Identifying Environmental Thresholds to Predict Suitable Habitats for Key Species

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Anchor QEA

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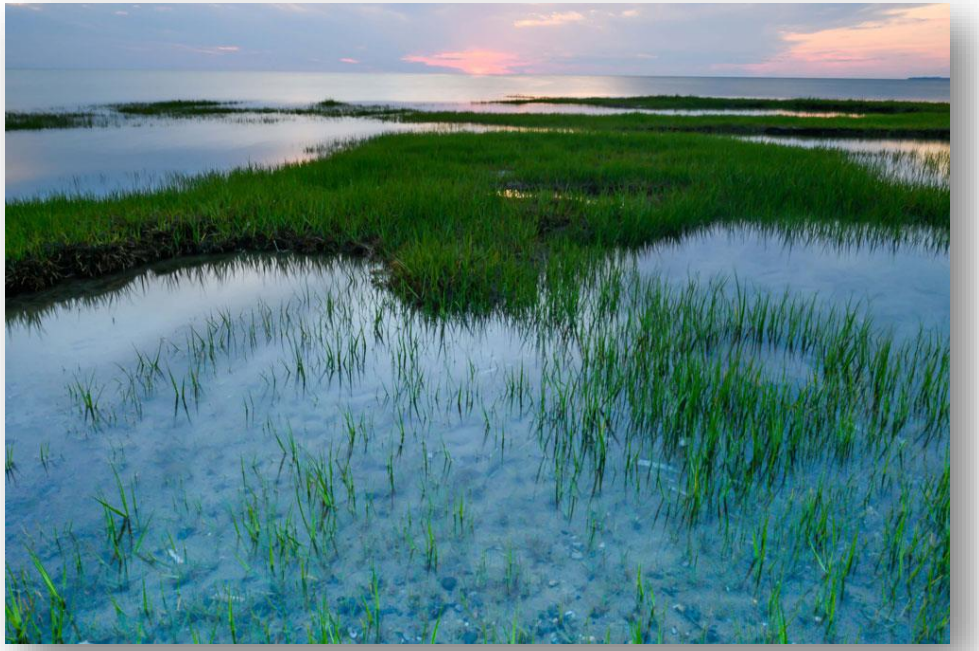
A Changing Chesapeake Bay

- What was then is not now
  - Oysters, blue crabs, striped bass, Atlantic sturgeon, American shad
- Chesapeake Bay TMDL plan (EPA)
  - A pollution ‘diet’ to protect and restore the Bay ecosystem
  - Nutrient and sediment inputs
  - Improve water quality, conserve habitat, prevent habitat degradation
- How do habitat conditions affect the distribution and abundance of harvestable species in the Bay?

Species – Habitat Models

Assumption: the distribution, abundance, and condition of organisms are

- determined by the local abiotic environment
- tightly linked to the **extent and quality of suitable habitat**



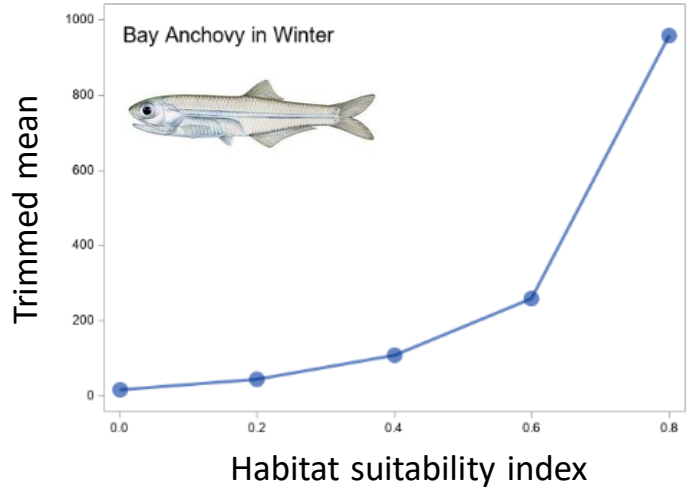
Kearney & Porter 2009; Guisan et al. 2017

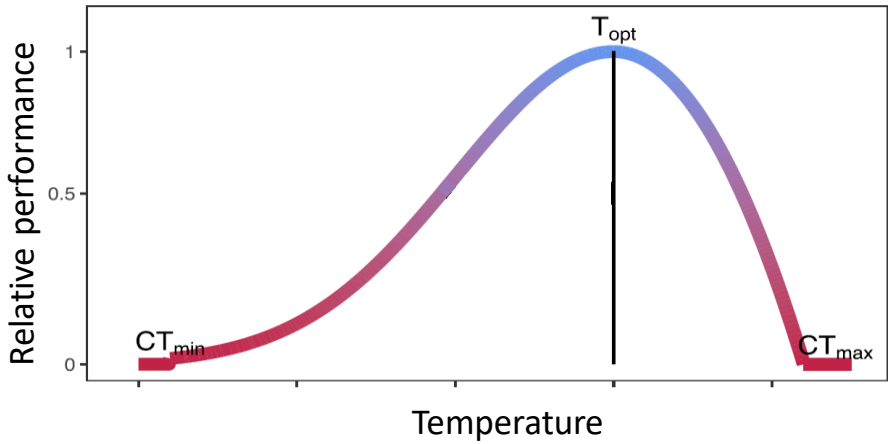
Two Types of Species - Habitat Models

- Correlative models
  - Statistical relationship between environmental covariates and presence/absence or abundance
  - Species Distribution Models (SDMs) and Ecological Niche Models

- Mechanistic models
  - Based on processes (e.g., physiology) that constrain demographics and species ranges

- With abundance data, both approaches assume species will be more likely to be present & at higher abundance in locations that are optimal



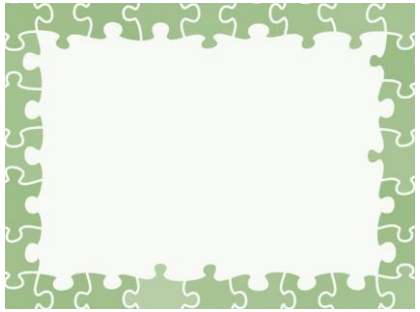


Fabrizio et al. 2021; Wagner et al. 2023

Species - Habitat Models & Projections

- Correlative models
  - Realized niche (environmental requirements conditional on species interactions and dispersal limitations)
  - Assume organisms and their environment are in **equilibrium,** i.e., that species occur at all locations where combined environmental conditions are favorable (**stationarity**)
  - High uncertainty when applied to future conditions (transferability)

- Mechanistic models
  - Fundamental niche (or at least a dimension thereof)
  - Assume, e.g., that performance approaches zero at temperatures $\geq CT_{max}$
  - More robust when examining future conditions



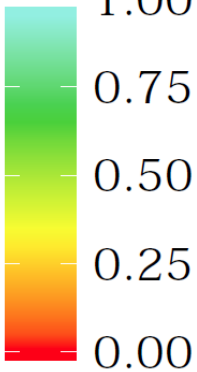
Kearney & Porter 2009; Teal et al. 2018; Wagner et al. 2023

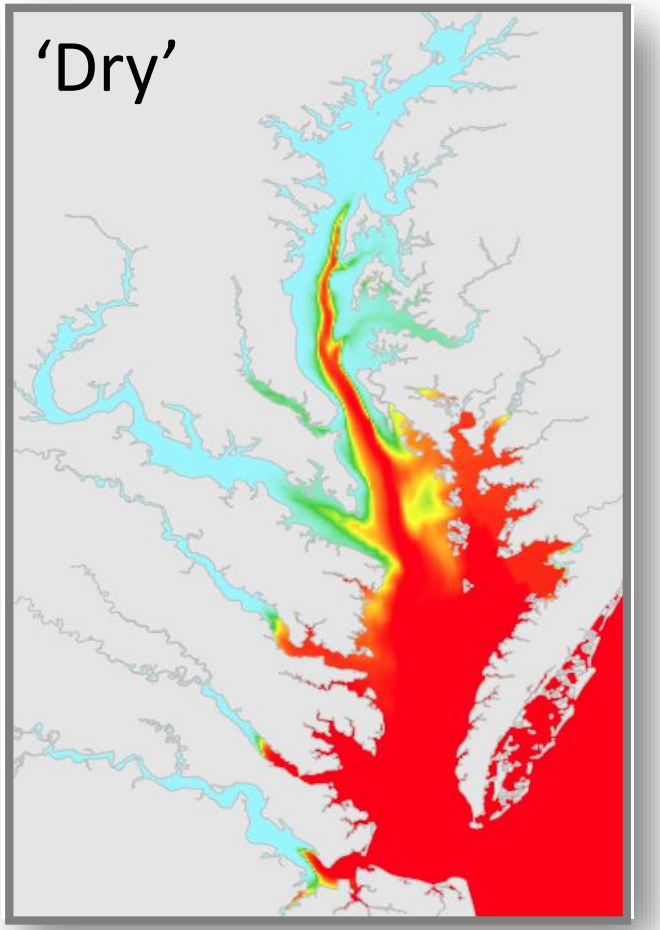
Physiology-Based Habitat Models

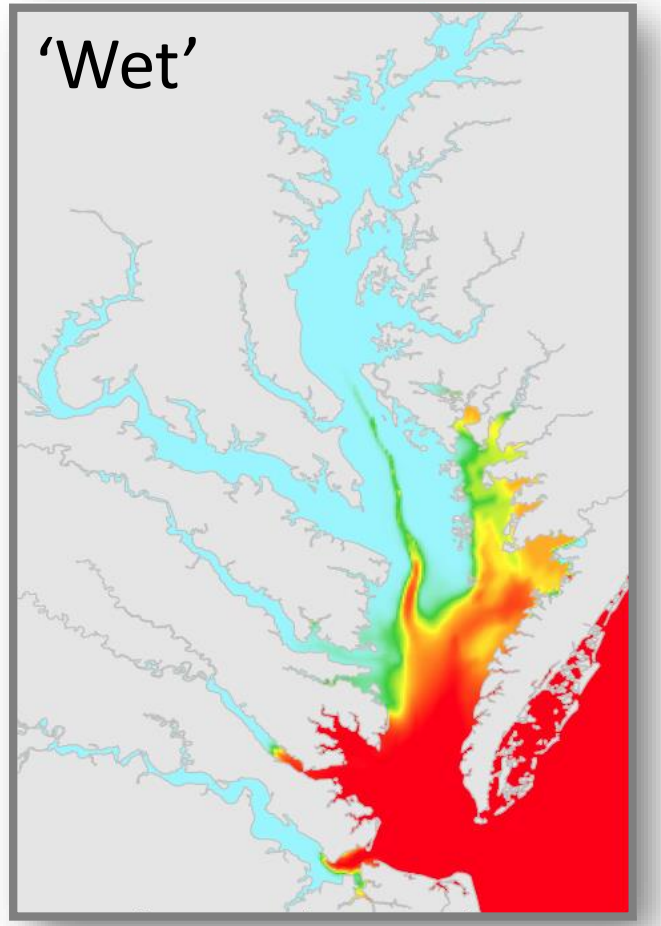
- Supported by underlying causal mechanisms

Blue catfish

Prob(Survival)



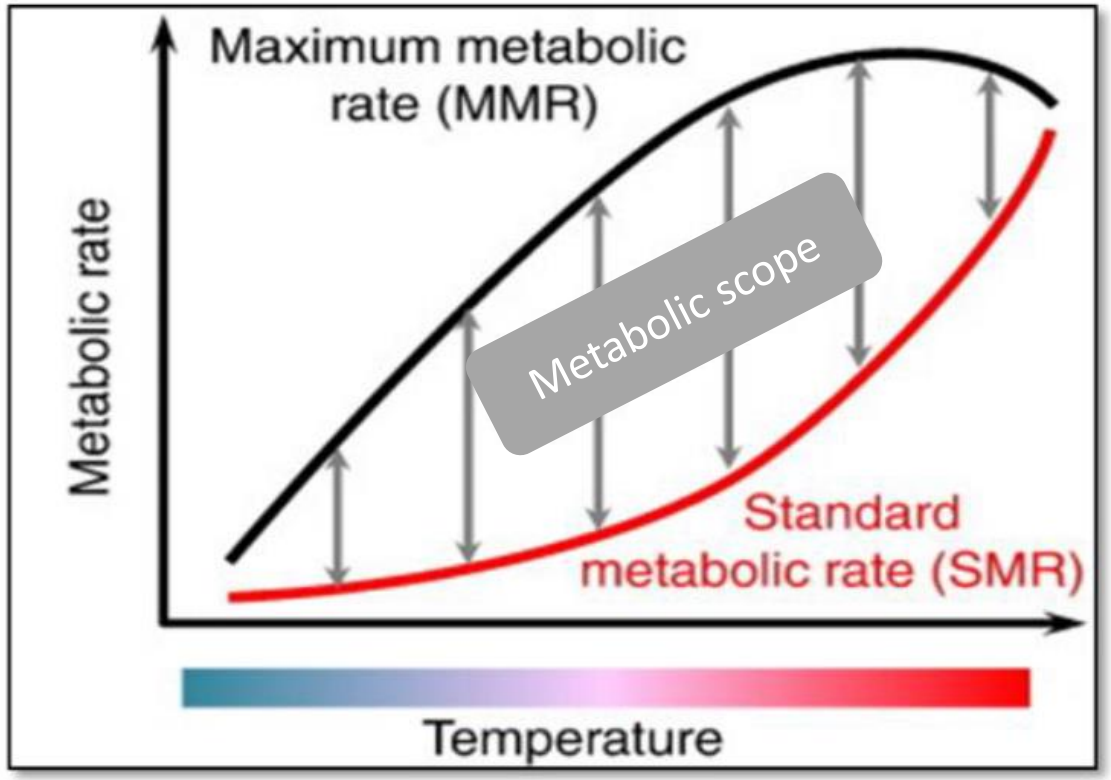




Kearney & Porter 2009; Nepal & Fabrizio 2019

Environmental Predictors & Physiological Metrics

- Predictors
  - Temperature
  - Dissolved oxygen
  - Salinity
- Metrics
  - Tolerance thresholds (e.g., upper & lower thermal limits)
  - Hypoxia tolerance
  - Consumption rate
  - Growth rate
  - Metabolic scope



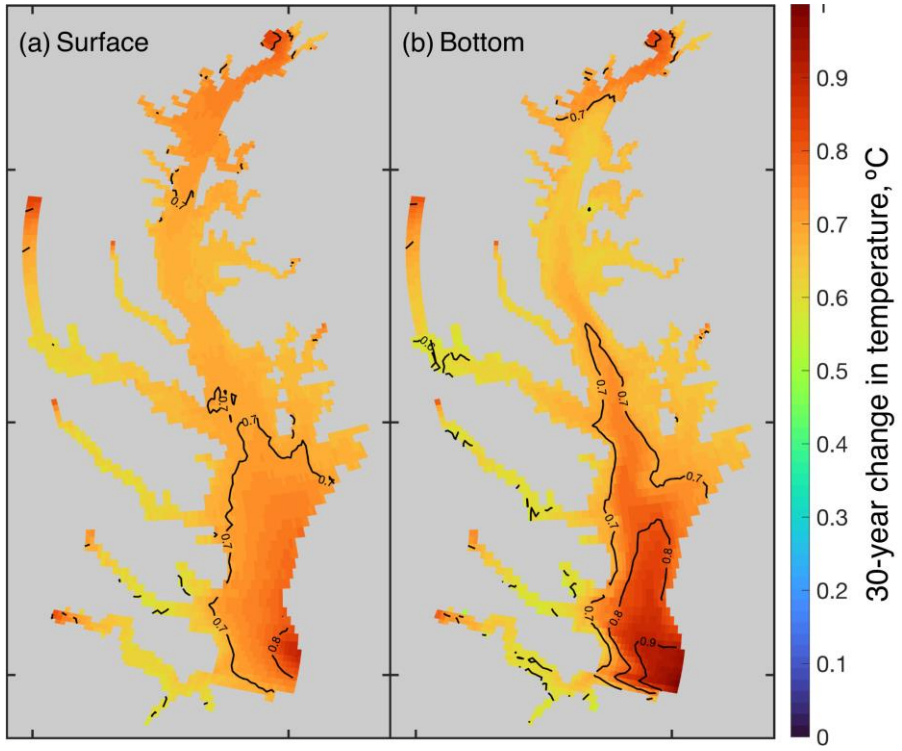
Evans et al. 2015; Lefevre et al. 2021

Beerkens 2016

Approach

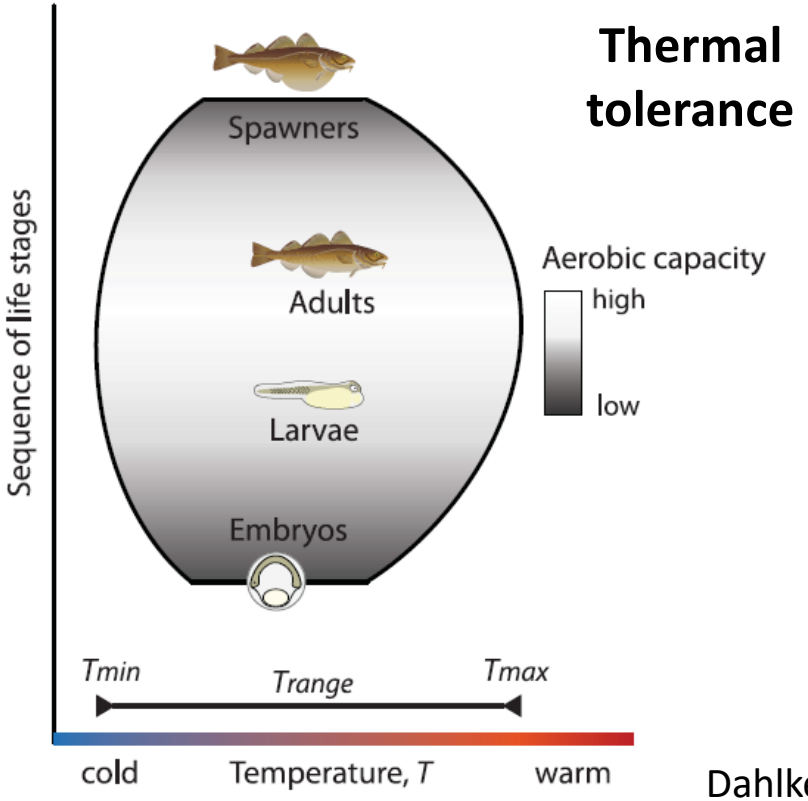
- Build, verify, and apply **physiology-based habitat models** to project potential suitable habitats for key fisheries resources in Chesapeake Bay
- Examine responses across life stages

Warming since 1985



Hinson et al. 2022

Thermal tolerance

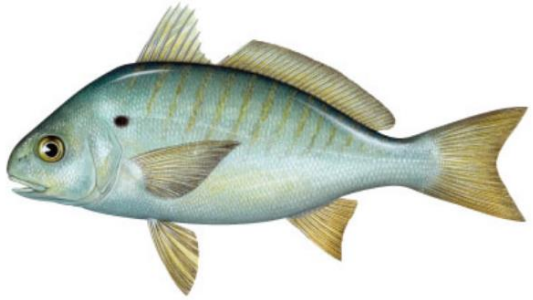


Dahlke et al. 2020

Objectives

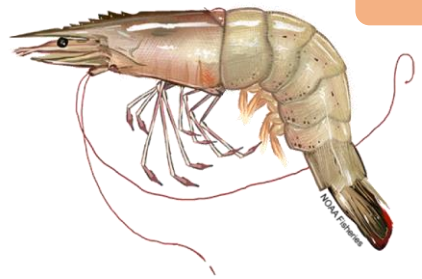
- Quantify suitable habitats for five species under historical and present-day climate conditions
- Project and quantify suitable habitats for study species under future climate conditions

Striped bass



Spot

Climate migrant



White shrimp

Commercial/recreational fisheries

Atlantic menhaden

Bay anchovy

Forage species

Chesapeake Bay Environmental Forecast System (CBEFS)

3-D Chesapeake Bay implementation of the open-source community Regional Ocean Modeling System (*Ches*ROMS) hydrodynamic model

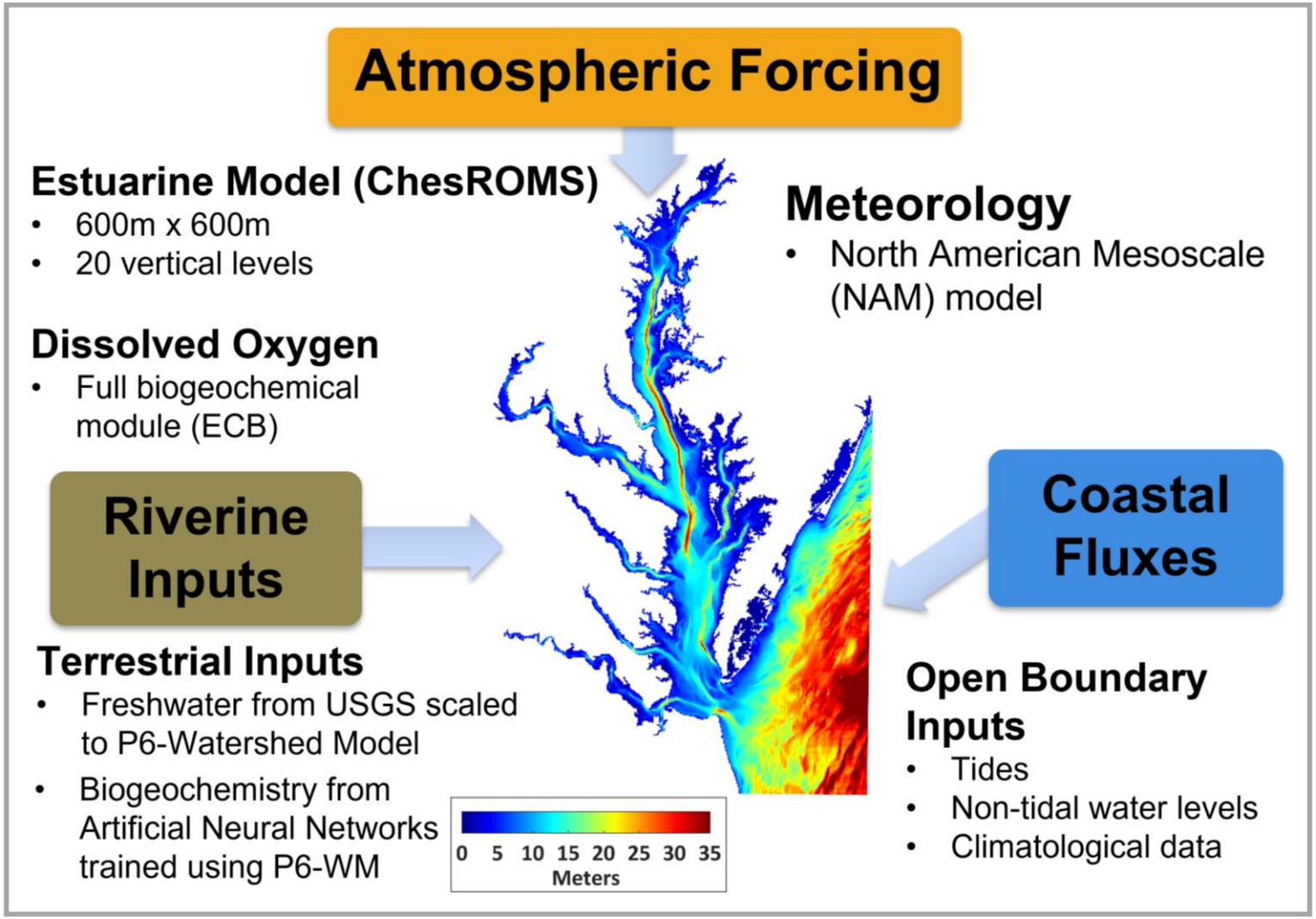
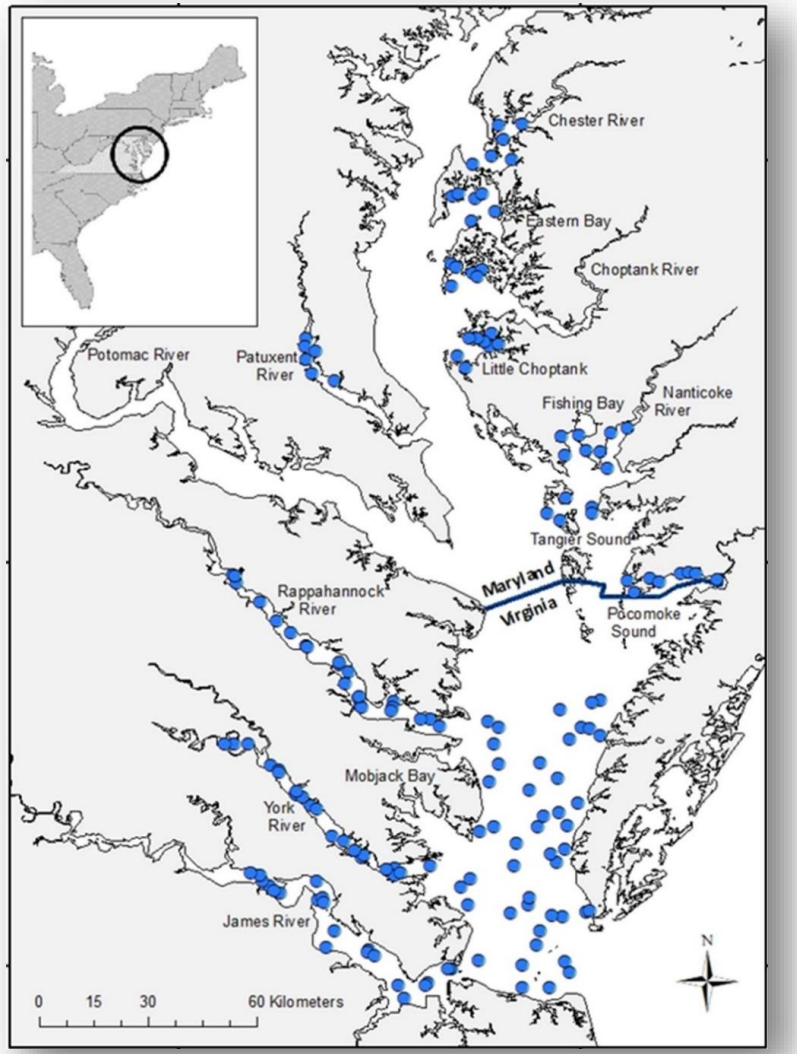


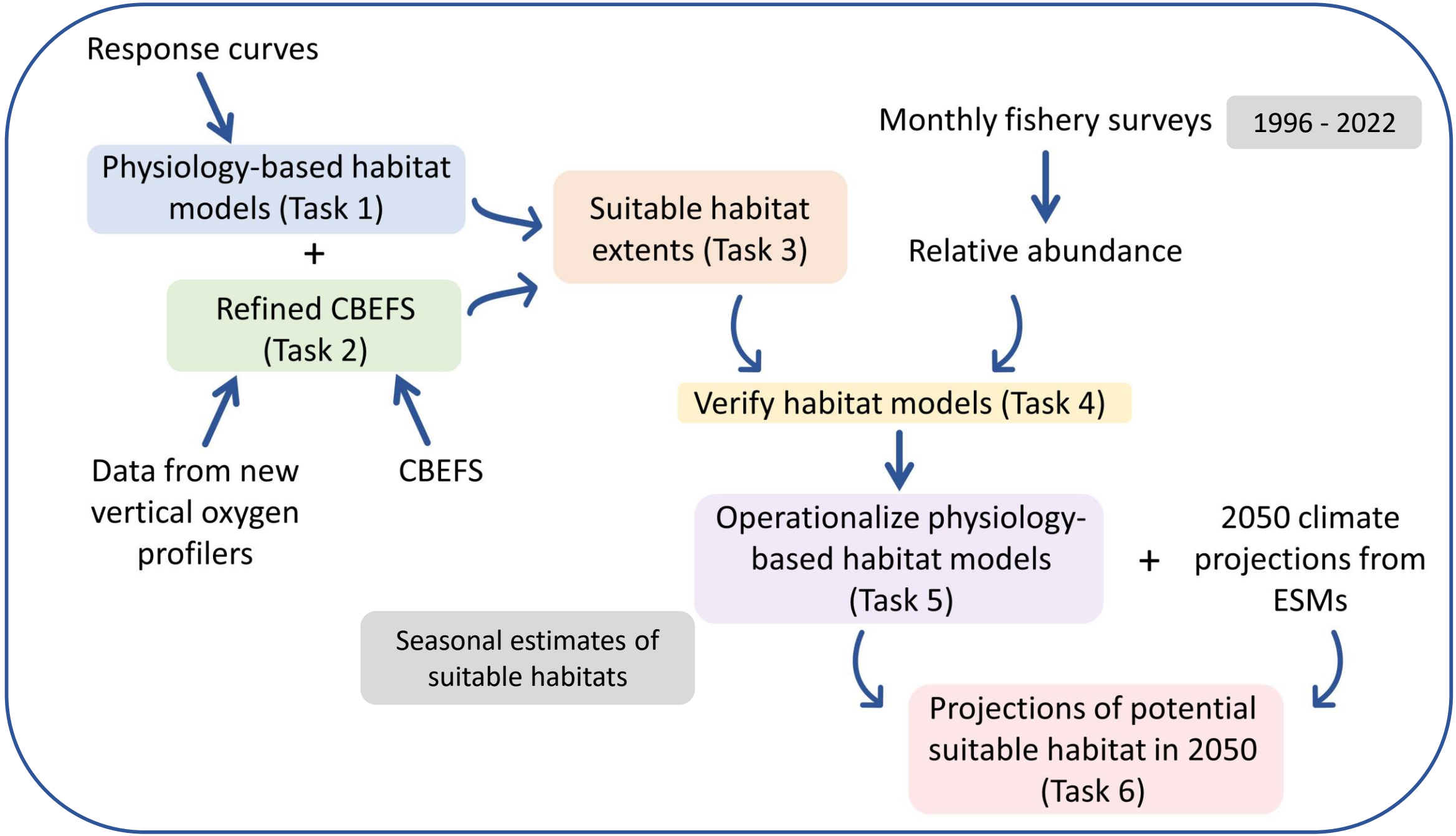
Image modified from Bever et al. 2021

Fishery Surveys

- VIMS Juvenile Fish Trawl Survey
- MD Small Trawl Survey
- ChesMMAP Survey (adult striped bass)
- Menhaden stock assessment (adult menhaden)



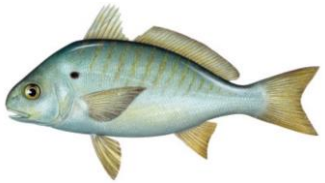
Fabrizio et al. 2021

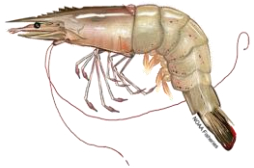

Response curves
Physiology-based habitat models (Task 1)
+
Refined CBEFS (Task 2)
Data from new vertical oxygen profilers
CBEFS
Suitable habitat extents (Task 3)
Monthly fishery surveys
1996 - 2022
Relative abundance
Verify habitat models (Task 4)
Operationalize physiology-based habitat models (Task 5)
Seasonal estimates of suitable habitats
+
2050 climate projections from ESMs
Projections of potential suitable habitat in 2050 (Task 6)

Products

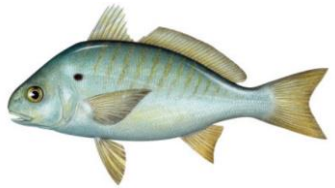
- Annual/Seasonal maps depicting habitat model-based projections of the extent of *potential habitats* suitable for fisheries production (1996 – 2022)
- Incorporation of habitat models into CBEFS to provide publicly available daily, seasonal, and annual indicators of suitable habitat extent
- Maps of suitable habitat extents in 2050 under ‘business as usual’ and one other scenario (SSP2-4.5)
- Identification of critical habitats lost (or gained) due to climate change
  - Comparison of extent of suitable habitats in 2050 with estimates of current extents
- Identification of areas to prioritize for protection or restoration to ensure sustainable fisheries production

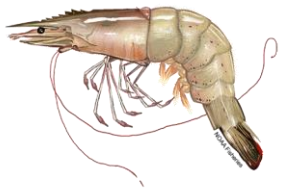







Thank you





Species	Response	Condition
Striped bass	Critical O_2 concentration	T
	Growth	T, DO
	Survival	T
Atlantic menhaden	Survival	T, DO
	Survival	T, S
	Growth	T, DO
	Consumption	T
Spot	Metabolic scope	T
	Critical O_2 concentration	T
	Survival	T
Bay anchovy	Survival	T
	Consumption	T
White shrimp	Growth; metabolic scope	DO
	Growth	S
	Survival; Growth	S