nine fisheries managers also cited the fact that climate variables are not generally incorporated into fish stock assessments as another reason why their use of climate information has been limited. Two of these fisheries managers and one other fisheries manager told us that incorporating quality climate information in stock assessments would be an important way for NMFS to help them consider climate change impacts on fisheries in their management activities. However, NMFS officials told us that they face limitations in incorporating climate information in fish stock assessments because marine ecosystems are complex, and identifying the relationship between different ecosystem variables is challenging.

Using our review of documents and interviews with NMFS and fisheries managers, we identified some examples of fish stock assessments that incorporate climate information. For instance, in the NMFS Alaska Region, the Bering Sea and Aleutian Islands yellowfin sole stock assessment incorporates temperature information in the estimate for catchability (i.e., the extent to which a stock is susceptible to fishing). The assessment considers ocean temperature effects on the timing of seasonal movement, using regularly updated survey data. In another example, the stock assessment update for chili pepper rockfish in NMFS' West Coast Region estimates growth based on the Pacific Decadal Oscillation, a climate variability pattern over the Pacific Ocean. (See app. VII for additional examples of fish stock assessments that incorporated climate information.) NMFS officials we interviewed said that additional data and research are needed to develop fish stock assessments that incorporate climate information.

We also found a few examples of fisheries managers informally using climate information to help inform fishery management decisions. For instance, according to our interviews with fisheries managers and NMFS, committees of three Councils consider information in the ecosystem status reports when making fisheries management decisions, such as when reviewing stock assessments and making annual recommendations on catch limits. In addition, contextual information, including ecosystem and socioeconomic indicators and risk information, presented with fish stock assessments and related evaluation reports, have been used to inform decisions on allowable catch limits. For example, a risk table

included with the 2020 stock assessment for sablefish in Alaska evaluated and ranked the uncertainties of stock assessment results related to environmental and other factors, including climate-related factors. According to North Pacific Council officials we interviewed, the risk table allowed the Council to have a more structured discussion about risk in making fisheries management decisions, and it set catch limits at 57 percent below the maximum level. NMFS officials told us that the Alaska Fisheries Science Center is planning to incorporate the risk table approach for other fish stock assessments in the region based on recommendations from a 2021 Council workshop on the use of risk tables.

Most Fisheries Managers Are Leading Initiatives to Begin Using Climate Information and Could Benefit from Regular Information-Sharing Across Regions

Most fisheries managers (seven of nine) are leading or partnering in initiatives to develop approaches that could eventually lead to additional use of climate change information in federal fisheries management.⁴⁶ Examples of climate-focused initiatives include the following:

- **Scenario planning.** Scenario planning is a method used to help identify and plan for uncertainties, such as the potential impacts of climate change on fisheries.⁴⁷ Scenario planning efforts are underway in three of five NMFS regions. For example, in the NMFS West Coast Region, the Pacific Council initiated a scenario planning process in 2019 as part of a Climate and Communities Initiative conducted to improve understanding of the near-term and long-term effects of climate change on fisheries and communities. NMFS also planned to identify ways the Council could incorporate lessons learned in its decision-making. The process involved a series of public workshops to develop climate scenarios for the next 20 years, examine potential impacts on fisheries and communities, and identify management approaches and tools to help deal with these impacts. A September 2021 project report made recommendations on potential Council activities to support climate efforts. As of March 2022, the Council had directed a workgroup to review these recommendations and advise on

⁴⁶Fishery ecosystem plans developed by fisheries managers under NMFS' Ecosystem-Based Fisheries Management Policy identified some of these climate-focused initiatives. NMFS encouraged Councils to develop fishery ecosystem plans to help advance ecosystem-based fisheries management.

⁴⁷NMFS has developed a technical memorandum that provides information for use by fisheries managers who are considering engaging in a scenario planning process by providing examples and analysis of previous scenario planning projects. See U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *Scenario Planning: An Introduction for Fishery Managers*, NOAA Technical Memorandum NMFS-OSF-9 (Silver Spring, MD: July 2020).

potential activities to be undertaken by the Council. A similar scenario planning effort led by the Mid-Atlantic Council is underway for the East Coast, which involves NMFS headquarters and regional offices and four relevant fisheries management organizations—the Mid-Atlantic, New England, and South Atlantic Councils, as well as the Atlantic Commission.

- **Special task force.** In 2019, the North Pacific Council created a Climate Change Task Force to facilitate the Council's planning toward climate-ready fisheries management and to help ensure both short- and long-term resilience for the Bering Sea. As described in its workplan for 2021-2025, the task force will conduct a gap analysis to determine areas where climate change information is incorporated in management advice and where it may be missing. According to the Council officials, the task force will develop recommendations for potential management actions and tools to better incorporate climate information in Council processes, such as updating fishery management plans.
- **Risk assessment process.** The Mid-Atlantic Council is using climate information in a risk assessment process to support the transition from single-species management toward a fisheries management approach within a broader ecosystem context.⁴⁸ The risk assessment process involves examining ecological, economic, social, and other risks and takes into account 25 different ecosystem risk factors. According to Council officials, this process can help the Council prioritize its efforts to improve fisheries management. For example, through this process, the Council decided to prioritize the development of a management strategy evaluation to manage recreational fishing of summer flounder based on its vulnerability to climate change, among other factors.

At the national level, however, there is limited sharing of fisheries managers' ongoing initiatives to use climate information in management activities. Specifically, we found that NMFS does not regularly collect or share information about actions that fisheries managers are taking to enhance the climate resilience of federal fisheries. Further, most fisheries managers (six of nine) told us that they are often unaware of some of the climate-related actions taken in other regions, and they were curious to know what other fisheries managers were doing in this area.

⁴⁸Mid-Atlantic Fishery Management Council, *Ecosystem Approach to Fisheries Management Guidance Document* (approved by the Council August 8, 2016, and revised February 8, 2019).

NMFS officials told us that the agency does disseminate information about the activities of fisheries managers in certain ways. For instance, climate-related fisheries management issues are sometimes discussed at biennial Council Coordination Committee meetings and annual Council Scientific Coordination Subcommittee meetings, which include NMFS staff and representatives from all of the Councils. In addition, NMFS has working groups that periodically hold national workshops and meetings to share information on common challenges. For example, in August 2021, NMFS hosted a workshop on improving the use of ecosystem status reports in fisheries management. NMFS officials told us that Council officials found the workshop to be useful for sharing information and discussing ongoing challenges. NMFS also published a report, which was made available on its website, summarizing the results of this workshop.⁴⁹

Nevertheless, representatives from two of 15 stakeholder organizations we interviewed said that fisheries managers could benefit from learning about actions that fisheries managers are taking, or are planning to take, to enhance the climate resilience of fisheries. NMFS documents indicate that information sharing between fisheries managers is helpful. For example, fisheries managers could benefit from learning about fishery management plans that were updated or amended to incorporate climate information and how other managers have used climate vulnerability assessments and ecosystem status reports to make decisions. Additionally, in 2021, NOAA solicited public comments about how to make fisheries more resilient to climate change,⁵⁰ and synthesized the comments in a technical memorandum.⁵¹ Some of the commenters noted that Councils could benefit from better information-sharing about best practices for effectively managing new or emerging fisheries resulting

⁴⁹U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *Investigating and Improving Applications of Ecosystem Status Reports in U.S. Fisheries Management. Report from a 2021 Workshop Organized by the National Marine Fisheries Service Ecosystem-Based Fisheries Management Working Group*, NOAA Technical Memorandum NMFS-OSF-11 (Silver Spring, MD: March 2022).

⁵⁰See Recommendations for More Resilient Fisheries and Protected Resources Due to Climate Change, 86 Fed. Reg. 12,410 (Mar. 3, 2021).

⁵¹U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *Synthesis of Public Comments to NOAA on Executive Order 14008, Tackling the Climate Crisis at Home and Abroad, Section 216(c): Recommendations on How to Make Fisheries and Protected Resources, Including Aquaculture, More Resilient to Climate Change*, NOAA Technical Memorandum NMFS-F/SPO-218 (Silver Spring, MD: October 2021).

from climate impacts. According to the information principle in GAO's *Disaster Resilience Framework*, federal efforts can help decision makers better identify and select actions to enhance climate resilience.⁵² An effort by NMFS to regularly collect and publicly share information on climate-related activities taken by fisheries managers across all regions could improve fisheries managers' abilities to identify and select future actions to enhance federal fisheries' resilience to climate change.

NMFS and Fisheries Managers Face Several Challenges to Enhancing the Climate Resilience of Federal Fisheries and Have Opportunities to Address Them

NMFS regions and fisheries managers face several challenges to enhancing the climate resilience of fisheries, including limited data and modeling information. However, we also found that opportunities exist to help address these challenges, according to our review of relevant literature and interviews. NMFS highlighted some of these opportunities in a 2018 guidance document for the Councils, but the agency has not effectively partnered with the Councils on how to implement them.

NMFS and Fisheries Managers' Challenges in Enhancing Fisheries' Climate Resilience

Using our interviews with NMFS, all eight Councils, and the Highly Migratory Species Division, we identified several challenges to enhancing the climate resilience of fisheries, which we organized into four categories.

Limited Data and Modeling Information

Limited data and modeling information on the impacts of climate change on fisheries is a challenge to enhancing the climate resilience of fisheries. Some Councils (three of eight), most NMFS regions (four of five), as well as one out of 15 stakeholders we interviewed said that there are limited baseline data for certain fish stocks. This restricts the ability to measure future changes against current conditions, such as detecting the impacts of climate change on fish stocks or predicting how species will behave under changing conditions, and making management decisions in response. There are also challenges related to the accessibility of existing fisheries data. According to one researcher and NMFS region we interviewed, there is a need to make existing survey data more accessible for users, such as fisheries modelers.

⁵²[GAO-20-100SP](#).

**National Marine Fisheries Service (NMFS)
Surveys and Offshore Wind Energy
Development in Federal Waters**



The United States has a goal of deploying 30 gigawatts of offshore wind energy by 2030 to help mitigate climate change. Developing these projects requires substantial monitoring and regulatory review to meet biodiversity and mixed ocean use goals. Stakeholders we interviewed and those that provided public comments to NMFS on the climate resilience of fisheries were supportive of offshore wind energy development but raised concerns about potential impacts to fish habitat and fishing activity. In addition, offshore wind development poses potential impacts to NMFS' ability to conduct aerial and vessel surveys. These surveys are important for managing fisheries and provide key data on climate impacts on marine resources.

To support offshore wind energy plans and address biodiversity and ocean co-use goals, in March 2022 NMFS and the Bureau of Ocean Energy Management (BOEM), the federal agency responsible for renewable offshore energy development, published a draft strategy, which includes an approach for mitigating the impacts of offshore wind projects on NMFS' fisheries surveys. It outlines actions for the next 2 years, such as documenting and analyzing impacts on NMFS' surveys during the environmental review process for offshore wind projects and establishing a joint NMFS – BOEM implementation team.

Sources: GAO analysis of NMFS and BOEM documents and stakeholder interviews; Department of Energy (image). | GAO-22-105132

One stakeholder organization said that data confidentiality agreements prevented them from receiving NMFS data needed to conduct climate fisheries research for 2 years. Moreover, NMFS officials told us that stock assessment analysts spend a large amount of time tracking down data and making it useable for assessments, which takes away from staff time that could be devoted to modeling efforts using the data.

According to a few fisheries managers (three of nine) and most NMFS regions (four of five), there is limited modeling information on possible future climate and ocean conditions at the geographic and time scales needed to better inform fisheries management decisions. Until recently, global climate models were used to provide projections of ocean conditions at global, national, and regional geographic scales but often lacked detail needed to adequately address fisheries management issues on regional and subregional scales.

Regarding time scales, officials from three Councils stated that they have received climate projections for 10 years or more into the future, which are of limited use in fisheries management, which has a shorter-term focus of making decisions in the next few months or years. Similarly, NMFS scientists need climate and ocean projections at shorter time scales to provide early warnings of near-term extreme events, such as marine heatwaves, and to incorporate near- and mid-term projections of ocean conditions into stock assessments for fisheries managers. According to officials from one Council, this limited modeling information stems in part from a misalignment between the research priorities of NMFS and the information needs of the Council.

Challenges to the Fisheries Management Process Posed by Changing Conditions

According to most Councils (six of eight), most NMFS regions (three of five), and a few stakeholders (two of 15) we interviewed, changing conditions caused by climate change, such as shifting distributions of fish stocks resulting from warming waters, present challenges to the existing fisheries management process. Most Councils (six of eight) and two stakeholders (two of 15) told us that the existing fisheries management structure is inadequately flexible to respond to climate-related changes in fisheries. Fishing quotas for fish stocks are often based on historical data that can be less predictive of future conditions, and fish productivity and distribution is often assumed to be similar to historical conditions when this assumption may no longer hold because of climate change. When the distribution of a fish stock moves across Council boundaries, a Council that has not historically managed the stock may need to develop a new fishery management plan for the stock, which can take 1 or 2 years, or longer.

In addition, there are political and economic pressures to maintain the status quo, which limits the adaptability of fisheries management to changing conditions. For example, according to one researcher, despite northward shifts in the distribution of fish, there is pressure for Councils to maintain current fishing quotas for states outlined in fishery management plans instead of updating them to reflect these shifts. Changing fishing quota allocations could negatively impact fishers in states that have historically received these quotas, according to that stakeholder. Further, fisheries managers also face competing management priorities tied to preparing for the upcoming fishing season, which limits their ability to prioritize and make longer-term management decisions related to climate resilience, according to NMFS officials.

Limited Collaboration

Some Councils (three of eight) and stakeholders (four of 15) and one NMFS region we interviewed, said that limited collaboration or communication between and across NMFS regions and the Councils is a challenge to enhancing the climate resilience of fisheries. For example, one stakeholder cited insufficient collaboration between NMFS regions and fisheries managers in NMFS' science development processes, where fisheries managers are seen as receivers of information from NMFS rather than collaborators. In addition, according to officials from one NMFS region and one Council, NMFS regions do not always coordinate with each other to ensure consistency in fish survey methods across jurisdictional boundaries. This limits the degree to which fisheries managers can understand changes in fish species distribution. Further, NMFS regions are not always aware that other regions are experiencing

similar challenges related to climate change, according to another stakeholder, and cross-regional learning could benefit the Councils.

Limited collaboration and communication from NMFS regions and the Councils with stakeholders, such as the fishing industry and the climate research community, can also contribute to stakeholders' mistrust of NMFS and Councils' actions related to addressing climate impacts on fisheries. Representatives from one stakeholder organization said that fishing communities feel that fisheries managers are not always responding to the changes that they are seeing on the water. Another said that fishing communities do not know if the science is reflecting these changes. Representatives from another stakeholder organization said that there is an absence of trust from stakeholders, such as the fishing industry, in the science produced by NMFS regions used to inform fisheries management changes. This occurs, in part, because the science development process is not as transparent as it could be. NMFS officials acknowledged this challenge and told us that there is more trust by stakeholders in some regions than in others in the information provided. According to a 2021 NOAA Science Advisory Board report, communication with diverse stakeholders is identified as an important element for maintaining trust in the science produced by NOAA.

Resource Constraints

According to most fisheries managers (five of nine), all NMFS regions (five of five), and many stakeholders we interviewed (seven of 15), resource constraints also pose challenges to enhancing the climate resilience of fisheries. Officials from a few Councils said that the amount of funding in NMFS regions limits the availability of climate information that can be produced and used in fisheries management. Specifically, NMFS regions are constrained by limited funding for efforts related to climate resilience and the absence of dedicated staff for these efforts. Officials from two NMFS regions explained that their ability to work on efforts related to climate resilience—such as downscaling climate models to a regional level or incorporating climate information into fish stock assessments—is dependent on receiving dedicated funding or additional staff capacity that they do not currently have. Further, according to officials in one NMFS region and the Council they serve, the region only has the resources to carry out key fish stock surveys and does not have the resources to carry out the full range of surveys that they implemented in the past.

Opportunities Exist to Address the Challenges to Enhancing Climate Resilience Faced by NMFS and Fisheries Managers

We identified opportunities to address the challenges facing NMFS and fisheries managers through a literature review, a review of NMFS' 2018 guidance document on improving the fisheries management process in response to climate change, and our interviews.⁵³

To help address the challenge of limited data, there are opportunities for NMFS to partner with the fishing industry and others to collect additional data and to expand monitoring of fish stocks. For example, according to three articles we reviewed, leveraging relationships with the fishing industry can increase data collection through outfitting commercial vessels with observation technologies such as cameras.⁵⁴ For instance, fisheries managers in Scotland have used information collected through a monitoring system on private vessels to support fishing closures to reduce the mortality and discard of cod species, according to one of the articles.⁵⁵ In addition, the 2018 NMFS guidance document identifies opportunities for NMFS to expand fisheries monitoring, such as by engaging stakeholders and fishers to collect data through what are called citizen science programs.⁵⁶

There are also opportunities to expand surveys for fish stocks that are under-surveyed or to cover new areas in response to the changing distribution of fish stocks. For example, in Alaska, NMFS conducted trawl surveys starting in 2010 in formerly ice-covered areas in the northern Bering Sea to gather information on fish stocks as they shifted northward. NMFS has been able to include the northern Bering Sea in its surveys most years from 2017 onward. In addition, as part of CEFI, NOAA plans to produce models of future ocean ecosystems, fish stocks, and fisheries at the time and geographic scales needed to help fisheries managers evaluate management approaches and make climate-informed decisions.

⁵³National Marine Fisheries Service, *Accounting for Shifting Distributions and Changing Productivity in the Fishery Management Process*.

⁵⁴Food and Agriculture Organization of the United Nations, *Deep-ocean climate change impacts on habitat, fish and fisheries*, FAO Fisheries and Aquaculture Technical Paper 638 (Rome, Italy: 2018); Darcy Bradley et al., "Opportunities to improve fisheries management through innovative technology and advanced data systems," *Fish and Fisheries*, vol. 20, no. 3 (2019): 564-583; and Matt Merrifield et al., "eCatch: Enabling collaborative fisheries management with technology," *Ecological Informatics*, vol. 52 (2019): 82-93.

⁵⁵Matt Merrifield et al., "eCatch: Enabling collaborative fisheries management with technology."

⁵⁶National Marine Fisheries Service, *Accounting for Shifting Distributions and Changing Productivity in the Fishery Management Process*.

As discussed above, these products from CEFI are in developmental stages, and the effort has not received dedicated funding but, if implemented, the initiative could provide a national integrated ocean modeling and decision support system. As of June 2021, the Northeast Fisheries Science Center is engaging with OAR on developing 2- to 10-year climate projections for use in stock assessments through CEFI-related efforts.

Using our review, we also identified some opportunities to address challenges to the fisheries management process posed by changing conditions. For example, according to one article we reviewed, fisheries managers can increase the flexibility of setting fishing quotas by moving away from setting these quotas based on the historic amount of fish harvested in these areas and incorporating current stock distribution data.⁵⁷ In addition, officials from the Atlantic Commission told us that fishery management plans for certain stocks, such as summer flounder and bluefish, allow states to transfer their fish stock quotas, if needed. States may decide to do this when market conditions or the distribution of fish change and fisheries in certain states are unable to fully harvest their available quota. This allows states greater flexibility to permit fishers to harvest additional fish, if there is limited availability of the species in their state's coastal area.⁵⁸

Another opportunity to address challenges to the fisheries management process involves using exempted fishing permits, which are issued by NMFS to authorize fishing activities, generally activities in support of fisheries-related research, which would otherwise be prohibited. For example, the NMFS West Coast Region and Pacific Council used exempted fishing permits to test new or revised gear types to address bycatch of protected or overfished species and to test monitoring techniques, such as electronic logbooks for capturing fishing data.

We also identified some opportunities to increase collaboration and communication between NMFS and the Councils. NMFS regions do

⁵⁷Richard Bell et al., "Actions to Promote and Achieve Climate-Ready Fisheries: Summary of Current Practice," *Marine and Coastal Fisheries: Dynamics, Management and Ecosystem Science*, vol. 12 (2020):166-190.

⁵⁸According to Atlantic States Marine Fisheries Commission officials, for some species, such quota transfers must be approved by the NMFS Regional Administrator for species in federal waters and by the Atlantic Commission's Executive Director for species in state waters. Quota transfers are generally approved, if there is an agreement between a donor state and a receiving state, according to Commission officials.

share some climate-related information with one another, such as through quarterly meetings of regional action plan teams across NMFS regions. In addition, the three Councils on the East Coast participate in each other's meetings to share information. However, additional opportunities exist for NMFS headquarters to facilitate knowledge-sharing between NMFS regions and the Councils, such as those described in the second objective of this report. In addition, there are opportunities to increase coordination of survey monitoring methods across jurisdictional boundaries, which can increase understanding of climate impacts. For example, in 2021 the Southeast Fisheries Science Center held a workshop with members from the Northeast Fisheries Science Center to discuss how fish survey coordination and data collection could be improved to better understand species distribution in the Atlantic Coast. According to officials from the Southeast NMFS region, greater investment in surveys can help ensure that survey methods are consistent between and within regions.

There are also opportunities to increase NMFS and Council collaboration and communication with research and industry stakeholders. According to the 2018 NMFS guidance document, creating mechanisms for regular and open dialogue between scientists, fisheries managers, and fisheries stakeholder organizations can support transparent decision-making and ensure that appropriate data are collected and used.⁵⁹ These mechanisms include scheduling workshops where managers, scientists, and stakeholders discuss what information is needed to better inform fisheries management decisions. For example, one stakeholder said that the Climate and Fisheries Adaptation program facilitates monthly meetings where NOAA-funded researchers, NMFS scientists, and other NOAA staff discuss ongoing climate-related research. Further, according to one article we reviewed, there is a need to consult with relevant stakeholders in work related to developing climate adaptation strategies.⁶⁰ Another article recommended that NMFS and the Councils develop a stakeholder involvement process to prepare for controversial discussions

⁵⁹National Marine Fisheries Service, *Accounting for Shifting Distributions and Changing Productivity in the Fishery Management Process*.

⁶⁰Hannah E. Fogarty et al., "Stakeholder perceptions on actions for marine fisheries adaptation to climate change," *Marine and Freshwater Research*, vol. 72 (2021):1430-1444.

that will arise related to quota reallocation and fisheries management driven by climate impacts.⁶¹

NMFS' 2018 Guidance Document Identified Potential Opportunities to Address Challenges, but NMFS Has Not Effectively Partnered with Fisheries Managers on Its Implementation

In 2018, NMFS headquarters provided a guidance document to NMFS regions and fisheries managers that identified six steps and associated actions for addressing changes in the distribution and productivity of fisheries related to climate change. Officials we interviewed in most NMFS regions (four of five) said that they have taken some actions identified in the NMFS 2018 guidance document, and three NMFS regions told us that they shared the guidance document with the Councils. For example, one NMFS region said that they are working to facilitate coordination across jurisdictional boundaries. NMFS regions have also assisted the Councils in some efforts related to climate change, such as scenario planning exercises, as well as with the establishment of the North Pacific Council's Climate Change Task Force. However, NMFS officials said that NMFS regions are not actively working with Councils on implementing actions identified in the guidance, and we found that one Council was not familiar with the guidance document.

NMFS headquarters officials said that the 2018 guidance document is non-binding. Therefore, according to these NMFS officials, the agency has not required Councils to use it in the development of fishery management measures. NMFS officials also noted that there are other guidance documents available to the agency and the Councils to inform their development of fishery management measures that take climate change into account.⁶² Nevertheless, the 2018 guidance document highlights the need for regional discussions and planning to prioritize actions and determine how to implement the steps and recommendations

⁶¹Don Gourlie, "Reeling in Uncertainty: Adapting Marine Fisheries Management to Cope with Climate Effects on Ocean Systems," *Environmental Law*, vol. 47, no. 179 (2017): 179-224.

⁶²Other guidance documents that inform development of climate-resilient fishery management measures identified by NMFS officials include the following: U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *Governance Case Studies on Marine Fisheries that Cross Jurisdictional Boundaries in the United States*, NMFS-OSF-10 (Silver Spring, MD: September 2021); and *A Review of Potential Approaches for Managing Marine Fisheries in a Changing Climate*, NMFS-OSF-6 (Silver Spring, MD: November 2016); Jason Link et al., "Proposed business rules to incorporate climate-induced changes in fisheries management," *International Council for the Exploration of the Sea Journal of Marine Science*, vol. 78, no. 10 (2021): 3562-3580; and Malin L. Pinsky and Nathan J. Mantua, "Emerging Adaptation Approaches for Climate-Ready Fisheries Management," *Oceanography*, vol. 27, no. 4 (2014): 146-159.

that it describes. The guidance document also states that NMFS regions should partner with the Councils and regional stakeholders to identify the most effective approaches for implementing actions.⁶³ Commerce's 2021 Climate Action Plan states that NOAA is to engage with partners to plan for and adapt to climate change, including by helping decision makers to prioritize adaptation measures. Furthermore, GAO's *Disaster Resilience Framework* states that those who provide oversight or management of federal efforts related to resilience should consider how these efforts can help decision makers prioritize resilience goals that reflect the most pressing challenges.⁶⁴ Improved collaboration on implementing potential opportunities in the 2018 guidance document and other sources between NMFS and the Councils could increase the use of climate information in fisheries management decisions and enhance fisheries' resilience to climate change.

Conclusions

According to the *Fourth National Climate Assessment*, marine fisheries are at high risk from climate-driven changes to ocean ecosystems, such as ocean warming and acidification that may cause changes in the productivity and distribution of certain species. These changes could have significant economic consequences for the industries and communities that depend on affected species and may contribute to future fishery disasters. Moreover, the *Fourth National Climate Assessment* stated that climate-change-related effects on ocean ecosystems are likely to increase, thereby creating additional challenges to effectively managing marine fisheries. To date, NMFS has taken actions to implement its *Climate Science Strategy* that have resulted in progress in the development of climate science information and tools. Moving forward, it is critical that NMFS take steps to support fisheries management actions that enhance the climate resilience of fisheries.

While fisheries managers have used climate information in their fisheries management activities to a limited extent, they have begun leading initiatives to advance the use of climate change information in managing federal fisheries in the future. Although NMFS has disseminated information on climate-related fisheries management activities in some instances, NMFS does not regularly collect or share information about such actions. Fisheries managers could benefit from better information-sharing about actions taken to effectively manage new or emerging

⁶³National Marine Fisheries Service, *Accounting for Shifting Distributions and Changing Productivity in the Fishery Management Process*.

⁶⁴[GAO-20-100SP](#).

fisheries resulting from climate impacts. An effort by NMFS to regularly collect and publicly share information on climate-related activities taken by fisheries managers across all regions could improve fisheries managers' abilities to plan and develop future actions to enhance federal fisheries' resilience to climate change.

In addition, NMFS and fisheries managers face several challenges to enhancing the climate resilience of federal fisheries, and there are opportunities to help address them. NMFS highlighted some of these opportunities in a 2018 guidance document on fisheries management and climate change and other sources, but the agency has not effectively partnered with fisheries managers to implement potential opportunities. Improved collaboration between NMFS regions and fisheries managers—the Councils and the HMS Division—on implementing the 2018 guidance and other opportunities to address region-specific challenges, could increase the use of climate information in fisheries management decisions and enhance the resilience of fisheries to climate change.

Recommendations for Executive Action

We are making the following two recommendations to NMFS:

The Assistant Administrator for NMFS should regularly collect and publicly disseminate information on actions taken by the Regional Fishery Management Councils and NMFS' Atlantic Highly Migratory Species Division to enhance the climate resilience of federal fisheries, such as fishery management plans that use climate information. (Recommendation 1)

The Assistant Administrator for NMFS should direct the agency's regional offices and fisheries science centers to work with the Regional Fishery Management Councils and NMFS' Atlantic Highly Migratory Species Division in their respective regions to identify and prioritize opportunities to enhance the climate resilience of federal fisheries, including by reviewing the opportunities described in this report and in NMFS' 2018 guidance document, *Accounting for Shifting Distributions and Changing Productivity in the Fishery Management Process*, and develop a plan to implement them. (Recommendation 2)

Agency Comments

We provided a draft of this report to the Department of Commerce for review and comment. In written comments (reproduced in appendix VIII), the Department of Commerce and NOAA agreed with our recommendations. NOAA commended GAO for its thorough review and stated that it concurs with our report's findings. In particular, NOAA agreed that the Regional Fishery Management Councils are helping to

lead efforts to incorporate climate-related information in fisheries management, and that additional information, tools, and capacity are needed for these efforts. NOAA agreed with our recommendation that NMFS should regularly collect and disseminate information on actions taken by the Councils and HMS Division to enhance the climate resilience of federal fisheries. NOAA said that the agency plans to create a website or other publicly available mechanism for compiling and sharing such information.

In addition, NOAA agreed with our recommendation that NMFS regional offices and fisheries science centers work with the Councils and the HMS Division in their respective regions to identify and prioritize opportunities to enhance the climate resilience of federal fisheries. For example, NOAA stated that NMFS plans to continue to work with the Councils to consider climate-related priorities and available resources as part of its annual processes to prioritize the science and management actions for the upcoming year. NOAA also provided technical comments, which we incorporated as appropriate.

We are sending copies of this report to the appropriate congressional committees, the Secretary of Commerce, and other interested parties. In addition, the report will be available at no charge on the GAO website at <http://www.gao.gov>.

If you or your staff have any questions about this report, please contact me at (202) 512-3841 or johnsoncd1@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. GAO staff members who made key contributions to this report are listed in appendix IX.



Cardell Johnson
Acting Director, Natural Resources and Environment

List of Committees

The Honorable Jeanne Shaheen
Chair

The Honorable Jerry Moran
Ranking Member
Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
United States Senate

The Honorable Matt Cartwright
Chairman

The Honorable Robert Aderholt
Ranking Member
Subcommittee on Commerce, Justice, Science, and Related Agencies
Committee on Appropriations
House of Representatives

The Honorable Jared Huffman
Chair

The Honorable Cliff Bentz
Ranking Member
Subcommittee on Water, Oceans, and Wildlife
Committee on Natural Resources
House of Representatives

Appendix I: Objectives, Scope, and Methodology

House Report 116-455 included a provision for GAO to examine federal efforts to prepare and adapt federal or jointly managed fisheries to the impacts of climate change.¹ Our report examines (1) the actions the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS) has taken to enhance the climate resilience of federal fisheries since GAO's 2016 report;² (2) the extent to which fisheries managers have used climate information provided by NMFS and others in fisheries management activities; and (3) the challenges NMFS and fisheries managers face in enhancing the climate resilience of federal fisheries, and opportunities that may exist to address such challenges.³

To identify actions taken by NMFS to enhance the climate resilience of federal fisheries since GAO's 2016 report, we reviewed relevant laws, regulations, executive orders, and past GAO reports. For this and the other two objectives, we reviewed our prior work on climate change and climate resilience, including GAO's 2016 report on fisheries management and climate change, and reviewed agency actions for consistency with relevant principles on providing information and integrated planning, using GAO's *Disaster Assistance Framework*.⁴

We also reviewed NMFS documents related to enhancing the climate resilience of federal fisheries. NMFS documents that we reviewed included NMFS' *Climate Science Strategy* that describes objectives for increasing the production, delivery, and use of climate-related information

¹H. Rept. 116-455, accompanying H.R. 7667, Commerce, Justice, Science, and Related Agencies Appropriations Bill, 2021.

²In 2016, we reviewed federal efforts to address the effects of climate change on federal fisheries. See GAO, *Federal Fisheries Management: Additional Actions Could Advance Efforts to Incorporate Climate Information into Management Decisions*, [GAO-16-827](#) (Washington, D.C.: Sept. 28, 2016).

³For the purposes of this report, enhancing climate resilience of federal fisheries means taking actions to reduce potential future impacts on fisheries by preparing and adapting for potential climate hazards, such as extreme storm events, sea level rise, and warming ocean temperatures.

⁴GAO, *Disaster Resilience Framework: Principles for Analyzing Federal Efforts to Facilitate and Promote Resilience to Natural Disasters*, [GAO-20-100SP](#) (Washington, D.C.: Oct. 23, 2019).

in the management of fisheries and other living marine resources.⁵ We reviewed regional action plans developed to support implementation of the strategy and a December 2021 *Climate Science Strategy Five Year Progress Report* on implementation of its strategy. We also reviewed other relevant NMFS policies and guidance, including two 2018 guidance documents—one on *Accounting for Shifting Distributions and Changing Productivity in the Fishery Management Process* and another on improving stock assessments.⁶ In addition, we reviewed available documents and tools related to fisheries climate information developed by NMFS. For example, we reviewed fish stock assessments identified by NMFS officials or fisheries managers as having incorporated climate-related information; climate vulnerability assessments used to identify which species may be most vulnerable to climate change; and ecosystem status reports that provide an overview of the status, trends, and possible future conditions of ecosystem components, including climate-related impacts.

We also interviewed officials from NMFS headquarters and all five NMFS regions (including officials from the five regional offices and six corresponding fisheries science centers) about the agency's progress on implementing its *Climate Science Strategy*, its application of relevant guidance, and other actions to make fisheries more resilient to climate change.⁷ We also interviewed officials in NOAA's Office of Oceanic and Atmospheric Research and NOAA's National Ocean Service about their collaboration with NMFS on activities to enhance the climate resilience of fisheries.

⁵U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *NOAA Fisheries Climate Science Strategy*, NOAA Technical Memorandum NMFS-F/SPO-155 (Silver Spring, MD: August 2015).

⁶U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, *Accounting for Shifting Distributions and Changing Productivity in the Fishery Management Process: From Detection to Management Action*, NOAA Technical Memorandum NMFS-F/SPO-188 (Silver Spring, MD: November 2018); and *Implementing a Next Generation Stock Assessment Enterprise; An Update to the NOAA Fisheries Stock Assessment Improvement Plan*, NOAA Technical Memorandum NMFS-F/SPO-183 (Silver Spring, MD: June 2018).

⁷Where possible, we jointly interviewed NMFS' regional offices and regional fisheries science centers—which are responsible for conducting research and providing scientific advice. We compiled information collected from these interviews on a regional basis for each of the five NMFS region where individual interviews were conducted.

To examine the extent to which fisheries managers have used climate-related information provided by NMFS and others in fisheries management activities, we reviewed websites and documentation from the eight Regional Fishery Management Councils (Councils) responsible for fisheries management in their respective regions (New England, Mid-Atlantic, South Atlantic, Gulf of Mexico, Caribbean, North Pacific, Pacific, and West Pacific), as well as NMFS' Atlantic Highly Migratory Species Division (HMS Division) for fishery management activities that use climate information.⁸ The types of documents that we reviewed included fishery management plans and amendments that establish fishery conservation and management measures for fish stocks, fishery ecosystem plans, workplans, and summary reports on climate-related activities.

We interviewed representatives from the eight Councils and NMFS' HMS Division about their use of climate-related information in fisheries management and other efforts to enhance the climate resilience of federal fisheries.⁹ In addition, we interviewed officials from NMFS headquarters and its five regions.

We also interviewed the three regional interstate marine fisheries commissions (Atlantic, Gulf of Mexico, and Pacific) and 15 selected stakeholders about their perspectives on the use of climate information in fisheries management activities. We selected a nongeneralizable sample of seven stakeholders representing groups from commercial and recreational fishery organizations and conservation organizations, and eight researchers from academic institutions conducting work in this area.¹⁰ We identified stakeholders from suggestions by NMFS and the eight Councils and from our literature search discussed below. We selected stakeholders that were familiar with different regions of the United States and different aspects of the fisheries management process and that could provide a range of views. Stakeholders we interviewed

⁸For the purposes of this report, we define fisheries managers as all eight Councils and NMFS' Atlantic Highly Migratory Species Division, which are the entities with responsibilities for managing fish stocks in federal waters.

⁹We considered interviews with fisheries managers, including Councils, as a unit of one, regardless of how many individuals participated.

¹⁰For the purposes of this report, we define researchers as individuals from academic institutions like universities. The term "stakeholders" is used to describe both researchers and other groups described above. We considered interviews with stakeholder organizations as a unit of one, regardless of how many individuals participated; for interviews with multiple researchers in a single interview, we considered each individual researcher's perspective as unique.

were affiliated with the following organizations: the American Sportsfishing Association, Cape Cod Fisherman’s Alliance, Environmental Defense Fund, Gulf of Maine Research Institute, Lenfest Ocean Program, Ocean Conservancy, Rutgers University, The Nature Conservancy, University of Puerto Rico, and University of Washington. Views from selected stakeholders cannot be generalized to those we did not select and interview as part of our review.

To examine challenges that NMFS and fisheries managers face in enhancing the climate resilience of fisheries, and to identify any opportunities to address these challenges, we interviewed officials from NMFS headquarters and its five regions, the eight Councils, and NMFS’ HMS Division by asking them a standard set of questions about their perspective on challenges to enhancing the climate resilience of fisheries and opportunities to address them. We also interviewed officials from all three regional interstate marine fishery commissions and the 15 selected stakeholders about their perspectives on challenges facing NMFS and fisheries managers in enhancing the climate resilience of federal fisheries and opportunities to address challenges.

We conducted a content analysis of interview statements to identify any challenges described, as well any opportunities to address them. Using a preliminary review of the interviews by one analyst, and reviewed by a second analyst, we developed categories by type of challenge to organize interview statements. After we defined the categories, one analyst reviewed the interview statements for any descriptions of climate-related challenges and opportunities, then categorized the statements according to our categories of challenges; a second analyst repeated this process. We came to full agreement on both the categories of challenges and the categorization of interview statements into those categories. For reporting purposes, we merged some of the categories. Overall, four categories of challenges and corresponding opportunities were identified.

We also conducted a literature search in August 2021 and identified and reviewed 34 articles from 2016 through 2021 that discuss approaches to increasing the climate resilience of fisheries. Parameters for the literature search, which was conducted over multiple iterations to increase the relevancy of results, included publications found in the Scopus and Proquest databases. Search terms included “National Marine Fisheries Service,” “extreme weather,” “climate change,” “fishery management council,” and “climate vulnerability,” among other terms. The search yielded 165 articles that matched the criteria. After two iterations of an independent review of abstracts and the full article by two analysts, a final

list of 34 articles was identified as most relevant to our work. We analyzed the 34 articles for descriptions of potential opportunities for enhancing climate resilience, and we categorized these opportunities according to the type of challenge that they addressed. We reported on a few of the climate resilience opportunities identified in the literature search along with other examples, such as those that emerged from interviews.

We conducted this performance audit from April 2021 to August 2022 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives.

Appendix II: Summary of Climate Vulnerability Assessments

Climate vulnerability assessments, prepared by the National Marine Fisheries Service (NMFS), in collaboration with partners such as other government scientists and academics, evaluate the vulnerability of species, habitats, and fishing communities to changing climate and ocean conditions. Climate vulnerability assessments completed or underway as of May 2022 are described in table 3. These assessments follow a methodology that relies on technical experts, including NMFS staff, other government officials, and academics, to score marine species for sensitivity to attributes (e.g., adult mobility, spawning cycle, sensitivity to ocean acidification or temperature) and exposure factors (e.g., ocean surface temperature, ocean acidity, sea level rise). Assessment authors use species profiles, scientific literature, and general knowledge to characterize the overall vulnerability of the resource to a changing climate (e.g., low, medium, high, or very high).

Table 3: Climate Vulnerability Assessments Listed by National Marine Fisheries Service (NMFS) Region and Regional Fishery Management Council (Council)

NMFS region	Council ^a	Assessment type: region (date)	Description
Alaska	North Pacific	Fish stocks: Eastern Bering Sea fish and invertebrate stocks (2019)	<p>In 2019, NMFS staff, in collaboration with academics and other government scientists, completed a climate vulnerability assessment of 36 fish and invertebrate stocks in the eastern Bering Sea. The vulnerability of all assessed stocks to climate change ranged between “low” (26 stocks) and “moderate” (10 stocks) because of limited exposure to climate change factors.</p> <p>According to the assessment, the climate vulnerability assessment results are anticipated to be part of the Bering Sea Fishery Ecosystem Plan, which will consider how climate change affects human communities and what types of adaptation strategies are suitable.</p>
Greater Atlantic	Mid-Atlantic & New England	Fish stocks: Northeast U.S. continental shelf fish and invertebrate stocks (2016)	<p>In 2016, NMFS staff, in collaboration with fish species experts, completed a climate vulnerability assessment of 82 fish and invertebrate stocks in the Northeast U.S. continental shelf. The 82 species included were split about equally between the different ranks of how vulnerable they were to climate change (“very high,” “high,” “moderate,” and “low”). A number of iconic species in the ecosystem, such as Atlantic sea scallop, Atlantic cod, and Atlantic mackerel, were found to have moderate-to-high overall climate vulnerability scores and were assessed to be negatively impacted by climate change.</p> <p>The assessment describes ways that fisheries managers can use the results, including to inform fishery management plans, inform regional ecosystem-based management, identify species-specific management and research needs, and provide potential links to other types of vulnerability assessments.</p>

Appendix II: Summary of Climate Vulnerability Assessments

NMFS region	Council^a	Assessment type: region (date)	Description
		Habitat: Northeast U.S. marine, estuarine, and riverine habitats (2021)	<p>In 2021, NMFS, in collaboration with other federal agencies and academic experts, completed a climate vulnerability assessment of 52 marine, estuarine, and riverine habitats in the Northeast U.S. continental shelf ecosystem. The assessment ranked the climate vulnerability of habitats across four categories, ranging from “low” to “very high” vulnerability according to their sensitivity and exposure to climate change. The results of the assessment found that 38 percent of the habitats studied had low climate vulnerability, 54 percent had moderate or high vulnerability, and 10 percent had very high vulnerability. In particular, according to the assessment results, the marine system (compared to the riverine and estuarine systems) had the highest proportion of habitats with high or very high vulnerability ranks (39 percent).</p> <p>The assessment describes several ways that managers can use its results, including to update essential fish habitat designations (areas that fish need to spawn, breed, feed, or grow to maturity) and habitat areas of particular concern.</p>
Pacific Islands	Western Pacific	Fish stocks	As of May 2022, NMFS was conducting a climate vulnerability assessment for 83 fish stocks for the Pacific Islands Region.
Southeast	Gulf of Mexico	Fish stocks	As of May 2022, NMFS was conducting a climate vulnerability assessment for 75 fish stocks for the Gulf of Mexico Region. According to NMFS officials, the assessment includes some highly migratory species managed by NMFS’ Atlantic Highly Migratory Species Division.
	South Atlantic	Fish stocks	As of May 2022, NMFS was conducting a climate vulnerability assessment for 71 fish stocks for the South Atlantic Region. According to NMFS officials, the assessment includes some highly migratory species managed by NMFS’ Atlantic Highly Migratory Species Division.

Appendix II: Summary of Climate Vulnerability Assessments

NMFS region	Council^a	Assessment type: region (date)	Description
West Coast	Pacific	Fish stocks: Pacific salmon and steelhead (2019)	<p>In 2019, NMFS staff, in collaboration with other federal agencies and academics, completed a comprehensive climate vulnerability assessment for six species of Pacific salmon and steelhead across 33 distinct population segments in the U.S. portion of the California Current Large Marine Ecosystem^b and associated watersheds. Chinook salmon had the highest vulnerability rankings overall, followed by coho salmon and sockeye salmon. Steelhead and chum scores were generally lower and nearly equally spread across high and moderate vulnerability categories. One species—pink salmon— was in the low vulnerability category.</p> <p>In addition, as of May 2022, NMFS was completing climate vulnerability assessments for other fish stocks, covering 64 species in the West Coast Region as well as assessments for 129 species of protected Pacific marine mammals (West Coast and Alaska Regions) and 51 populations of sea turtles (U.S. waters).</p>
Multiple: Northeast & Southeast	Mid-Atlantic, New England, South Atlantic, & Gulf of Mexico	Fishing community: U.S. Eastern and Gulf Coast communities (2016)	<p>In 2016, NMFS staff in the Northeast Fisheries Science Center and Southeast Regional Office, along with academic partners, completed a study to assess the climate change and social vulnerability of fishing-dependent communities on the East and Gulf Coasts. The study used existing Community Social Vulnerability Indicators to develop a new set of climate vulnerability measures. The new measures were used to assess the impact of sea level rise on critical fishing infrastructure and community dependence on species that are vulnerable to climate change. Examples of these measures include “percent unemployed” and “number of commercial fishing permits by population.” The study found that 174 out of 2,659 communities analyzed (6.5 percent) were in the high range for commercial fishing engagement or reliance.</p> <p>According to the study, the indicators could be used to inform ecosystem models and to build a more integrated picture of climate change that could enhance policy decisions.</p>

Source: GAO analysis of NMFS and Council documents and interviews. | GAO-22-105132

^aEight Regional Fishery Management Councils (Councils) established under the Magnuson-Stevens Act, as amended, are responsible for managing fish stocks in federal waters. In addition, we include relevant information for NMFS’ Atlantic Highly Migratory Species Division, which is responsible for managing Atlantic highly migratory species from Maine to Texas in federal waters (generally 3 to 200 nautical miles from the shoreline).

^bThe U.S. portion of the California Current Large Marine Ecosystem is a region of the Pacific Ocean that spans the entire West Coast of the continental U.S., extending from the southern end of California to the northern tip of Washington State.

Appendix III: Summary of National Marine Fisheries Service Ecosystem Status Reports

The National Marine Fisheries Service (NMFS) regularly develops Ecosystem Status Reports in collaboration with academic, nonprofit, and state partners, with Regional Fishery Management Councils (Council) as the primary audience. The reports provide the Councils and other users with an overview of the status, trends, and potential future conditions of the components of specified marine ecosystems across the five NMFS regions. The reports, which are published annually or intermittently, describe ecosystem trends using sets of ecosystem indicators. Examples of ecosystem indicators include fishery species diversity and stock abundance, as well as climate-related indicators such as sea surface temperature and sea level rise. According to NMFS officials, the National Oceanic and Atmospheric Administration's (NOAA) National Marine Ecosystem Status webpage was established in 2021 to provide increased access to information on ecosystem conditions based on the regional Ecosystem Status Reports and other indicators.¹ For three of the Councils—the Mid-Atlantic, New England, and North Pacific Councils—their respective Scientific and Statistical Committees are the primary users of the reports. According to Council officials, committees use information in the report to help inform the process of setting annual catch limits, such as to adjust catch limits or targets for fish stocks, if caution is warranted.

As of May 2022, at least one Ecosystem Status Report was produced or in progress for seven of eight Councils.² In addition, NMFS' Atlantic Highly Migratory Species Division officials told us they use and review ecosystem status reports covering the Greater Atlantic and Southeast Regions for general information and fisheries management of highly migratory species. Ecosystem Status Reports completed and in progress for use by Councils as of May 2022 are described in table 4.

¹NOAA National Marine Ecosystem Status Report webpage: <https://ecowatch.noaa.gov/home>.

²NMFS' Pacific Islands Fisheries Science Center has not developed an ecosystem status report for the Western Pacific Council, but has developed one targeted for use by state fisheries managers in that region. See NMFS' website with Information on Ecosystem Status Reports: <https://www.integratedecosystemassessment.noaa.gov/ecosystem-status-reports>.

**Appendix III: Summary of National Marine
Fisheries Service Ecosystem Status Reports**

Table 4: Ecosystem Status Reports Developed by National Marine Fisheries Service (NMFS) Regions for Use by Regional Fishery Management Councils (Council)

NMFS region	Council^a	Areas covered	Frequency
Alaska	North Pacific	Eastern Bering Sea, Gulf of Alaska, and Aleutian Islands	Individual reports for each area produced annually since 2016; no report for the Aleutian Islands in 2017 or 2019
Greater Atlantic	Mid-Atlantic	Mid-Atlantic Bight (a region extending from Cape Hatteras, North Carolina, to Cape Cod, Massachusetts)	Produced annually since 2017
	New England	Gulf of Maine and Georges Bank (a large elevated area of sea floor separating the Gulf of Maine from the Atlantic Ocean)	Single report covering both areas produced annually since 2016
Southeast	Caribbean	Caribbean	In progress
	Gulf of Mexico	Gulf of Mexico	Produced intermittently since 2013
	South Atlantic	South Atlantic Bight from North Carolina to Florida	First produced in 2021
West Coast	Pacific	California Current Ecosystem	Produced annually since 2014

Source: GAO analysis of NMFS documents and interviews. | GAO-22-105132

^aEight Councils, established under the Magnuson-Stevens Act, as amended, are responsible for managing fish stocks in federal waters.

Appendix IV: Examples of Regional Management Strategy Evaluations Used to Examine Potential Climate Change Impacts on Fisheries

The National Marine Fisheries Service (NMFS) supports the development of management strategy evaluations (MSE) that can help fisheries managers evaluate the potential short- and long-term outcomes of management actions. MSEs use models to simulate possible future conditions (e.g., climate change scenarios) and potential effects of various management actions on ecosystems and fishing-dependent communities, such as revising catch limits for specific fish stocks or closing certain areas to fishing. Overall, MSEs can help fisheries managers determine what strategies could be most effective for achieving specific management objectives. Examples of MSEs completed or under development as of May 2022 are described in table 5.

Table 5: Examples of Management Strategy Evaluations (MSE) Developed with Support from the National Marine Fisheries Service (NMFS)

NMFS region	Council ^a	Example	Description
Alaska	North Pacific	Alaska Climate Integrated Modeling project	<p>The Alaska Climate Integrated Modeling project is being developed to help fisheries managers understand the current and future impact of various fisheries management options on living marine resources in the Bering Sea under different climate scenarios. The project connects physical, biological, and socioeconomic research and models. The effort involves more than 50 scientists from NMFS, academia, and other partners and includes physical oceanographers, ecosystem modelers, economists, social scientists, and fishery and living marine resource managers. As of October 2021, the project was in a pilot phase and being further developed for use in helping evaluate management of crab and other species.</p> <p>There is also a similar model being developed for the Gulf of Alaska.</p>
Greater Atlantic	Mid-Atlantic & New England	Northeast Climate Integrated Modeling project	<p>The Northeast Climate Integrated Modeling project is a collaborative effort of the Gulf of Maine Research Institute, Rutgers University, and the NMFS' Northeast Fisheries Science Center. This project aims to develop a framework to inform fisheries management decisions in the Northeast region of the U.S. The framework plans to integrate global climate models, regional oceanic models, ecosystem and population models, and human dimensions models to explore future scenarios for key Northeast fish stocks and species that have demonstrated shifts in distribution and changes in productivity. The project was funded in fiscal year 2020 by the National Oceanic and Atmospheric Administration's Climate and Fisheries Adaptation Program and was underway as of November 2021.</p>

Appendix IV: Examples of Regional Management Strategy Evaluations Used to Examine Potential Climate Change Impacts on Fisheries

NMFS region	Council ^a	Example	Description
	New England	Groundfish MSE	The groundfish MSE is underway to help (1) evaluate how principal groundfish stocks, such as cod, will respond to regional climate change; (2) investigate plausible approaches to tailoring fisheries management procedures to consider climate-informed information; and (3) quantify the expected ecological and economic performance of alternative fisheries management procedures in a changing climate. The project is being led by the Gulf of Maine Research Institute and is under development as of November 2021.
West Coast	Pacific	Future Seas	Future Seas is a collaborative modeling effort to explore the potential impacts of climate change on U.S. West Coast fisheries and to evaluate strategies for managing those impacts. The effort is focused on swordfish, albacore tuna, and coastal pelagic fisheries off the U.S. West Coast. For example, the Future Seas modeling system was used to develop a management strategy evaluation in 2020 for the swordfish fishery to examine fisheries management options under variable environmental conditions, such as evaluating the effectiveness of fishing area closures under climate variability. There are more than 30 scientists from NMFS, academia, and other partners involved in the project team.
		JISAO's Seasonal Coastal Ocean Prediction of the Ecosystem (J-SCOPE)	The J-SCOPE model forecasts were developed to support the California Current Integrated Ecosystem Assessment, which is used to help managers consider ecosystem factors in ocean management, including fisheries. In particular, J-SCOPE provides short-term (1- to 9-month) forecasts of climate-driven ocean conditions and species distribution that are relevant to management decisions for some target species, such as sardines for coastal waters in Washington State and Oregon. For example, forecast information for chlorophyll, sea surface temperature, and sardine biomass has been provided to managers at least annually since 2013. Forecast information from J-SCOPE is included in the ecosystem status report provided by NMFS to the Pacific Regional Fishery Management Council.
		California Current model using Atlantis	According to NMFS officials, this is an ecosystem model of the California Current System, which is the coastal ecosystem that includes U.S. coastal waters from Washington State to California. The model simulates oceanography, biogeochemistry, food webs, fisheries, and fisheries management and can be used for an ecosystem-scale management strategy evaluation that includes climate change projections. NMFS officials told us that their researchers are developing simulations that will test management actions across all fishery management plans under climate change scenarios to provide longer-term strategic advice, using this ecosystem model.

Appendix IV: Examples of Regional Management Strategy Evaluations Used to Examine Potential Climate Change Impacts on Fisheries

NMFS region	Council ^a	Example	Description
		Pacific hake MSE	According to NMFS officials, in 2022 NMFS plans to link climate projections to the MSE model to project the cumulative effects of climate change on hake recruitment, movement, and growth. The modeling effort will also involve testing alternative harvest control rules that meet established objectives of the international management committee and consider future climate scenarios.
Multiple	HMS Division	MSEs for northern albacore, bluefin tuna, northern swordfish and tropical tunas	The International Commission for the Conservation of Atlantic Tunas oversees the conservation and management of a variety of Atlantic marine species, including tunas and swordfish. This responsibility is shared among its 52 members, including the United States. In 2019 the commission developed a roadmap for MSE processes. As of 2021, the commission had several MSEs under development for species managed by NMFS' HMS Division including for northern albacore, bluefin tuna, northern swordfish and tropical tunas.

Source: GAO analysis of NMFS and Regional Fishery Management Council (Council) documents and interviews. | GAO-22-105132

^aEight Councils, established under the Magnuson-Stevens Act, as amended, are responsible for managing fish stocks in federal waters. In addition, we include relevant information for NMFS' Atlantic Highly Migratory Species Division (HMS Division), which is responsible for managing Atlantic highly migratory species from Maine to Texas in federal waters (generally 3 to 200 nautical miles from the shoreline).

Appendix V: Examples of National and Regional Mapping Tools

The National Marine Fisheries Service (NMFS) has supported the development of various national and regional mapping tools that provide information on climate impacts on fisheries to help inform the decision-making of fisheries managers and fishers. Many of these tools are web-based and map various types of data, including projected or real-time ocean information (e.g., ocean temperature, wind, sea level rise), fisheries survey data, and social indicators to provide information on predicted climate impacts on fisheries and communities. Examples of mapping tools completed or under development as of May 2022 are described in table 6.

Table 6: National and Regional Mapping Tools Listed by National Marine Fisheries Service (NMFS) Region and Regional Fishery Management Council (Council)

NMFS region	Council ^a	Example	Description
National		Distribution Mapping and Analysis Portal (DisMAP)	DisMAP is a new web portal that provides information about how distributions of fish stocks and other marine species have changed over time. The first version of the tool launched in April 2022 provides access to distribution information for more than 800 marine species in U.S. marine areas over the past 40 or more years. The site uses data collected annually by NMFS and will be expanded to include data from other sources in the future. Users can select a species of interest and visually examine changes in its distribution over time by viewing maps and graphs of key indicators of a species distribution, such as changes in species latitude, depth, and range limits. According to NMFS officials, future versions will provide additional information, including projections of future distributions, information on species interactions, and patterns of fishing effort. NMFS developed DisMAP in collaboration with the Global Change Ecology and Evolution Lab at Rutgers University. See https://apps-st.fisheries.noaa.gov/dismap/
		Community Social Vulnerability Indicators Toolbox	NMFS developed a Community Social Vulnerability Indicators Toolbox—a web-based mapping tool with community social vulnerability indicators covering most regions. Indicators include those related to sea level rise and storm surge, as well as indicators on social vulnerability, such as poverty. All NMFS regions have used these indicators, including to assess potential impacts of proposed fishery management plan amendments on affected fishing communities, such as potential environmental justice effects. NMFS is also developing indicators for fishing-dependent communities' reliance on species vulnerable to climate impacts, as identified in climate vulnerability assessments. See https://www.st.nmfs.noaa.gov/data-and-tools/social-indicators/
Pacific Islands	Western Pacific	TurtleWatch	TurtleWatch is a web-based mapping tool that provides up-to-date information about the habitat of loggerhead sea turtles in the Pacific Ocean north of the Hawaiian Islands. It was created as an experimental product by the Pacific Islands Fisheries Science Center to help reduce inadvertent interactions between Hawaii-based longline fishing vessels and sea turtles. The TurtleWatch map displays sea surface temperature and the predicted location of waters preferred by the turtles. See https://www.fisheries.noaa.gov/resource/map/turtlewatch

Appendix V: Examples of National and Regional Mapping Tools

NMFS region	Council ^a	Example	Description
Southeast	HMS Division	Predictive Spatial Modeling (PRiSM) tool	PRiSM combines data from observers on fishing vessels with environmental data from survey vessels to predict where and when fishery interactions resulting in unintended bycatch may occur. Data used includes sea surface temperature, salinity, and chlorophyll concentrations. NMFS' HMS Division used PRiSM to help develop a proposed rule for Atlantic highly migratory species that evaluates the effectiveness of time and area closures and options for collecting data from closed areas in the future. Information provided by PRiSM could be used by fisheries managers to guide future spatial management decisions for fisheries, such as determining locations of monitoring areas or new or modified closed areas. An approach similar to PRiSM could also be applied to improve essential fish habitat designations and assess impacts of marine uses, such as offshore energy development, on highly migratory species.
West Coast	Pacific	WhaleWatch	WhaleWatch is a National Aeronautics and Space Administration-funded web-based mapping tool coordinated by NMFS' West Coast Region to help reduce human impacts on whales by providing information on where the whales are located and thus most at risk from threats, such as ship strikes, entanglements with fishing gear, and loud underwater sounds. The project uses information from satellite tracking of whales and environmental models and can be used by ship captains to identify whale hot spots to avoid. See https://www.fisheries.noaa.gov/west-coast/marine-mammal-protection/whalewatch
		EcoCast	EcoCast Map is a web-based mapping tool that helps fishers and managers maintain target fish catch while minimizing bycatch of protected species. The tool combines the predicted distributions of target catch species, and those that may be unintentionally caught, into a single map using satellite data on ocean conditions, including sea surface temperature and wind, to suggest better and poorer locations to fish off the U.S. West Coast. See https://coastwatch.pfeg.noaa.gov/ecocast/
		Temperature Observations To Avoid Loggerhead (TOTAL) tool	Higher-than-normal sea temperatures, like those observed during El Niño events, have been correlated with the presence of loggerhead turtles in the waters off Southern California that overlap with California drift gillnet fishing grounds for swordfish and thresher shark. The TOTAL tool was designed to guide the timing of when these areas should be closed to fishing to protect loggerhead turtles. The tool uses monthly temperature data and threshold levels to inform closures of the conservation area and provides information on a data dashboard on the web. See https://coastwatch.pfeg.noaa.gov/loggerheads/loggerhead_closure.html

Source: GAO analysis of NMFS and Council documents and interviews. | GAO-22-105132

^aEight Councils, established under the Magnuson-Stevens Act, as amended, are responsible for managing fish stocks in federal waters. In addition, we include relevant information for NMFS' Atlantic Highly Migratory Species Division (HMS Division), which is responsible for managing Atlantic highly migratory species from Maine to Texas in federal waters (generally 3 to 200 nautical miles from the shoreline).

Appendix VI: Examples of Fishery Management Plans That Consider Climate-Related Information

This appendix provides examples of fishery management plans or amendments that consider climate-related information and impacts on fisheries. Fishery management plans and corresponding amendments are documents that identify the conservation and management measures that will be used to manage a fishery, such as permitting policies, restrictions on the timing or location of permissible fishing, and restrictions on certain fishing equipment.

Federal fisheries managers, which include eight Regional Fishery Management Councils (Councils), are responsible for developing fishery management plans and amendments for federal fish stocks within their respective jurisdictions based on guidelines developed by the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS). Councils regularly review plans and may update or modify fishery management plans to accommodate changing conditions and needs. Councils submit proposed plans or plan amendments to NMFS for review and approval. NMFS is responsible for determining whether a proposed plan or amendment is consistent with the national standards and other provisions of the Magnuson-Stevens Act, as amended, and any other applicable law and for issuing and enforcing final regulations to implement approved plans or amendments. To ensure transparency and incorporate stakeholder feedback, proposed plans or amendments are also subject to public review and comment before they can be adopted and implemented. Table 7 below includes examples of fishery management plans or amendments that consider climate-related information and impacts on fisheries.

Appendix VI: Examples of Fishery Management Plans That Consider Climate-Related Information

Table 7: Examples of Fishery Management Plans That Consider Climate-Related Information, Listed by National Marine Fisheries Service (NMFS) Region and Regional Fishery Management Council (Council)

NMFS region	Council ^a	Example	Description
Alaska	North Pacific	2009 Fishery Management Plan for Fish Resources of the Arctic Management Area restricted fishing in the area	A 2009 fisheries management plan for the Arctic, using a precautionary, eco-system-based approach, prohibited all commercial fishing until sufficient information is available on how to manage sustainable commercial fisheries. According to NMFS officials, in 2008, NMFS and the North Pacific Council recognized that important fishery resources were expanding north into the Arctic as a response to climate change but did not have adequate data and processes in place to manage the resource. NMFS officials added that Arctic research is expensive and logistically challenging, so the Council decided to pause any fishing activity in the Arctic management area until more information was available. The plan outlines a process and scientific and management review criteria for considering the authorization of a commercial fishery, should the Council receive a petition for fishery development in the Arctic. NMFS officials told us that, in the last 12 years, they have observed stocks moving north, but sufficient data are not yet available, and the area remains closed to fishing.
Greater Atlantic	Mid-Atlantic	2020 Amendment 21 to the Mackerel, Squid, and Butterfish Fishery Management Plan added management measures for Atlantic chub mackerel	The Mid-Atlantic Council approved conservation and management measures for Atlantic chub mackerel in federal waters from North Carolina through Maine because of increased landings of the fish in the Mid-Atlantic and southern New England starting in 2013. According to Council officials, the squid fishery in the Mid-Atlantic uses fishing gear that can also be used for chub mackerel, so there was interest in fishing for chub mackerel which, at the time, was an emerging and unmanaged fish stock. In 2017, the Council established temporary measures for managing chub mackerel that were set to expire in 2020. New management measures implemented under Amendment 21 replaced the temporary measures.
		2017 Amendment 6 to the Tilefish Fishery Management Plan added blueline tilefish for management by the Mid-Atlantic Council	Blueline tilefish was added to the Mid-Atlantic Council's Tilefish Fishery Management Plan in 2017 because of northward expansion of the fishery and increased catch in the Mid-Atlantic. NMFS implemented emergency regulations on June 4, 2015, which were extended via an interim rule through December 14, 2016, as the Mid-Atlantic Council developed its amendment. Prior to the Council's proposal of the amendment, there was no permanent federal management of blueline tilefish north of North Carolina. Blueline tilefish are primarily distributed from Campeche, Mexico, northward through the Mid-Atlantic. According to NMFS Southeast region officials, within the last decade, more and more of the species have been caught off the Mid-Atlantic coast.

Appendix VI: Examples of Fishery Management Plans That Consider Climate-Related Information

NMFS region	Council^a	Example	Description
Pacific Islands	Western Pacific Council	2021 draft regulatory amendment under the Pelagic Fishery Ecosystem Plan to modify seabird interaction mitigation measures in the Hawaii deep-set longline fishery	In December 2021, the Western Pacific Council recommended a regulatory amendment to modify mitigation measures to replace blue-dyed fish bait with tori lines (also known as bird scaring lines, or streamer lines) in the Hawaii deep-set longline fishery. The use of tori lines is intended to help prevent seabird interactions with longline fishing gear. Seabird interactions with longline fishing have increased, in part because of climate variables, such as the Pacific Decadal Oscillation, winds, and sea surface temperature fronts. The recommended amendment was based on a fishing-industry-led collaborative project with Hawaii longline vessels that conducted field experiments to compare seabird interaction rates with baited hooks over the previous 3 years.
Southeast	Caribbean Council	2019 Island-Based Fishery Management Plans for (1) Puerto Rico, (2) St. Croix, (3) St. Thomas and St. John	The Caribbean Council is in the process of adopting island-based fishery management plans that use an ecosystem-based approach and consider various issues, including climate change impacts on fisheries and island-specific cultural factors. According to Council and NMFS officials, the advantage of the island-based plans is that they focus on individual island areas (i.e., Puerto Rico, St. Croix, St. Thomas and St. John) and consider unique cultural factors, market and seafood preferences, fishing gear types, and ecological impacts specific to each island. After the island-based plans were approved by NMFS in 2020, NMFS proposed regulations in 2022 that, if finalized, will replace regulations implementing the existing Caribbean-wide, species-based plans.
West Coast	Pacific Council	Coastal Pelagic Species Fishery Management Plan considers ocean temperature information in the harvest control rule for sardines	The Coastal Pelagic Species Fish Management Plan includes a harvest control rule for sardines that considers the recent average sea surface temperature off of Southern California. It is predicted that sardine productivity increases in warm water ocean conditions. With greater average sea surface temperatures, the number of sardines that can be caught by fishers is adjusted upward. However, since July 1, 2015, the Pacific sardine fishery has been closed because of low estimated biomass. Small-scale and live bait, fishing can continue but remains subject to annual catch limits and other management measures.

Appendix VI: Examples of Fishery Management Plans That Consider Climate-Related Information

NMFS region	Council ^a	Example	Description
Multiple	Multiple: Atlantic Commission & Mid-Atlantic Council	2020 Amendment 21 to the Summer Flounder, Scup, and Black Sea Bass Fishery Management Plan adjusted state commercial quota allocations for summer flounder ^b	In 2019, the Atlantic Commission and the Mid-Atlantic Council approved an amendment to modify the state-by-state commercial quota allocations and objectives for summer flounder under an existing fish management plan. According to Mid-Atlantic Council officials, these modifications were made in response to changes in the distribution of summer flounder related to stock expansion and climate change. According to NMFS officials, fish survey data indicated that the northward movement of summer flounder to areas with warmer water was related to the effects of climate change on the ocean. The amendment revised state-by-state commercial quota allocations for years in which the annual coast-wide quota exceeded a specified trigger amount.
		2021 Atlantic Commission Addendum XXXIII and a complementary Mid-Atlantic Council amendment to the Summer Flounder, Scup, and Black Sea Bass Fishery Management Plan adjusting state commercial quota allocations for black sea bass ^b	The Atlantic Commission and the Mid-Atlantic Council increased state quota allocations for black sea bass commercial fisheries in some northern states. The revised allocations were based on a combination of current data on biomass distribution and states' historical dependence on the black sea bass fishery. These changes address significant expansion and increased abundance of black sea bass in the northern region since the original allocations were implemented in 2003, including some areas with historically minimal fishing efforts and allocations. Under the changes, annually, 75 percent of the coast-wide quota for black sea bass will be distributed to states using modified baseline allocations, and the remaining 25 percent of the coast-wide quota will be allocated based on recent biomass proportions from the most recent stock assessment. The Atlantic Commission's 2021 Addendum XXXIII revised measures for state waters that became effective January 1, 2022. According to Mid-Atlantic Council officials, the Council submitted its complementary amendment to NMFS for review, approval, and implementation in 2022.
	Multiple: Atlantic Commission & South Atlantic Council	2019 Amendment 1 to the Interstate Fishery Management Plan for Atlantic Migratory Group Cobia revised management jurisdiction for Atlantic cobia	According to NMFS Southeast region officials, because of changes in the distribution of Atlantic migratory group cobia, and the fact that most cobia were being found in state waters, sole management of the fishery was transferred to the Atlantic Commission in 2019. Previously, the Atlantic migratory group cobia fishery was jointly managed by the Atlantic Commission and the South Atlantic Council. One stated objective of Amendment 1 is to provide a flexible management system that could address potential future changes in scientific information, resource abundance, and fishing patterns among user groups. For example, according to Atlantic Commission officials, the Atlantic Commission process allows additional states to participate in management decision-making as species distributions change because of climate change or other factors.

Source: GAO analysis of NMFS, Council, and Atlantic States Marine Fisheries Commission documents and interviews. | GAO-22-105132

**Appendix VI: Examples of Fishery
Management Plans That Consider Climate-
Related Information**

^aEight Councils, established under the Magnuson-Stevens Act, as amended, are responsible for managing fish stocks in federal waters. We also include examples involving the Atlantic States Marine Fisheries Commission (Atlantic Commission), which has the authority to manage certain fish stocks in interstate waters. Where a fishery occurs in both federal and Atlantic interstate waters, the Atlantic Commission works collaboratively with NMFS and the Councils to jointly manage those resources.

^bSummer flounder and black sea bass are jointly managed in state and federal waters by the Mid-Atlantic Fishery Management Council with the Atlantic States Marine Fisheries Commission. The Atlantic Commission and the Mid-Atlantic Council make joint management decisions that are incorporated into the respective fishery management plans developed and implemented by each entity.

Appendix VII: Examples of Fish Stock Assessments That Incorporate Climate-Related Information

This appendix provides examples of fish stock assessments for federal fisheries that incorporate climate-related information, described in table 8.¹ Fish stock assessments are scientific efforts that involve data collection, data processing, and modeling and are used to evaluate the health and size of a fish stock. These assessments consider information about the past and current status of a managed fish stock, including information on fish biology, abundance, and distribution. To the extent possible, stock assessments also predict future trends of stock abundance. National Marine Fisheries Service (NMFS) regional fisheries science centers are responsible for conducting fish stock assessments for certain fish stocks in their region. NMFS provides the results of its stock assessments to federal fisheries managers—Regional Fishery Management Councils (Council) and NMFS’ Atlantic Highly Migratory Species Division—for use in managing fisheries. Fisheries managers use these assessments to set annual catch limits, which contain other information, such as reference points that can be used to inform management decisions.²

Table 8: Examples of Fish Stock Assessments That Incorporate Climate-Related Information

NMFS region	Council ^a	Example	Description
Alaska	North Pacific	Single species stock assessments that incorporate climate effects on mortality or catchability, such as the stock assessments for the Bering Sea and Aleutian Islands yellowfin sole, Bering Sea snow crab, and red king crab, and Gulf of Alaska Pacific cod.	According to National Marine Fisheries Service (NMFS) officials, many single species stock assessments involved the use of models that incorporate climate effects on mortality or catchability (which refers to the extent to which a stock may be caught by fishers). For example, the Bering Sea and Aleutian Islands yellowfin sole stock assessment incorporates temperature information in the catchability estimate. Among other things, it considers ocean temperature effects on the timing of the annual migration of the fish stock, using regularly updated survey data.

¹Examples included in the table are based on interviews and review of documents provided by the National Marine Fisheries Service (NMFS). Although NMFS began more detailed tracking of ecosystem linkage in fish stock assessments in fiscal year 2019, NMFS does not explicitly track whether fish stock assessments incorporate climate information.

²Reference points provide targets, thresholds, and other decision criteria used in the fisheries management process, such as determining a numeric threshold that, if exceeded, would indicate that overfishing had occurred.

Appendix VII: Examples of Fish Stock Assessments That Incorporate Climate-Related Information

NMFS region	Council ^a	Example	Description
		Risk tables in fish stock assessments including for the 2020 sablefish stock assessment	A risk table evaluation is provided with some stock assessments to help fisheries managers better understand uncertainties with and outside the stock assessment model, including uncertainty related to climate change factors. Ecosystem change, which provides related information on climate change factors, is one of the four categories of risk evaluated in the risk tables. According to North Pacific Council officials, the risk tables allow the Council to have more structured discussions about risk and uncertainties when making fisheries management decisions. For instance, the risk table assessment could result in decisions to reduce the annual catch limit for a fishery. The 2020 sablefish stock assessment is one of the first stock assessments to include such risk assessment information, according to these officials. NMFS officials said that they are planning to incorporate the risk table approach for other fish stock assessments in the region in the future.
Greater Atlantic	Mid-Atlantic	Contextual ecosystem indicators included in stock assessments, such as for the 2019 research stock assessment for summer flounder	According to Council officials, the 2019 summer flounder research stock assessment was the first to include ecosystem indicators. For example, this assessment included information on potential factors affecting the productivity and distribution of summer flounder, including surface and bottom temperature and salinity, and habitat changes. According to the assessment, in recent decades, the ecosystem for summer flounder has changed, as indicated by increasing temperature and water salinity. These changes may indicate a shift in ecosystem function and productivity. Ecosystem indicators can be used to interpret population status when making fisheries management decisions and may also be used to improve model responsiveness to ecosystem factors. NMFS' Northeast Fisheries Science Center is planning to incorporate these indicators in other research stock assessments that are currently under development.
		2017 butterfish stock assessment update incorporates bottom temperature information	The 2017 stock assessment update for butterfish on the Atlantic Coast adjusted its catchability estimates based on bottom temperature information.
Pacific Islands	Western Pacific	2018 Hawaiian Islands deep 7 bottomfish benchmark stock assessment included wind intensity as a factor	The 2018 benchmark stock assessment for the main Hawaiian Islands deep 7 bottomfish included wind speed and direction, a climate-related factor, as a predictor of catchability. Wind speed and direction data were included upon request from fishers who participated in the data workshop in 2016. Wind was found to have had a negative effect on catchability. According to Council officials, climate change will impact not only the frequency but also the intensity of the regional wind patterns and may have some influence on coastal circulation.

Appendix VII: Examples of Fish Stock Assessments That Incorporate Climate-Related Information

NMFS region	Council^a	Example	Description
Southeast	Gulf of Mexico	2019 Gulf of Mexico red grouper stock assessment includes red tide information	The 2019 Gulf of Mexico red grouper stock assessment includes information on the 2018 red tide event (a type of harmful algal bloom that may, in part, be influenced by climate change) using historical mortality data. Specifically, according to NMFS Southeast region officials, red tides were explicitly modeled using an index derived from satellite oceanography in the red grouper stock assessment. In addition, in response to stakeholder concerns about the 2018 red tide event, NMFS' Southeast Fisheries Science Center gathered local ecological knowledge to compare the 2017 to 2019 red tide to previous red tides in terms of severity, recovery time, and species killed, using oral history and participatory mapping to help inform the stock assessment.
		HMS Division 2017 swordfish stock assessment integrates climate information, such as weather pattern changes	The 2017 swordfish stock assessment considers climate-related weather patterns related to the Atlantic Multidecadal Oscillation and environmental drivers of productivity. According to NMFS officials, these factors are also explicitly used for ongoing management strategy evaluations.
		2018 Atlantic bluefin tuna stock assessment integrates climate information, including weather pattern changes	The 2018 Atlantic bluefin tuna stock assessment integrates the Atlantic Multidecadal Oscillation, a climate-related weather pattern, as a factor in the spatial availability of Atlantic bluefin tuna.
West Coast	Pacific	2019 sablefish stock assessment incorporates a climate-based index and appendix with information on ecological factors and socioeconomic impacts.	The 2019 sablefish stock assessment incorporates climate-based factors, such as ocean temperature and sea level, in estimating recruitment. Fish stock recruitment is used to examine the amount of fish available for fishing each year because of growth and migration into the fishing area. Sablefish is ranked very high in their likelihood of experiencing distributional shifts because of climate effects based on results of a climate vulnerability assessment that is described in the fish stock assessment. The assessment also includes an appendix with information on ecological factors affecting sablefish productivity and distribution and socioeconomic considerations in the management of sablefish.
		2015 chili pepper rockfish incorporates climate weather patterns in growth estimates	The 2015 fish stock assessment update for chili pepper rockfish estimates stock growth after considering the Pacific Decadal Oscillation, a climate-related weather variability pattern over the Pacific Ocean.
		2020 Pacific sardine stock assessment uses temperature data	The Pacific sardine stock assessment has used sea surface temperature data in the stock assessment (as well as in the harvest control rule to set catches) since 2014.

Source: GAO analysis of NMFS documents and interviews. | GAO-22-105132

^aEight Councils, established under the Magnuson-Stevens Act, as amended, are responsible for managing fish stocks in federal waters. In addition, we include relevant information for NMFS' Atlantic Highly Migratory Species Division (HMS Division), which is responsible for managing highly migratory species in certain federal waters (generally 3 to 200 nautical miles from the shoreline).

Appendix VIII: Comments from the Department of Commerce



UNITED STATES DEPARTMENT OF COMMERCE
Office of the Acting Chief Financial Officer and
Assistant Secretary for Administration
Washington, D.C. 20230

August 4, 2022

Mr. Cardell Johnson
Acting Director
Natural Resources and Environment
U.S. Government Accountability Office
441 G Street, NW
Washington, DC 20548

Dear Mr. Johnson:

Thank you for the opportunity to review and comment on the Government Accountability Office's (GAO) draft report entitled *Federal Fisheries Management: Opportunities Exist to Enhance Climate Resilience* (GAO-22-105132).

The Department of Commerce agrees with GAO's two recommendations directed to the National Oceanic and Atmospheric Administration. Enclosed is our response to the draft report.

Should you have any questions, please contact MaryAnn Mausser, GAO Liaison, at (202) 482-8120 or MMAusser@doc.gov.

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Jeremy Pelter

Acting Chief Financial Officer and Assistant
Secretary for Administration

Enclosure

Department of Commerce
National Oceanic and Atmospheric Administration
Response to the GAO Draft Report Entitled
*Federal Fisheries Management: Opportunities
Exist to Enhance Climate Resilience*
(GAO-22-105132, August 2022)

General Comments

The Department of Commerce's National Oceanic and Atmospheric Administration (NOAA) appreciates the opportunity to review the Government Accountability Office's (GAO) report on efforts, challenges and opportunities to enhance climate-informed fisheries management and the resilience of the nation's valuable marine fisheries in a changing climate. GAO conducted a thorough review and is commended for collecting and synthesizing information from a range of internal and external sources.

The report recognizes that achieving climate-informed fisheries management will require major advances in both the production and delivery of actionable science, and the use of climate-related information in fisheries decision making. NOAA concurs with the report's conclusions that Fishery Management Councils are helping lead the way in identifying innovative ways to incorporate climate-related information into fisheries management. NOAA also strongly agrees with the findings that additional information, tools, and capacity are needed to advance climate-related science and management activities. NOAA asserts that additional resources are needed to meet these requirements. Specifically, NOAA's Climate, Ecosystem and Fisheries Initiative calls for tracking current changes, projecting future changes, and identifying and implementing management strategies to reduce risks and increase resilience. Additional surveys, research, and modeling would be needed to implement this Initiative. This would also include increasing the capacity of fisheries managers to create nimble management systems that effectively prepare for and respond to a changing climate. NOAA is committed to working with the Regional Fishery Management Councils, partners, and stakeholders to advance climate-informed fisheries management and help safeguard the nation's valuable fisheries and the many people, businesses and communities that depend on them.

NOAA Response to GAO Recommendations

Recommendation 1: "The Assistant Administrator for National Marine Fisheries Service (NMFS) should regularly collect and publicly disseminate information on actions taken by the Regional Fishery Management Councils and NMFS' Atlantic Highly Migratory Species Division to enhance the climate resilience of federal fisheries, such as fishery management plans that use climate information."

NOAA Response: NOAA agrees with this recommendation. NOAA will create a website or other publicly available mechanism for compiling and sharing information on how the Fishery Management Councils and NMFS are enhancing the climate resilience of fisheries including adapting fisheries management to account for current or predicted environmental changes.

**Appendix VIII: Comments from the Department
of Commerce**

Recommendation 2: “The Assistant Administrator for NMFS should direct the agency’s regional offices and fisheries science centers to work with the Regional Fishery Management Councils and NMFS’ Atlantic Highly Migratory Species Division in their respective regions to identify and prioritize opportunities to enhance the climate resilience of federal fisheries, including by reviewing the opportunities described in this report and NMFS’ 2018 guidance document: *Accounting for Shifting Distributions and Changing Productivity in the Fishery Management Process*, and develop a plan to implement them.”

NOAA Response: NOAA agrees with this recommendation. Changing ocean conditions are affecting the distribution and productivity of fish stocks, changing the fishing industry’s interactions with bycatch, protected species, and other ocean users, and impacting fisheries and fishing communities. A regional response/approach to these changes is necessary as ecosystems, climate impacts, fisheries, management, and economics vary between regions. Several NMFS/Council pairs are already actively engaged in efforts to identify opportunities to enhance climate resilience in their respective fisheries. NOAA will continue to work with the Regional Fishery Management Councils and NMFS’ Atlantic Highly Migratory Species Division to identify and prioritize opportunities to advance climate resilience of federal fisheries, including opportunities identified in this report, the NMFS 2018 guidance document, and other information available to the agency and Councils. NMFS and the Councils engage in annual processes to prioritize the science and management actions for the upcoming year, and will take the identified climate-related priorities and available resources into account when conducting those planning efforts.

Appendix IX: GAO Contact and Staff Acknowledgments

GAO Contact

Cardell Johnson, Acting Director (202) 512-3841 or johnsoncd1@gao.gov

Staff Acknowledgments

In addition to the contact above, Scott Heacock (Assistant Director), Swati Sheladia Thomas (Analyst-in-Charge), Sophie Beavin, Xiang Bi, John Delicath, Andrew Edkins, Leah English, Cindy Gilbert, Claudia Hadjigeorgiou, Patricia Moye, Edward Rice, Dan Royer, and Joe Thompson provided key contributions to this report.

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