Climate-Change Effects on Fishes of Chesapeake Bay

Observations and Anticipated Responses

Mary C Fabrizio

Troy D Tuckey

VIMS | William & Mary

Virginia Institute of Marine Science

Climate Change

- Disrupt behaviors, habitat use, migrations, & reproduction in fishes
- Lead to cascading effects on food web
- Jeopardize the functional integrity of the Chesapeake Bay

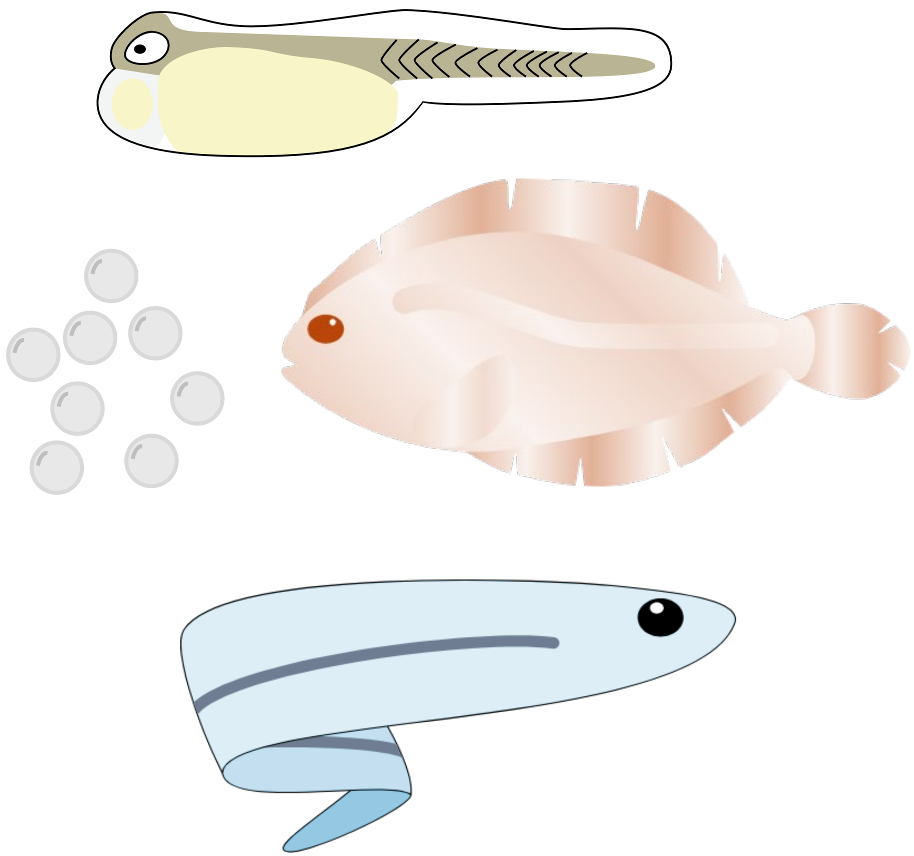
Image: Pew Charitable Trust

Climate-Change Impacts on Fishes of Chesapeake Bay

Depend on species

Depend on life stage

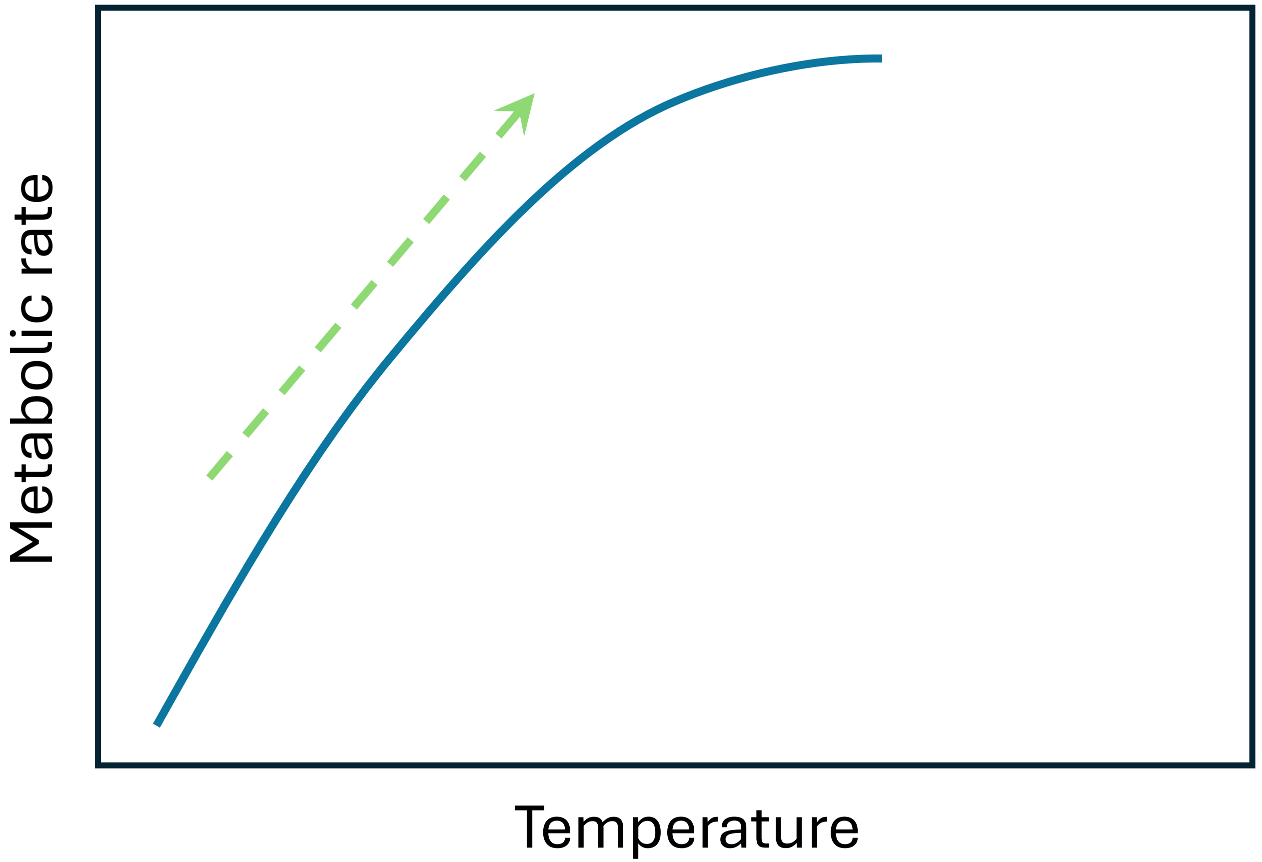
Some life stages occur in marine environments



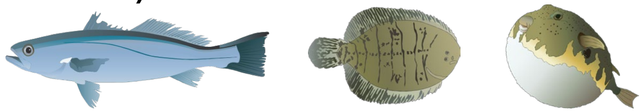
Images: Integration and Application Network (ian.umces.edu/media-library)

Physiological Changes due to Warming

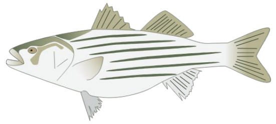
Greater energy demand



- Greater consumption rate
- In absence of other stressors → increased growth
- If prey is limiting
  - decreased growth, decreased body condition of fishes (Latour et al. 2017)



  - greater prevalence and severity of disease (Jesse et al. 2021)



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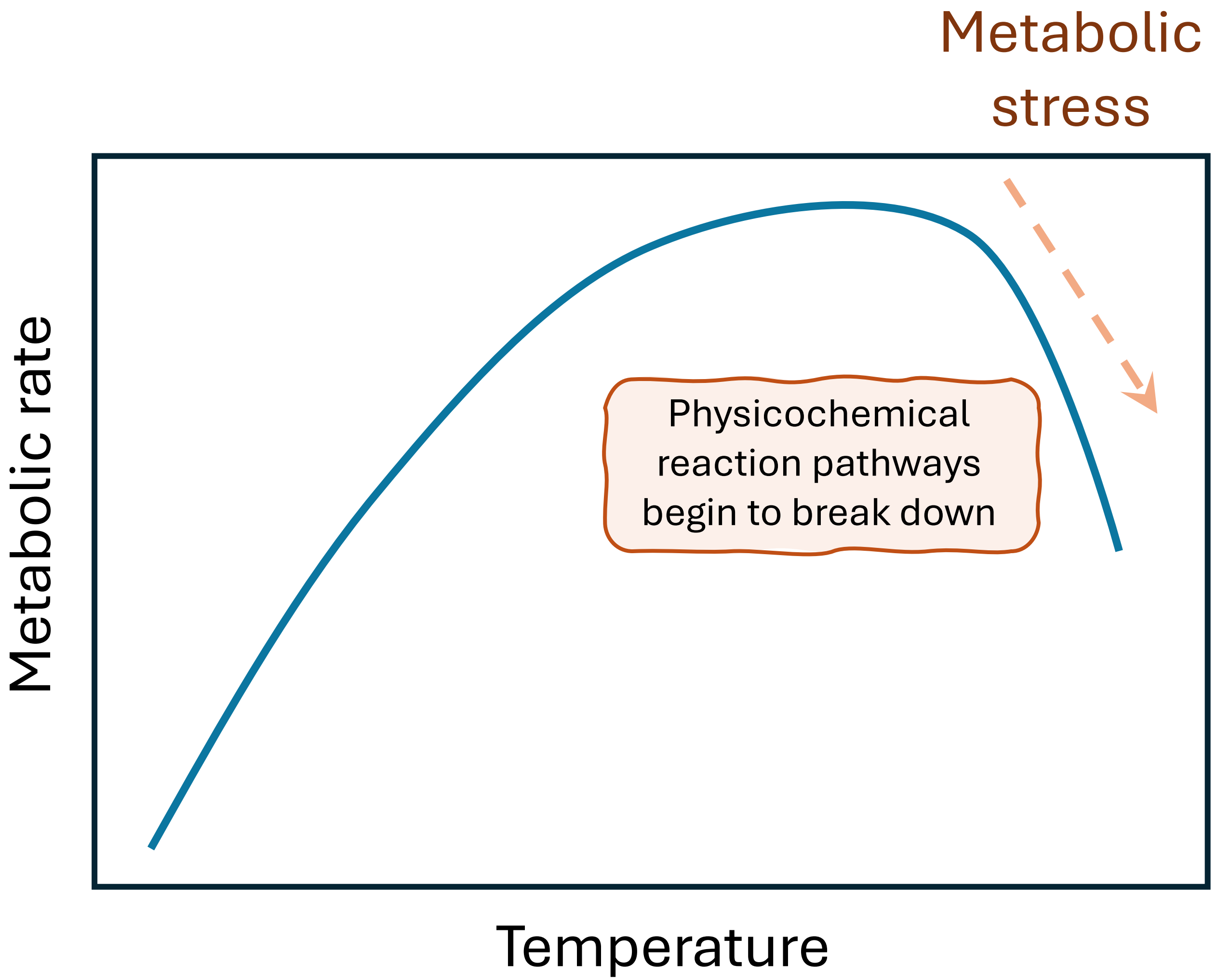
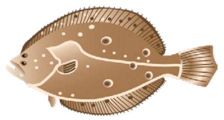
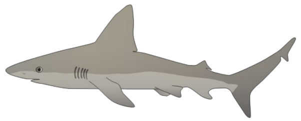
Physiological Changes due to Warming



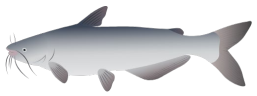
- At 26 °C summer flounder exhibit reduced growth (Nys et al. 2016)



- At 32 °C swimming declines in juvenile sandbar shark (Crear et al. 2019)



- At 32 °C blue catfish become emaciated (Nepal et al. 2024)



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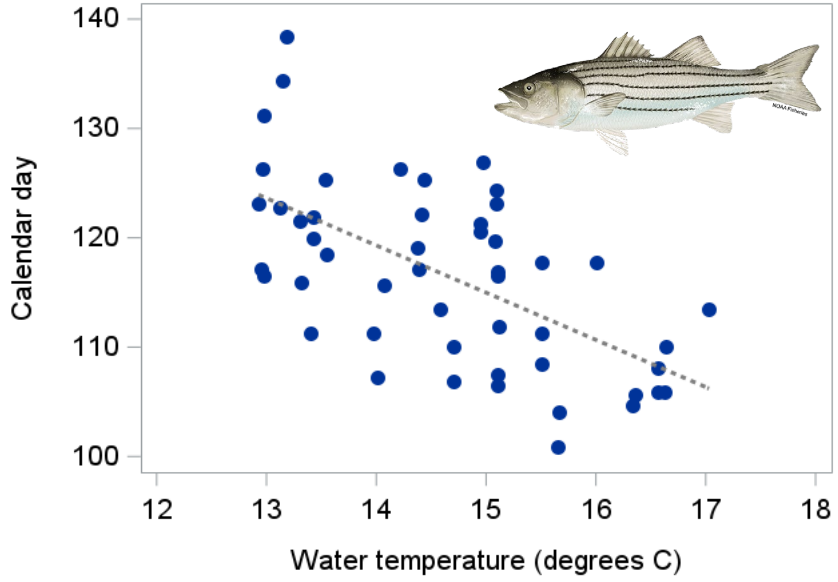
Rising Temperatures Shift Phenologies

- Spawning migration and spawning season
  - Shifted to earlier in the year (Peer & Miller 2014)
  - No change in duration because spawning cessation occurs earlier (Giuliano 2023)
  - With a 5 °C increase → spawning may occur 15 days earlier (Peer & Miller 2014)
  - As spring warming accelerates, the spawning season may shorten with potentially negative consequences for recruitment
- Spawning phenology of some fishes changes faster than the rate of change of phytoplankton blooms
  - Mismatch between first-feeding larvae & prey (Asch et al. 2019)

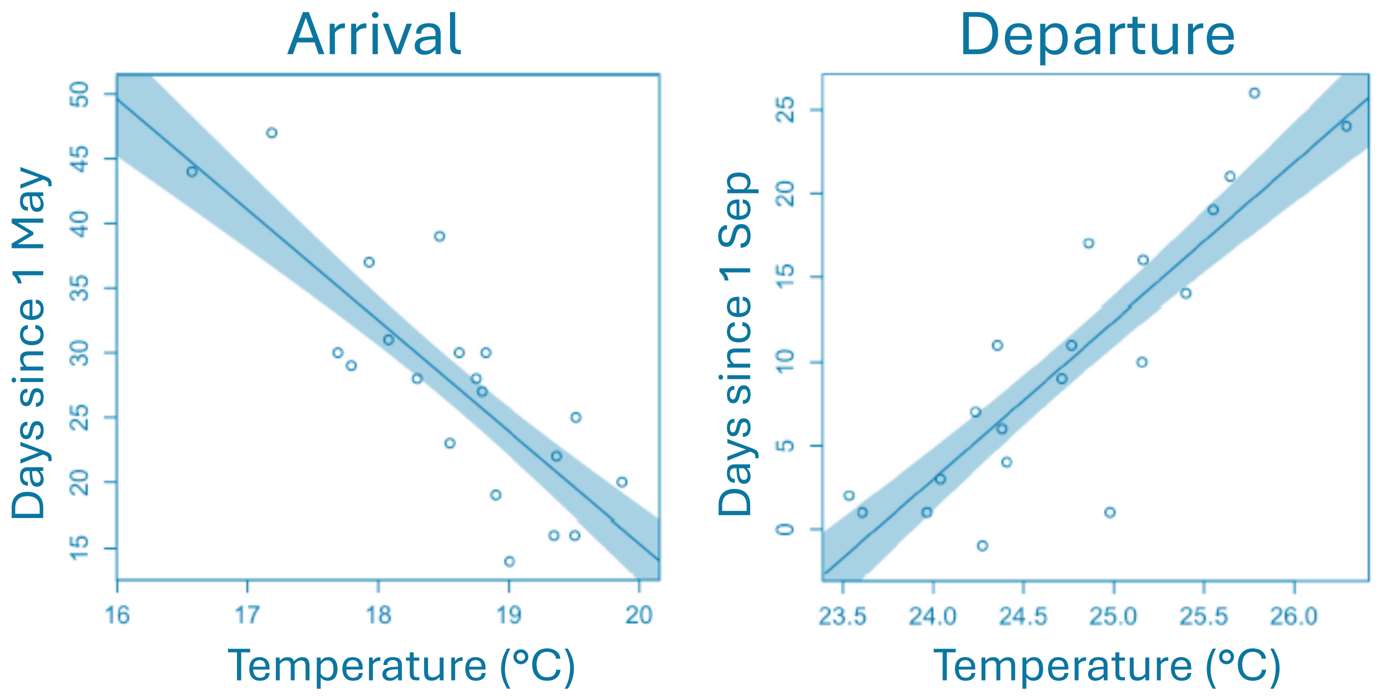
Arrive on spawning ground 3 days earlier for every 1 °C increase



Data replotted from Peer & Miller (2014)

Projected Shifts in Phenology: Cobia

- Earlier spring immigration and later emigration in fall
- 2 °C increase → 30 day longer residency
- 5 °C increase → 65 day longer residency
- Longer duration of predation pressure on blue crabs, shrimp, small fishes
- Higher post-release mortality



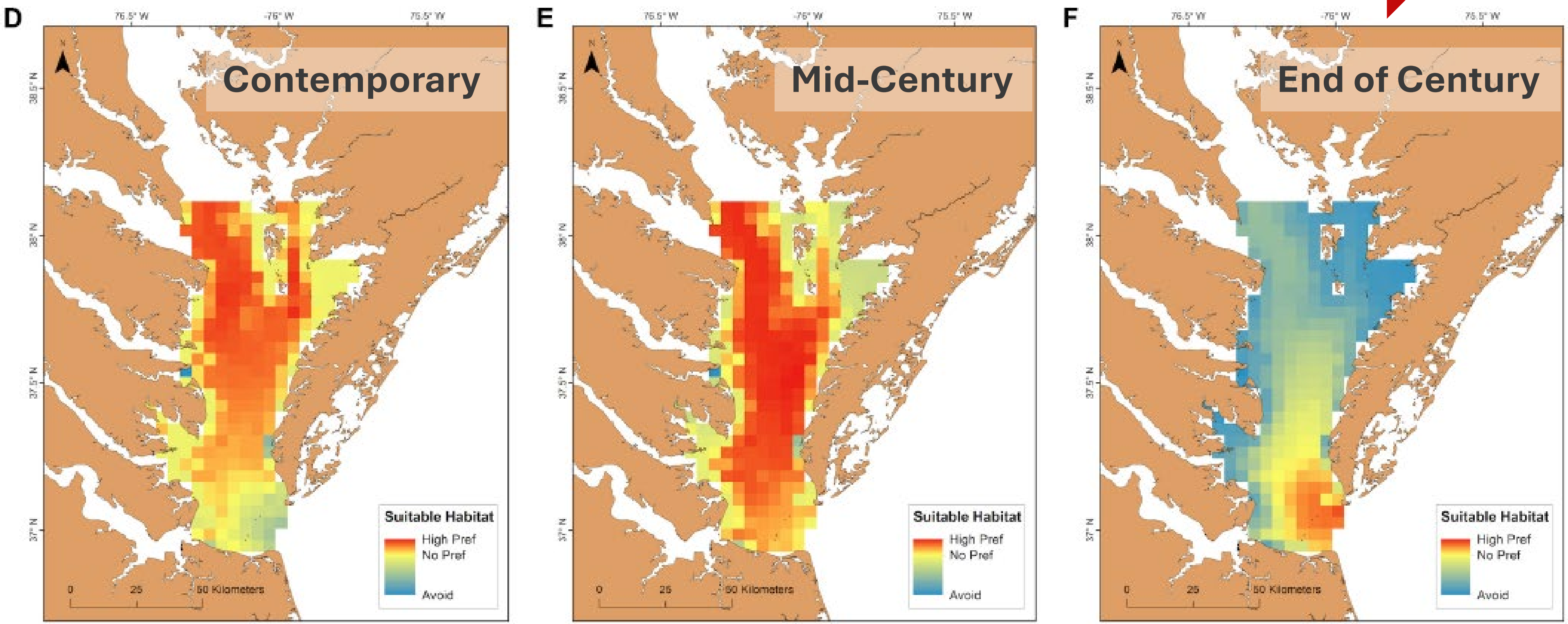
Images: Crear et al. 2020

Projected Shifts in Habitat Use: Cobia

5 °C increase in water temperature

May – Sep Habitat Suitability for Cobia

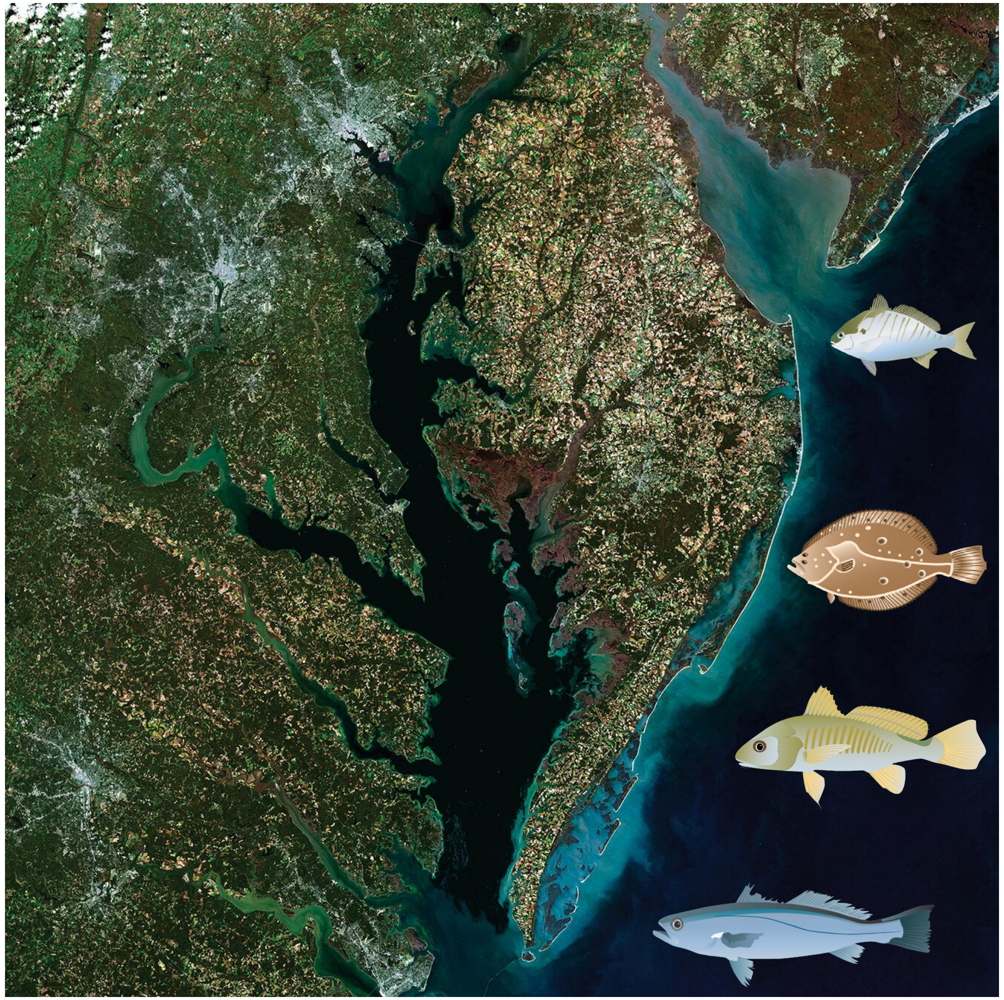
(Crear et al. 2020)



Cobia can use offshore coastal areas for spawning, where salinity is suitable for eggs & larvae (Ditty and Shaw 1992)

Images: Crear et al. 2020

Warming Reduces Use of Chesapeake Bay Habitats



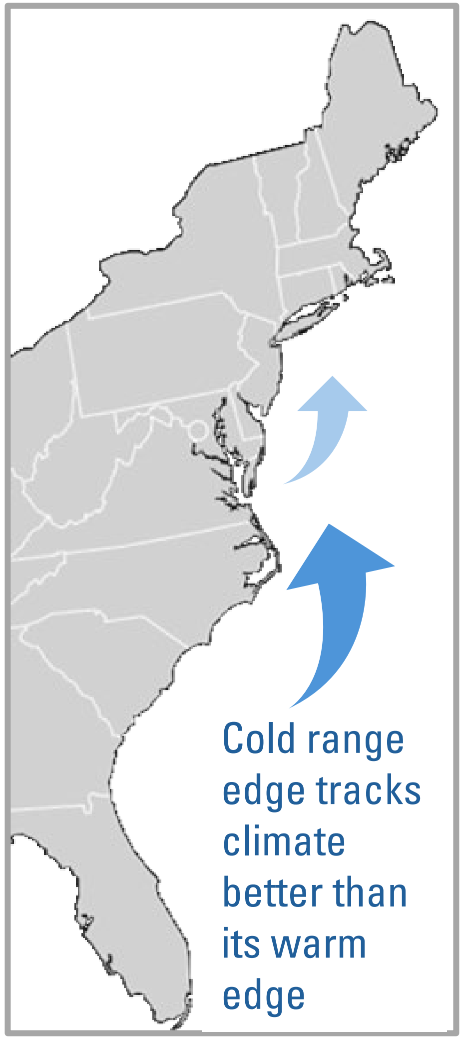
- Seasonal migrants: Atlantic croaker, spot, summer flounder, windowpane flounder, weakfish, and clearnose skate
- More likely to use coastal ocean habitats or habitats in northerly estuaries, such as Delaware Bay (Schonfeld et al. 2022)

Images: ian.umces.edu/media-library

Rising Temperatures Promote Range Expansion of Species at Cool Edge of Their Range

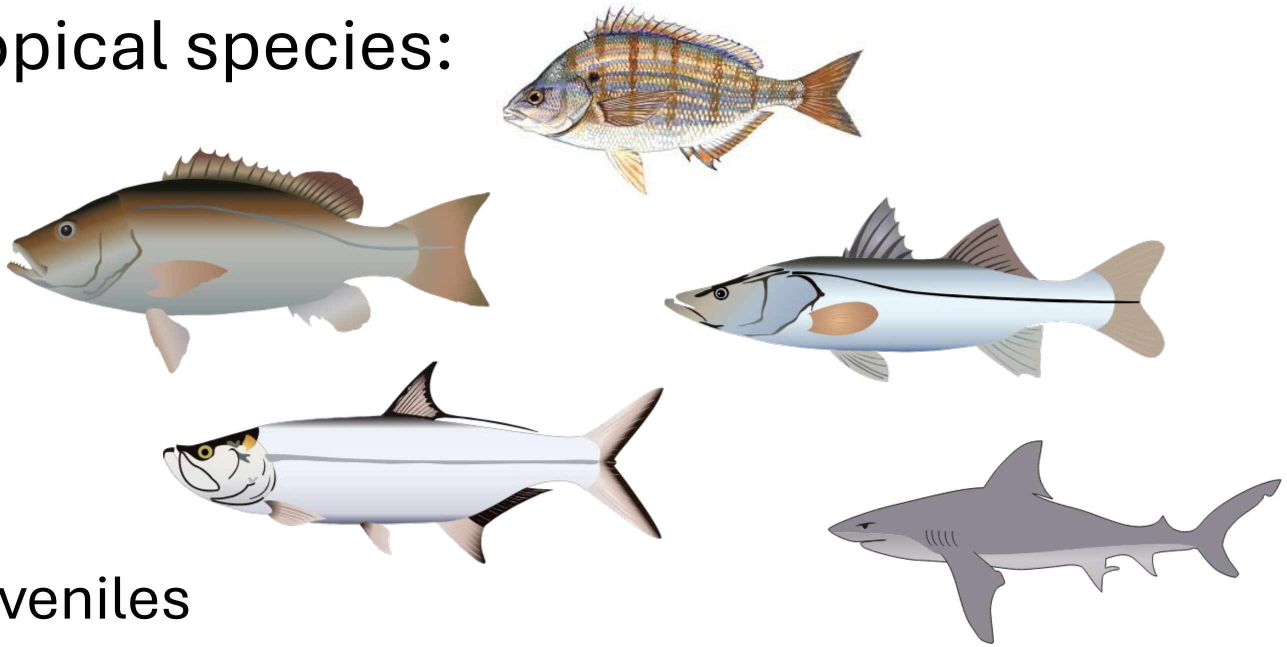
- Carolinean Province species:
  - Southern flounder (Lusk et al. 2014)
  - Red drum (Buchheister et al. 2013)
  - Spotted sea trout (Buchheister et al. 2013; Smith et al. 2008)
  - Atlantic spadefish (Schaffler et al. 2013; Sobocinski & Latour 2015)
  - Penaeid shrimp (Tuckey et al. 2021)
- Cold winters limit year-round occupancy for spotted seatrout
  - winter mortality ~5 °C (Ellis et al. 2017; Song et al. 2019)

Fredston-Hermann et al. 2020;
Rubenstein et al. 2023



Warming May Lead to Tropicalization of the Bay

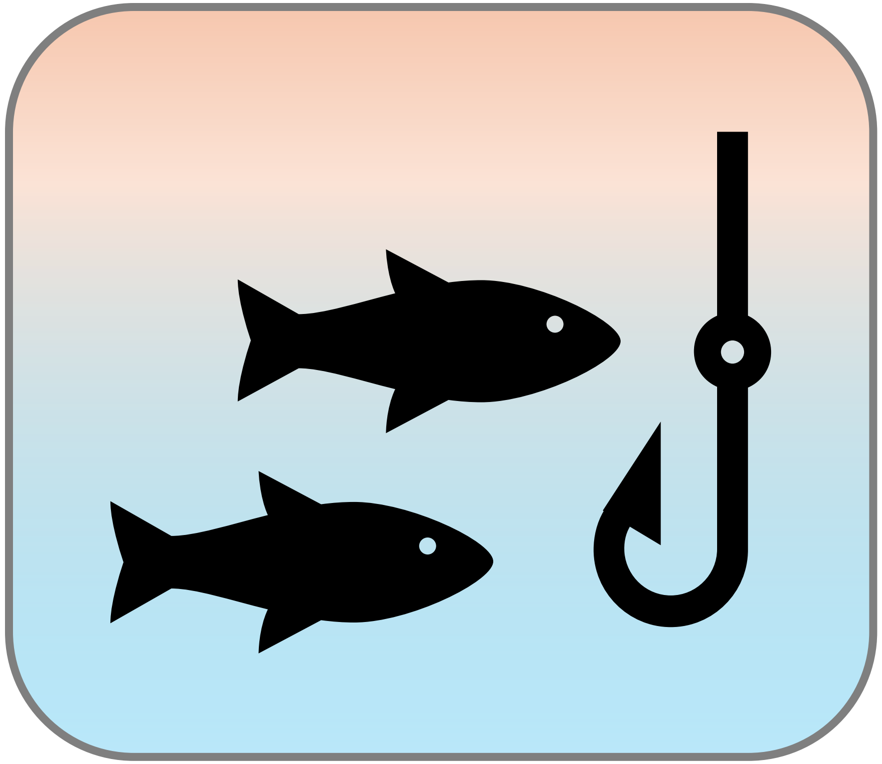
- Increased abundance of subtropical species:
  - Pinfish (Lefcheck et al. 2024)
  - Gray snapper
  - Common snook
  - Atlantic tarpon
  - Bull shark



- Tropicalization depends on
  - Lethal winter temperatures for juveniles
  - Adults can leave the Bay in fall (e.g., gray snapper)
  - Juvenile snook lethal temperature =10 °C (Osland et al. 2016)
  - Under RCP 8.5, 10 °C threshold will be exceeded in upper tributaries, which can be used by juvenile snook as a nursery

Images: ian.umces.edu/media-library

Warming Interacts with Other Stressors

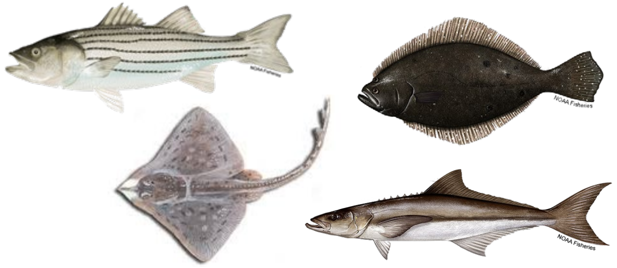


- Catch-and-release fishing
- Minimum length restrictions and slot limits result in regulatory releases of undersized or oversized fish
- Hooking and handling are physiologically stressful & released fish can experience significant **post-release mortality**
    - bluefish (Fabrizio et al. 2008)
    - striped bass (Dinkelacker et al. 2025)

It’s Not Just Temperature . . . . [DO]

- Hypoxia projected to increase in frequency, extent, and severity

- Some fishes are relatively tolerant of hypoxic conditions (~2 mg L^{-1} , < 30 °C)
  - striped bass (Lapointe et al. 2014)
  - summer flounder (Capossela et al. 2012; Schwieterman et al. 2019)
  - clearnose skate (Schwieterman et al. 2019)
  - Atlantic cobia (Crear et al. 2020)



- Multiplicative effects of low [DO] & high temperature (>30 °C) are likely (Lapointe et al. 2014; Schwieterman et al. 2019)

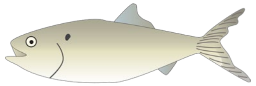
- Hypoxia is an endocrine disruptor (Thomas & Rahman 2007; Wu et al. 2003)
  - May affect fishes that undergo maturation and oogenesis in the Bay
    - Atlantic croaker (Tuckey & Fabrizio 2016)
    - Summer flounder (Nys et al. 2016)
    - Spot

It’s Not Just Summer . . . .

Increase in mean surface and bottom water temperatures is projected to be similar across seasons (+1.5 to 2.3 °C by midcentury under RCP 8.5 scenario)

Positive Effects of Warming in Winter

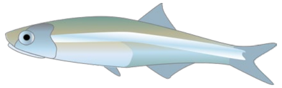
Atlantic menhaden



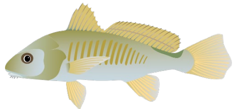
- Enter Bay in late fall/early winter
- Improved conditions for larval growth & survival (Atkinson & Secor 2017)

Bay anchovy

- Abundance is positively related to extent of suitable winter habitats
- Warmer winters support greater abundance (Fabrizio et al. 2021)



Juvenile Atlantic croaker

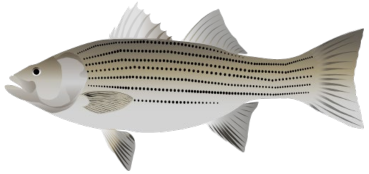


- Survival of juvenile croaker increases during warmer winters (Lankford & Targett 2001)

Negative Effects of Warming in Winter

Striped bass

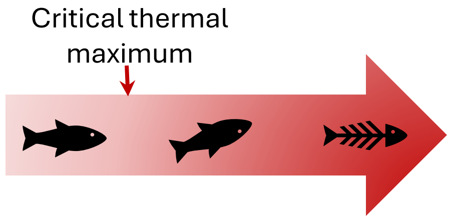
- Larval survival decreases during warm winters and with low freshwater discharge rates in spring due to mis-match with prey (Millette et al. 2019)
- Gametogenesis requires cool conditions in fall and winter (Clark et al. 2005)
- Wintering areas off NC/VA shifted north (MD/DE/NJ) and deeper; fish may require more energy for migration to spawning habitats in Chesapeake Bay, potentially reducing reproductive output



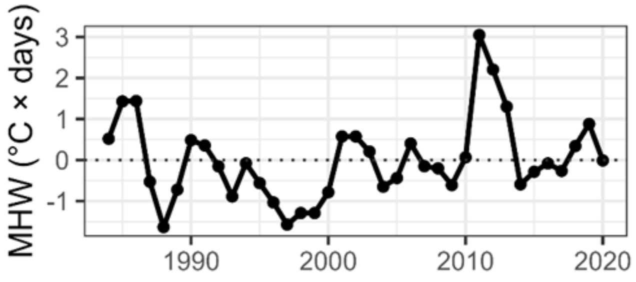
Images: ian.umces.edu/media-library

Outstanding Questions

- Not all species will track climate (Mills et al. 2024; Le Luherne et al. 2024)
  - Non-trackers: American shad, alewife, spotted hake, summer flounder, winter flounder, windowpane flounder (Mills et al. 2024)
  - Need to understand climate vulnerabilities, esp. for juveniles
- Adaptations such as changes in growth, reproduction, and ultimate body size (Lefevre et al. 2021), have not yet been studied for Chesapeake Bay fishes
- Predicting climate change effects requires knowledge about lethal thermal conditions – few studies on this

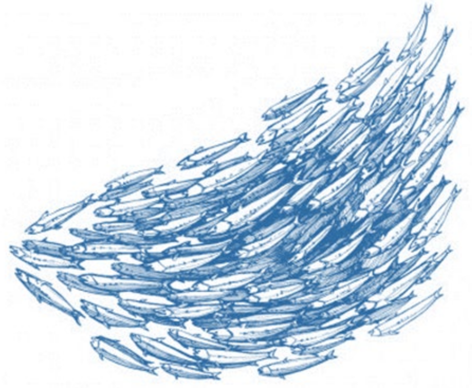


- Marine heat waves – long-term synoptic surveys are critical (Dixon et al. *in review*)



Implications for Management

- Continue to reduce nutrient loadings to address hypoxia
- Maintain robust prey resources
  - Warming → increased consumption by predators
  - New species in the Bay may contribute to increased competition among predators
- Reconsider spawner-recruit relationships or otherwise adjust expected production
- Consider managing sport fisheries using temperature-dependent advisories
- Consider potential to develop new fisheries
- Strive to reduce non-climate stressors in shallow, warm-water habitats (e.g., passive gear, construction)
- Revisit time-of-year restrictions for anadromous and other fishes



Thank you!

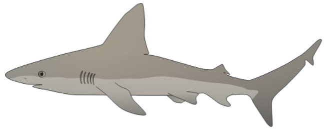
Image: S. Retzbach

Other Projected Impacts

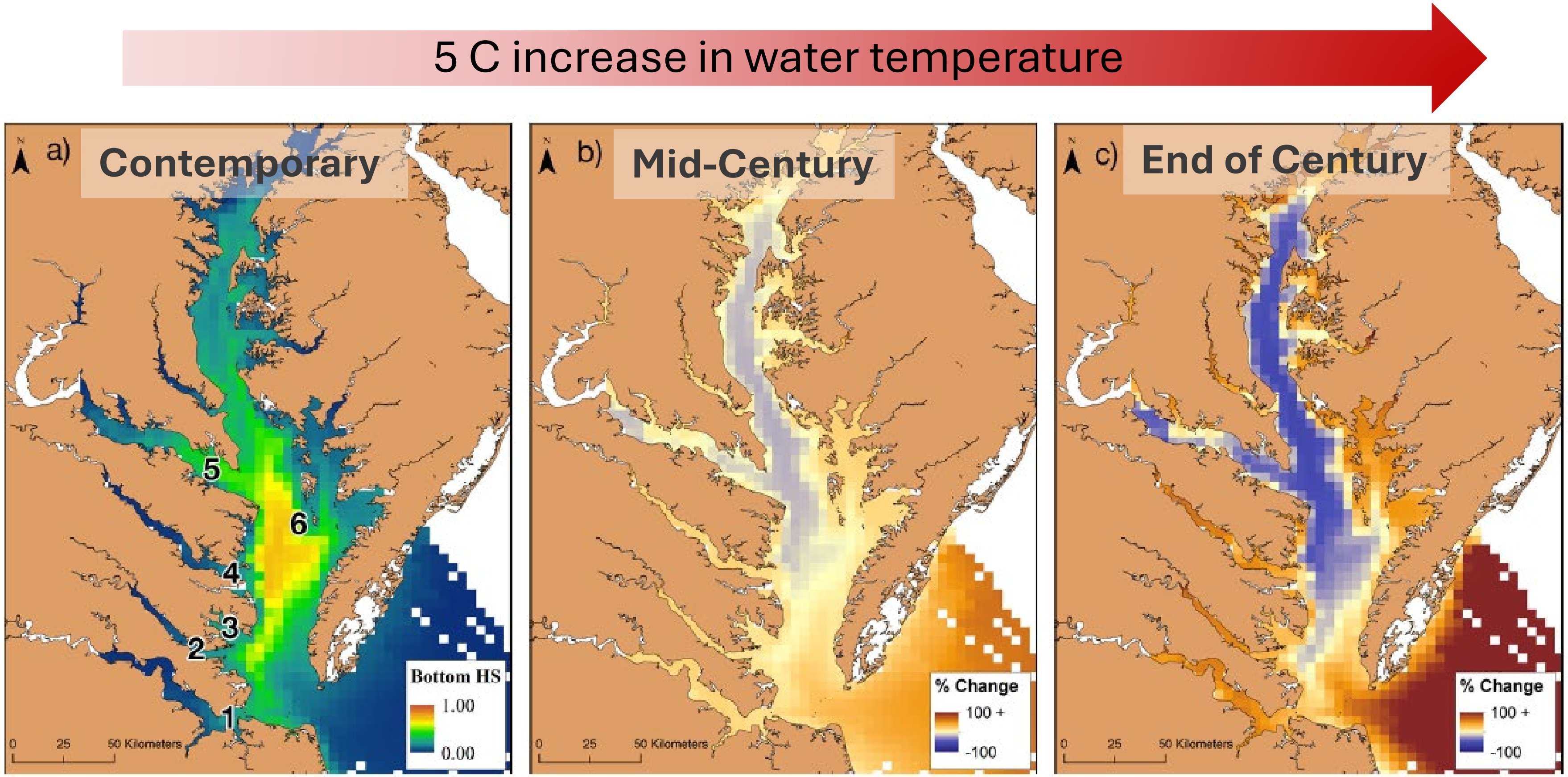
- Masculinization of species that exhibit environmental sex determination
  - Elevated temperatures in nursery habitats → primarily male fish
  - Atlantic silverside (Conover & Kynard 1981)
  - Paralichthyid flounders (southern flounder, Honeycutt et al. 2019)
  - Potential outcome: highly skewed sex ratios, decreased population productivity (Anderson et al. 2024)
- Invasive species
  - Range expansion of Indo-Pacific lionfish – may use wind-development projects as ‘stepping stones’
  - Juvenile blue catfish will experience increase growth rates (Nepal & Fabrizio 2020)
    - Average conditions by end of century under RCP 4.5 may reach or exceed 9 C, allowing blue catfish to grow year-round
    - Year-round growth = year-round consumption of blue crabs (Fabrizio et al. 2025; Hilling et al. 2023)
- Shifts in life-history strategies
  - American shad may respond to warming in Chesapeake Bay tributaries by shifting from iteroparity to semelparity – to reduce energetic costs associated with reproduction

Projected Shifts in Habitat Use: Sandbar Shark

- Contraction of nursery area → thermal-predation squeeze (Crear et al. 2020)



- Shifting distribution to cooler, saltier waters near the mouth of the Bay may not be ideal due to increased predation by adult sandbar sharks (Crear et al. 2020)



Images: Crear et al. 2020; ian.umces.edu/media-library

The Rate of Warming is Important

- Slow warming in spring supports greater forage abundance than fast warming in spring (Woodland et al. 2021)

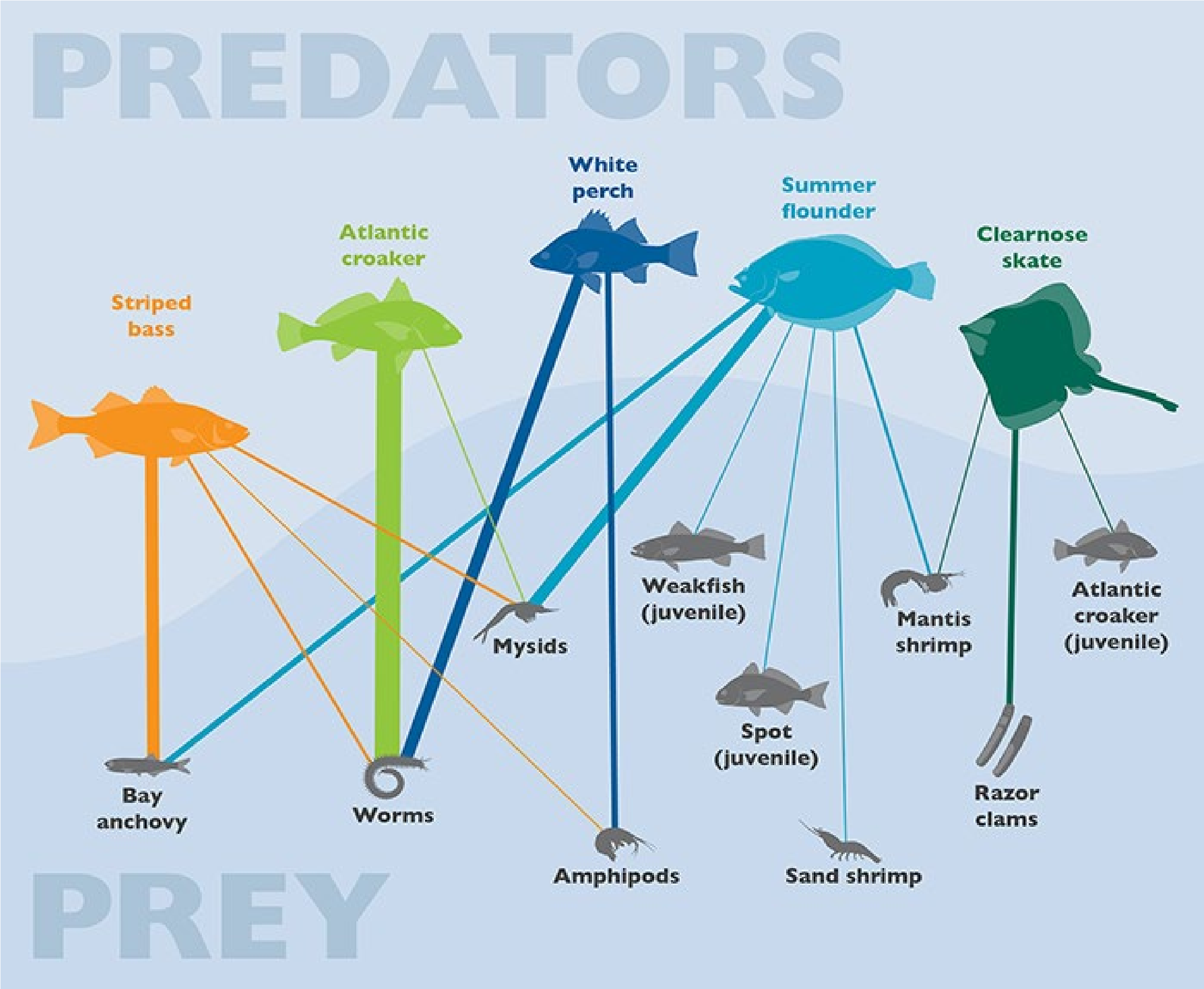


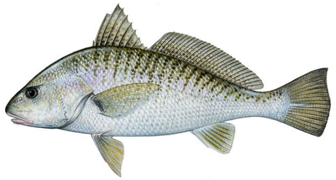
Image: Nicole Lehming; Scientific and Technical Advisory Committee, Chesapeake Bay Program

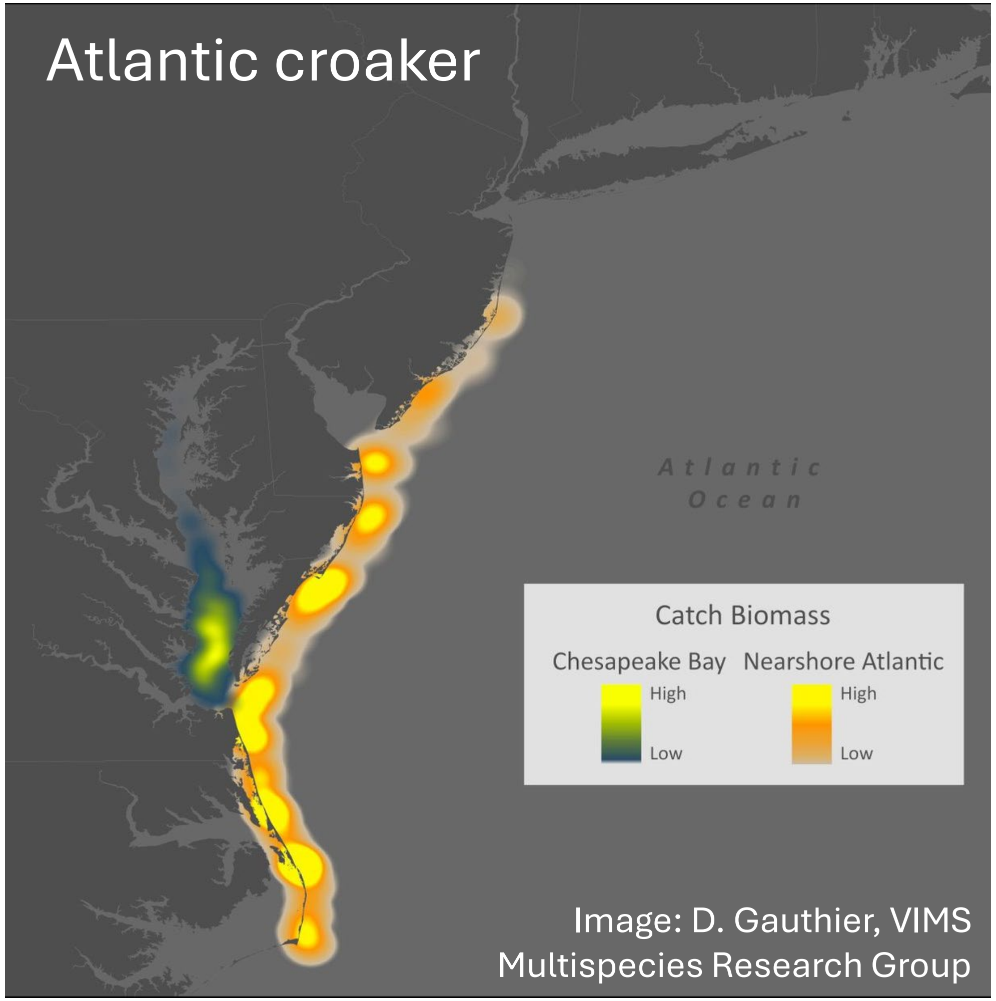
Potential Projected Impacts: Further Shifts in Phenology

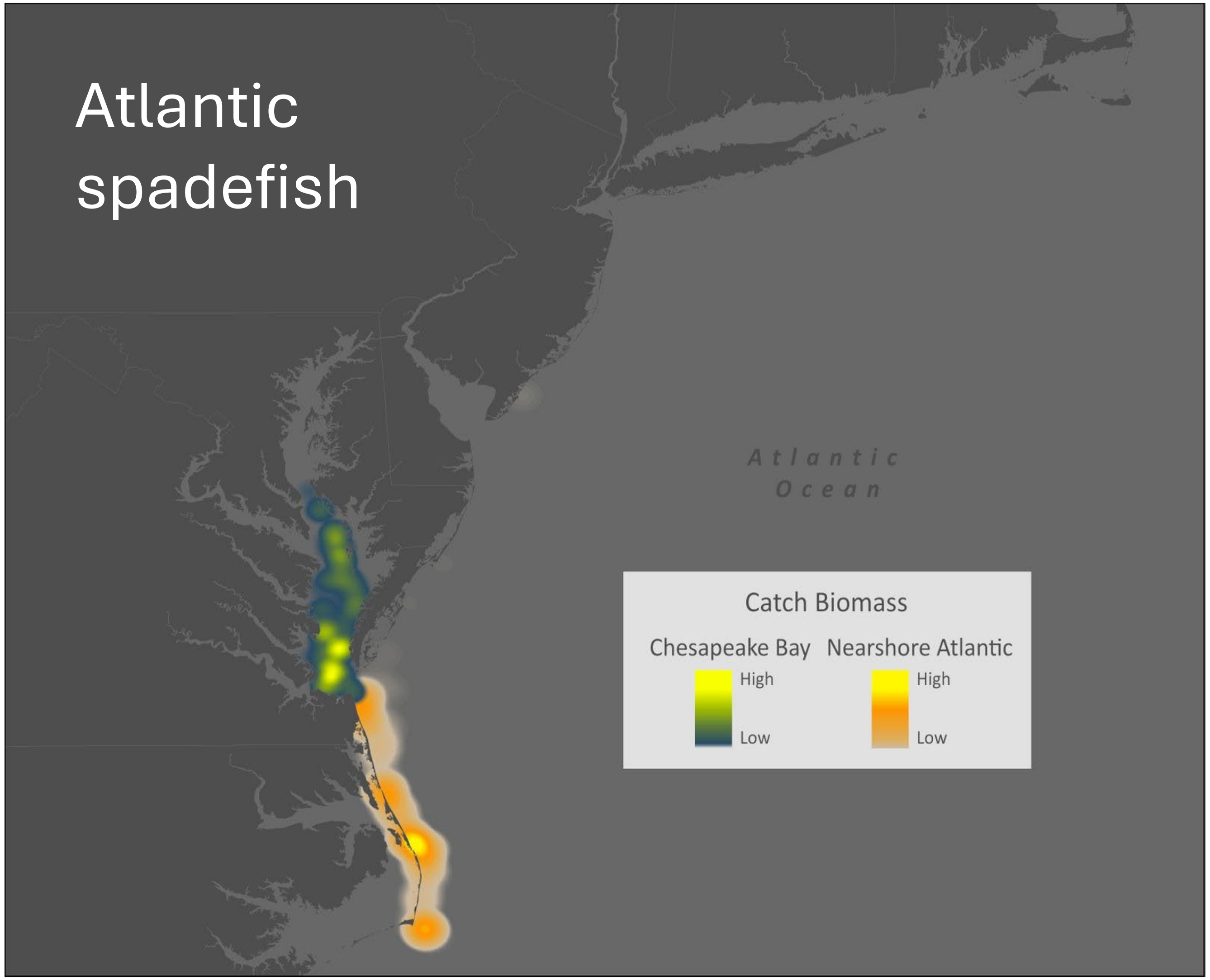
- Marine heat waves may disrupt migratory behaviors
  - Hypothesize that multiple, consecutive exposures to MHW may disrupt timing of emigration → shorten opportunities for foraging and potentially resulting in lower body condition and lower reproductive output

Projected Impacts: Changes in Fish Assemblages

- Atlantic croaker -- cold-edge range of distribution, shifting northwards
- Changes in coastal currents: may impact larval transport and further decrease use of the Bay (Diamond et al. 2013; Hare et al. 2010)
- RCP 8.5, mid-century → bottom temperatures will average ~29.5 C, croaker abundance < spot abundance (differences in metabolic scope of croaker and spot, Marcek et al. 2019)

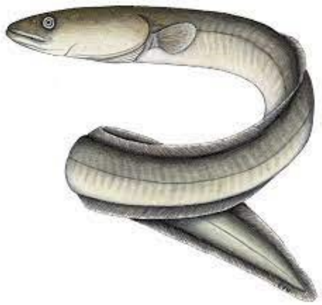





Atlantic
spadefish
Atlantic
Ocean
Catch Biomass
Chesapeake Bay
High
Low
Nearshore Atlantic
High
Low

Projected Shifts in Phenology: American Eel

- American eel (Drouineau et al. 2018)
  - Outmigration in fall responds to streamflow/precipitation
  - Precipitation patterns are projected to be highly variable
  - Reduced precipitation in fall may delay outmigration and negatively affect recruitment, thereby pushing the species closer to ESA protections



Eel image: Gulf of Maine Council on the MarineEnvironment