CLIMATE-READY FISHERIES PLANNING MENU

Challenges, opportunities, and adaptation strategies for resilient Maryland fisheries

MDNR 14-062524-2

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Published: July 2024

Publication Number: 14-062524-2

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This report was prepared by Amanda Small using Federal funds from NOAA, U.S. Department of Commerce. The statements, findings, conclusions, and recommendations are those of the author(s) and do not necessarily reflect the views of NOAA or the U.S. Department of Commerce.

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Acknowledgements

This climate-ready fisheries planning menu is the culmination of many virtual and in-person meetings, sampling trips, workshops, and conversations. The project team especially wants to thank the Chesapeake and Coastal Service unit and Fishing and Boating Services unit staff who contributed their climate and fisheries expertise. Their passion and dedication over the past two years shaped these recommendations, encouraging us all to think big and to think ahead. We also acknowledge the Advisory Commission members for their commitment to leadership for the fishing community. Thank you to everyone who contributed your ideas and time!

Cover Image: Craig Weedon, MDNR – Fishing and Boating Services.

Photographs: MDNR flickr, flickr.com/photos/marylanddnr/albums and Amanda Small, MDNR – NOAA Coastal Management Fellowship.

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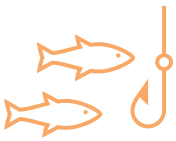
EXECUTIVE SUMMARY

This document serves as a menu of adaptation and resilience strategies for preparing climate-ready fisheries for Maryland. Recreational and commercial fishing are widely integrated into Maryland's economy and culture. Abundant fishing opportunities extend from the mountains in the west to the Atlantic Ocean in the east. The Maryland Department of Natural Resources (department) is charged with stewardship of a diverse array of freshwater, estuarine, and marine species that occupy Maryland's waters. However, climate change poses both challenges and opportunities for aquatic ecosystems, fishing communities, and management systems.

Climate Impacts to Fisheries:

Ecology
Warming temperatures will likely affect fish life history characteristics (e.g. growth and reproduction) and the abundance of species along the coast. Ocean acidification may impair shellfish development and further exacerbate hypoxic conditions. Fluctuations in precipitation will correspond to fluctuations in water quality. Sea level rise may drown out tidal and shallow water habitats if migration cannot keep pace.



Socioeconomic
With warming temperatures, the composition of available fish species along the coast will likely shift and novel species may establish in the region. Excessively hot or stormy conditions may limit fishing activity due to the risk of safety hazards. Precipitation and sea level rise will both increase flooding of shoreside infrastructure and water access points. Ocean acidification may pose concerns for shellfish management and restoration efforts.

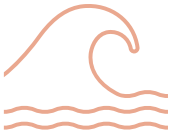
Governance
The collective impacts of multiple climate factors will challenge the fisheries management system to be more adaptive. Managers and constituents need to be informed of current and potential changes to fisheries so that timely action can be taken. Warming temperatures combined with other environmental shifts may disrupt expected stock dynamics and change the array of species that require monitoring and management.

There are many opportunities for climate adaptation and resilience across these three major components:

1. *Ecology* - Climate vulnerability assessments provide a synthesis of impacts to fish species and habitats. These can be combined with survey data to assess how species abundance, distribution, and life history characteristics may change over time. Fisheries scientists and managers can also expand partnerships with land conservation and restoration programs to promote the persistence of habitats like oyster reefs, salt marshes, and seagrass beds.

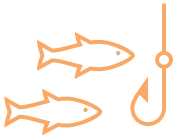
2. *Socioeconomic* - The department can expand existing programs to ensure the public can access the water on public lands and that fishing communities build resilient coastal infrastructure. Fisheries scientists and managers can encourage diversified fishing operations and support markets for novel and invasive species.
3. *Governance* - Fisheries management is designed to be adaptive to changes in fish stocks and fishing effort. Integrating climate science into existing data analysis processes can allow managers and fishing communities to make informed management decisions and work proactively.

Key Recommendations



Monitor changes to fish species

Integrate fisheries data with habitat and ecosystem data



Build resilient fishing infrastructure

Ensure safe and reliable public access to the water

Utilize climate data to inform adaptive management

Encourage diversification of fishing activities

The strategies presented here and throughout the planning menu are recommendations, thus specific actions are not necessarily required by the department or its partners. Rather, this planning menu can act as a prioritization tool by highlighting opportunities for the department to assess both its internal programs and how it supports external partnerships. The department is already engaged in adaptation and resilience efforts across geographies and sectors. Fostering partnerships with communities, local governments, managers, non-governmental organizations, and researchers will help expand capacity for planning and implementation now and into the future.

INTRODUCTION

Objective

Climate change is already showing measurable shifts in environmental conditions that have the potential to impact natural resources. These impacts are complex and require dynamic management strategies that are interdisciplinary and address the needs of resource users. Climate change planning incorporates the concepts of adaptation and resilience so that natural and human systems can continue to thrive under novel environmental conditions.

Maryland is a leader in climate change adaptation and resilience. The Department of Natural Resources (department) is continuously committed to stewardship of both terrestrial and aquatic resources. The department works proactively to ensure that the necessary plans and programs are in place to support vibrant natural resources and the industries and communities that rely on them in the face of climate change.

To advance the department's climate change priorities, the Fishing and Boating Services unit and the Chesapeake and Coastal Services unit partnered to develop a vision for climate-ready fisheries for the state of Maryland. This planning menu provides recommendations for adaptation strategies aimed towards implementing this vision. While climate impacts pose challenges to current resource management structures, they also present opportunities to expand and evolve commercial and recreational fishing through collaboration with resource users and partners.

Vision for Climate-Ready Fisheries

Maryland's fisheries resources, fishing communities, and the ecosystems that support them are resilient to changes in the environment, especially due to climate change. Maryland builds a management system that is rooted in partnership and informed by science to support adaptive decision-making across sectors. Fisheries managers and fishing communities work proactively and optimize opportunities that arise as a result of changing natural and human environments.

This document serves as a starting point towards preparing a climate-ready fisheries management structure. It provides managers and partners with the following:

1. an overview of the major impacts of climate change to the ecological, socioeconomic, and governance components of Maryland's fisheries;
2. adaptation and resilience strategies that address these specific challenges and optimize opportunities; and
3. resources and tools for targeted expertise on climate science, planning initiatives, and implementing adaptation and resilience strategies.

These recommendations are not necessarily requirements, but serve as a set of guidelines that may be consulted when prioritizing management decisions. This document is designed to complement existing climate adaptation and resilience initiatives and expand collaboration with fishing industry participants, community members, and other partners.

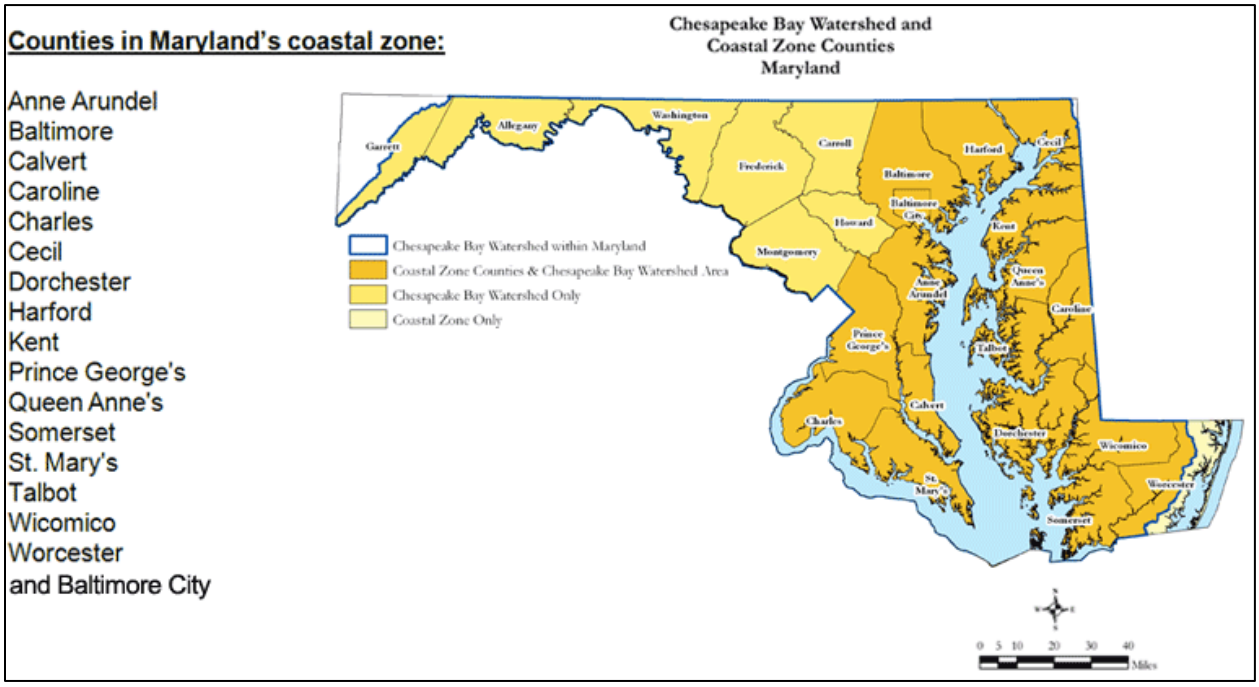


Figure 1 – Maryland's coastal zone includes the counties that border the Atlantic Ocean, Chesapeake Bay, and the Potomac River up to the District of Columbia. The coastal zone boundary extends from three miles out into the Atlantic Ocean to the inland boundaries of these 16 counties and Baltimore City. Maryland's Coastal Zone Management Program is housed within the department's Chesapeake and Coastal Service unit.

This project is sponsored by the Coastal Zone Management Program, thus efforts were focused on the fisheries concentrated in Maryland's coastal zone: the Chesapeake Bay, its tidal tributaries, and offshore waters.

Adaptation – Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects. Climate adaptation refers to those actions taken to reduce vulnerability to the impacts of climate change, aimed to enhance the resilience of natural and human-based systems.

Resilience – The capacity of natural and human-based systems to anticipate disturbances, reduce vulnerability, and respond to and recover from heavy disturbances and chronic stresses.

Characterizing Maryland's Tidal Fisheries

Background

Even though Maryland is a relatively small state, it has an expansive coastline of 3,190 mi to 7,719 mi considering the streams and tributaries that flow into the Chesapeake Bay (Maryland Department of Natural Resources [MDNR], 2013). The prevalence of the Chesapeake Bay, its tributaries, and the coastal bays supports the fishing industry as a key component of Maryland's culture. The Chesapeake Bay[1] runs through the heart of the state, with major tributaries including the Chester, Choptank, Patapsco, Patuxent, Potomac, and Susquehanna rivers. The coastal bays[2] border Ocean City and Assateague Island to the west, with the Atlantic Ocean to the east. In 1939, a hurricane created the Ocean City inlet, an unprecedented opportunity to expand fishing operations with direct access to the ocean from the coastal bays. Long before then, the inhabitants of this region lived a long, rich, and evolving history off the water. Today still continues a strong presence of generational fishing operations and seafood dealing businesses. Maryland is recognized for its seafood specialties. Blue crab is the state's unofficial mascot and mainstay of summer crab feasts. Striped bass, locally known as rockfish, is the official state fish and prized for its taste and fight as a game fish. Oysters are celebrated for their local harvest and as a natural filter for the region's estuaries. To harvest these and the many other fish and shellfish that occupy Maryland waters, fishing operations utilize a variety of gear ranging from nets to hook and line depending on the species of interest. The array of tidal rivers, estuaries, and the ocean provide ample opportunities for both commercial and recreational fishing.

[1] For the scope of this menu, the Chesapeake Bay includes the main stem and tidal portions of the tributaries. Whenever possible, tidal and nontidal management coordinate for a watershed approach.
[2] From north to south, the coastal bays include Assawoman, Isle of Wight, Sinepuxent, Newport, and Chincoteague bays. mdcoastalbays.org

Chesapeake Bay

Across the state, the top commercial fisheries are blue crab, Eastern oyster, and striped bass. In contrast to the coastal bays, commercial fishing is based out of multiple access points distributed across the Chesapeake Bay and its tidal tributaries. The GDP earned from commercial fishing and seafood dealing is highest in Baltimore, Dorchester, and Somerset counties, respectively (Office for Coastal Management, 2021). Species of recreational interest vary by salinity zone, though blue crab and striped bass are widely distributed. The stronger freshwater influence in the upper bay supports low salinity species (e.g. perch, largemouth bass, shad). The mixed salinity zone in the middle bay supports brackish species (e.g. bluefish, Spanish mackerel, perch). The saltwater influence in the lower bay supports coastal and offshore species (e.g. bluefish, cobia, red drum, mackerel, sheepshead, summer flounder, black sea bass, speckled trout). For-hire charter and party boats are active around the bay. These businesses provide guided opportunities for recreational fishing and also contribute to Maryland's coastal economy.

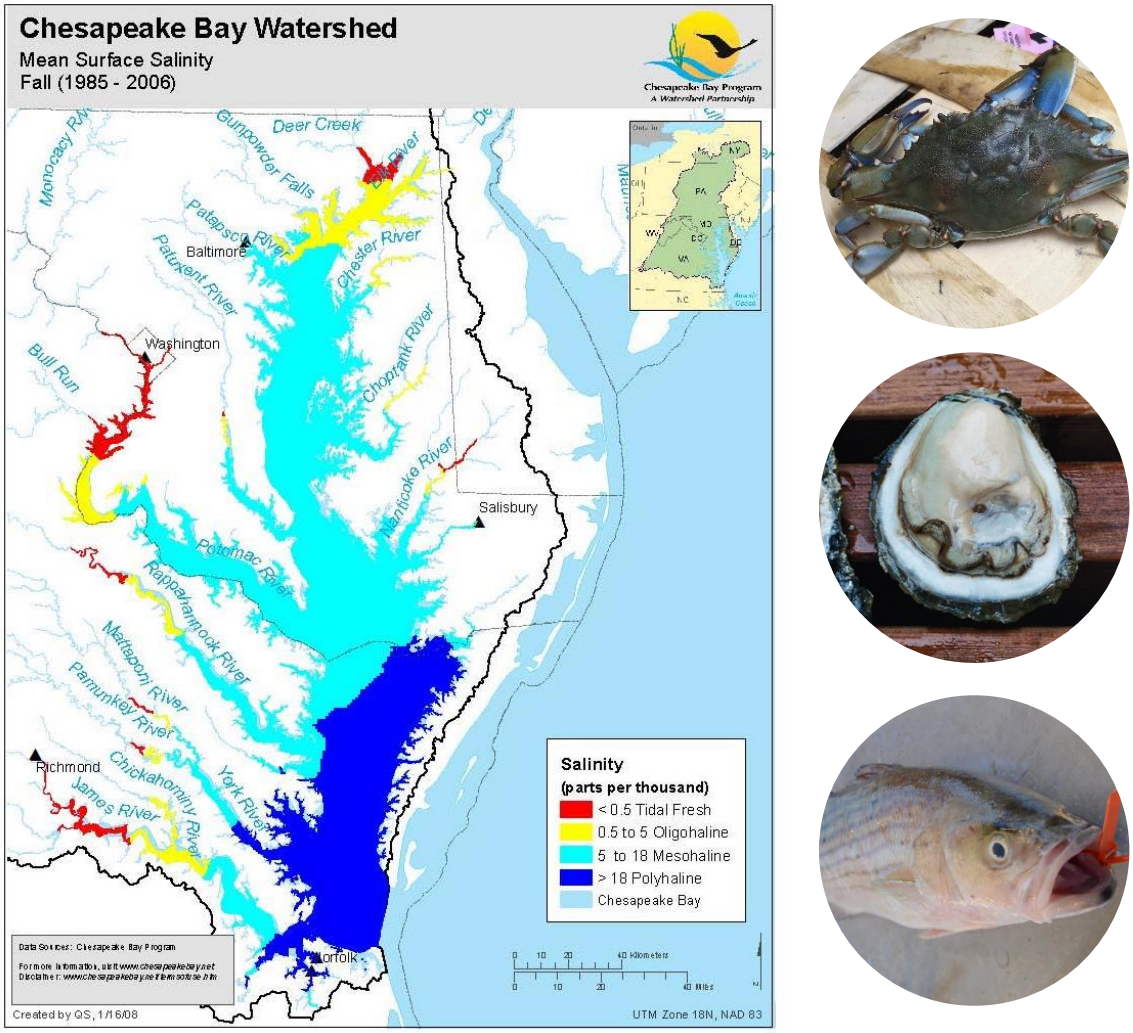
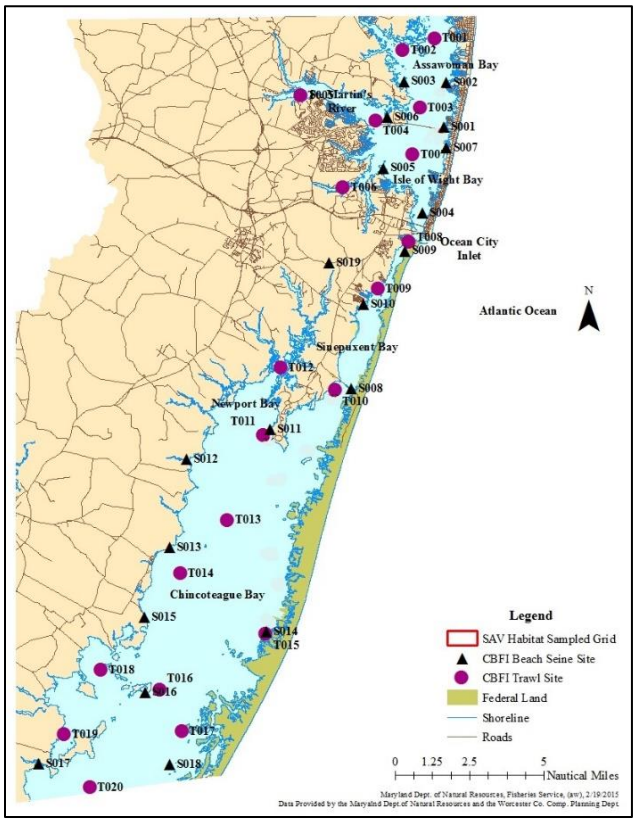


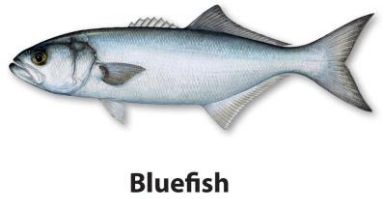
Figure 2 – Left: Map of the Chesapeake Bay illustrating the salinity gradient from freshwater in the upper bay to saltwater in the lower bay (Chesapeake Bay Program). Right: Blue crab, Eastern oyster, and striped bass represent the top commercial fisheries across the state (MDNR).

Coastal Bays

Fishing activity along the coastal bays and Atlantic coast also varies by location. Within the coastal bays species of interest include blue crab, clam, croaker, menhaden, and spot. Off the beach and along the shore species like horseshoe crab, spiny and smooth dogfish, striped bass, and summer flounder are present. Offshore species include American lobster, black sea bass, Jonah crab, mahi mahi, monkfish, scallop, scup, spiny and smooth dogfish, summer flounder, whelk, and a variety of highly migratory species.

In contrast to the Chesapeake Bay, commercial fishing along the Atlantic coast is centralized in a single harbor off the Ocean City inlet. There are fewer license holders and crews typically consist of one to three people. A single operation may own multiple boats rigged for different gear. Recreational fishing occurs year-round, and peaks in the summer with tourism to Ocean City and Assateague Island. There are multiple opportunities for public water access through boating, fishing piers, and in the surf. Species of recreational interest include black sea bass, bluefish, mahi-mahi, striped bass, summer flounder, tautog, and wahoo. Historically southern species like cobia, red drum, and black drum are becoming more available. The Mid-Atlantic is also a hot spot for highly migratory species (e.g. billfish, tuna, sharks). The White Marlin Open is known as the largest billfishing tournament in the world and is held annually in Ocean City. For-hire charter and party boats provide opportunities for recreational fishing nearshore and in the Atlantic Ocean.





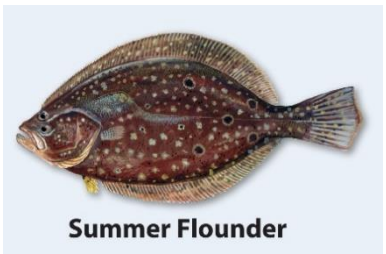


Figure 3 – Left: Map of the Maryland Coastal Bays (MDNR). Right: Mahi mahi, bluefish, and summer flounder represent species of interest when fishing along the Atlantic coast. Fish illustrations by Duane Raver and Diane Rome Peebles for the Maryland Guide to Fishing and Crabbing 2024.

Fisheries Components

Mason et al. (2021) organize fisheries systems into three major components: ecological, socioeconomic, and governance.[3] The project team further divided these categories into a hierarchy of management, starting with individual fish species and expanding out to the community of resource users.

Ecology

Fish Biology

Sustainable fisheries rely on fish populations that continue to be productive and resilient over time. Each species has a unique set of life history characteristics that describe how the fish grows and lives. The rate of growth, reproduction, maturation, and mortality are some of the many factors that influence how quickly a population can grow. Species also differ in how specialized their lifestyles are. Some species thrive under very specific conditions, while others can tolerate a wider range of environments. The combination of biological characteristics influences how well a species may acclimate to environmental changes.

Habitats and Ecosystems

Maryland is home to a variety of coastal habitats, and the Chesapeake Bay is a major spawning ground for multiple coastwide species. Key intertidal and shallow water habitats include marshes, oyster reefs, submerged aquatic vegetation (SAV), and tidal rivers. These habitats provide food, nursery areas, shelter from predators, and spawning habitat. Fish may occupy different habitats at certain times of the year or as they progress through their life cycles.

Socioeconomic

Fishing Effort

Regulations on commercial and recreational fishing effort are tailored for each species to prevent or reverse overfishing. Managers regulate factors such as fishing gear, license types, seasons, and size limits. Fishing effort also depends on the level of access licensees have to the water and how safe the weather and water conditions are.

Shoreside Processes

Fresh commercial catch is brought to seafood dealers and processors around the Chesapeake Bay and coastal bays. This step feeds the supply chain so that the product can be distributed for its end use.

Cultural Significance

Fishing supports local waterfront economies, which in turn support Maryland's connection to seafood as a source of nutrition and cultural identity.

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[3] For each of the three components, Mason et al. (2021) propose attributes that foster resilience in fisheries systems. The project team considered these attributes when developing this menu of adaptation and resilience strategies.

Governance

Science and Management

Fishery Management Planning

Managers work with advisory bodies to develop goals, strategies, and actions that protect the resource while allowing sustainable harvest. The department then establishes conservation and management measures that implement the fishery's goals.

Stock Dynamics / Monitoring and Data

Managers utilize data collected from fishing activity in addition to scientifically designed surveys to inform mathematical modeling that determines the current status of each fish stock. The stock status indicates whether the stock can sustain itself given the current fishing levels. If a stock is considered overfished, the abundance (number of fish) or biomass (weight) is below a sustainable threshold.

Writing Regulations

Managers develop commercial and recreational regulations that allow enough harvest to sustain and build the industry while protecting the productivity and sustainability of the resource.

Communication and Partnership

Management decisions are made with industry and public input through interim commissions, task forces, and committees. Advisory bodies are opportunities for managers, fishing licensees, and other interested and impacted parties to discuss and collaborate on fisheries issues.

Multiple Jurisdictions

Maryland's fisheries span across the Appalachian Mountains, Chesapeake Bay watershed, and Atlantic coast. Thus, collaboration with multiple jurisdictions is essential to manage fish species at different spatial scales.

Regional

Through the Chesapeake Bay Program, partner jurisdictions coordinate regional activities that support sustainable fisheries across the watershed. The program allows managers, academic researchers, and other partners to discuss current topics and share science and resources.

Coastwide

The Atlantic States Marine Fisheries Commission (ASMFC) is an interstate compact that provides coordination for fish stocks whose fisheries are predominantly located in waters zero to three miles from shore. ASMFC's boards and committees are comprised of members from participating states, the District of Columbia, the Potomac River Fisheries Commission, the National Marine Fisheries Service (NOAA Fisheries), and the U.S. Fish and Wildlife Service.

Offshore

The Regional Management Councils coordinate management for fish stocks whose fisheries are predominantly located in federal waters three to 200 miles from shore. Maryland is represented on the Mid-Atlantic Fisheries Management Council (Mid-Atlantic Council).

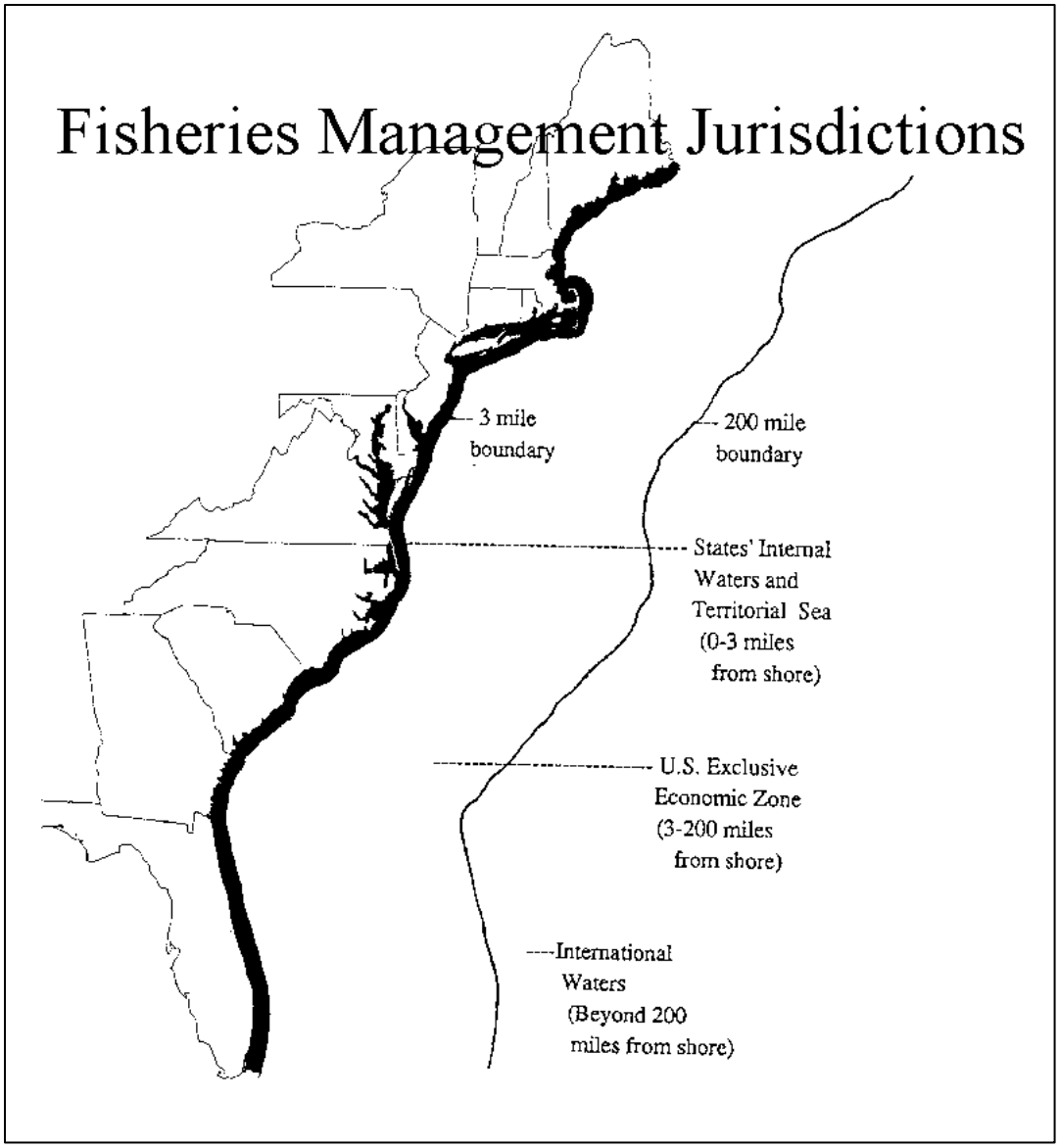

Figure 4 – Map of the Atlantic coast fisheries management jurisdiction boundaries (MDNR). ASMFC coordinates regional management of fisheries zero to three miles from shore. The Regional Management Councils and NOAA Fisheries coordinate management of fisheries in federal waters three to 200 miles from shore.

For more information on governance, see the Fishing and Boating Services "Management" page dnr.maryland.gov/fisheries/Pages/management.aspx and the Atlantic States Marine Fisheries Commission "Management 101" and "Fisheries Science 101" pages asmfc.org/

Climate Change Overview

Climate change encompasses a suite of environmental parameters that are shifting primarily due to the increased concentration of greenhouse gasses in the Earth's atmosphere. The following climate factors have been identified as most prevalent considering Maryland's position in the Mid-Atlantic region. While long-term datasets support the occurrence of these environmental shifts, it is important to acknowledge that climate interactions are complex and can be challenging to predict, thus some uncertainties are inherent. For example, oceanic conditions are driven by a combination of currents, water temperature, winds, and weather patterns (e.g. El Niño and La Niña) that in turn influence biological patterns and processes (Northeast Fisheries Science Center, 2024).

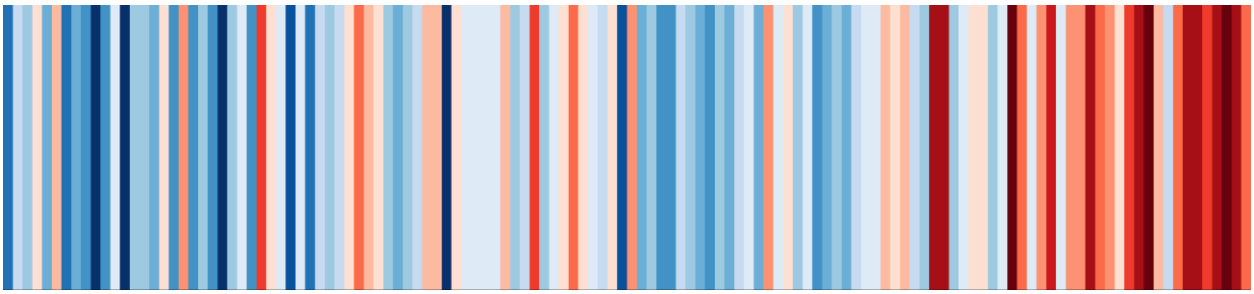

Figure 5 -Climate stripes for Maryland. Each bar represents a year from 1895-2022. The color of the bar indicates whether the annual temperature for that year was warmer (orange/red) or cooler (blue) than the average temperature (Show Your Stripes, showyourstripes.info/s/northamerica/usa/maryland).

Climate Factors

Warming Temperatures

Global warming is driven by greenhouse gas emissions that prevent heat from escaping out of the atmosphere. Maryland's annual air temperature has risen nearly 4°F (about 2°C) above the pre-Industrial average from 1985-1915 (University of Maryland [UMD] Extension, 2023). Warming temperatures in the atmosphere are in turn warming the oceans and coastal water bodies. Water temperatures throughout the watershed have risen up to 4°F from 1960-2010, and tidal surface water temperatures have risen up to 4.5°F (about 2.5°C) from 1985-2019 (Scientific and Technical Advisory Committee [STAC], 2023). A marine heat wave is a short period of anomalous higher ocean temperatures that can be caused by ocean currents, air-sea heat flux, and warming through the ocean surface. Marine heat waves are associated with harmful algal blooms, bacteria, heat stress mortality, and decreased dissolved oxygen (STAC, 2023).

Sea Level Rise

Global sea levels are rising primarily due to melting polar ice and glaciers combined with thermal expansion that increases the ocean's volume. On Maryland's Eastern Shore, sea level rise is exacerbated by subsidence of land masses. Across the United States, the Chesapeake Bay region is the third most vulnerable area to sea level rise (McClure et al., 2022; National Centers for Environmental Information, 2022; UMD Extension, 2023). In Maryland, relative sea level has increased by 1.3-1.5 in per decade over the past 100 years (National Centers for

Environmental Information, 2022). Sea level is projected to increase approximately 1.7 ft by 2050, but varies by location and carbon emissions scenario (McClure et al., 2022; University of Maryland Center for Environmental Science [UMCES], 2023).

Sea level rise exacerbates “high tide” or “nuisance” flooding by shifting the tidal range between the mean lower low water and mean higher high water tides. This type of flooding is also called “sunny day” flooding because it can occur with or without the presence of rain (UMCES, 2023). Rising sea levels and increased exposure of coastal lands to brackish water are increasing the salinity of aquifers, surface waters, and water within soils. The saltwater intrusion and salinization of coastal areas are already impacting the type of vegetation that can grow, thus driving coastal habitats to shift upland (Maryland Department of Planning [MDP], 2019).

Precipitation Patterns and Storms

Precipitation is projected to show greater fluctuations with an increased number of days with heavy rainfall followed by dry periods. Average annual precipitation in Maryland has increased about 4.5 in above the 1895-1915 average. Tropical storms and hurricanes are expected to increase in intensity rather than occurring more frequently. About 30% of rainstorms during the period 2007-2016 would have fallen into the top 1% of storm intensity had they occurred in the 1950s. Intensity is driven by warmer ocean temperatures that give storms more energy with higher winds and rainfall. Duration may also lengthen as hurricanes move away from the coast more slowly (UMD Extension, 2023).

Sufficient stormwater management helps mitigate flash flooding and water quality during precipitation events and storms (UMD Extension, 2023). Fluctuations in precipitation would directly influence fluctuations in salinity and other water quality parameters (e.g. nutrient load, dissolved oxygen, chemical pollution) (Maryland Department of the Environment [MDE], n.d.). Higher intensity storms combined with sea level rise are expected to further exacerbate coastal flooding.

Ocean Acidification

Globally, the oceans absorb about 25% of the carbon dioxide (CO_2) that is annually released into the atmosphere. When CO_2 gas combines with water a series of chemical reactions occur that produce a weak acid. Over time, waters become more acidic as the pH lowers. The environmental processes that influence pH levels vary between the open ocean and shallow coastal waters. In the tidal waters of the Chesapeake Bay pH fluctuates between 7-9. Monitoring is ongoing to assess how natural and human-induced processes affect pH fluctuations in Maryland and the Mid-Atlantic (Maryland Ocean Acidification Task Force, 2015). Eutrophication is one process that interacts with pH. When nutrient runoff feeds algal blooms, increased cellular respiration and reduced photosynthesis by aquatic vegetation collectively increase the dissolved CO_2 concentration and lower the pH (MDE et al., 2020).

Climate Adaptation Principles

NOAA Fisheries, the Regional Management Councils, ASMFC, and their partners are expanding upon existing climate change guidance to support planning and implementation of strategies for climate-ready fisheries along the coast. These regional initiatives serve as a springboard for how the department can take action both at the state level and in coordination with interjurisdictional fisheries management programs. In particular, the Climate Science Strategy and corresponding Northeast Regional Action Plan detail a set of high-level, interrelated objectives (NOAA Fisheries, 2015, 2023).

The East Coast Climate Change Scenario Planning[4] initiative prioritized three management themes that apply across future conditions and highlight areas for building resilience.

1. Cross-Jurisdictional Governance and Management
   Maryland is positioned centrally along the Atlantic coast and has the potential to experience species moving out of Maryland waters to the north and new species moving into Maryland waters from the south. If the composition of available species fluctuates, the department will need to give fishing licensees flexibility in the species they can target and support partners in developing a market for stocks that are new to the state. The department should support these and other opportunities for licensees to diversify their operations. Additionally, the department should continue to coordinate with ASMFC and the Regional Management Councils and maintain collaboration with partners and jurisdictions across the Chesapeake Bay watershed.

2. Managing Under Increased Uncertainty
   Maryland may experience severe or acute changes in fish stocks. The department will need the ability to respond quickly with the best information available. In the case that historical data can no longer be used to predict the future, robust management should be pursued over accounting for all kinds of uncertainty in models.

3. Data Sources and Partnerships
   Maryland participates in state, regional, and coastwide monitoring programs. The department should foster collaboration with partners and leverage data networks to:
   - address data gaps and standardize data collection processes;
   - improve access to existing data sources;
   - consolidate tools to match management needs; and
   - strengthen communication with the fishing community and build understanding of the stock assessment and management processes.

[4] The East Coast Climate Change Scenario Planning initiative is coordinated by the three U.S. East Coast Fishery Management Councils, ASMFC, and NOAA Fisheries.
mafmc.org/climate-change-scenario-planning

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IMPACTS AND OPPORTUNITIES

The department should work proactively to establish climate adaptation strategies that support the resilience of Maryland's fisheries to climate change impacts. The following sections present a high-level overview of the complex and interconnected challenges and opportunities associated with climate change impacts. The first section addresses the fisheries components related to ecology. The second section addresses the fisheries components related to socioeconomics. The third section addresses the fisheries components related to governance. Under each fisheries component are a selection of adaptation principles and strategies. The department should consider these adaptation items when making management decisions. While the department may not be the appropriate entity to take the lead on each item, it may provide support to partners to help advance climate change adaptation and resilience initiatives.

ECOLOGY

Fish Biology

Habitats and Ecosystems

The biological characteristics of fish species combined with the surrounding environmental conditions influence how fish grow and live within aquatic ecosystems. Fisheries scientists collect extensive data on the biology of each species to establish metrics for monitoring population growth and determining stock status. Since ecosystem characteristics (e.g. interactions with other species, water quality) shape the capacity for a fishery to thrive, they are also considered as part of the fisheries management process. Using ecosystem-based fisheries management approaches allows managers to recognize these ecosystem interactions and holistically manage fishery resources within an ecosystem.

These approaches require collaboration between fisheries management bodies and jurisdictions involved in land use and landscape-level planning. The following categories encompass how the department works to understand how Maryland's coastal and aquatic ecosystems function and apply that knowledge to fishery resources stewardship.

Fish Biology

Climate Impacts

Warming Temperatures

Spawning and Recruitment – Many species synchronize spawning and recruitment with seasonal cycles. If the timing of seasonal cues changes, so may the timing of spawning and recruitment (Hare et al., 2016s7; STAC 2022).

Larvae and Young-of-Year Survival – Plankton are the foundation of the food web and are the major food source for larval fish and other filter feeders. Phytoplankton utilize photosynthesis to produce biomass, and this process follows seasonal cycles based on the environmental conditions. In 2022, phytoplankton biomass in the Mid-Atlantic was above average in winter, but below average in August and September. In 2023, a large-scale phytoplankton bloom peaked, but the dinoflagellate species was not a food source. Zooplankton (e.g. fish larvae) feed on phytoplankton and other small zooplankton. Zooplankton diversity is increasing, but the dominance of an important copepod food source may be decreasing (Northeast Fisheries Science Center, 2023, 2024). Climate change has the potential to shift the seasonality of plankton blooms and the composition of species present. Shifting primary productivity would alter the productivity across forage fish and predatory fish at multiple levels of the food web. Climate change may also have variable impacts to ocean currents depending on large scale thermohaline circulation and local scale tides, wind stress, and density gradients. Wind driven flow on the outer continental shelf, buoyancy driven flow on the inner shelf, and local estuarine currents may alter recruitment and larval dispersal patterns (Hare et al., 2016s2).

Growth and Maturity – For some species, temperature may impact the life stages when growth is associated with seasons. For example, if prey are available, juvenile blue crabs and oysters are expected to show improved growth and survival and reach maturation size earlier to due a longer growing season. Striped bass larvae and age-O juveniles are also expected to show increased growth (STAC, 2022).

Physiology – Warming surface and bottom temperatures, combined with additional stressors like low dissolved oxygen and disease, may induce or exacerbate chronic stress on managed fish species. When a marine heat wave occurs, additional warming may approach the thermal limits for sensitive species and induce mortality (STAC, 2022, 2023). For example, striped bass experience a “habitat squeeze” during the summer where the surface water is too warm and the bottom water has low dissolved oxygen. They are limited to an intermediate band in the water column called the “squeeze zone” (STAC, 2022). These conditions also contribute to discard mortality from stress of being handled by humans. If available, fish may migrate to more favorable habitats. See the Habitats and Ecosystems section (p. 19) for more information on habitat-specific impacts. Some species may show positive responses to warmer temperatures. For example, blue crabs are expected to show decreased winter mortality and may not bed down into the sediment to the same extent as previous winters. Additionally, oysters are tolerant to high temperatures and salinity. They are expected to show longer periods of activity and filter feeding, and the spawning season may lengthen (STAC, 2022).

Sea Level Rise / Precipitation and Storms

Water Quality – Periods of intense precipitation and severe storm events increase runoff over impervious, natural, and vegetated landscapes that reduces water quality. The amount of freshwater flow contributes to estuarine salinity levels, which would fluctuate between dry and wet periods. Increased stormwater volume and speed further loads waterways with chemicals, heat, nutrients, and other pollutants (MDE, n.d.). If fluctuations in salinity are sharp, osmotic stress may be placed on estuarine species. Nutrient pollution contributes to low dissolved oxygen levels and harmful algal blooms that degrade fish health. Chemical pollution additionally poses risks for bioaccumulation, biomagnification, hormone disruptions, microplastics, and toxicity.

Ocean Acidification

Larval Development and Growth – When CO_2 dissolves in water, the resulting carbonate chemistry reduces the amount of available carbonate ions in the water. Bivalves, like oysters and clams, rely on calcium carbonate to build shells. Under acidified conditions, larval bivalves build weaker and thinner shells, especially when salinity is low (Maryland Ocean Acidification Task Force, 2015). Acidification can contribute to reduced growth, lower reproductive success, vulnerability to predation and disease, and increased mortality (Hare et al., 2016s1). Though crustaceans like blue crabs have calcium carbonate shells, the process by which they build shells differs from oysters. Some studies suggest that under acidic conditions blue crabs may have higher calcification rates and maintain shell mineralization. Finfish show mixed results depending on the species. The combined effects of hypoxia and acidification can reduce growth and survival of shad, river herring, and silversides (Maryland Ocean Acidification Task Force, 2015).

Recommendations

The department conducts regular monitoring of tidal species that informs the current stock status and associated management actions. These datasets may be helpful in assessing long-term patterns and providing a baseline to compare future conditions. Collaborating with academic or research institutions can increase capacity for collecting data on the specific impacts of climate change for key species.

- Monitor seasonal changes in population dynamics parameters (e.g. growth, mortality, reproduction). Assess if these parameters are shifting over the long term. Determine how long a pattern needs to be observed before it can be attributed to climate change.
- Determine the physiological limits of key fish species. Establish thresholds for parameters such as dissolved oxygen, pH, salinity, and temperature. These metrics will assist in projecting when conditions may be unfavorable or increase mortality.
- Monitor species distribution changes along the coast and within the Chesapeake Bay, its tidal tributaries, and the coastal bays. Assess the potential for new species to establish in Maryland.
- Utilize regional and local tools to synthesize climate data for key fish species. For example, the National Oceanic and Atmospheric Administration (NOAA) conducted a Northeast Fish and Shellfish Climate Vulnerability Assessment (FSCVA), which includes

species narratives that highlight specific climate impacts for each species (Hare et al., 2016). Engage with species experts through partnership networks and academic institutions.

Habitats and Ecosystems

Climate Impacts

Warming Temperatures

Fish Distribution – As waters warm, the distribution of suitable habitat is shifting and influencing fish distributions. Depending on its habitat needs, a species' distribution may shrink, expand, shift, or remain stable. NOAA Fisheries has already documented range shifts for Mid-Atlantic species moving northward and offshore to deeper water (Hare et al., 2016s8; NOAA Fisheries, 2022). Maryland is positioned centrally along the Atlantic coast and has the potential to experience species moving out of Maryland waters to the North and new species moving into Maryland waters from the south. A fluctuating composition of fish species may lead to altered food web dynamics and opportunities for new fisheries (STAC, 2023). At a smaller spatial and temporal scale, species may utilize different areas of habitat within the Chesapeake Bay, its tidal tributaries, and coastal bays throughout the year.

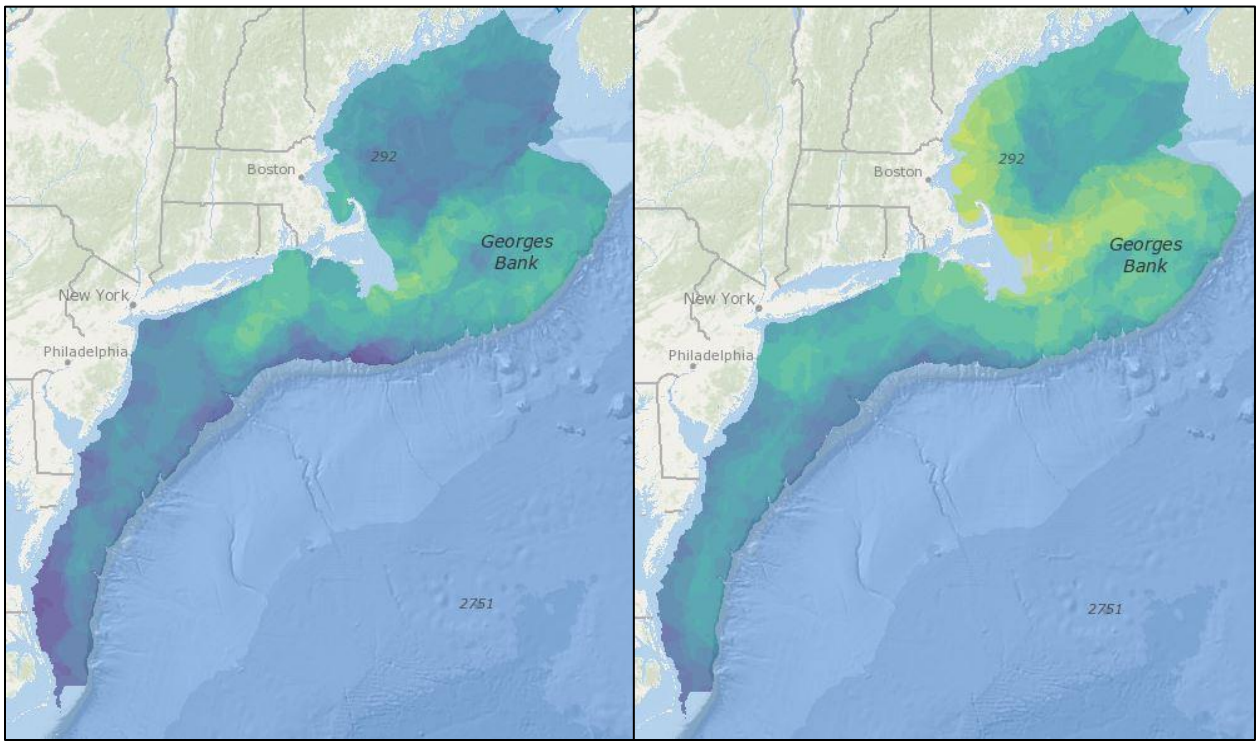

Figure 6 – Aggregate change in location of marine species surveyed in the Northeast region from 1974 (left) to 2022 (right). Colors represent core species richness values ranging from 7-9 (dark purple) to 37-39 (light yellow). On average, marine fish and invertebrates have shifted 0.61 degrees north and 8.6 meters deeper over this time period (NOAA Fisheries, 2022).

SAV – Major habitats of Maryland's coastal waters include SAV (i.e. seagrass), tidal marshes, and oyster reefs. SAV is a key nursery and foraging habitat for Chesapeake Bay species. It provides additional benefits for oxygen production and buffering against acidification (STAC, 2023). The climate vulnerability rank for SAV is "High" (Farr et al., 2021s4). SAV is sensitive to temperature, pH, and sunlight, and high summer temperatures combined with marine heat waves are associated with mass die offs of eelgrass. As temperatures warm, heat-tolerant seagrass species like widgeon grass may be favored over eelgrass (STAC, 2023).

Sea Level Rise

Wetlands – The climate vulnerability rank for native wetlands is "Very High" (Farr et al., 2021s4). Increased exposure to high tide flooding has contributed to erosion and saltwater intrusion in coastal habitats, especially tidal marshes. As water levels increase, previously upland habitats are expected to transition into intertidal habitats. This transition is evidenced by the appearance of ghost forests where the soil has become too saline for trees to grow (UMCES, 2023). The department is working with its partners to model the migration potential of wetland and salt marsh habitat along the Chesapeake Bay and its tributaries. In areas where marsh migration is blocked by gray infrastructure or sediment accretion cannot keep pace with sea levels rise, marsh habitat could be lost.

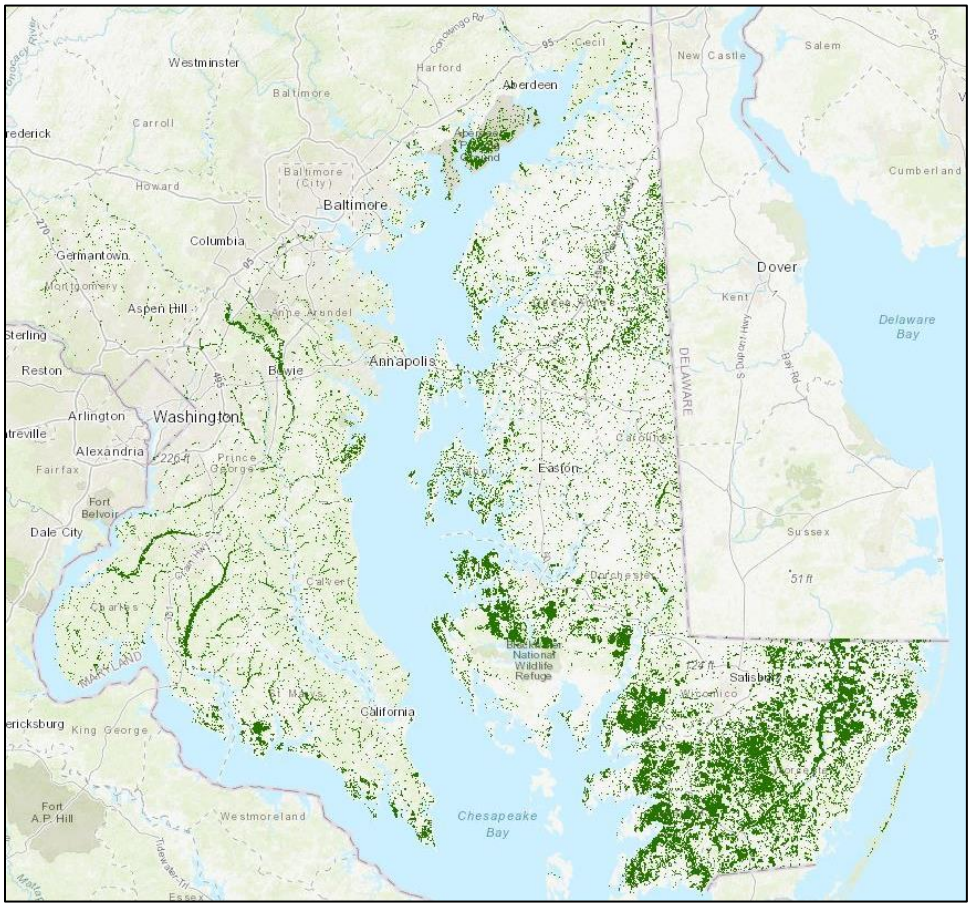

Figure 7 – Projected spatial distribution of wetlands in 2100, calculated by the Sea-Level Affecting Marshes Model (Wetland Adaptation Areas 2100 data layer, Maryland Coastal Atlas, dnr.geodata.md.gov/CoastalAtlas/)

Subtidal – Similarly, subtidal habitats like SAV and oyster reefs will experience deeper inundation as sea levels rise. Deeper water may reduce the amount of light available for SAV and limit growth if the grasses cannot expand into shallower bottom (STAC, 2023).

Estuarine habitats, including salt marshes and seagrass beds, create habitat for fish. Some species are year round residents, while many commercial and game fish utilize estuaries during certain life stages or times of the year. For example, adult striped bass from along the Atlantic coast migrate into the Chesapeake Bay tributaries to spawn, while blue crabs and summer flounder occupy seagrass beds as protective nurseries during the juvenile life stage (Northeast Regional Management Councils, 2022). Developing comprehensive habitat migration projections will help managers determine how habitat composition and distribution may change as sea levels rise and water quality parameters change.

Precipitation and Storms

Water Quality – As stated in the previous section, periods of intense precipitation and severe storm events increase runoff over vegetated, natural, and impervious landscapes. The amount of freshwater flow contributes to estuarine salinity levels, which would fluctuate between dry and wet periods. Increased stormwater volume and speed further loads waterways with heat, nutrients, chemicals, and other pollutants (MDE, n.d.). Nutrient pollution can drive eutrophication that results in low dissolved oxygen levels and occasionally harmful algal blooms that degrade both fish and SAV health. Runoff also deposits sediments that lower water clarity and smother SAV.

Structural Integrity – Severe storms can directly damage tidal and subtidal habitats and deposit debris into these areas. Increased wave action also exacerbates erosion of natural and nature-based shorelines, further removing fish habitat.

Ocean Acidification

Shellfish – The effects of ocean acidification in coastal habitats often occur with additional stressors like high temperatures, low dissolved oxygen, and contamination (Maryland Ocean Acidification Task Force, 2015). The climate vulnerability rank for subtidal shellfish reef is “High” (Farr et al., 2021s4). Since acidification makes shell building more energetically demanding for individual oysters, further research is needed to determine how acidification could impact oysters at the reef and ecosystem scales. The higher sensitivity of larval and juvenile oysters to acidification may inhibit reef building over the long term. Oysters serve a key function as habitat engineers and provide a variety of ecosystem services like filtration, food, and shelter for other fish and prey species (Maryland Ocean Acidification Task Force, 2015). Determining the compounding effects of water quality stressors on oysters will help managers plan conservation and restoration strategies and promote ecosystem functions.

Invasive Species

While the establishment of invasive species is not necessarily a direct result of climate change, this issue acts as a co-stressor with other climate impacts. Invasive species have the potential to cause harm to the ecology of the system, to the economy, or to human health. From an ecological perspective, invasive species disrupt native species interactions. They also inhibit

recovery of native species that have already experienced reduced abundance and habitat degradation.

Assessment and Mitigation – Two aquatic invasive species of priority concern are blue catfish and Northern snakehead, also known as Chesapeake Channa. Both have proliferated across the Chesapeake Bay tributaries due to their varied diets and high reproductive capacity. Blue catfish diets are especially generalized. Research efforts in Maryland and Virginia are currently focused on developing a comprehensive understanding of their diet, abundance, distribution, and habitat use. These studies will help determine if blue catfish are negatively impacting native species like white catfish and major fisheries species like blue crab. Snakeheads are also opportunistic feeders but primarily hunt other fish. The U.S. Fish and Wildlife Service coordinates monitoring in the Chesapeake Bay tributaries. Since both species have become established in the watershed, they demonstrate opportunities for supporting novel fisheries markets as a mediation method. As environmental conditions change, the capacity for novel or introduced species to become invasive should be assessed.

Recommendations

Key factors for ensuring the persistence of fish stocks are assessing:

1. if current habitat will continue to be suitable;
2. if habitat distributions are changing; and
3. if suitable habitat can be accessed if stock distributions change.

A challenge to managing fish habitat at the state level is that habitat conservation, restoration, and protection strategies are often outside the jurisdiction of fisheries authorities. Department staff should pursue creative partnership with entities and staff outside of individual units to integrate fisheries data and priorities into the greater scope of land and aquatic management. The following recommendations provide opportunities for communication and collaboration.

- Take an ecosystem-based approach to management. Connect fisheries community members, managers, and scientists with jurisdictions involved in landscape-level planning, including conservation and restoration. Facilitate coordination between academic institutions, non-governmental organizations, state agencies, and other partners to promote data sharing and informed decision making.
- Assess the current status of coastal habitats and living resources.
    - Assess the spatial distribution of key habitats such as oyster reefs, SAV, and tidal marshes. Incorporate data on habitat quality.
    - Determine habitat use patterns for Maryland's key fish species. Consider how habitat use changes across life stages and times of the year.
    - Translate these data into a visual format that can be used for spatial analyses and planning.
    - Utilize regional and local tools to synthesize climate data for key habitats. For example, the Northeast Regional Management Councils and NOAA conducted a Northeast Regional Habitat Assessment (NRHA), which includes habitat narratives that highlight specific climate impacts for each habitat (Farr et al., 2021). Engage with habitat experts through partnership networks and academic institutions.

- Assess the potential future condition of coastal habitats and living resources by utilizing modeling and projection techniques.
    - Project future habitat distributions (e.g. marsh migration potential).
    - Perform a habitat suitability analysis for key fish species.
- Determine priority areas for habitat conservation and restoration based on current and projected distributions (e.g. Targeted Ecological Areas).
    - Consider co-siting areas that have spatial connectivity between terrestrial and aquatic habitats. Enhancing upland and intertidal habitats will help reduce nutrient and sediment runoff and support SAV and oyster reef subtidal habitats. This approach would also facilitate migration corridors so that subtidal habitats can migrate into shallower sediments with sea level rise.
    - Strategically plan conservation and restoration in areas where survival and reproduction of living resources are optimized.
- Incorporate fish habitat as a co-benefit into ranking systems for awarding funding to green infrastructure and nature-based projects.
- Prioritize habitats that are recommended in the Maryland Ocean Acidification Action Plan (MDE et al., 2020).
    - Forests, riparian buffers, and tidal marshes reduce nutrient pollution and sedimentation from runoff. Reduced nutrient load lessens eutrophication and the buildup of CO_2 in the water column, while clearer water promotes CO_2 removal by SAV. Increasing SAV cover enhances CO_2 removal.

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[S1 supporting information: Sensitivity attributes]
[S2 supporting information: Ocean currents exposure]
[S7 supporting information: Species narratives]
[S8 supporting information: Climate vulnerability and distribution change potential]

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SOCIOECONOMIC

Fishing Effort

Shoreside Processes

Cultural Significance

Maryland's economy inherently relies on the ocean and the state's waterways. NOAA's Office for Coastal Management (2021) reported that the Ocean Economy contributed $10.2 billion to Maryland's gross domestic product (GDP). Collectively, industries that rely on living resources made up 3.7% of Maryland's Ocean Economy and contributed $376.2 million to Maryland's GDP. These living resources industries in part fuel Maryland's coastal tourism and recreation industries.

Ocean Economy	Living Resources	Tourism and Recreation
Living Resources	*Commercial Fishing*	Eating and Drinking Establishments
Marine Construction	Fish Hatcheries	Hotels, Campsites, RV Parks
Ship and Boat Building	Aquaculture	Marinas
Marine Transportation	Seafood Processing	Boat Dealers, Sporting Goods
Offshore Mineral Resources	Seafood Markets	Scenic Water Tours
Tourism and Recreation		*Charters, Recreational Fishing*
Suppressed/Confidential		Amusement and Recreation Services, Zoos, Aquariums

The act of fishing and the economic network of industries surrounding fishing contribute to the cultural foundation of Maryland's coastal communities. The following categories encompass how the department contributes to managing fishing effort and supports the development of resilient communities across the coastal zone.

Fishing Effort

Climate Impacts

Warming Temperatures

Fish Distribution – NOAA Fisheries has documented distribution shifts for fish stocks in the Mid-Atlantic region (NOAA Fisheries, 2022). Maryland's central position along the Atlantic coast potentially gives commercial and recreational licensees an opportunity to catch a new composition of species. While catch may be reduced for species that decline or migrate out of Maryland waters, new fisheries can be established for warmer water species. To effectively harvest established and novel fish species, industry participants may need to change when, where, and how they operate. Both commercial vessels and charter boats may need to travel further offshore into deeper waters to catch coastal and Atlantic species, which requires additional travel time and resources. They may also need to equip their vessels with different gear.

Sea Level Rise / Precipitation and Storms

Fishing Conditions – The intensity of tropical storms and hurricanes is expected to increase. Storms create hazardous conditions that increase the risk for injury and damage to gear both offshore and in coastal waters. Additionally, periods between storms may be extremely hot and dry and increase the risk for heat-related illness. Commercial operations, especially in larger offshore vessels, may be more tolerant to poor conditions, but smaller commercial and charter vessels the Chesapeake Bay and coastal bays may be more limited by weather advisories. Extreme conditions may reduce the number of fishing days throughout the year. Recreational participation during extremely stormy or extremely dry conditions may be more variable depending on the individual person's tolerance. Personal vessels may be more restricted by small craft advisories when navigation is hazardous. Heat advisories would apply to individuals fishing from vessels and the shore.

Ocean Acidification

Shellfish – Wild harvest of shellfish in the Chesapeake Bay has been a key fishery throughout the history of the region. The oyster fishery is supported by a set of closed sanctuaries that protect disease resistance, ecosystem services, habitat connectivity, and reproductive capacity (Maryland Ocean Acidification Task Force, 2015). A subset of these sanctuaries were selected for tributary-scale oyster restoration with a completion goal of 2025 (Chesapeake Progress, 2024). NOAA's Ocean Acidification Program[5] is currently supporting research on modeling the potential impacts to Chesapeake Bay oysters, restoration efforts, and aquaculture at scale. A recent model found that the pH levels of mid-bay bottom waters are low enough to negatively

[5] Current Ocean Acidification Program projects can be found at oceanacidification.noaa.gov/project-search/

impact young oysters. In future scenarios, the spatial extent of low pH waters is anticipated to expand and contribute to an increase in juvenile mortality (Cai et al., 2021). While adult oysters are generally more resilient than juveniles to acidification, the scaled impacts to the fishery resource are still uncertain.

Recommendations

The department is not the lead agency for addressing the economic operations of the fishing industry, but can provide support to other agencies and partners for issues concerning fishing effort. For example, the department may establish regulations that dictate fishing seasons, licenses, gear types, and catch limits that influence how commercial fishing businesses operate. However, how those regulations are implemented is carried out by each licensee. See the Governance section (p. 32) for more information on fishing regulations and diversification.

- Adjust daily fishing times to accommodate weather patterns. For example, during the summer commercial licensees could start and end the day earlier to avoid extreme heat out on the water.
- Provide incentives and connect licensees with programs that decrease financial barriers to using new gear.

Shoreside Processes

Climate Impacts

Warming Temperatures

Markets – If key commercial fish become less available, the supply chain may experience disruptions until an alternative product is established. Markets for new fisheries must be established and supported with appropriate infrastructure to collect, process, and distribute the product. Additionally, fish may become more susceptible to diseases and exposed to higher contaminant loads. If seafood sources pose a health risk, recalls and temporary closures could lead to loss of product and revenue.

Sea Level Rise / Precipitation and Storms

Infrastructure – Sea level rise, heavy precipitation events, and intense storms are expected to collectively increase risk for coastal flooding and can cause both long term and acute damage to infrastructure (UMCES, 2023). Commercial and recreational fishing activity could be limited if access to marinas, ports, and boat ramps is blocked. Commercial licensees also need to access locations for offloading their harvest. Such processing, distributing, and market facilities may be at risk especially if they are located waterfront. Flooded roads would block access points to the water and the movement of people and products in and out of dockside facilities. Waterfront aquaculture facilities would face similar risks which could lead to compromised conditions for the harvest (Adaptation and Response Working Group, 2008).

Ocean Acidification

Aquaculture – Shellfish aquaculture is a growing industry throughout the Chesapeake Bay region. When compared to the challenges of acidification on the Pacific coast, Maryland will not experience pulses of acidification that are driven by coastal upwelling. Instead, aquaculture operations that use natural flow of bay water will face the compounded challenges of multiple stressors associated with shallow estuarine environments (Maryland Ocean Acidification Task Force, 2015).

Recommendations

The department is not the lead agency for addressing the economic operations of the fishing industry, but can provide support to other agencies and partners for issues concerning shoreside operations. The department's Chesapeake and Coastal Service unit works across the coastal zone (Fig. 1) to ensure communities are equipped to balance the demands of coastal resource use, economic development, and conservation. The unit provides access to science and tools, coordination with partners, financial and technical assistance, and public engagement. The following items are opportunities for the Chesapeake and Coastal Service unit and Fishing and Boating Services unit to support partners and programs.

- Conduct an analysis for establishing and expanding economic markets for novel and invasive species. Building market demand helps to incentivize seafood dealers and distributors to purchase and stock new products for consumer purchase. See the Governance section (p. 32) for more information on diversification.
- Assist waterfront communities in identifying points of critical infrastructure. Points of interest may include aquaculture, commercial access (e.g. boat ramps, docks, marinas), processing facilities, and transportation. Connect these communities with local governments to identify resilience needs, then provide adaptation resources such as opportunities for shoreline protection and restoration.
    - The Resiliency Through Restoration program provides funding to design and construct shoreline protection projects. These projects use a combination of green and gray infrastructure to protect against coastal flooding and erosion and restore habitat wherever possible.
    - The Waterway Improvement Fund provides funding for capital projects and services for the boating public. These funds are often used for boating access facilities, dredging channels and harbors, and purchasing fire and rescue vehicles.
    - Some facilities embody the history and culture of coastal communities, and are of additional priority for preservation.
    - Advance a working waterfronts model to community planning.
- Utilize the Coast Smart Construction Program as an example of practices that address sea level rise and coastal flooding impacts. The program currently applies to certain types of state and local capital projects. While other projects are not required to follow these practices, the department can encourage local-scale projects to adopt them and further enhance coastal resilience.

Cultural Significance

Climate Impacts

Warming Temperatures

Public Access – A warming temperature regime may shift the historical distribution of fish and their habitats across Maryland's waterways. As a result, cultural expectations of when and where to find fish may become less reliable. Periods of extremely hot and dry weather increase the risk for heat-related illness. Recreational licensees are discouraged to be on the water during heat and air quality advisories, which may reduce opportunities for fishing. Extreme heat is exacerbated in urban areas, which further reduces recreational access in urban underserved communities.

Sea Level Rise / Precipitation and Storms

Public Access – The expected increases in storm intensity and fluctuations in precipitation may result in alternations between periods of intense wet and stormy conditions and dry and hot conditions. The combined effects of sea level rise and precipitation are expected to exacerbate coastal flooding, inundation, and/or damage to natural and built areas along the coast. Water access points are essential to allow public access to boating, paddling, and recreational fishing. Flooding and damage to boat ramps, fishing piers, parking areas, and walking trails would limit the safety and accessibility of these areas. Intense rainfall and storms also create hazardous conditions out on the water. Recreational licensees are discouraged to be on the water during small craft advisories, which would reduce opportunities for fishing. Coastal ecosystems provide the multiple benefits of enhancing the recreational experience through immersion in nature, protecting against coastal erosion, flooding, and water pollution, and supporting fish habitat. Ecosystem services have already been reduced from land development, and these losses are exacerbated by sea level rise and erosion.

Ocean Acidification

Ecosystem Processes – Previous sections discussed how ocean acidification interacts with other environmental factors such as temperature, nutrients, and dissolved oxygen. The impacts of ocean acidification in the Mid-Atlantic region are still under study. Negative interactions with bivalves have been established, which pose concern for Maryland's oyster industry. Chesapeake oysters play a key role in Maryland's culture, economy, and history. Additional research and modeling is needed to tease apart the confounding environmental factors associated with ocean acidification, then project (1) future pH levels based on carbon load, and (2) the impacts to shellfish and other fisheries at a bay-wide scale.

Recommendations

Maryland's economy and culture are closely tied to the state's waterways. Aquatic resources have supported the region's occupants throughout its history. The department is committed to sustainable stewardship of the state's natural resources for the benefit of the environment, society, and economy. The following items are opportunities for building and maintaining community identity around Maryland's coastal landscapes and aquatic resources. A key priority should be empowering communities to establish goals, make informed decisions, and prepare for their future.

- Work with fishing communities to identify geographic locations of interest. Connect with local governments at these locations to identify resilience needs.
- Ensure that the public has safe and reliable access to waterfront recreational opportunities. These spaces provide multiple benefits for community building, human health, natural habitat, and shoreline protection. Assist underserved and climate-vulnerable communities in obtaining resources for constructing waterfront green spaces.
    - The Resiliency Through Restoration program provides funding to design and construct shoreline protection projects. These projects use a combination of green and gray infrastructure to protect against coastal flooding and erosion and restore habitat wherever possible. When evaluating grant proposals, establish co-benefits for natural resources, including fisheries, in the scoring criteria.
    - The Waterway Improvement Fund provides funding for capital projects and services for the boating public. These funds are often used for boating access facilities, dredging channels and harbors, and purchasing fire and rescue vehicles.
    - Program Open Space provides funding for acquiring land that becomes established as recreational space, including state and local park areas.
    - Establish and advertise a series of safe fishing and boating practices for the public to follow if hazardous weather conditions arise while recreating. Investigate long-term trends in the number of small craft and heat advisories. Determine how these trends are projected into the future with climate change.
- Build and expand effective communication and partnership strategies with coastal and fishing communities. Incorporate social science principles into engagement approaches.
    - Leverage existing pathways for interested and impacted parties, especially fishing community members, to be involved in management and decision-making processes. Ensure that decision makers represent Maryland's citizens and that under engaged populations are included.

    - Develop visualization and education materials for communicating fisheries and climate topics of interest. Deepen understanding of fishing behavior and motivations behind fishing. Build trust in the scientific process. Highlight the need for investing in habitat conservation and restoration.
    - Continue investment in engagement and education programs to garner interest in commercial and recreational fishing opportunities (e.g. Fishing and Boating Services, 2022).
- Embrace change as part of an evolving sense of community identity. Maryland's built and natural landscapes will continue to develop as the state's population grows and demand for natural resources increases, especially in coastal areas. Climate change may disrupt established fishing practices and available fisheries. The goal of adaptation is to establish a system that is flexible and accommodates a "new normal."
    - Deepen understanding of historical, local, and traditional knowledge. Engage with indigenous groups and generational fishing operations.
    - Adopt novel species as part of Maryland's natural history. Support communities in establishing markets for novel and invasive species.

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GOVERNANCE

- Fishery Management Planning
- Stock Dynamics
- Monitoring and Data
- Writing Regulations
- Encouraging Diversification
- Communication and Partnership

Fisheries management combines data collected from fishing effort and scientific surveys to assess the status of fish stocks and determine conservation and management measures that allow sustainable harvest while preventing overfishing. Management processes are conducted in coordination and compliance with regional and federal management bodies for coastwide and offshore fisheries. State advisory bodies also play a critical role in the management process by providing public and constituent input on natural resource management for the department. The climate challenges and recommendations detailed in the previous sections greatly influence how governance must operate to support the ecological and socioeconomic components of Maryland's fisheries.

The following categories encompass the department's fisheries governance components. In addition, the department conducts adaptive management planning that addresses specific needs for freshwater fisheries. A focus of those efforts is on coldwater resource management. While those management strategies extend beyond the scope of this document, they should be consulted when considering the impacts of climate change on freshwater fisheries.

Fishery Management Planning

Climate Impacts

Fishery management plans (FMPs) are one avenue by which the department is granted authority to manage a species. They include goals, objectives, strategies, and actions that are informed by science and agreed upon by fisheries professionals. Their purpose is to enhance and restore species in decline, to promote ethical fishing practices, and to ensure public involvement in the fishery management process. FMPs also allow the department to address issues that are unique to Maryland resources.

After an FMP is adopted into the Code of Maryland Regulations, the state's fishery shall be harvested in accordance with the conservation and management measures in the FMP and any regulations that implement or amend the plan. Given the climate change impacts described in the previous sections, it is important that FMPs provide a framework that is adaptable to potential changes in the fishery. Many of the original FMPs were written before climate change data were widely available. As FMPs continue to be updated, managers can incorporate language for climate change and adaptive management.

Recommendations

- Establish objectives, strategies, and actions that are tailored to an adaptive management approach. Allow for future data to shape how conservation measures will be developed and implemented to support resilient operation of the fishery.
- When applicable, coordinate objectives, strategies, and actions with the appropriate interjurisdictional management bodies.

Stock Dynamics

Climate Impacts

Changing environmental conditions have the potential to influence fish population dynamics such as growth, mortality, reproduction, and survival which are essential variables in current stock assessment methods. Species exhibit varying levels of sensitivity to climate change factors and their overall resilience may be determined by the genetic capacity, habitat specialization, and population structure (Mason et al. 2021). Accurate stock status assessments and projections are necessary for establishing conservation measures and seasonal regulations that preserve the resource and, if needed, rebuild. Understanding how climate change could enhance or reduce a fishery will allow managers to work proactively.

Recommendations

- Monitor changes in population parameters (e.g. growth, mortality, reproduction, survival) that may be shifting in response to environmental conditions.

- Determine how specialized the individual stocks are to current habitat conditions and their capacity for genetic adaptation.
- Determine species-specific environmental thresholds (e.g. thermal limits) that would significantly decrease survival. Climate vulnerability assessments can assist in identifying climate impacts for key species.
- Incorporate climate parameters into stock assessments. Utilize projections to plan for potential changes to stocks.

Monitoring and Data

Climate Impacts

Fisheries management is informed by a combination of fishery-dependent and fishery-independent datasets. Long-term datasets allow for short and long term trends to be differentiated, yet require consistency in sampling protocol over time to maintain accurate data. If stock abundance and distribution are shifting from climate change, the current sampling protocols may not accurately reflect the stock. Additionally, the abundance of coastal species may increase or decrease along the coast, which would impact the total number of species the department is required to monitor. Increased abundance of new species presents fishing opportunities, but may also strain departmental capacity if new monitoring protocols are required.

Recommendations

- Ensure that long-term datasets maintain their integrity. Changes to sampling methodology may be necessary to accommodate changes in stock production and distribution.
- Maximize departmental capacity for monitoring species under Maryland jurisdiction or allocation. Develop a process for onboarding species that are new to the region and offboarding species that have become low or non-existent in abundance.
- Improve fisheries-dependent datasets.
- Build and expand partnerships with local and regional jurisdictions to broaden access to data networks and management tools.

Writing Regulations

Climate Impacts

Climate factors include a combination of long-term incremental changes and short-term acute changes. For example, the long-term increase in average water temperature is exacerbated during periods of marine heat waves. Determining the physiological limits for key species will help determine if acute environmental changes will enhance or reduce the fish resource. Periods of acute stress could have unexpected interactions with other environmental and

fishing-related factors. In this case, management action may need to be taken on a more rapid timeline than the current regulatory process allows.

Recommendations

- Enable the department to take timely management action in the case that severe or acute changes to fish stocks occur.
- Assess thresholds for climate tipping points. Develop management protocols that can be triggered when environmental conditions are unsuitable.

Encouraging Diversification

Climate Impacts

While there is some overlap in the species recreational and commercial licensees target, some fisheries are dominated by one sector over the other. Additionally, fisheries operate differently in the Chesapeake Bay and its tidal tributaries than in the coastal bays and Atlantic coast. The department's licensing and gear systems work in tandem to allow licensees to target species of interest. As environmental conditions change, species abundance and distribution may shift within Maryland waters and along the Atlantic coast. As a result, the current selection of available fisheries may fluctuate over time. If new fisheries arise, licensees must have the correct license and gear to participate in a more diverse selection of fisheries. Additionally, there must be market demand and the shoreside infrastructure to support new fisheries. Supporting diversification will give licensees flexibility in the species they can target depending on what is available at the time.

Another opportunity for diversifying the commercial seafood industry is through aquaculture. Cultivating clams, mussels, oysters, and other shellfish in outplanted areas supplements the ecosystem services from wild shellfish. Alternatives include seaweed and kelp.

Recommendations

- Establish licensing and gear requirements that allow fishing licensees the flexibility to catch a changing composition of species.
- Enable fishing licensees to participate in new wild harvest fisheries. Assist in building market demand and partner with industry professionals to streamline supply chains.
- Encourage fishing licensees to participate in other water-dependant industries such as aquaculture operations.
- When possible, streamline regulations and provide business flexibilities.

Communication and Partnership

Climate Impacts

Addressing multiple climate impacts across fisheries components is a complex challenge. Any individual entity may be limited in capacity to implement adaptation strategies. Factors that contribute to capacity include funding, data, programs, staff, and time. Building and fostering partnerships expands capacity through facilitating communication, garnering trust, and sharing resources. As new climate and fisheries data are collected and synthesized, this information needs to be communicated between interested and impacted parties. Communication will be especially important if climate trends conflict with current expectations based on historical stock trends and management actions.

Recommendations

- Improve department-wide implementation of adaptation strategies by sharing climate change resources among units and coordinating common goals.
- Expand partnerships with regional coordination groups, other jurisdictions, and academic institutions to align climate adaptation and resilience goals and increase capacity.
- Expand meaningful engagement with community members, fishing licensees, and other interested and impacted parties. Enable and support equitable access to commercial and recreational fishing for all Marylanders.
- Utilize the advisory bodies as opportunities for collaboration and co-development of management decisions. Encourage active participation from interested and impacted parties.
- Foster a comprehensive understanding of how science informs management and what role each entity plays in the management process.

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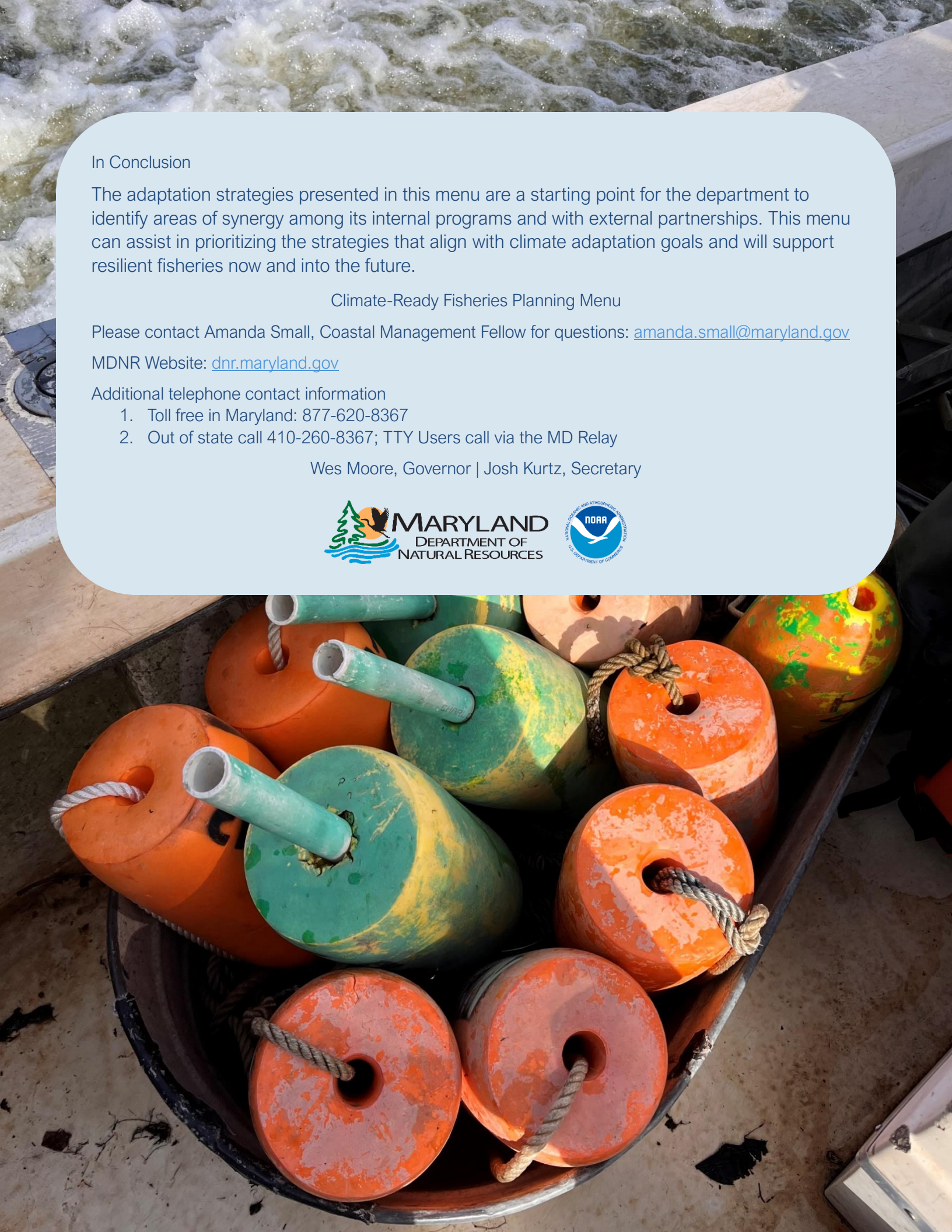
CONCLUSIONS

Maryland's fisheries are characterized by the species and habitats that occupy the region, a rich history of the seafood industry, and a robust system for monitoring and managing stocks. While fisheries management is already based on an adaptive management approach, climate change impacts are complex and require dynamic solutions. Multiple climate factors are likely to act simultaneously on the various fisheries components. Thus, adaptation strategies must work across the ecology, socioeconomic, and governance components to support the resilience of Maryland's fisheries in the long term.

The themes of proactivity, opportunity, and partnership can guide the department in developing adaptation and resilience strategies. For many stocks, management action is based on data from prior years and is inherently reactive. When applicable, climate science can inform projections for life history characteristics and for ecosystem conditions. This approach would allow fisheries and land managers, community members, and other partners to work proactively to prepare for anticipated changes. While climate change poses a number of challenges, it also presents new opportunities for fisheries. Adaptive strategies such as supporting markets for novel species and aquaculture encourage industry participants to optimize opportunities as they arise. Additionally, climate change is a cross-cutting issue that extends beyond the scope of traditional fisheries management. Building and expanding partnerships are key to implementing adaptation strategies across fisheries components. Fishing communities are essential to the management process and provide perspective on industry needs. Academic partners expand capacity for research and data analysis. The department also partners with and provides guidance to local governments and jurisdictions involved in land use, spatial planning, and coastal ecosystem resilience. These and other partnerships highlight the need for aligning fisheries adaptation and resilience goals with the department's goals for natural resources and the larger scope of climate adaptation across the state and region.

The Maryland Commission on Climate Change's Adaptation and Resiliency Working Group supports the state in reducing climate change vulnerability and providing tools for adaptation. The working group represents multiple sectors including water resources, human health, natural resources, ecosystems, and infrastructure. As a member agency, the department has the opportunity to collaborate with state partners on cross-sector topics such as habitat conservation and restoration and water quality.

The department is also a member of the Chesapeake Bay Program, which coordinates Chesapeake Bay jurisdictions in progressing towards environmental and economic sustainability of the watershed. The Chesapeake Bay Watershed Agreement includes a goal for climate resiliency and a corresponding outcome for climate adaptation. The Chesapeake Bay Program's Executive Council initiated the process of charting a course to 2025 and beyond. This Beyond 2025 initiative is developing a path forward for meeting watershed goals and outcomes, including for living resources and climate change. Now is a pivotal time to synergize with broad-scale climate adaptation and resilience planning to streamline efforts across sectors and increase capacity for implementing shared goals.



In Conclusion

The adaptation strategies presented in this menu are a starting point for the department to identify areas of synergy among its internal programs and with external partnerships. This menu can assist in prioritizing the strategies that align with climate adaptation goals and will support resilient fisheries now and into the future.

Climate-Ready Fisheries Planning Menu

Please contact Amanda Small, Coastal Management Fellow for questions: amanda.small@maryland.gov

MDNR Website: dnr.maryland.gov

Additional telephone contact information

1. Toll free in Maryland: 877-620-8367
2. Out of state call 410-260-8367; TTY Users call via the MD Relay

Wes Moore, Governor | Josh Kurtz, Secretary

MARYLAND DEPARTMENT OF NATURAL RESOURCES

NOAA

APPENDIX

A – Definitions

Adaptation	Adjustment in natural or human systems to a new or changing environment that exploits beneficial opportunities or moderates negative effects. Climate adaptation refers to those actions taken to reduce vulnerability to the impacts of climate change, aimed to enhance the resilience of natural and human-based systems.[1]
Adaptive Management	A systems approach that prioritizes action, even in the face of uncertainty, while including feedback loops and assessments along the system to inform management decisions and improve outcomes.[2]
Climate Change	Changes in long-term average weather patterns on a global, continental, regional, or local scale occurring as a result of greenhouse gas emissions. Heightened levels of emissions are being generated by human activities, including burning and producing fossil fuels, agricultural practices, and deforestation. As a result, heat is trapped in the Earth's atmosphere at increased levels, causing global temperatures to rise. As temperatures rise, additional environmental changes, or climate impacts, occur.[1]
Conservation and Management Measures	One or more techniques through which the objectives of a fishery management plan are achieved.[3]
Ecosystem-Based Fishery Management	A systematic approach to fisheries management in a geographically specified area that contributes to: the resilience and sustainability of the ecosystem; recognizes the physical, biological, economic, and social interactions among the affected fishery-related components of the ecosystem, including humans; and seeks to optimize benefits among a diverse set of societal goals.[4]
Fish	Finfish, crustaceans, mollusks, and amphibians and reptiles which spend the majority of their life cycle in water and any part, egg, offspring, or dead body of these species.[5]
Fishery (Fishery Resource)	(i) One or more stocks of fish which can be treated as a unit for purposes of conservation and management and which are identified on the basis of geographic, scientific, technical, recreational, and economic characteristics; or (ii) The group or industry harvesting those stocks.[3]

Fishery Management	The system used to conserve and allocate the fishery resource, including research and data collection, determination of objectives and management measures, and establishment, enforcement, and periodic evaluation of regulations.[3]
Fishery Management Plan	A document or report that contains a systematic description of a given fishery and the objectives and conservation and management measures for the fishery.[3]
Fishing Effort	The amount of time and fishing power used to harvest fish. Fishing power includes gear size, boat size, and horsepower.[6]
Gray Infrastructure	A feature of the urban built environment that collects and conveys excess stormwater through curbs, gutters, drains, piping, and collections systems.[2]
Green Infrastructure	Using natural processes to improve water quality and manage the volume of stormwater runoff at its source through interventions such as rain gardens, bio-retention street planters, and curb cuts to control the flow and direction of water. Green infrastructure can reduce the need for constructing additional gray stormwater infrastructure in many instances by reducing the burden on existing excess water runoff systems.[2]
Mitigation	Implementing actions to reduce greenhouse gas emissions or increase the amount of carbon dioxide absorbed and stored by natural and man-made carbon sinks.[7]
Nature-Based Approach	Using natural features and processes to develop infrastructure projects that provide resilience benefits to coastal communities and habitats. These projects leverage the natural protection that dunes, marshes, wetlands, and reefs provide against flooding, storm damage, and erosion, and may strategically combine pre-existing and engineered features for hazard mitigation.[2]
Invasive Species	A species that evolved outside Maryland or the Mid-Atlantic states of the U.S. and has caused, or has the potential to cause, ecological or economic harm, or endanger human health.[8] Note: Not all non-native species are invasive.
Population	A biological unit referring to individuals of the same species living in the same area.[9]
Projection	The potential evolution of a quality or set of quantities, often computed with the aid of a model. Projections are distinguished from predictions in order to emphasize that projections involve assumptions-–concerning, for example, future socio-economic and technological developments, that may or may not be realized and are therefore subject to substantial uncertainty.[7]

	The forecasting of future stock conditions based on information from a stock assessment; used to establish future catch allowances, management restrictions, and time frames for rebuilding overfished stocks.[6]
Recruitment	A measure of the weight or number of fish that enter a defined portion of the stock, such as the spawning stock or fishable stock.[6]
Resilience	The capacity of natural and human-based systems to anticipate disturbances, reduce vulnerability, and respond to and recover from heavy disturbances and chronic stresses.[1, 7]
Stock	A management unit grouped by genetic relationship, geographic distribution, and movement patterns.[9]
Stock Assessment	An evaluation of a stock, including age and size composition, reproductive capacity, mortality rates, stock size, and recruitment.[6]
Stock Status	A determination of whether a stock is large enough to sustain itself at current fishing levels, or whether the fishing level is too high.[9] Overfished: A stock exploited to a level of abundance considered too low to ensure safe reproduction.[6] Overfishing: Harvesting from a stock at a rate greater than the stock's reproductive capacity to replace fish removed through harvest.[6]
Sustainable	Sustainable fisheries follow fishery management objectives that balance biological constraints with human needs, reconcile present and future costs and benefits, and integrate the diversity of public and private interests.[10]
Vulnerability	The characteristics of exposure, sensitivity, and adaptive capacity that make a system, asset, or the natural environment more or less susceptible to harm or change.[2]

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10. 50 C.F.R. § 600.310, (National Standard 1 – Optimum Yield).

B – Acronyms

ASMFC	Atlantic States Marine Fisheries Commission
FMP	Fishery Management Plan
GDP	Gross Domestic Product
MDE	Maryland Department of the Environment
MDNR	Maryland Department of Natural Resources
MDP	Maryland Department of Planning
NOAA	National Oceanic and Atmospheric Administration
SAV	Submerged Aquatic Vegetation
STAC	Science and Technical Advisory Committee of the Chesapeake Bay Program
UMCES	University of Maryland Center for Environmental Sciences
UMD	University of Maryland

C – Adaptation Strategies List

Ecology

Fish Biology

The department conducts regular monitoring of tidal species that informs the current stock status and associated management actions. These datasets may be helpful in assessing long-term patterns and providing a baseline to compare future conditions. Collaborating with academic or research institutions can increase capacity for collecting data on the specific impacts of climate change for key species.

- Monitor seasonal changes in population dynamics parameters (e.g. growth, mortality, reproduction). Assess if these parameters are shifting over the long term. Determine how long a pattern needs to be observed before it can be attributed to climate change.
- Determine the physiological limits of key fish species. Establish thresholds for parameters such as dissolved oxygen, pH, salinity, and temperature. These metrics will assist in projecting when conditions may be unfavorable or increase mortality.
- Monitor species distribution changes along the coast and within the Chesapeake Bay, its tidal tributaries, and the coastal bays. Assess the potential for new species to establish in Maryland.
- Utilize regional and local tools to synthesize climate data for key fish species. For example, the National Oceanic and Atmospheric Administration (NOAA) conducted a Northeast Fish and Shellfish Climate Vulnerability Assessment (FSCVA), which includes species narratives that highlight specific climate impacts for each species (Hare et al., 2016). Engage with species experts through partnership networks and academic institutions.

Habitats and Ecosystems

A challenge to managing fish habitat at the state level is that habitat conservation, restoration, and protection strategies are often outside the jurisdiction of fisheries authorities. Department staff should pursue creative partnership with entities and staff outside of individual units to integrate fisheries data and priorities into the greater scope of land and aquatic management. The following recommendations provide opportunities for communication and collaboration.

- Take an ecosystem-based approach to management. Connect fisheries community members, managers, and scientists with jurisdictions involved in landscape-level planning, including conservation and restoration. Facilitate coordination between academic institutions, non-governmental organizations, state agencies, and other partners to promote data sharing and informed decision making.
- Assess the current status of coastal habitats and living resources.
    - Assess the spatial distribution of key habitats such as oyster reefs, SAV, and tidal marshes. Incorporate data on habitat quality.
    - Determine habitat use patterns for Maryland's key fish species. Consider how habitat use changes across life stages and times of the year.
    - Translate these data into a visual format that can be used for spatial analyses and planning.
    - Utilize regional and local tools to synthesize climate data for key habitats. For example, the Northeast Regional Management Councils and NOAA conducted a

Northeast Regional Habitat Assessment (NRHA), which includes habitat narratives that highlight specific climate impacts for each habitat (Farr et al., 2021). Engage with habitat experts through partnership networks and academic institutions.

- Assess the potential future condition of coastal habitats and living resources by utilizing modeling and projection techniques.
    - Project future habitat distributions (e.g. marsh migration potential).
    - Perform a habitat suitability analysis for key fish species.
- Determine priority areas for habitat conservation and restoration based on current and projected distributions (e.g. Targeted Ecological Areas).
    - Consider co-siting areas that have spatial connectivity between terrestrial and aquatic habitats. Enhancing upland and intertidal habitats will help reduce nutrient and sediment runoff and support SAV and oyster reef subtidal habitats. This approach would also facilitate migration corridors so that subtidal habitats can migrate into shallower sediments with sea level rise.
    - Strategically plan conservation and restoration in areas where survival and reproduction of living resources are optimized.
- Incorporate fish habitat as a co-benefit into ranking systems for awarding funding to green infrastructure and nature-based projects.
- Prioritize habitats that are recommended in the Maryland Ocean Acidification Action Plan.
    - Forests, riparian buffers, and tidal marshes reduce nutrient pollution and sedimentation from runoff. Reduced nutrient load lessens eutrophication and the buildup of CO_2 in the water column, while clearer water promotes CO_2 removal by SAV. Increasing SAV cover enhances CO_2 removal.

Socioeconomic

Fishing Effort

The department is not the lead agency for addressing the economic operations of the fishing industry, but can provide support to other agencies and partners for issues concerning fishing effort. For example, the department may establish regulations that dictate fishing seasons, licenses, gear types, and catch limits that influence how commercial fishing businesses operate. However, how those regulations are implemented is carried out by each licensee. See the Governance section (p. 32) for more information on fishing regulations and diversification.

- Adjust daily fishing times to accommodate weather patterns. For example, during the summer commercial licensees could start and end the day earlier to avoid extreme heat out on the water.
- Provide incentives and connect licensees with programs that decrease financial barriers to using new gear.

Shoreside Processes

The department is not the lead agency for addressing the economic operations of the fishing industry, but can provide support to other agencies and partners for issues concerning shoreside operations. The department's Chesapeake and Coastal Service unit works across the coastal zone to ensure communities are equipped to balance the demands of coastal resource use, economic development, and conservation. The unit provides access to science and tools, coordination with partners, financial and technical assistance, and public engagement. The

following items are opportunities for the Chesapeake and Coastal Service unit and Fishing and Boating Services unit to support partners and programs.

- Conduct an analysis for establishing and expanding economic markets for novel and invasive species. Building market demand helps to incentivize seafood dealers and distributors to purchase and stock new products for consumer purchase.
- Assist waterfront communities in identifying points of critical infrastructure. Points of interest may include aquaculture, commercial access (e.g. boat ramps, docks, marinas), processing facilities, and transportation. Connect these communities with local governments to identify resilience needs, then provide adaptation resources such as opportunities for shoreline protection and restoration.
    - The Resiliency Through Restoration program provides funding to design and construct shoreline protection projects. These projects use a combination of green and gray infrastructure to protect against coastal flooding and erosion and restore habitat wherever possible.
    - The Waterway Improvement Fund provides funding for capital projects and services for the boating public. These funds are often used for boating access facilities, dredging channels and harbors, and purchasing fire and rescue vehicles.
    - Some facilities embody the history and culture of coastal communities, and are of additional priority for preservation.
    - Advance a working waterfronts model to community planning.
- Utilize the Coast Smart Construction Program as an example of practices that address sea level rise and coastal flooding impacts. The program currently applies to certain types of state and local capital projects. While other projects are not required to follow these practices, the department can encourage local-scale projects to adopt them and further enhance coastal resilience.

Cultural Significance

Maryland's economy and culture are closely tied to the state's waterways. Aquatic resources have supported the region's occupants throughout its history. The department is committed to sustainable stewardship of the state's natural resources for the benefit of the environment, society, and economy. The following items are opportunities for building and maintaining community identity around Maryland's coastal landscapes and aquatic resources. A key priority should be empowering communities to establish goals, make informed decisions, and prepare for their future.

- Work with fishing communities to identify geographic locations of interest. Connect with local governments at these locations to identify resilience needs.
- Ensure that the public has safe and reliable access to waterfront recreational opportunities. These spaces provide multiple benefits for community building, human health, natural habitat, and shoreline protection. Assist underserved and climate-vulnerable communities in obtaining resources for constructing waterfront green spaces.
    - The Resiliency Through Restoration program provides funding to design and construct shoreline protection projects. These projects use a combination of green and gray infrastructure to protect against coastal flooding and erosion and restore habitat wherever possible. When evaluating grant proposals, establish co-benefits for natural resources, including fisheries, in the scoring criteria.
    - The Waterway Improvement Fund provides funding for capital projects and services for the boating public. These funds are often used for boating access facilities, dredging channels and harbors, and purchasing fire and rescue vehicles.

    - Program Open Space provides funding for acquiring land that becomes established as recreational space, including state and local park areas.
    - Establish and advertise a series of safe fishing and boating practices for the public to follow if hazardous weather conditions arise while recreating. Investigate long-term trends in the number of small craft and heat advisories. Determine how these trends are projected into the future with climate change.
- Build and expand effective communication and partnership strategies with coastal and fishing communities. Incorporate social science principles into engagement approaches.
    - Leverage existing pathways for interested and impacted parties, especially fishing community members, to be involved in management and decision-making processes. Ensure that decision makers represent Maryland's citizens and that under engaged populations are included.
    - Develop visualization and education materials for communicating fisheries and climate topics of interest. Deepen understanding of fishing behavior and motivations behind fishing. Build trust in the scientific process. Highlight the need for investing in habitat conservation and restoration.
    - Continue investment in engagement and education programs to garner interest in commercial and recreational fishing opportunities (e.g. Fishing and Boating Services R3 Plan).
- Embrace change as part of an evolving sense of community identity. Maryland's built and natural landscapes will continue to develop as the state's population grows and demand for natural resources increases, especially in coastal areas. Climate change may disrupt established fishing practices and available fisheries. The goal of adaptation is to establish a system that is flexible and accommodates a "new normal."
    - Deepen understanding of historical, local, and traditional knowledge. Engage with indigenous groups and generational fishing operations.
    - Adopt novel species as part of Maryland's natural history. Support communities in establishing markets for novel and invasive species.

Governance

Fishery Management Planning

- Establish objectives, strategies, and actions that are tailored to an adaptive management approach. Allow for future data to shape how conservation measures will be developed and implemented to support resilient operation of the fishery.
- When applicable, coordinate objectives, strategies, and actions with the appropriate interjurisdictional management bodies.

Stock Dynamics

- Monitor changes in population parameters (e.g. growth, mortality, reproduction, survival) that may be shifting in response to environmental conditions.
- Determine how specialized the individual stocks are to current habitat conditions and their capacity for genetic adaptation.
- Determine species-specific environmental thresholds (e.g. thermal limits) that would significantly decrease survival. Climate vulnerability assessments can assist in identifying climate impacts for key species.
- Incorporate climate parameters into stock assessments. Utilize projections to plan for potential changes to stocks.

Monitoring and Data

- Ensure that long-term datasets maintain their integrity. Changes to sampling methodology may be necessary to accommodate changes in stock production and distribution.
- Maximize departmental capacity for monitoring species under Maryland jurisdiction or allocation. Develop a process for onboarding species that are new to the region and offboarding species that have become low or non-existent in abundance.
- Improve fisheries-dependent datasets.
- Build and expand partnerships with local and regional jurisdictions to broaden access to data networks and management tools.

Writing Regulations

- Enable the department to take timely management action in the case that severe or acute changes to fish stocks occur.
- Assess thresholds for climate tipping points. Develop management protocols that can be triggered when environmental conditions are unsuitable.

Encouraging Diversification

- Establish licensing and gear requirements that allow fishing licensees the flexibility to catch a changing composition of species.
- Enable fishing licensees to participate in new wild harvest fisheries. Assist in building market demand and partner with industry professionals to streamline supply chains.
- Encourage fishing licensees to participate in other water-dependent industries such as aquaculture operations.
- When possible, streamline regulations and provide business flexibilities.

Communication and Partnership

- Improve department-wide implementation of adaptation strategies by sharing climate change resources among units and coordinating common goals.
- Expand partnerships with regional coordination groups, other jurisdictions, and academic institutions to align climate adaptation and resilience goals and increase capacity.
- Expand meaningful engagement with community members, fishing licensees, and other interested and impacted parties. Enable and support equitable access to commercial and recreational fishing for all Marylanders.
- Utilize the advisory bodies as opportunities for collaboration and co-development of management decisions. Encourage active participation from interested and impacted parties.
- Foster a comprehensive understanding of how science informs management and what role each entity plays in the management process.

D – Resources Library

Adaptation Planning Resources

Provided here is a collection of resources to support climate-ready fisheries in Maryland. The Maryland Department of Natural Resources (department) follows a climate change planning process of "understand, plan, act." This process is supported using the steps to resilience as identified by the U.S. Climate Resilience Toolkit. The following identified steps have been modified from the toolkit steps to encompass specific resources that the department has access to.

1	Framing the Issue
2	Assessing Vulnerability and Risk
3	Identifying Adaptation and Resilience Options
4	Prioritizing and Planning
5	Taking Action

For each step in the planning process, the ecological, socioeconomic, and governance components of a fishery or fisheries should be considered.

1 – Framing the Issue

Gathering basic information about the fishery is an essential part in understanding the threats of climate change and will help guide the planning process. The following questions are used to guide the first steps in formulating a climate change adaptation and resilience strategy.

Who manages the fishery? Is there a regional or joint management program?
Potential managers for tidal fisheries could include:

- Maryland Department of Natural Resources, Fishing and Boating Services
- Chesapeake Bay Program, Sustainable Fisheries Goal Implementation Team
- Atlantic States Marine Fisheries Commission
- Regional Fishery Management Councils
- National Marine Fisheries Service (NOAA Fisheries)

What are the biological and ecological characteristics of the fish species?

- The respective management bodies collect comprehensive data on managed species that are available to the public. Managers work closely with academic partners to research these various characteristics.
- For example, these data include life history traits and how species interact with their surrounding environments. In addition, current research is focused on understanding how species and their environments may be impacted by climate change.

Where is the fishery located? Where and how is the water accessed?

- Some species reside primarily within state waters, while others have ranges that expand along the coast or into the ocean. The spatial distribution of the fishery impacts how it is managed and how licensees approach commercial and recreational fishing activity, including infrastructure and fishing gear.
- While the focus of this document is on Maryland's tidal fisheries, the department conducts adaptive management planning that addresses specific needs for nontidal (i.e. freshwater) fisheries. Those management strategies should be consulted when considering the impacts of climate change on freshwater fisheries.
    - Fishing and Boating Services. (n.d.). *Coldwater Fisheries Advisory Committee Meetings*. Maryland Department of Natural Resources. Retrieved May 23, 2024 from dnr.maryland.gov/fisheries/pages/mgmt-committees/cfac-meetings.aspx
    - Fishing and Boating Services. (n.d.). *Freshwater fisheries program*. Maryland Department of Natural Resources. Retrieved May 23, 2024 dnr.maryland.gov/fisheries/pages/inland.aspx

Who or what is the target market for the fishery? Does this market interact with other aquatic and ocean uses? Is the fish commercially or recreationally significant, or both?

- The fish's commercial value impacts its end use and distribution as a product.
- Mid-Atlantic Regional Council on the Ocean. (2022). *New perspectives on the ocean economy of the Mid-Atlantic states*. Middlebury Institute of International Studies at Monterey. midatlanticocean.org/wp-content/uploads/2022/12/MARCO-New-Perspectives-on-the-Ocean-Economy-of-the-Mid-Atlantic-States.pdf
- Office for Coastal Management. (2021). *ENOW explorer* [Economics: National ocean watch portal]. National Oceanic and Atmospheric Administration. Retrieved April 24, 2024 from coast.noaa.gov/enowexplorer/

Does the fishery have cultural value in addition to market value?

- Maryland has a long history of fishing activity that is tied to the Atlantic coast, the Chesapeake Bay, and its tributaries.
- Fisheries like blue crab, oyster, and striped bass are considered iconic for the region.

Are there existing platforms to access a wide range of environmental data?

- Chesapeake Bay Program. (nd.) *Chesapeake Bay Open Data Portal*. Retrieved April 30, 2024 from data-chesbay.opendata.arcgis.com/
- Mid-Atlantic Regional Council on the Ocean. (n.d.). *Mid-Atlantic Ocean Data Portal*. Retrieved April 30, 2024 from portal.midatlanticocean.org/

2 – Assessment Tools

Climate change has the potential to impact fisheries, the people who value fisheries, and the structures and processes in place to manage fisheries as a resource. The items listed here will assist in assessing which fisheries and fishing communities are the most vulnerable to climate impacts and what their risk is.

Assessments

Technical Reports

- NOAA Chesapeake Bay Office. (n.d.). *Seasonal summaries*. Chesapeake Bay Interpretive Buoy System. Retrieved April 30, 2024 from buoybay.noaa.gov/explore/seasonal-summaries
- Northeast Fisheries Science Center. (2023). *2023 state of the ecosystem: Mid-Atlantic*. National Oceanic and Atmospheric Administration. doi.org/10.25923/vy6j-w454
- Northeast Fisheries Science Center. (2024). *2024 state of the ecosystem: Mid-Atlantic*. National Oceanic and Atmospheric Administration. doi.org/10.25923/vz5a-d111
- Scientific and Technical Advisory Committee. (2024). *Achieving water quality goals in the Chesapeake Bay: A comprehensive evaluation of system response*. Chesapeake Bay Program. chesapeake.org/stac/wp-content/uploads/2023/05/CESR-Final-update.pdf

Climate Change Vulnerability

- Farr, E. R., Johnson, M. R., Nelson, M. W., Hare, J. A., Morrison, W. E., Lettrich, M. D., Vogt, B., Meaney, C., Howson, U. A., Auster, P. J., Borsuk, F. A., Brady, D. C., Cashman, M. J., Colarusso, P., Grabowski, J. H., Hawkes, J. P., Mercaldo-Allen, R., Packer, D. B., & Stevenson, D. K. (2021). An assessment of marine, estuarine, and riverine habitat vulnerability to climate change in the Northeast U.S. *PLOS ONE*, 16(12). doi.org/10.1371/journal.pone.0260654
- Hare, J. A., Morrison, W. E., Nelson, M. W., Stachura, M. M., Teeters, E. J., Griffis, R. B., Alexander, M. A., Scott, J. D., Alade, L., Bell, R. J., Chute, A. S., Curti, K. L., Curtis, T. H., Kircheis, D., Kocik, J. F., Lucey, S. M., McCandless, C. T., Milke, L. M., Richardson, D. E., … Griswold, C. A. (2016). A vulnerability assessment of fish and invertebrates to climate change on the Northeast U.S. continental shelf. *PLOS ONE*, 11(2). doi.org/10.1371/journal.pone.0146756
- Maryland Coastal Bays Program. (2018). *Climate change vulnerability assessment of the Maryland Coastal Bays Program comprehensive conservation and management plan*. mdcoastalbays.org/app/uploads/2020/06/Final-Report-MCBP-CCVA-October-2018-2.0.pdf
- Mid-Atlantic Fishery Management Council. (2015). *Climate change and variability: A white paper to inform the Mid-Atlantic Fishery Management Council on the impact of climate change on fishery science and management*. static1.squarespace.com/static/511cdc7fe4b00307a2628ac6/t/54e90736e4b01dbc250f6a7c/1424557904186/Climate+Change+and+VariabilityWhite+Paper.pdf
- National Centers for Environmental Information. (2022). *Maryland and the District of Columbia state climate summary 2022.* National Oceanic and Atmospheric Administration. Technical Report NESDIS 150. statesummaries.ncics.org/chapter/md/

- National Oceanic and Atmospheric Administration, & Mississippi-Alabama Sea Grant. (2015). *Fisheries resilience index: Understanding how prepared your business is for a disaster.* masgc.org/assets/uploads/publications/1141/fisheries_resilience_index.pdf
- NOAA Fisheries. (n.d.). *Climate vulnerability assessment tool* [CVA data portal]. National Oceanic and Atmospheric Administration. Retrieved April 30, 2024 from fisheries.noaa.gov/data-tools/climate-vulnerability-assessment-tool
- Northeast Regional Management Councils. (2022). Northeast Regional Habitat Assessment Inshore Habitat Information. In, *Northeast Regional Habitat Assessment Data Explorer* [NRHA data portal]. Mid-Atlantic Fishery Management Council, & New England Fishery Management Council. Retrieved April 8, 2024 from nrha.shinyapps.io/dataexplorer/_w_97ead596/_w_00800d94/#!/
- University of Maryland Extension. (2023, February 14). *The effects of climate change in Maryland*. University of Maryland. extension.umd.edu/resource/effects-climate-change-maryland/

Data and Visualization Tools

- *Climate vulnerability assessment tool* [CVA data portal]. (n.d.). NOAA Fisheries. Retrieved April 30, 2024 from fisheries.noaa.gov/data-tools/climate-vulnerability-assessment-tool
- *Coastal County Snapshots* [Data visualization tool]. (n.d.). NOAA Digital Coast. Retrieved May 2, 2024 from coast.noaa.gov/snapshots/
- *Eyes on the bay* [Data portal]. (n.d.). Maryland Department of Natural Resources. Retrieved May 2, 2024 from eyesonthebay.dnr.maryland.gov/
- *GreenPrint* [Mapping tool]. (n.d.). Maryland Department of Natural Resources. Accessed May 2, 2024 from geodata.md.gov/greenprint/
- *Maryland Coastal Atlas* [Mapping tool]. (n.d.). Maryland Department of Natural Resources. Accessed May 2, 2024 from dnr.geodata.md.gov/CoastalAtlas/
- *Maryland iMAP portal* [Geospatial database]. (n.d.). State of Maryland. Retrieved May 2, 2024 from imap.maryland.gov/
- *Northeast Regional Habitat Assessment Data Explorer* [NRHA data portal]. (2022). Mid-Atlantic Fishery Management Council, & New England Fishery Management Council. Retrieved April 8, 2024 from nrha.shinyapps.io/dataexplorer/_w_97ead596/_w_00800d94/#!/

Increasing Temperature

- Scientific and Technical Advisory Committee. (2022). *Tidal briefing paper for March 15, 2022 rising water temperature STAC workshop*. Chesapeake Research Consortium. chesapeake.org/stac/wp-content/uploads/2022/03/Tidal-Briefing-Materials_DAY-2_FINAL_c3.pdf
- Scientific and Technical Advisory Committee. (2023). *Rising watershed and bay water temperatures: Ecological implications and management responses - A STAC workshop*. Chesapeake Research Consortium. Publication Number 23-001. chesapeake.org/stac/wp-content/uploads/2023/01/FINAL_STAC-Report-Rising-Temps_April.pdf

Sea Level Rise / Precipitation and Storms

- University of Maryland Center for Environmental Science. (2023). *Sea-level rise projections for Maryland 2023*. umces.edu/sites/default/files/Maryland%20Sea-Level%20Rise%20Projections%202023%20report.pdf
- Maryland Department of Natural Resources. (n.d.). *MyCoast: Maryland*. MyCoast. Retrieved April 30, 2024 from mycoast.org/md
- National Oceanic and Atmospheric Administration. (n.d.). *Coastal flood exposure mapper*. Retrieved April 30, 2024 from coast.noaa.gov/floodexposure/#-10575352,4439107,5z
- National Oceanic and Atmospheric Administration. (n.d.). *Coastal inundation dashboard*. Retrieved April 30, 2024 from tidesandcurrents.noaa.gov/inundationdb/#
- National Oceanic and Atmospheric Administration. (n.d.). *Sea level rise viewer*. Retrieved April 30, 2024 from coast.noaa.gov/slr/

Ocean Acidification

- Maryland Ocean Acidification Task Force. (2015). *Task force to study the impact of ocean acidification on state waters*. dnr.maryland.gov/waters/bay/Documents/MDOATF/OA_Report_010915.pdf
- Mid-Atlantic Coastal Acidification Network. (n.d.). *Monitoring acidification*. Retrieved May 2, 2024 from midacan.org/
- Ocean Acidification Partnership. (n.d.). *Ocean acidification research*. Retrieved May 6, 2024 from oceanacidification.noaa.gov/ocean-acidification-research/

Changing Biodiversity

- Maryland Department of Natural Resources. (n.d.). *Maryland's invasive species tracker* [Reporting form]. Retrieved June 7, 2024 from survey123.arcgis.com/share/bf026700cada433296cab48ab2a090b6
- Maryland Department of Natural Resources. (2023). *Maryland's invasive fishes: The short story of invasive fishes in Maryland* [ArcGIS story map]. Retrieved June 7, 2024 from storymaps.arcgis.com/stories/508bda04273f4cdca22f2108c1c8863e
- NOAA Fisheries. (2022). *DisMAP data records* [Distribution mapping and analysis portal]. National Oceanic and Atmospheric Administration. Retrieved April 5, 2024 from apps-st.fisheries.noaa.gov/dismap/
- United States Geological Survey. (n.d.). *Nonindigenous aquatic species* [Database]. Retrieved June 7, 2024 from nas.er.usgs.gov/default.aspx

3 – Adaptation Options

This section highlights initiatives for developing climate change adaptation and resiliency plans along with programs focused on implementing adaptation and resilience strategies. These resources offer a range of adaptation and resilience approaches, including guidance for managing fish habitat.

Adaptation Plans and Guidance

Adaptation Plans

- Adaptation and Resiliency Working Group. (2024). *Next Generation Adaptation plan* [NextGen]. Maryland Commission on Climate Change.
- Adaptation and Resiliency Working Group. (2021). *Maryland climate adaptation and resilience framework recommendations*. Maryland Commission on Climate Change. mde.maryland.gov/programs/air/ClimateChange/MCCC/Documents/MD%20Climate%20Adaptation%20and%20Resilience%20Framework%20Recommendations.pdf
- NOAA Fisheries. (2015). *Climate science strategy*. National Oceanic and Atmospheric Administration. NOAA Technical Memorandum NMFS-F/SPO-155. spo.nmfs.noaa.gov/sites/default/files/TM155.pdf
- NOAA Fisheries. (2023). *Northeast Regional Action Plan*. National Oceanic and Atmospheric Administration. NOAA Technical Memorandum NMFS-NE-310. fisheries.noaa.gov/s3/2023-11/NERAP-Nov2023.pdf

Management Strategies

- Atlantic States Marine Fisheries Commission. (2018). *Management, policy, and science strategies for adapting fisheries management to changes in species abundance and distribution resulting from climate change*. asmfc.org/files/pub/ClimateChangeWorkGroupGuidanceDocument_Feb2018.pdf
- Atlantic States Marine Fisheries Commission. (2022). *Report on Atlantic states' climate change initiatives*. asmfc.org/files/Habitat/2022Report_on_AtlanticStates%27ClimateChangeInitiatives.pdf
- Dancy, K., Kerns, T., Kelly, M., Ford, T., Bachman, M., Lucey, S., Morrison, W., Pugliese, R., & Gore, Karla. (2023). *Report of the February 2023 east coast climate change scenario planning summit meeting*. East Coast Climate Change Scenario Planning Initiative. static1.squarespace.com/static/511cdc7fe4b00307a2628ac6/t/645e5d7dd274170678a4b114/1683905918257/ECSP+Summit+Report_April+2023.pdf
- Eurich, J. G., Friedman, W. R., Kleisner, K. M., Zhao, L. Z., Free, C. M., Fletcher, M., Mason, J. G., Tokunaga, K., Aguion, A., Dell'Apa, A., Dickey-Collas, M., Fujita, R., Golden, C. D., Hollowed, A. B., Ishimura, G., Karr, K. A., Kasperski, S., Kisara, Y., Lau, J. D., … Mills, K. E. (2023). Diverse pathways for climate resilience in marine fishery systems. *Fish and Fisheries*, 25(1), 38–59. doi.org/10.1111/faf.12790
- Heck, N., Agostini, V., Reguero, B., Pfliegner, K., Mucke, P., Kirch, L., & Beck, M. W. (2020). *Fisheries at risk – Vulnerability of fisheries to climate Change*. The Nature Conservancy, Berlin. nature.org/content/dam/tnc/nature/en/documents/Fisheries-at-Risk-Technical-Report.pdf

- Tokunaga, K., Kerr, L. A., & Pershing, A. J. (2023). Implications of fisheries allocation policy on anticipated climate change impacts. *Marine Policy*, 148(105402). doi.org/10.1016/j.marpol.2022.105402
- Mason, J. G., Eurich, J. G., Lau, J. D., Battista, W., Free, C. M., Mills, K. E., Tokunaga, K., Zhao, L. Z., Dickey-Collas, M., Valle, M., Pecl, G. T., Cinner, J. E., McClanahan, T. R., Allison, E. H., Friedman, W. R., Silva, C., Yáñez, E., Barbieri, M., & Kleisner, K. M. (2021). Attributes of climate resilience in fisheries: From theory to practice. *Fish and Fisheries*, *23*(3), 522–544. doi.org/10.1111/faf.12630
- Mid-Atlantic Fishery Management Council. (n.d.). *How is the Mid-Atlantic Council responding to climate change?.* Retrieved April 30, 2024 from mafmc.org/climate-change

Ecosystem Approaches

- Atlantic States Marine Fisheries Commision. (n.d.). *Conserving fish habitat*. Atlantic States Marine Fisheries Commission. Retrieved April 30, 2024 from asmfc.org/habitat/program-overview
- Maryland Coastal Bays Program. (2015). *Comprehensive conservation and management plan*. University of Maryland Center for Environmental Science. mdcoastalbays.org/app/uploads/2020/05/2015-comprehensive-conservation-amp-management-plan.pdf
- Mid-Atlantic Fishery Management Council. (2019). *Ecosystem approach to fisheries management guidance document.* mafmc.org/s/EAFM-Doc-Revised-2019-02-08-palr.pdf
- NOAA Fisheries. (n.d.). *Ecosystem-based fishery management*. Ecosystems: Management. Retrieved April 30, 2024 from fisheries.noaa.gov/topic/ecosystems/ecosystem-based-fishery-management
    - NOAA Fisheries. (2016). *Ecosystem-Based Fisheries Management Policy*. National Oceanic and Atmospheric Administration. NOAA Fisheries Policy 01-120. fisheries.noaa.gov/s3//2024-02/Revised-EBFM-Policy-FINAL-2.12.24-508-signed-JC.pdf
    - NOAA Fisheries. (2016). *Ecosystem-Based Fisheries Management Road Map*. National Oceanic and Atmospheric Administration. NOAA Fisheries Procedure 01-120-01. fisheries.noaa.gov/s3//dam-migration/01-120-01.pdf
    - NOAA Fisheries. (2016). *Northeast regional implementation plan of the NOAA Fisheries ecosystem-based fishery management roadmap*. National Oceanic and Atmospheric Administration. media.fisheries.noaa.gov/dam-migration/northeast_implementation_plan.pdf

Maryland Programs

- Chesapeake and Coastal Service. (n.d.). *Grants managed by Chesapeake and Coastal Service Center for waterway improvement and infrastructure* [Waterway improvement fund]. Maryland Department of Natural Resources. Accessed May 2, 2024 from dnr.maryland.gov/boating/pages/grants.aspx
- Chesapeake and Coastal Service. (n.d.). *Resiliency through restoration initiative* [RTR]. Maryland Department of Natural Resources. Retrieved May 2, 2024 from dnr.maryland.gov/ccs/Pages/Resiliency-through-Restoration.aspx

- Fishing and Boating Services. (2022). *Angler recruitment, retention, and reactivation plan* [R3 plan]. Maryland Department of Natural Resources. dnr.maryland.gov/fisheries/Documents/FABSR3Plan_2021.pdf
- Land Acquisition and Planning (n.d.). *Maryland's green infrastructure assessment introduction* [Targeted ecological areas]. Maryland Department of Natural Resources. Accessed May 2, 2024 from dnr.maryland.gov/land/Pages/Green-Infrastructure.aspx
- Land Acquisition and Planning (n.d.). Program open space: An overview. Maryland Department of Natural Resources. Retrieved May 2, 2024 from dnr.maryland.gov/land/Pages/ProgramOpenSpace/Program-Open-Space-101.aspx

Increasing Temperature

- Scientific and Technical Advisory Committee. (2023). *Rising watershed and bay water temperatures: Ecological implications and management responses - A STAC workshop*. Chesapeake Research Consortium. Publication Number 23-001. chesapeake.org/stac/wp-content/uploads/2023/01/FINAL_STAC-Report-Rising-Temps_April.pdf

Sea Level Rise / Precipitation and Storms

- Maryland Department of Planning. (2019). *Maryland's plan to adapt to saltwater intrusion and salinization*. planning.maryland.gov/Documents/OurWork/envr-planning/2019-1212-Marylands-plan-to-adapt-to-saltwater-intrusion-and-salinization.pdf
- McClure, K., Breitenother, A., & Land, S. (2022). *Guidance for using Maryland's 2018 sea level rise projections.* University of Maryland Sea Grant Extension, & Maryland Department of Natural Resources. dnr.maryland.gov/ccs/Documents/MD_SLRGuidance_June2022.pdf
- McClure, K., Land, S., & Vogel, K. (2024). *Guidance for using Maryland's 2023 sea level rise projections.* University of Maryland Sea Grant Extension, & Maryland Department of Natural Resources.

Ocean Acidification

- Maryland Department of the Environment, Maryland Department of Natural Resources, University of Maryland Center for Environmental Science, & International Alliance to Combat Ocean Acidification. (2020). *Maryland ocean acidification action plan*. mde.maryland.gov/programs/Air/ClimateChange/MCCC/STWG/OA%20Action%20Plan.pdf
- Mid-Atlantic Coastal Acidification Network. (n.d.). *Reference library*. Mid-Atlantic Coastal Acidification Network. Retrieved May 2, 2024 from midacan.org/
- Mid-Atlantic Coastal Acidification Network (n.d.). *Work groups & collaborative efforts*. Mid-Atlantic Regional Council on the Ocean. Retrieved May 6, 2024 from midatlanticocean.org/mid-atlantic-coastal-acidification-network/

Changing Biodiversity

- Aquatic Nuisance Species Task Force. (2016). *Maryland aquatic nuisance species management plan*. Maryland Department of Natural Resources. dnr.maryland.gov/invasives/documents/maryland_aquatic_nuisance_species_plan.pdf
- Chesapeake Bay Northern Snakehead Plan Working Group. (2023). *Northern snakehead control and management plan for the Chesapeake Bay watershed.*

dnr.maryland.gov/fisheries/Documents/fmp/ChesapeakeBay_NorthernSnakehead_FMP_3-2023.pdf
- Invasive Catfish Workgroup. (2020). *Invasive catfish management strategy*. Chesapeake Bay Program. d18lev1ok5leia.cloudfront.net/chesapeakebay/documents/Invasive_Catfish_Management_Strategy_Aug_2020_final.pdf
- Maryland Department of Agriculture. (n.d.). *Maryland's best*. Retrieved June 3, 2024 from marylandsbest.maryland.gov/
- Maryland Department of Natural Resources. (2021). *Fishery management plan for tidewater catfish*. dnr.maryland.gov/fisheries/Documents/FMPTidewaterCatfish_December2021.pdf

4 – Prioritize and Plan

This resource library is adapted from the U.S. Climate Resilience Toolkit and designed in coordination with the Department of Natural Resources' A Guide to Planning for Climate Change on Maryland's Public Lands format. These guides and the others listed here provide a stepwise framework for planning and prioritizing climate change adaptation efforts.

- *Chesapeake assessment scenario tool* [Planning tool]. (n.d.). Chesapeake Bay Program. cast.chesapeakebay.net/
- *A Guide to Planning for Climate Change on Maryland's Public Lands* [Planning tool]. (n.d.). Maryland Department of Natural Resources. Retrieved April 30, 2024 from sites.google.com/umich.edu/marylandclimatechange/home
- *Climate ecosystems and fisheries initiative portal* [Decision-support tool]. (n.d.). National Oceanic and Atmospheric Administration. psl.noaa.gov/cefi_portal/
- *Climate mapping for resilience & adaptation* [Planning tool]. (n.d.). U.S. Global Change Resource Program. resilience.climate.gov/
- *U.S. climate resilience toolkit* [Planning tool]. (n.d.). U.S. Global Change Resource Program. toolkit.climate.gov/

5 – Take Action

This resource library expands upon the recommendations outlined in the Climate Ready Fisheries Planning Menu. While it provides targeted information to address climate change impacts from multiple perspectives, it is intended to serve as a starting point to identify adaptation priorities for further exploration and analysis. Adaptation priorities may involve updating internal management processes or implementing external projects. Taking action includes accessing and managing funding and assessing departmental and partner capacity. Continued fostering of partnerships, such as those listed below, enables the department to expand capacity and share resources.

Adaptation and Resiliency Working Group, Maryland Commission on Climate Change
Chesapeake Bay Program
Maryland Coastal Bays Program
Regional Fishery Management Councils (New England, Mid-Atlantic, South Atlantic)
NOAA Fisheries
Atlantic States Marine Fisheries Commission
and many more…