Forecasting the effects of climate change and nutrient management on fisheries species in the Chesapeake Bay

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Image courtesy of Chesapeake Bay Foundation and ArcGIS

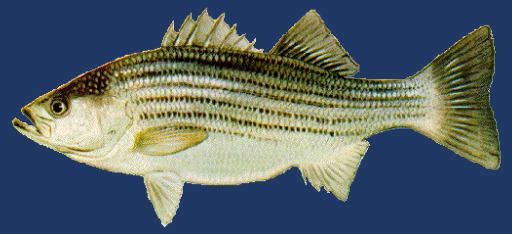
Objectives

- **Use bioenergetics-based models to quantify suitable Chesapeake Bay habitat for multiple key species**

- **Pair habitat suitability models with 3-D mechanistic estuarine model output**

- **Project spatial extent and annual duration of suitable Chesapeake Bay habitat for study species under historical and future climate conditions**

Bay Anchovy

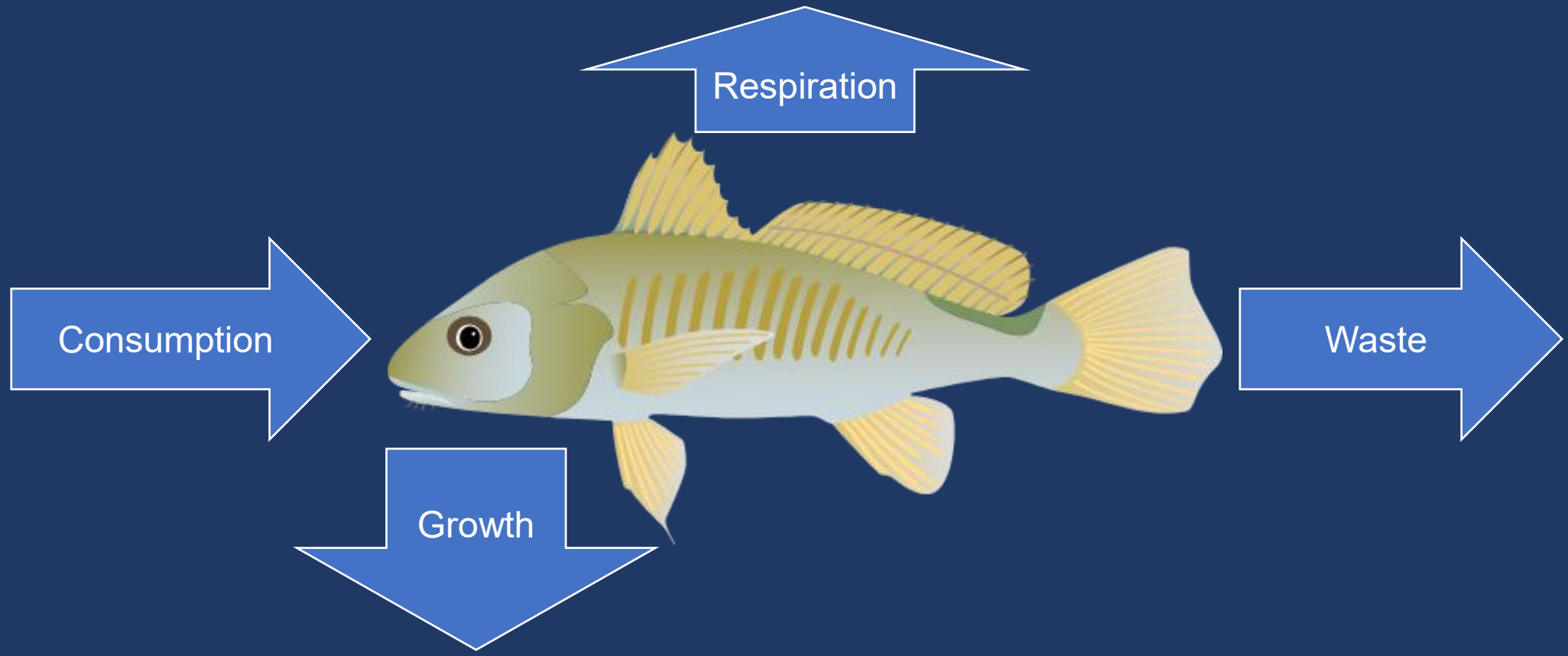


Striped Bass

Atlantic Menhaden

Atlantic Croaker

Example Bioenergetics Model: Juvenile Atlantic Croaker



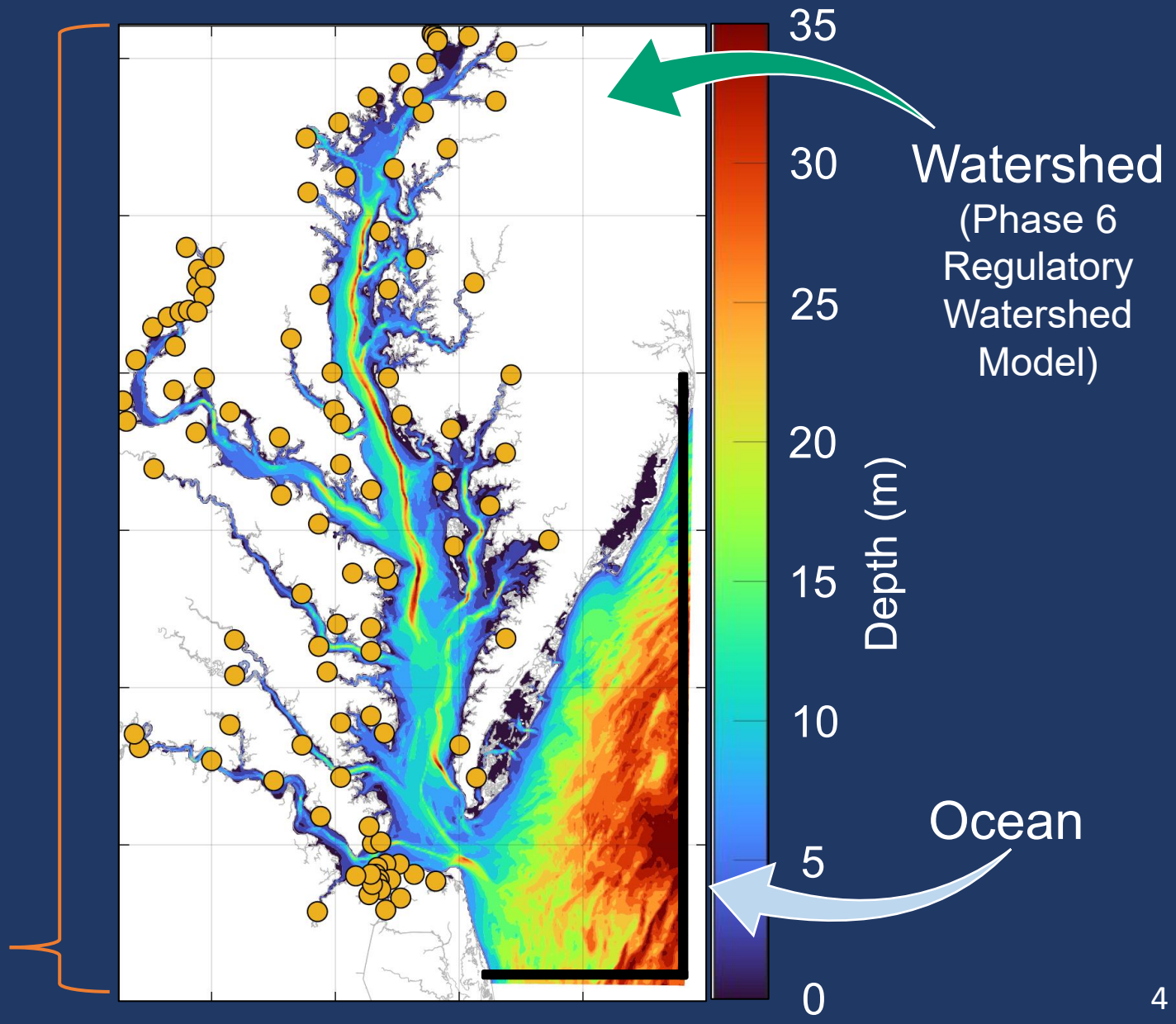
$if\ Growth(T, S, O_2) \leq 0$
$if\ HSI(Growth) \leq 0.5$
Unsuitable habitat

$if\ Growth(T, S, O_2) > 0$
$if\ HSI(Growth) > 0.5$
Suitable Habitat

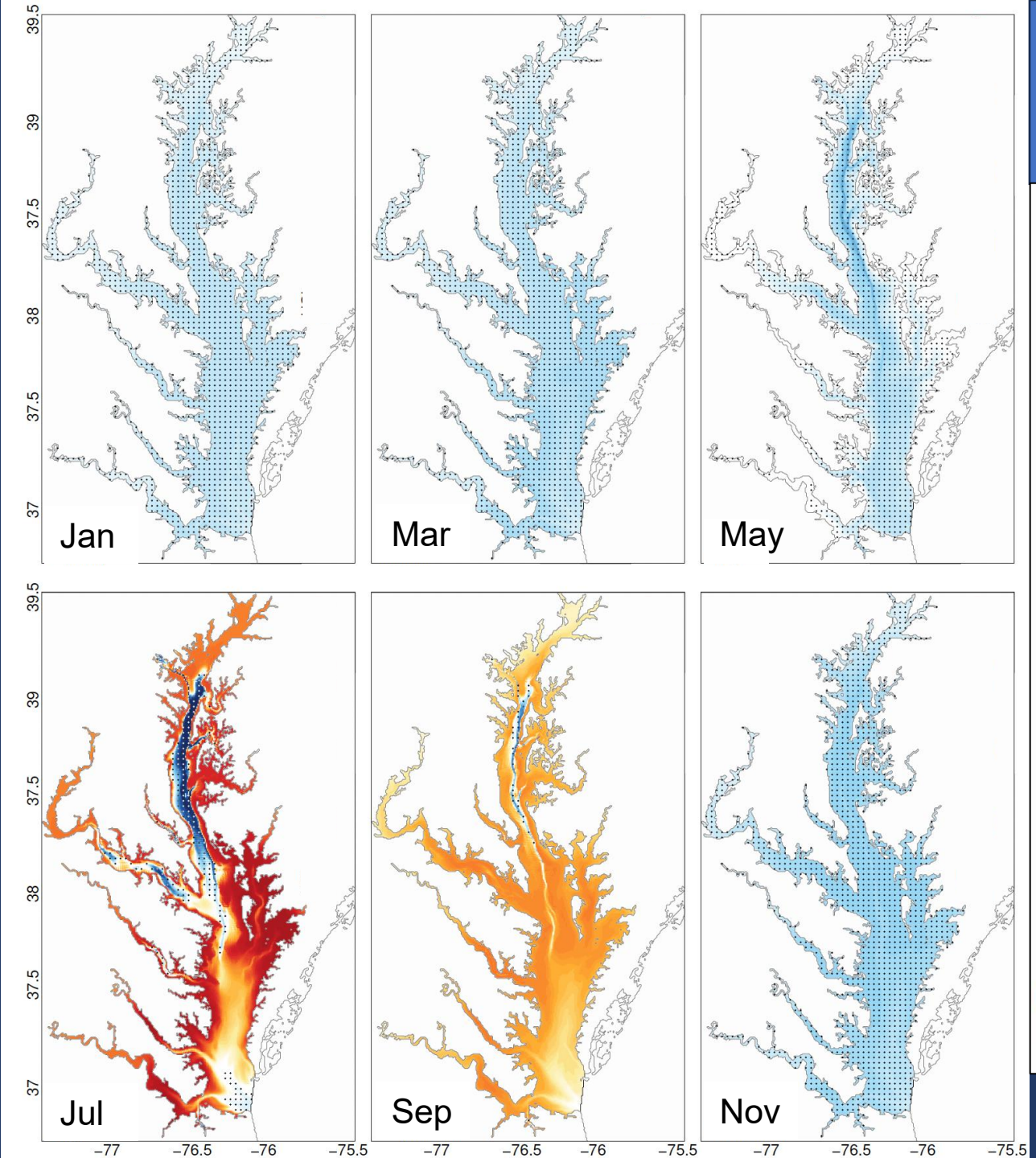
Nye, 2008
Rose et al., 2018

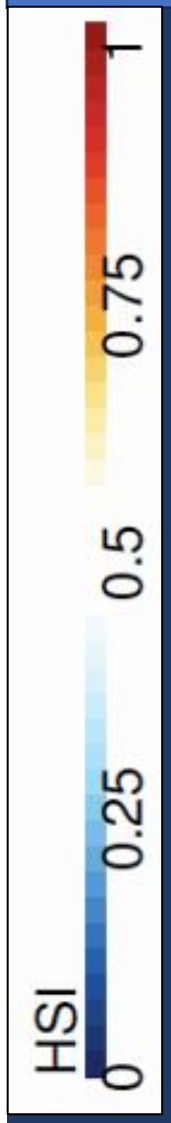
Estuarine Model: ROMS-ECB

- Coupled hydrodynamic-biogeochemical model
- 600m horizontal resolution
- 20 terrain-following vertical levels
- Model skill evaluated with observations at Chesapeake Bay Program stations, from 1980s to present



Juvenile Croaker Habitat Suitability during 1985-2025

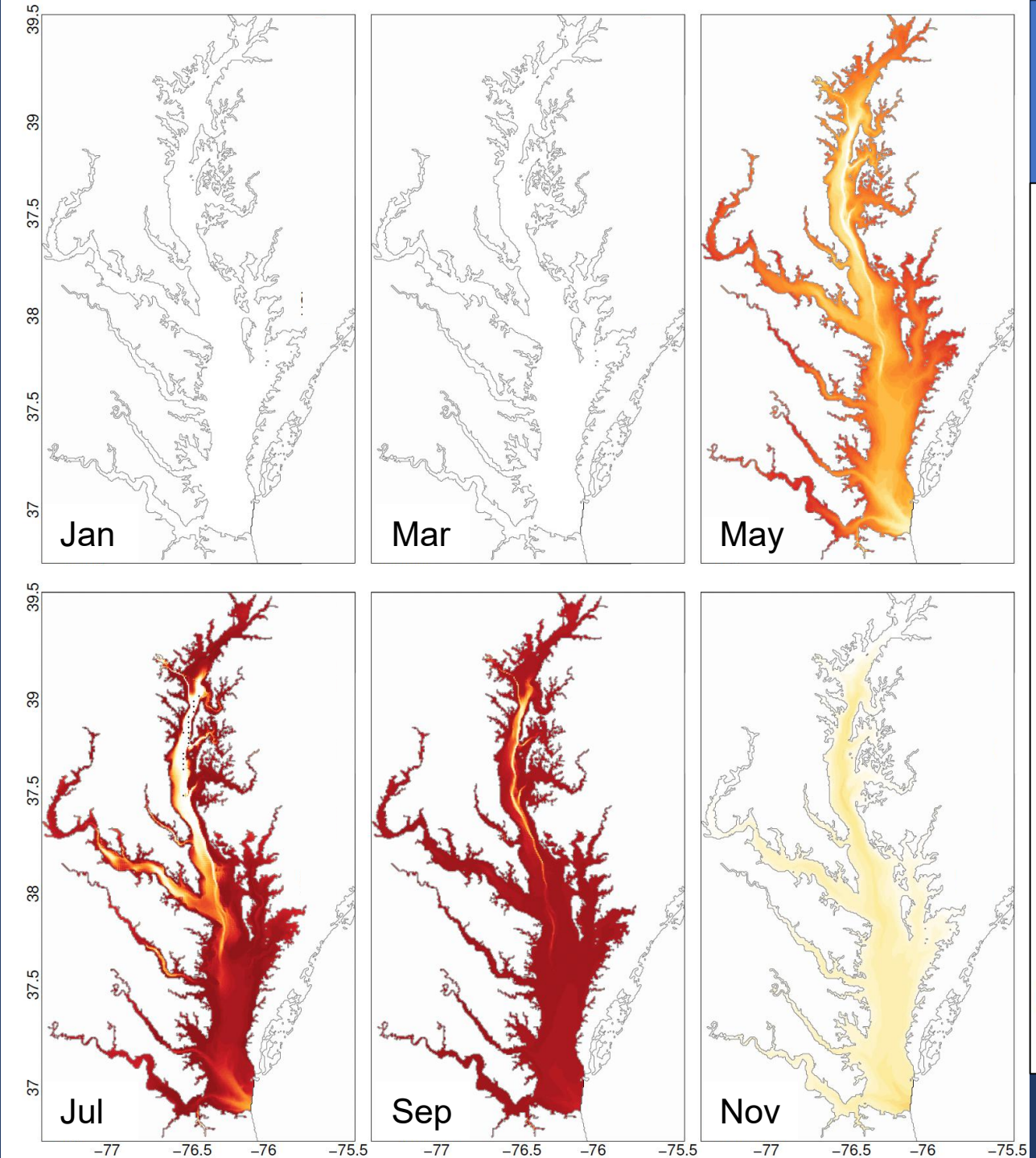




- Polka dots indicate a Habitat Suitability Index (HSI) ≤ 0.5
- HSI = 1 corresponds to the maximum Growth computed
- We assume feeding efficiency is constant 65% of maximum
- Croaker's modeled habitat phenology aligns with known migration pattern
- Croaker experiences peak potential for growth during summer

Figure by Pierre St-Laurent

Juvenile Menhaden Habitat Suitability during 1985-2025

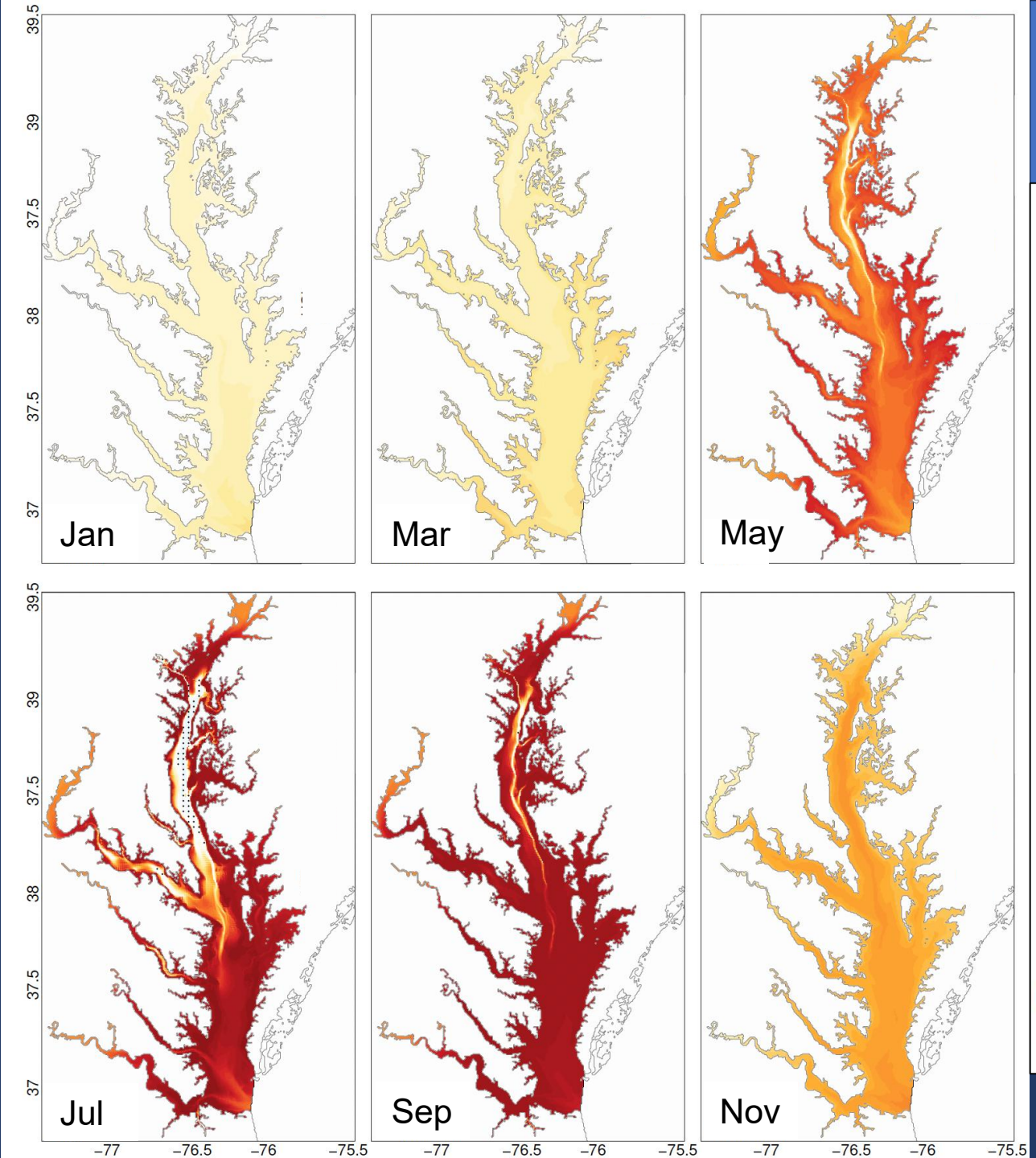


These results are preliminary

- HSI = 0.5 corresponds to Growth = 0 g g^{-1} d^{-1}
- We assume feeding efficiency is constant 65% of maximum
- Menhaden experiences peak potential for growth from spring through fall
- HSI only drops below 0.5 due to hypoxia

Figure by Pierre St-Laurent

Bay Anchovy Habitat Suitability during 1985-2025

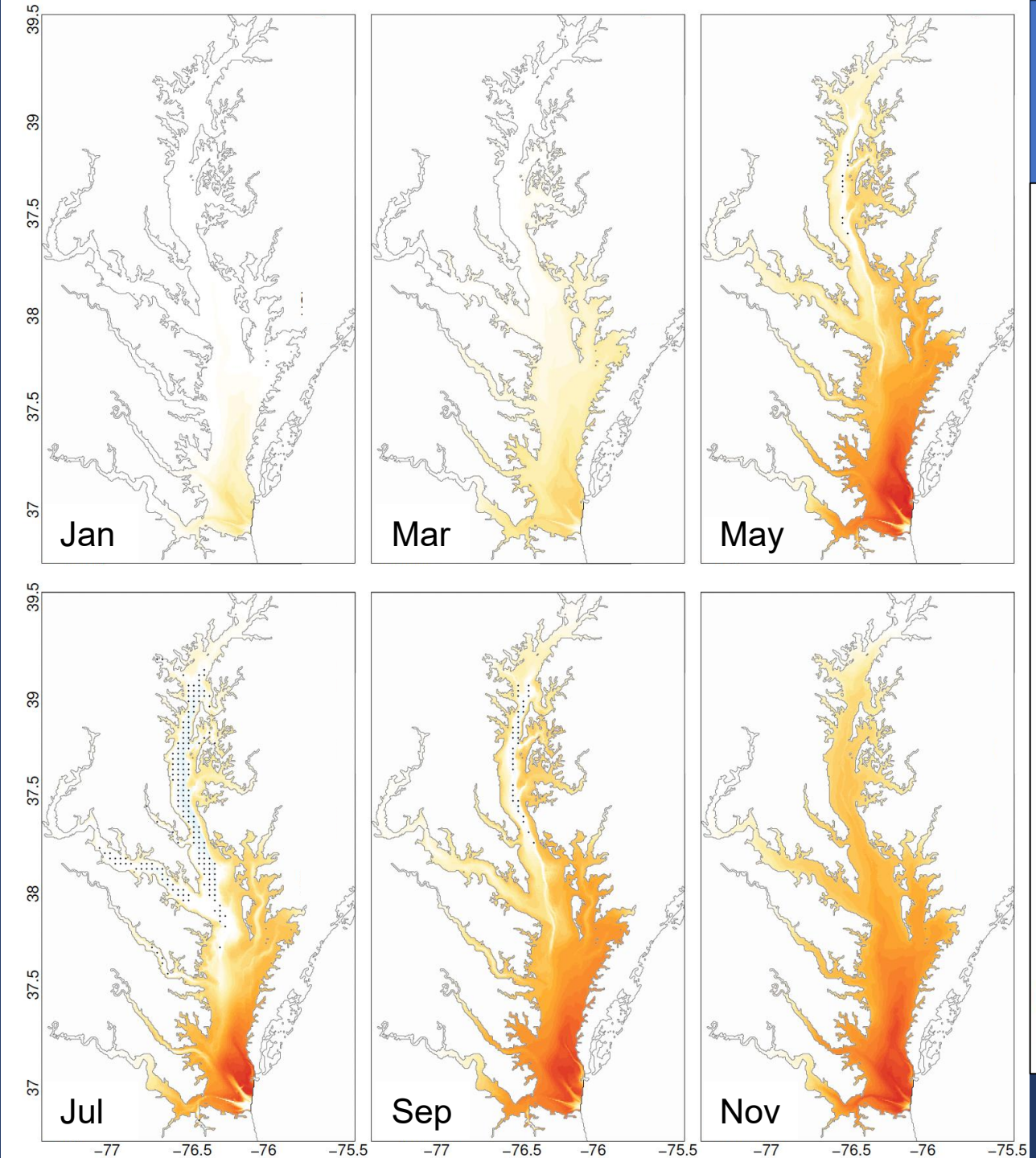


These results are preliminary

- HSI = 0.5 corresponds to Growth = 0 g g^{-1} d^{-1}
- We assume feeding efficiency is constant 65% of maximum
- Like Menhaden, Bay Anchovy HSI only drops below 0.5 due to hypoxia
- Conditions remain more favorable for Bay Anchovy throughout the year, but still peaks in warmer months

Figure by Pierre St-Laurent

Juvenile Striped Bass Habitat Suitability during 1985-2025



These results are preliminary

- HSI = 0.5 corresponds to Growth = 0 g g^{-1} d^{-1}
- We assume feeding efficiency is constant 65% of maximum
- Striped Bass growth is more dependent on salinity than other species
- Striped Bass growth less dependent on temperature than other species

Figure by Pierre St-Laurent

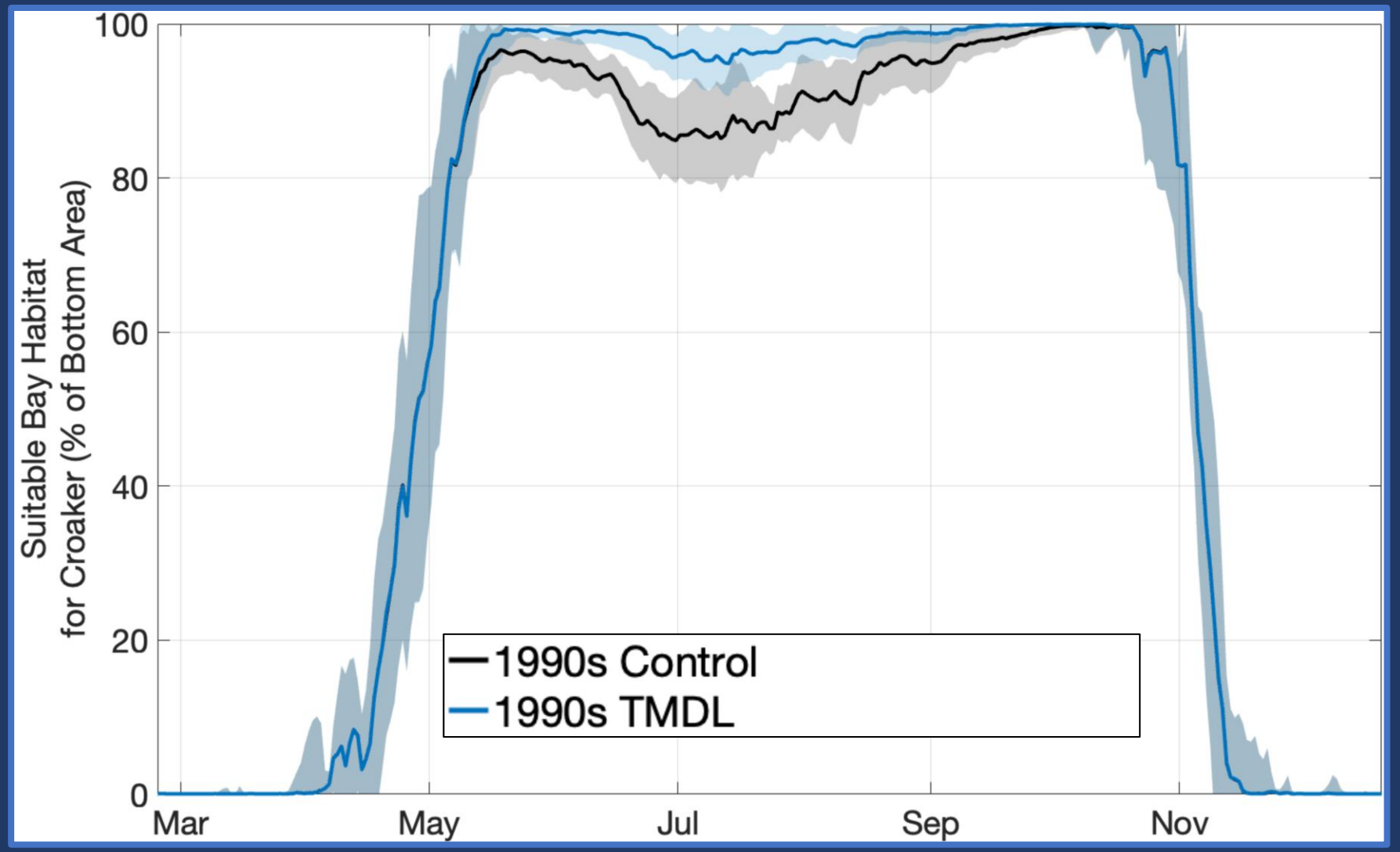
Juvenile Atlantic Croaker Habitat Suitability: 1990s, Nutrient Management and 2070s

ROMS-ECB nutrient reduction and 2070s future runs

Years	Simulation	Estuarine Forcings	
1991-2000	Control	Realistic	
	TMDL	With planned nutrient reductions implemented per Chesapeake Bay Total Maximum Daily Load (TMDL)	
		Earth System Model	**Emissions Scenario**
2071-2080 ***All include TMDL***	**MPI-N 245**	**MPI-N (Max Planck Institute - Netherlands)**	**SSP 2-4.5 ("most likely future")**
	MRI-J 245	**MRI-J (Meteorological Research Institute - Japan)**	**SSP 2-4.5**
	ACC 245	**ACCESS (Australian Community Climate and Earth System Simulator)**	**SSP 2-4.5**
	MPI-N 585	MPI-N	SSP 5-8.5 ("business as usual")
	MRI-J 585	MRI-J	SSP 5-8.5
	ACC 585	ACCESS	SSP 5-8.5

Nutrient load reductions improve summer conditions

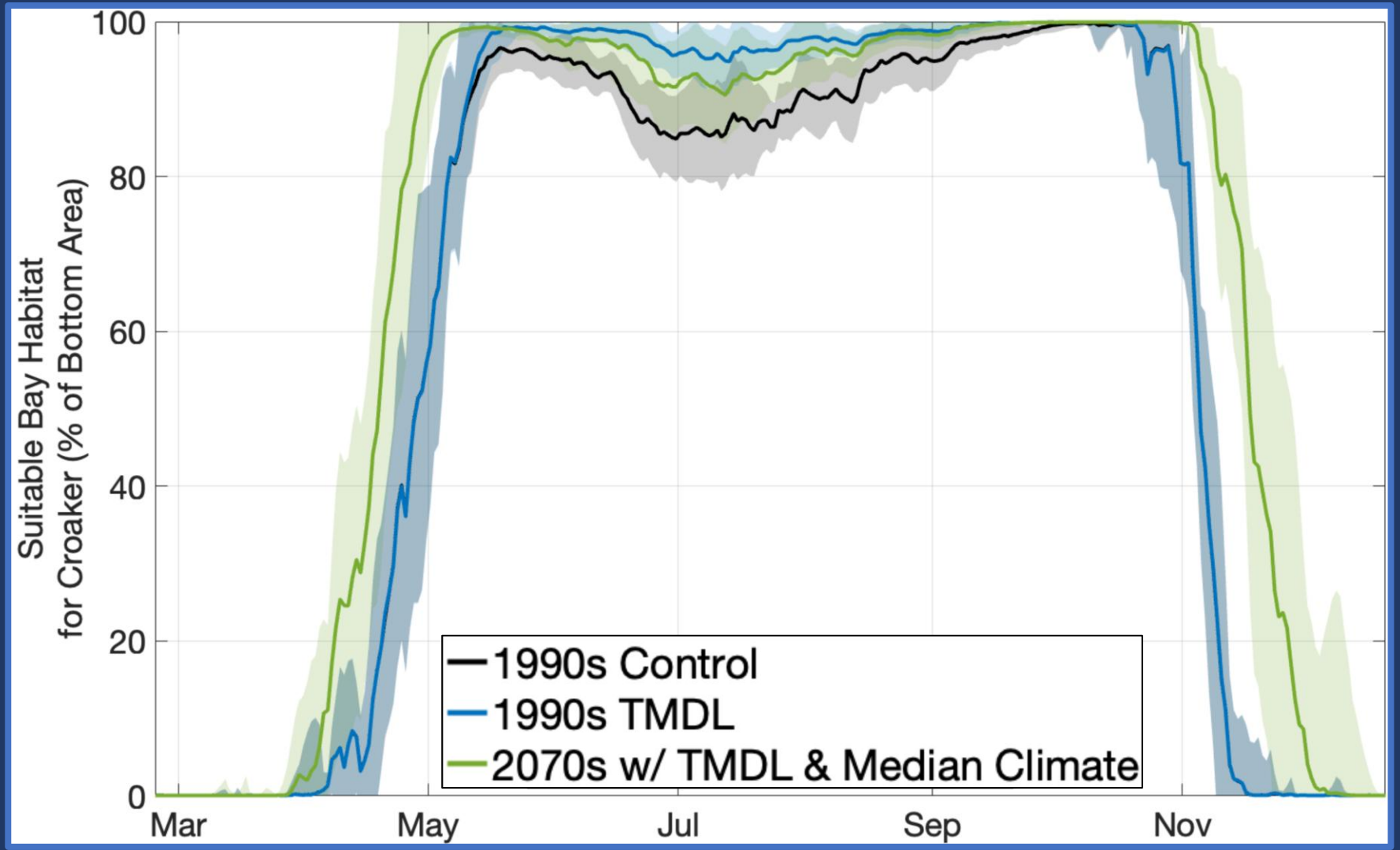
- Nutrient reductions would not impact possible duration of suitable habitat
- They would improve summer conditions by up to 10% of the Bay's total bottom area, via improved bottom O_2



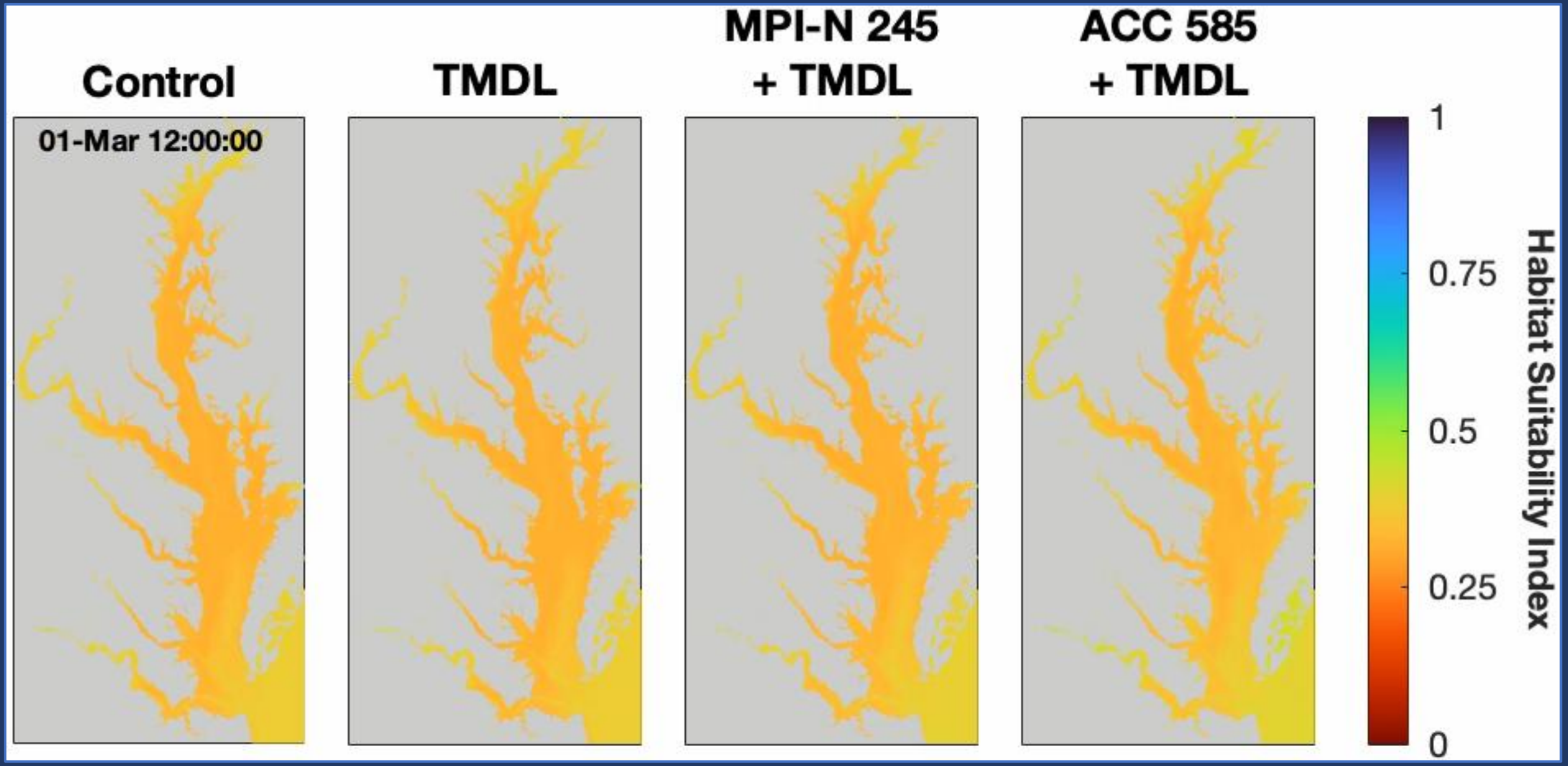
Warming causes habitability to start earlier and end later

- Increases in duration range from 1-4 weeks, depending on ESM and SSP choice

- Summer habitat, with TMDL goals met, would be reduced by warming, but not made worse than Control conditions



Seasonal changes and nutrient reduction improvements occur in shallow areas first



Modeling Atlantic Croaker Habitat Suitability

Nutrient reductions increased the summer spatial extent of suitable habitat,

- Expanding suitable area by ~10% of total Bay bottom area, even combined with warming.
- Driven by higher concentrations of summer bottom dissolved oxygen.

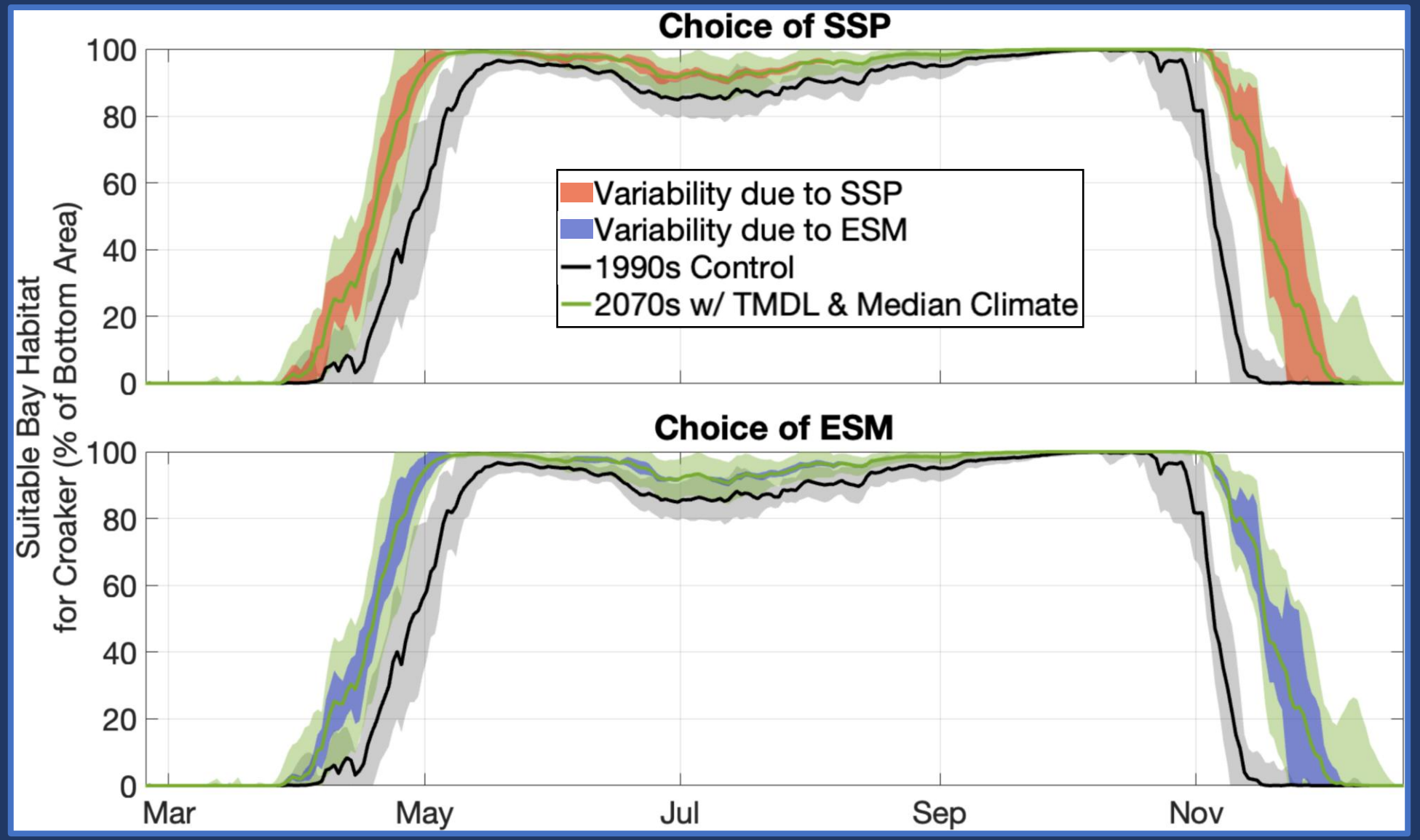
Warming increased the annual duration of suitable habitat,

- By 1-4 weeks in 2070s, depending equally on ESM and SSP choice.
- Slightly increasing the year-to-year variability in habitat duration.

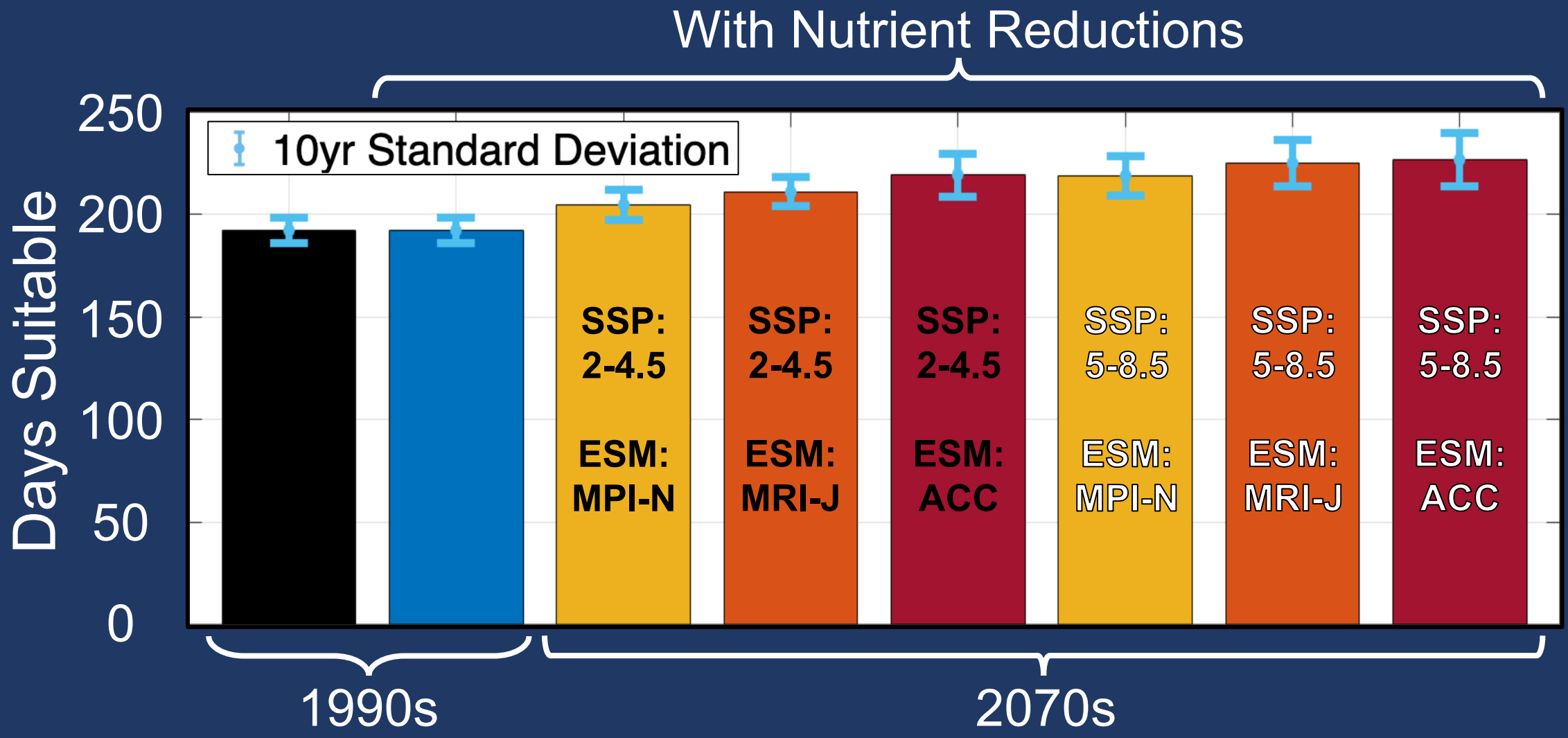
Extra Slides

Choice of ESM and SSP are equally important

- The variability, due to choice of ESM and of SSP, greatest in spring and fall
- For most of the year, the year-to-year variability in the Control run is still greater, except in fall



Warming increases the # days suitable for Croaker growth



- Choice of ESM and SSP are equally impactful to days habitable
- The full range of possible increase is ~1-4 weeks