Synthesis Element 2: Identification of Where Rising Bay Water Temperatures will have the Most Impacts on Bay Fish, Shellfish and Crab Populations and Their Prey Including Identification of Critical Temperatures/Temperature Changes

Abstract

Impacts of rising Chesapeake Bay water temperatures on living resources were explored through the context of five key species chosen on the basis of their economic, ecological, and cultural importance; blue crab, oysters, summer flounder, striped bass, and forage (bay anchovy and menhaden). A review of regional species climate vulnerability scores and bay-specific research, showed a range of positive and negative responses of living resources to temperature and other climate change related factors. Positive impacts are likely for blue crab and some forage species, as warmer temperatures support higher productivity and increased habitat range as species move northward. Negative impacts are predicted for oysters due to their already depressed populations as a result of disease, overfishing and habitat loss. While oysters can thrive in higher temperature regimes and may experience an increase in habitat range, they are highly vulnerable to other climatic impacts such as ocean acidification and changes in salinity driven by precipitation. Striped bass and Summer flounder may experience both negative and positive impacts at different stages of life (larval to adult) and habitat use (rivers and estuaries to marine). The range of responses and potential for localized impacts (for example changes in habitat quality and reproductive success within specific tributaries) leads to higher uncertainty in evaluating Striped bass and Summer flounder vulnerability. The review showed that while rising temperatures are important and do affect species, other climate factors are as if not more important. It also recognizes that rising water temperatures are driven by larger atmospheric air temperature changes and are therefore not likely able to be mitigated through watershed restoration strategies. This suggests existing fishery management approaches will need to adapt by better incorporating climate change impacts into their decision making for currently managed Bay species as well as additional species that are moving north into the bay and increasing in abundance, such as brown shrimp.

A. **Contributors**

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B. **Resources**

- NOAA's Northeast Species Climate Vulnerability Ranking Profiles
- NOAA's Habitat Vulnerability Ranking Profiles
- MD Sea Grant Ecosystem-based Fisheries Management Species Fact Sheets
    - Striped Bass
    - Blue Crab

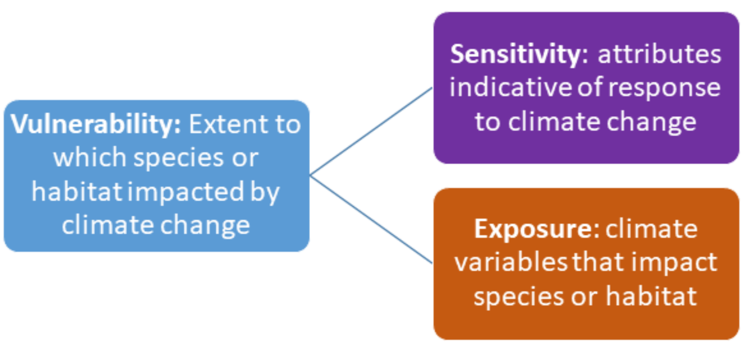
- Other Chesapeake Bay-specific literature put forward by working group members and scientists (Found in bibliography)

C. **Approach**

The synthesis uses representative bay species to contextualize effects from rising temperatures. A number of factors were considered in choosing the representative species. These included, ecological importance, economic value, cultural significance, biological diversity, management structure, and differing anticipated responses to increasing temperatures. These considerations led to synthesis summaries on blue crab, eastern oyster, striped bass, summer flounder, and forage species (bay anchovy, Atlantic menhaden, and polychaetes).

All of the above mentioned species (with the exception of polychaetes) are assigned a climate vulnerability ranking from NOAA's Northeast Fish and Shellfish Climate Vulnerability Assessment (Hare et al. 2016). This assessment ranks species vulnerability by calculating exposure and sensitivity scores using a process of expert elicitation under agreed-upon criteria. Exposure refers to climate variables that impact the species (e.g., rising water temperature), while sensitivity refers to attributes of the species that determine their response to those climate impacts (e.g., occurs in a limited temperature range).

Figure 1. Definitions of Vulnerability, Sensitivity and Exposure used in the assessments



The vulnerability assessment also provides species narratives with a focus on life history, drivers of climate vulnerability, likely climate effects, and predicted distributional shifts. The assessment process can be seen in the flow diagram. Specifics about the vulnerability ranking methodology can be seen here. **An important note on the term "vulnerability": under this assessment vulnerability is the extent to which the abundance or productivity of a**

species may be impacted by climate change, which may be either positive or negative. For example, blue crabs are ranked as very highly vulnerable, but will most likely be a climate change "winner" in the Chesapeake Bay region. Below is a summary of each species, their vulnerability to climate change, sensitivity to increasing temperatures, and impacts on key habitats of interest.

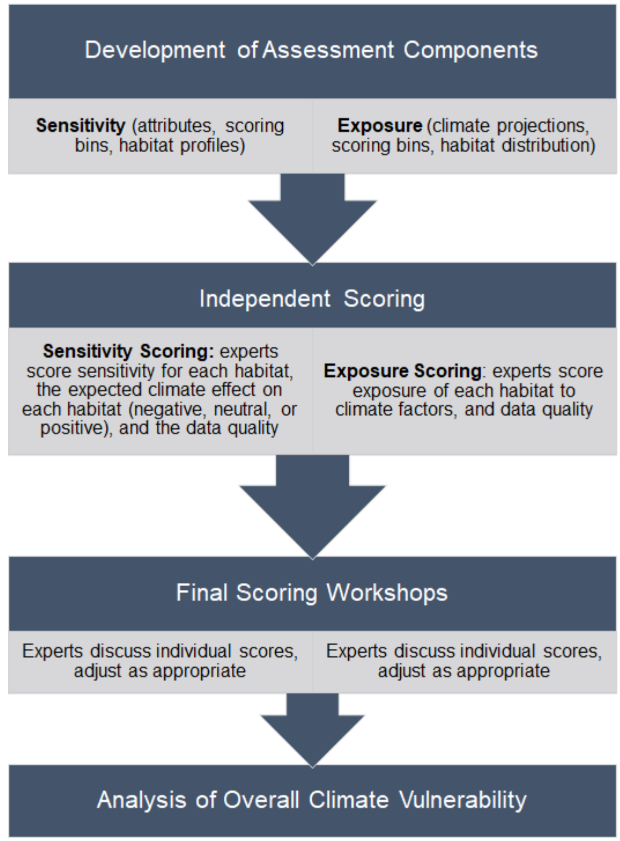


Figure II-2: Process methodology for NOAA's Northeast Climate Vulnerability Rankings

It is important to recognize that temperature is just one of many interconnected stressors that impact species recruitment, health, and abundance. A good example of temperature not telling the full story is the eastern oyster (detailed below). Oysters are classified as "low" for temperature sensitivity according to the NOAA Climate Vulnerability Assessment, as they can be found as far south as the Gulf of Mexico. Other related climatic stressors such as ocean acidification and freshwater input score as "highly sensitive" for oysters, making the species "very highly" vulnerable to a changing climate.

A recently completed NOAA assessment of the climate vulnerability of marine, estuarine, and riverine habitats in the Northeast U.S. using a very similar framework to the one described for fish and shellfish species above (Farr et al. 2021, in prep) was used to consider temperature impacts on key habitats required by the representative species. Estuarine habitats evaluated include salt marsh, SAV, and shellfish reef. Lastly the synthesis provides an overview of existing management frameworks being used to advance climate science priorities and include climate impacts to guide ecosystem based fishery management efforts.

Tasks completed/pursued for this synthesis:

- Compile a table listing temperature sensitivities of key Bay fish, shellfish and crab species/communities and their principal prey cross referenced with the geographical range of their habitats and existing information on where their habitats are most endangered due to increasing water temperatures.
    - Complete
- Describe where observed declines in Bay fish, shellfish and crab can be partially explained by observed increasing water temperatures.

    - We didn't have the resources to answer this on a fine spatial scale. Not completed
- Based on the Partnership's spatial and temporal projections for increasing tidal Bay water temperature in the coming years to decades, lay out the anticipated implications for Bay fish, shellfish and crab species/communities with high sensitivities to water temperatures.
    - Complete
- Share information on the vulnerability, impacts, uncertainty, and science gaps for increasing temperature on key species and habitats using oysters, blue crab, striped bass and bay anchovy as representative species
    - Complete

D. **Synthesis**

<u>Eastern Oyster</u>

Climate Vulnerability: Very High
Temperature Sensitivity: Low

The Eastern Oyster inhabits a wide temperature range from the Gulf of St Lawrence to Venezuela. Given its tolerance for higher temperatures in the southern parts of this range, increasing temperatures in the Bay are not likely to negatively impact oysters. However, other climate factors such as changes in salinity and ocean acidification or lower pH are expected to have negative consequences. Especially since oyster abundances in the Bay are already very low due to overfishing, habitat loss, poor water quality, and disease. Climate change is predicted to increase precipitation in the Chesapeake Bay which could lower salinities and increase run off resulting in more severe hypoxia. Lower salinities can cause mortality of oysters as observed in 2018 and 2019 and create conditions not suitable for reproduction. Higher salinities are associated with higher oyster disease prevalence and greater shell degradation. Ocean acidification (in this case lower pH) makes it more difficult for oysters to create shell and grow. This may lead to the already limited amount of oyster reef habitat to dissolve more quickly or set up a scenario where live oysters cannot grow quickly enough to outpace loss of shell. Current studies are investigating the impacts of ocean acidification further on oyster growth, filtration, reproduction and other functions.

The Chesapeake Bay Program is leading the world in large scale oyster restoration in implementing the outcome to restore 10 tributaries by 2025. Underpinning this approach to restore oysters at a tributary scale is the assessment that these larger scale projects will help oysters be more resilient to changes in the environment. It will be important to consider climate impacts on oysters in future restoration siting, design, reef construction, seeding, hatchery production and monitoring.

Temperature Narrative Information:

- Spawning & Recruitment:
  - Northern climates - spawning occurs in the summer only (EOBRT 2007)
  - Southern climates - spawning can occur all year if temperatures remain above 20 degrees celsius (EOBRT 2007)
  - Reductions in recruitment in Chesapeake Bay were due to decreased spawning stock biomass (decreased spawning stock biomass has also contributed to a decrease in oyster reef substrate needed for recruitment) and climate-driven changes in environmental conditions (Kimmel and Newell, 2007).
- Juveniles:
  - Larvae do not tolerate high temperatures and have a narrower salinity tolerance range than adults (Sellers and Stanley, 1984; EOBRT, 2007).
  - Shell growth of juvenile Eastern Oysters is lower under lower aragonite saturation states (Ries et al., 2009) and lower pH (Waldbusser et al., 2011).
- General:
  - Oyster growth and reproductive rates peak in waters ranging in temperature from 20-30°C and they can live in water temperatures of 0-36°C (Shumway 1996; Lenihan 1999).
  - Though temperature sensitivity for oysters is classified as low, other climatic factors closely connected with temperature, such as ocean acidification and freshwater increases, are driving the species' high vulnerability scores (NOAA Climate Vulnerability Assessment). Warming coupled with eutrophication common in many coastal estuaries will likely amplify the conditions that result in bottom water hypoxia, further contributing to subtidal shellfish reef habitat loss.
  - Exposure to warming (and other stressors) may influence oyster tissue and shell growth later in the oyster's life. Responses to current stress can be strongly shaped by previous stress exposure, and may influence the fitness, production, and restoration. (Donelan et al. 2021)
  - Warming air and water can increase the susceptibility of shellfish to disease, parasites and predation by local and invasive species (Smolowitz 2013; Burge et al. 2014).

Likely Distributional Shift/Impact from Climate:

- The effect of climate change on Eastern Oyster on the Northeast U.S. Shelf is very likely to be negative (>95% certainty in expert scores).

<u>Blue Crab</u>

Climate Vulnerability: Very High
Temperature Sensitivity: Moderate

Temperature Narrative Information:

- Spawning & Recruitment:
  - Female blue crabs may mature and mate earlier because of warming temperatures. However small size at maturation increases vulnerability to predation and diminishes the number of offspring produced per brood. (MD Sea Grant EBFM)
- Juvenile:
  - Predation and cannibalism on juveniles is also higher during warm seasons; therefore the juvenile portion of the population might also be negatively impacted by the extended warm temperatures predicted. (MD Sea Grant EBFM)
- General:
  - Blue Crab survival in Chesapeake Bay is higher during mild winters (Rome et al., 2005; Bauer and Miller, 2010), meaning warmer winters should lead to higher survival and population productivity.
  - Blue Crab also are moving into the Gulf of Maine and this has been linked to increasing temperatures (Johnson, 2014).

Likely Distributional Shift/Impact from Climate:

- The effect of climate change on Blue Crab on the Northeast U.S. Shelf is estimated to be neutral, but with a moderate degree of uncertainty (66-90% certainty in expert scores).
- Warming may lead to increased productivity and northward shifts in the region, both of which would represent positive effects of climate change, but more research is needed to confirm these effects.

<u>Striped Bass</u>

Climate Vulnerability: Very High
Temperature Sensitivity: Low/Moderate

Temperature Narrative Information:

- Spawning & Recruitment:
  - Temperature induced overwinter mortality of juveniles is important for recruitment in northern portions of striped bass range. (Hurst and Conover, 1998)
  - Survival of striped bass larvae is highest at temperatures of 18 degrees celsius. (Secour and Houde, 1995). Continued Bay warming will likely result in a fast transition of spring to summer, reducing optimal temperature time for larval survival (MD Sea Grant EBFM).
- General:

- Increasing summer temperatures resulted in a reduction of Chesapeake Bay striped bass habitat. (Coutant and Benson 1990)
- Winter warming could also promote year-round residency, and reduce overwinter juvenile mortality leading to increased pressure on the forage species targeted by striped bass. (MD Sea Grant EBFM)
- Earlier migrations, during warmer springs, can increase chances of spawning/recruitment prior to set catch seasons hence lowering fish mortality prior to reproduction. (Peer and Miller 2014)
- As found by Coutant and Cox, striped bass' thermal niches in mature specimens are most optimal between 24 and 26 degrees (Uphoff, 2011)
- Striped bass detections indicated tolerance of a wide range of surface water temperatures, including those >25°C, which regional regulatory bodies stipulate are stressful for this species. Still, during summer and fall striped bass selected the lowest-available temperature and avoided water temperature >27°C, demonstrating that Chesapeake Bay striped bass can encounter habitat compressions due to the behavioural avoidance of bottom hypoxia and high temperatures. (Itakura et al. 2021)

Likely Distributional Shift/Impact from Climate:

- The effect of climate change on Striped Bass on the Northeast U.S. Shelf is estimated to be neutral, but with a moderate degree of uncertainty (66-90% certainty in expert scores). The uncertainty likely stems from the complex life history and the potential for different aspects of climate change to affect the species differently.
- Increasing temperatures could reduce habitat in the southern part of the Northeast U.S. Shelf while increasing habitat in the northern portions.

Summer Flounder

Climate Vulnerability: Moderate
Temperature Sensitivity: Low

Temperature Information Narrative:

- Summer Flounder productivity may change with the changing climate. Recent changes in Summer Flounder distribution also have been identified and linked to climate (Pinsky et al 2013)
- Other evidence suggests that changes in Summer Flounder distribution are linked to reductions in fishing and expanding population rather than changes in temperature. (Bell et al, 2014; Murawski, 1993)

Likely Distributional Shift/Impact from Climate:

- The effect of climate change on Summer Flounder on the Northeast U.S. Shelf is estimated to be neutral but with high uncertainty (<66% certainty in expert scores).
- Adult distribution has shifted northward, but this is linked to changes in fishing.
- Also, productivity of the stock has remained fairly constant over the past 3 decades, during which temperatures in the ecosystem have increased.

<u>Forage (Anchovy, Menhaden, Polychaetes)</u>

Climate Vulnerability: Low to Moderate
Temperature Sensitivity: Low

Temperature Information Narrative:

- There have been surprisingly few studies of the effect of climate change on Anchoa spp., especially in the Northeast U.S. Shelf ecosystem.
    - A bioenergetics model was developed for anchovies in the Chesapeake Bay; work indicated that bay anchovy consumption of zooplankton will increase with warming waters. (Lou and Brandt, 1993)
    - A Black Sea ecosystem bioenergetics model was also developed, indicating population productivity of anchovies would increase as temperature increases. (Güraslan et al., 2014)
- The rate of springtime warming, i.e. how quickly water temperatures rise in the spring, is a primary driver of forage fish abundance. Faster (earlier) springtime warming leads to decreased abundance of forage fishes. (Woodland et. al, 2021)

Likely Distributional Shift/Impact from Climate:

- The effect of climate change on anchovies on the Northeast U.S. Shelf is very likely to be positive (>95% certainty in expert scores). As warming continues more habitat in the Northeast U.S. is expected to become available.
- Based on research in other regions, population productivity is also likely to increase with continued warming.
- The effect of climate change on Atlantic Menhaden on the Northeast U.S. Shelf is very likely to be positive (90-95% certainty in expert scores). Recruitment will likely increase as temperature warm and more spawning occurs in the region. Adult distribution will likely extend northwards and the species may re-occupy the Gulf of Maine during summertime.

<u>Shifting species distributions</u>

- There is evidence that climate drivers including temperature are allowing range expansion for cobia, brown shrimp, and red drum. The impacts of southern species moving into the Bay are not fully understood. However, the increased abundance of brown shrimp has led to a new fishery in the Bay and some scientists have pointed to red drum increasing predation pressure on species such as blue crab.

Invasive Species

- There were no vulnerability assessments conducted specific to invasive species in the Chesapeake Bay. Here we classify invasive species as those introduced to non-native habitats from factors other than northward climate-driven distribution shifts. A number of key invasive generalists (ie. Blue Catfish) are increasing in abundance, impacting trophic interactions, and driving attention to management response. Typically, these generalists are classified as climate change "winners" with less restrictive temperature/salinity ranges than many native bay specialists. More on invasive catfish is available in the 2017 Invasive Catfish Symposium Workshop Summary.
- The Northeast habitat climate vulnerability assessment included invasive wetlands, which were determined to be moderately vulnerable to climate change. Invasive wetlands were the only habitats in the assessment expected to be positively impacted by climate change, given their high adaptation to disturbance and the likelihood that invasive wetland plants will outcompete native salt marsh species.

Vulnerable Habitats Important to Representative Bay Species

Changing temperature impacts these species in both direct and indirect ways. Importantly, eastern oyster, blue crab, striped bass, and forage species all rely on nearshore habitats that are highly or very highly vulnerable to climate change. The impact of rising temperatures on these habitats will therefore have implications for the species that depend on those habitats. The table below details the habitat dependence of each of these species by life stage on a few key estuarine habitats: salt marsh, SAV, and shellfish reef. The impacts of rising temperature on water column habitat is described in the text below, but not included in the table, since each of the representative species depends on the water column throughout its life cycle. The importance of each habitat by life stage comes from a habitat-species matrix developed by the Atlantic Coastal Fish Habitat Partnership (ACFHP). The habitat climate vulnerability rankings come from Farr et al. 2021, and the species vulnerability rankings from Hare et al. 2016.

Habitat Name	Species	Importance of habitat by life stage (ACFHP)			
		Eggs/Larva	**Juvenile/YOY**	**Adult**	**Spawning Adult**
Estuarine emergent wetland	Striped bass		Moderate	Moderate	
	Blue crab		High	High	
	Summer flounder		High	Moderate	
	Winter flounder	High	Moderate		High

Estuarine submerged aquatic vegetation	Striped bass		Moderate	Moderate	
	Black sea bass		High		
	Blue crab	Very high	Very high		
	Summer flounder		High	Moderate	
Estuarine shellfish reef	Black sea bass		High	High	
	Blue crab	Moderate	Moderate	Moderate	
	Summer flounder		Moderate		
	Menhaden			Low	
Legend		*Very High Vulnerability*	*High Vulnerability*	*Moderate Vulnerability*	*Low Vulnerability*

Climate Vulnerability and Impacts of Rising Temperature on Key Habitats

Estuarine Emergent Wetland:

Very highly vulnerable to climate change

- Most salt marsh flora are eurythermal. Rising temperatures may lead to changes in plant physiological processes including an increase in photosynthetic rates and plant biomass (Charles and Dukes 2009; Gedan and Bertness 2010; Kirwan and Mudd 2012).
- Temperature can have indirect effects on salt marshes by influencing production of soil organic matter, rates of evaporation and decomposition, and salt marsh community composition (Najjar et al. 2000; Charles and Dukes 2009; Gedan and Bertness 2009; Gedan and Bertness 2010; Carey et al. 2017). Salt marshes are also sensitive to changes in the marsh platform, as rising temperatures can cause an increase in decay rate of organic matter. This may offset the enhanced productivity and soil carbon accumulation associated with increased temperatures (Kirwan and Blum 2011).
- The precise responses of coastal wetlands to increased warming are difficult to predict given the complexity of interactions among biological and environmental factors (Cahoon et al. 2009). For example, Kirwan et al. (2009) reported an increase in productivity of smooth cordgrass throughout its range in North America by about 50-100 g per m^2 per year under a projected warming of 2-4°C. For the Mid-Atlantic and New England regions, this would represent a 10-40% increase in productivity for smooth cordgrass, which approximates the projected marsh losses due to sea level rise.

Estuarine Submerged Aquatic Vegetation:

Highly vulnerable to climate change

- Increases in water temperature may impact the normal timing of flowering and seed production in both eelgrass and widgeon grass (Short and Neckles 1999). Increases in water temperature as small as 1°C have been shown to advance flower formation in eelgrass by 12 days and seedling maturation by 10.8 days (Blok et al. 2018). It is not clear what changes in the timing of the normal reproductive cycle may mean for the long term survival of individual meadows.

- Increased water temperatures may lead to a reduction in the distribution and productivity of eelgrass over its existing range (Moore et al. 1996; Short and Neckles 1999). Widgeon grass is unlikely to be negatively affected by increasing water temperature along the Atlantic coast due to its higher temperature tolerance (Kantrud 1991). As water temperatures increase, widgeon grass distribution is likely to increase in the study area, replacing eelgrass meadows in the southern portion of eelgrass' current distribution (Moore et al. 2014). For most of its range, eelgrass actively grows from spring through fall. At the southern edge of its range, eelgrass grows from fall through spring, disappearing in the summer (Thayer et al. 1984; Short and Neckles 1999). As sea surface temperature increases, it is likely this adaptation in the growing season will move northward (Short and Neckles 1999).
- Increased water temperature may also lead to greater survival and distribution of invasive species that negatively impact eelgrass (Neckles 2015; Carman et al 2019; Young and Elliot 2020). Warmer winter temperatures have led to greater green crab overwinter survival (Young and Elliott 2020), which have been shown to cause the decline of hundreds of acres of eelgrass in Maine and Canada (Neckles 2015). Invasive tunicates also have the potential to lead to eelgrass shoot mortality (Wong and Vercaemer 2012). Latitudinal changes in invasive tunicates distribution on eelgrass have been documented, and changing water temperature is likely contributing to this shift (Carman et al. 2016; Carman et al. 2019).
- Meadows with higher genetic diversity have proven more resilient to extended heat waves (Dubois et al. 2019).

<u>Estuarine Shellfish Reef</u>

Very highly vulnerable to climate change
See above section on Eastern Oyster climate vulnerability

<u>Estuarine Water Column</u>

Highly vulnerable to climate change

- Water temperature in estuaries is largely influenced by heat exchange with the atmosphere and freshwater input, the temperature of which is also influenced by heat exchange with the atmosphere (Hare et al. 2010). The temperature of the region's estuaries have warmed over the past several decades (Bell et al. 2014).
- Stratification in estuaries is unlikely to change much because of wind and tidal mixing. However, stratification could increase as a result of increased freshwater inflows and increased air temperatures (Najjar et al. 2010). Changes in stratification could have consequences for oxygen-levels; hypoxia does occur in estuarine systems throughout the Northeast largely as a result of summertime thermal stratification and increased primary production (Nixon et al. 2009)

<u>Science Gaps:</u>

- There is a need for downscaled climate models with better resolution in the nearshore and coastal environments for projected temperature and other factors.
- Both the species and habitat climate vulnerability assessments described here were conducted at a regional scale. Climate change often impacts species and habitats at much smaller scales, with variability between estuaries, watersheds, or basins. Finer-scale assessments of climate vulnerability may be something to work towards.
- Spatial information on the distribution of habitats is fairly limited for several habitat types, highlighting a need for better data.

E. **Evaluation**

Key Findings

- Species-specific vulnerability reports highlight differential impacts of rising water temperatures and other climate change impacts in Chesapeake Bay.
    - Blue crab, menhaden, bay anchovy are likely to experience positive impacts as increasing temperatures expand habitat range and productivity.
    - Oysters are likely to experience negative impacts due largely to climate change factors other than temperature.
    - Striped bass and Summer flounder may experience both negative and positive impacts at different life stages (larval to adult). Localized impacts on spawning timing and/or nursery habitats caused by temperature could drive changes in populations at a coast wide scale. There is uncertainty about the overall trajectory of impact.
- Northward shifts in species range are being documented for several species. This is resulting in some Bay species shifting populations north while other species from the south are becoming more prevalent in the Bay. These range shifts can result in changes to species abundance and distributions, food web dynamics, fishing behavior and new fisheries. Likewise habitats required by fish and shellfish species are shifting in range and experiencing impacts that lead to changes in fish abundance, distribution and reproduction success.
- Better information on and integration of species and habitat specific impacts within the Chesapeake Bay are needed to track changes and inform management strategies.

Management Implications

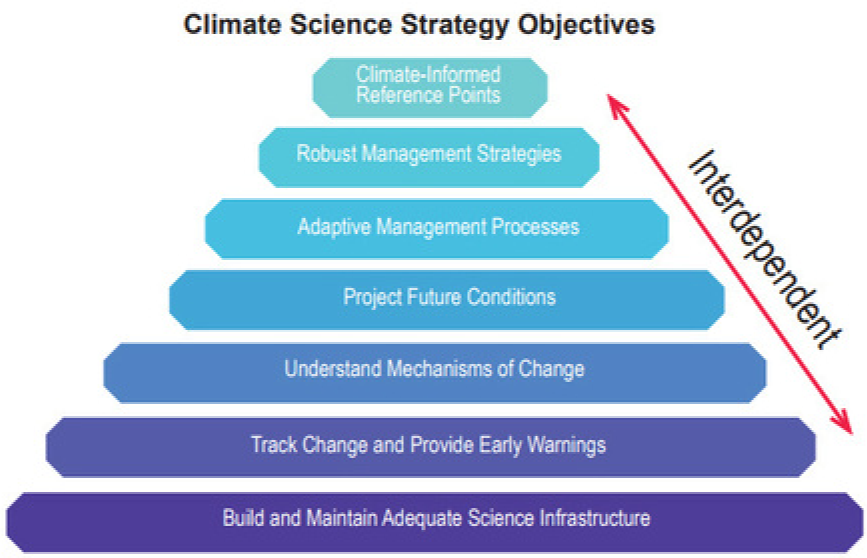
- Mitigation of rising water temperatures is not a likely option. Therefore fishery management approaches will require better information on species and habitat impacts to help incorporate climate change into existing management structures. The ongoing shift to ecosystem based fishery management is laying the groundwork for this type of information to be utilized in a management context. It is important to note that some species such as blue crabs and oysters are managed by Bay jurisdictions, some such as Striped bass, Summer flounder and Menhaden are managed by regional bodies and some such as bay anchovy are not managed at all. This suggests different approaches

and decision makers will need to be considered in evaluating any new climate change management scenarios.
- Oyster reefs are a key habitat type that could be significantly impacted by climate change. Future restoration will likely need to consider climate impacts on oyster project siting, design, reef construction, seeding, hatchery production and monitoring.
- Warming winter temperatures may impact the methods by which blue crab populations are assessed and the current management framework.
- Species range shifts will require management frameworks as new fisheries emerge and existing fisheries are modified.

Next steps

Climate impacts on fisheries threaten fishing communities, the economy, and require new science based approaches to managing fishery resources. The NOAA Fisheries Climate Science Strategy is part of a proactive approach to increase the production, delivery, and use of climate-related information needed to support management. The Strategy identifies seven objectives which will provide decision-makers with the information they need to reduce impacts and increase resilience with changing climate and ocean conditions.

Figure II-3: Climate Strategy Objectives from NOAA Fisheries Climate Science Strategy



- The Strategy responds to growing demands for information and tools to prepare for and respond to climate impacts on marine and coastal resources. It is being implemented through **Regional Action Plans** that focus on building regional capacity, partners, products and services to address the seven objectives.
- The NOAA Chesapeake Bay Office has prioritized impacts of changing environmental conditions including climate change in recent research funding opportunities. NCBO is collaborating with scientists funded through those opportunities to develop habitat suitability models and indicators that link temperature and other climate factors to impacts on striped bass, summer flounder and forage fish. The results of these studies can help inform Bay Program and regional fishery management decisions.
- NOAA publishes an annual State of the Ecosystem Report for the Mid Atlantic. This report includes a section on habitat risks, climate and species implications. The report is used by the Mid Atlantic Fishery Management Council to update their Ecosystem Approach to Fisheries Management Risk Assessment. This is an example of how climate information can be synthesized for use by managers.

The Fisheries GIT, NOAA, USGS and others are sponsoring critical research on the impacts of changing environmental conditions of fishery resources and habitats. The Fish GIT will track findings from this emerging science and convene partners to discuss applications of this work for indicator development and management. Some of the projects under way or recently completed include:

- Seasonal summaries tracking changes in temperature and salinity using NOAA observations with a narrative on likely impacts to blue crab, striped bass, oysters, summer flounder, forage and their habitat.
- Estuarine Habitat Condition Index for Summer flounder (Gartland, VIMS)
- Forage Habitat Suitability Models (Mary Fabrizio, VIMS)
  - Suitable habitat for anchovy was classified as bottom average of 23.7-27 degrees celsius
  - Increased temperature is expected to increase suitability for anchovy (and other high tolerance forage) but it's unclear the interaction with other climate change factors like lowered salinity
- Suitability of Striped Bass Nursery Habitat (Rachel Dixon, VIMS)
- Leveraging multi-species and multi-year telemetry datasets to identify seasonal, ontogenetic, and interannual shifts in habitat use and phenology of Chesapeake Bay fishes (Furey, UNH; Ogburn, SERC)
- Striped bass and summer flounder abundance trends and influencing factors in the Chesapeake Bay: an ecosystem-based evaluation (Jiao, VT)
- SST Heat Wave Forecasts for the Chesapeake Bay (Andrew Ross NOAA)

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