Forecasting the effects of climate change on juvenile Atlantic Croaker in the Chesapeake Bay

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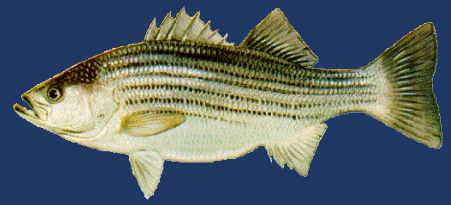
Image courtesy of Chesapeake Bay Foundation and ArcGIS

Objectives

- To use physiologically informed models to quantify suitable habitats for multiple Chesapeake Bay species
- To pair these habitat suitability models with a 3-D mechanistic estuarine model
- To project and quantify suitable Chesapeake Bay habitat for study species under historical, present-day and future climate conditions

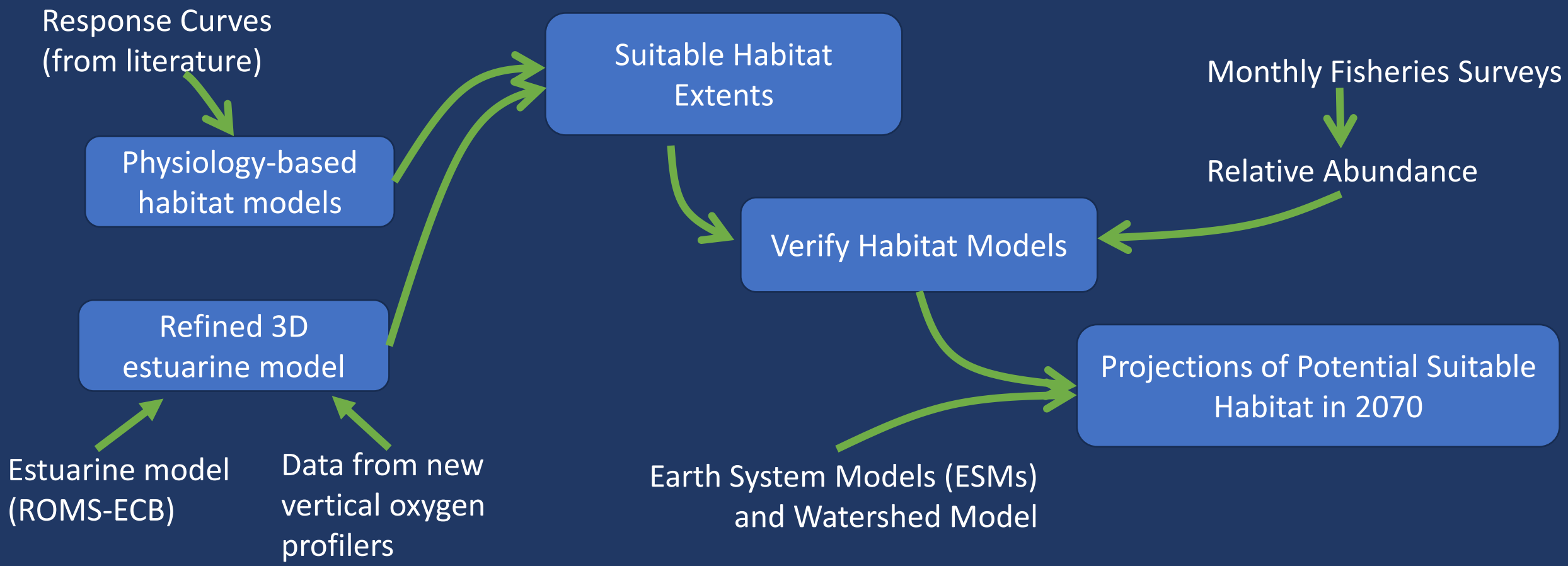
Bay Anchovy



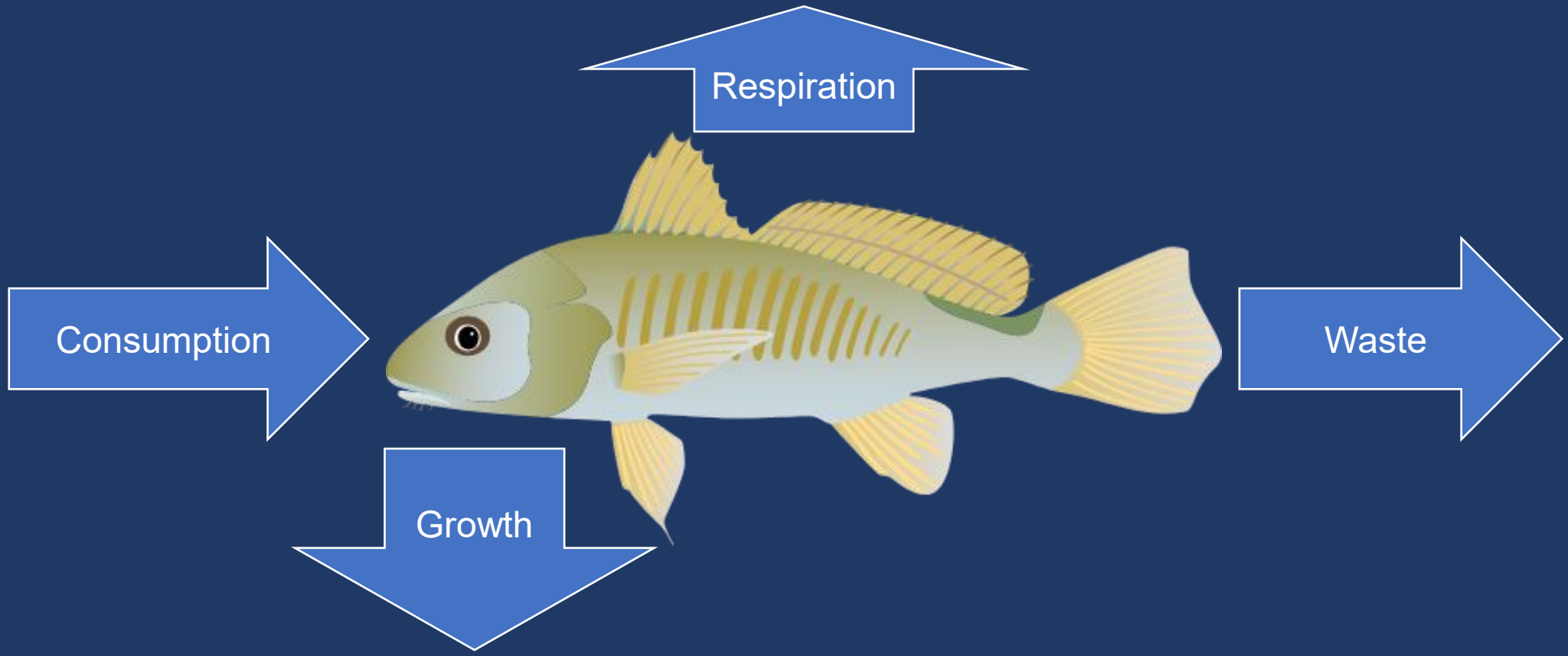
Striped Bass

Atlantic Croaker

Framework


Response Curves (from literature)
Physiology-based habitat models
Refined 3D estuarine model
Estuarine model (ROMS-ECB)
Data from new vertical oxygen profilers
Suitable Habitat Extents
Monthly Fisheries Surveys
Relative Abundance
Verify Habitat Models
Earth System Models (ESMs) and Watershed Model
Projections of Potential Suitable Habitat in 2070

Juvenile Atlantic Croaker Model: physiologically-based habitat suitability



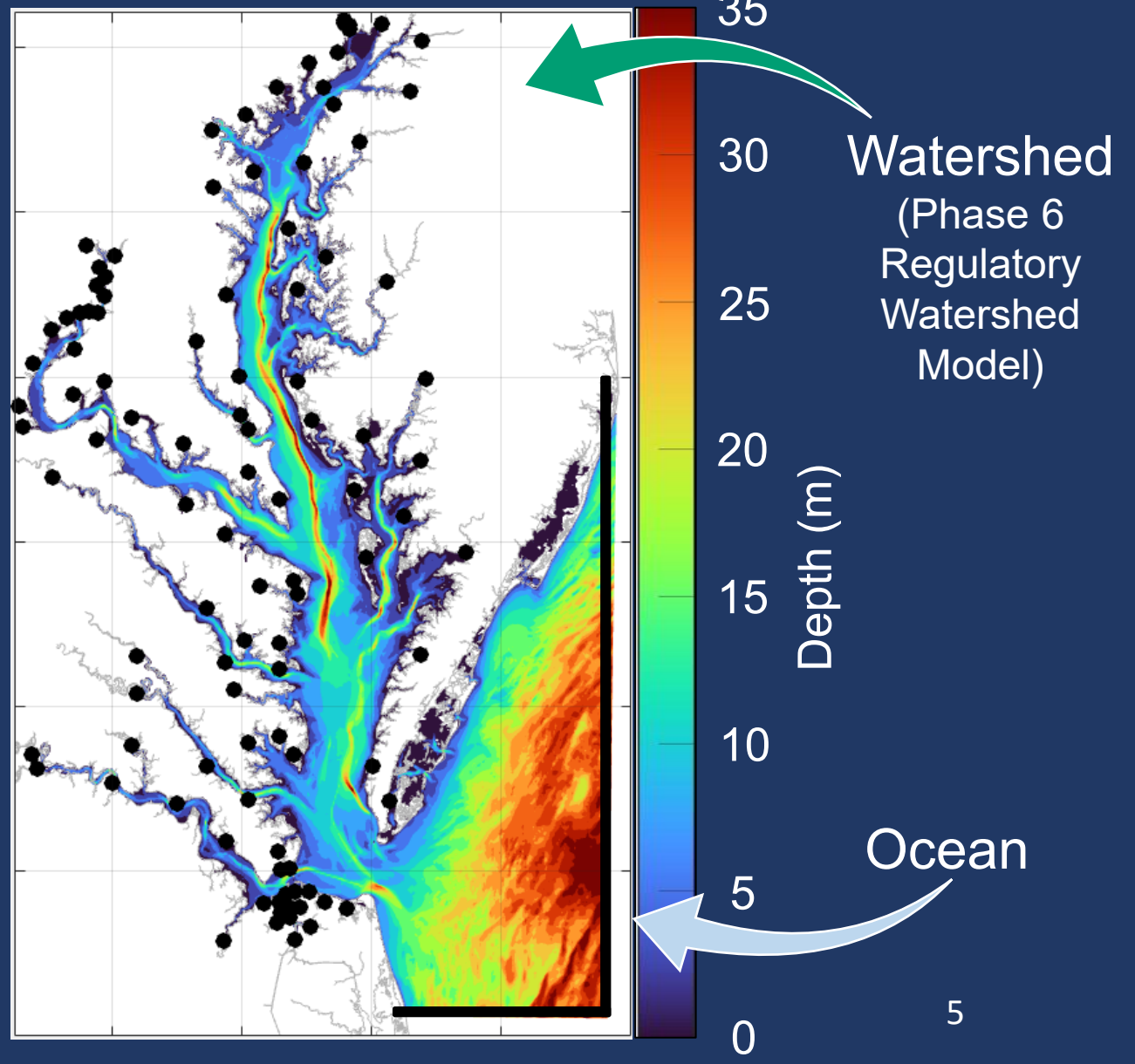
$if\ Growth(T, S, O_2) < 0$
Unsuitable habitat

$if\ Growth(T, S, O_2) > 0$
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



ROMS-ECB 1990s baseline and 2070s future runs

Simulation Name - Marshmallow Scale	Climate	Watershed Inputs
Control	• 1990s	1990s
Golden	• Coolest ESM (2070s) • Lower Emissions	1990s*
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* Future climate experiments do not include changes over the watershed, yet. These will be shown in later slides

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TMDL	• 1990s	All planned nutrient reductions implemented per Chesapeake Bay Total Maximum Daily Load (TMDL)

* Future climate experiments do not include changes over the watershed, yet. These will be shown in later slides

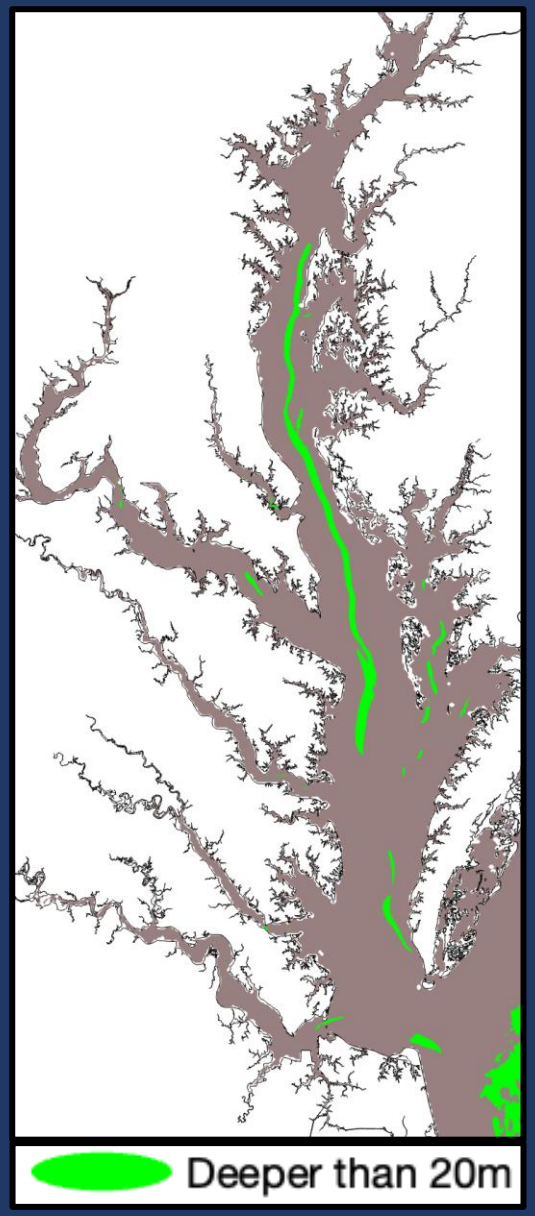
Atlantic Croaker can occupy the whole Bay, not just shallows

Capture Depths Report 9/11/25

Juvenile Atlantic Croaker	Juvenile Striped Bass
Annual median depths: 7.7 to 9.5 meters	Annual median depths: 5.0 to 9.0 meters
Depth threshold: **20 meters**	Depth threshold: **18 meters**

Depth report by Aileen H. McDonald and Mary Fabrizio

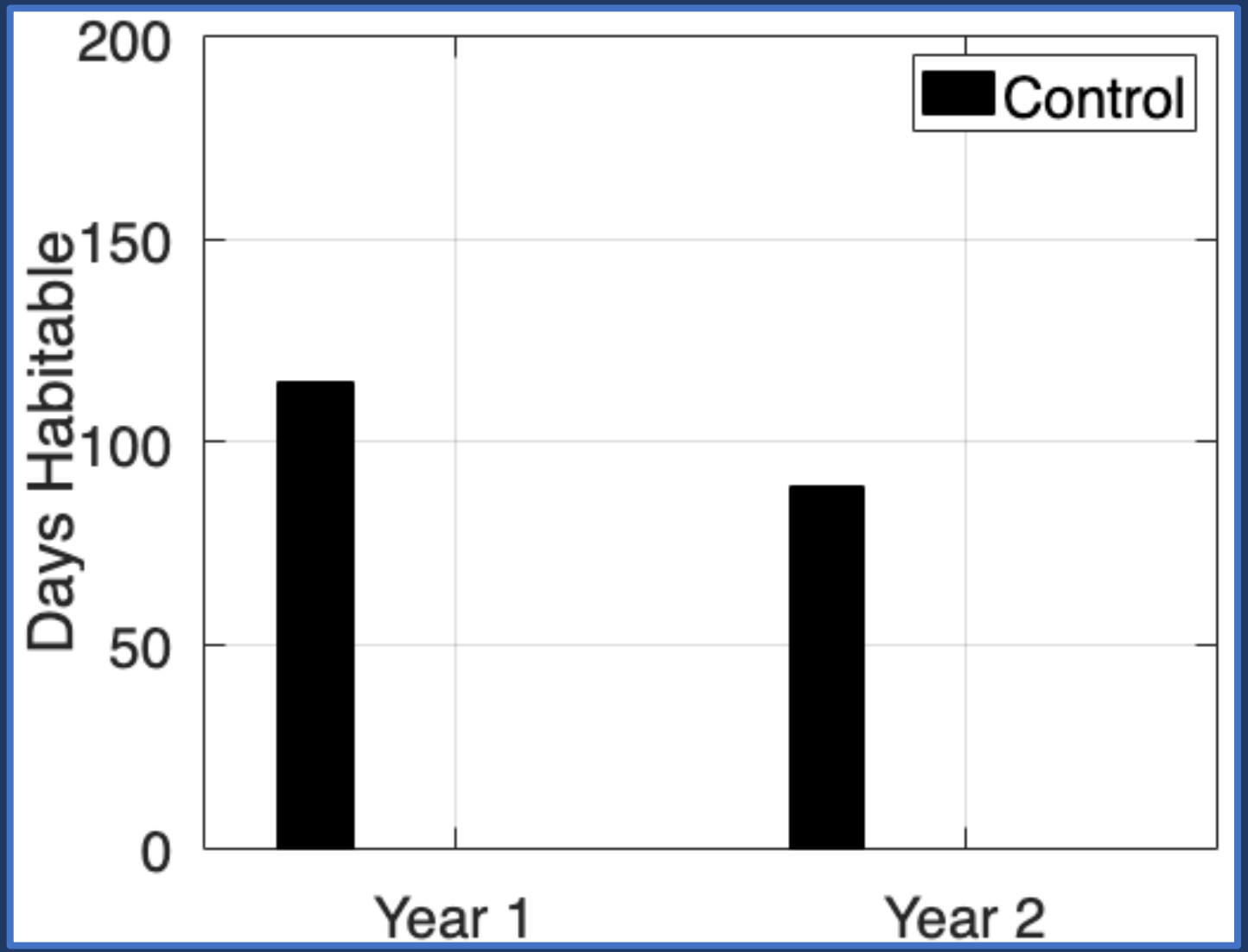
- Our analysis considers the entire Chesapeake Bay, not just shallow regions
- Analysis of depths from a dataset of captures for Atlantic Croaker show that they are caught at depths of up to 20 m
- Given how small the bottom area of Bay deeper than 20 m is, we analyze the full Bay bottom area



Atlantic Croaker can spend only part of the year in the Bay

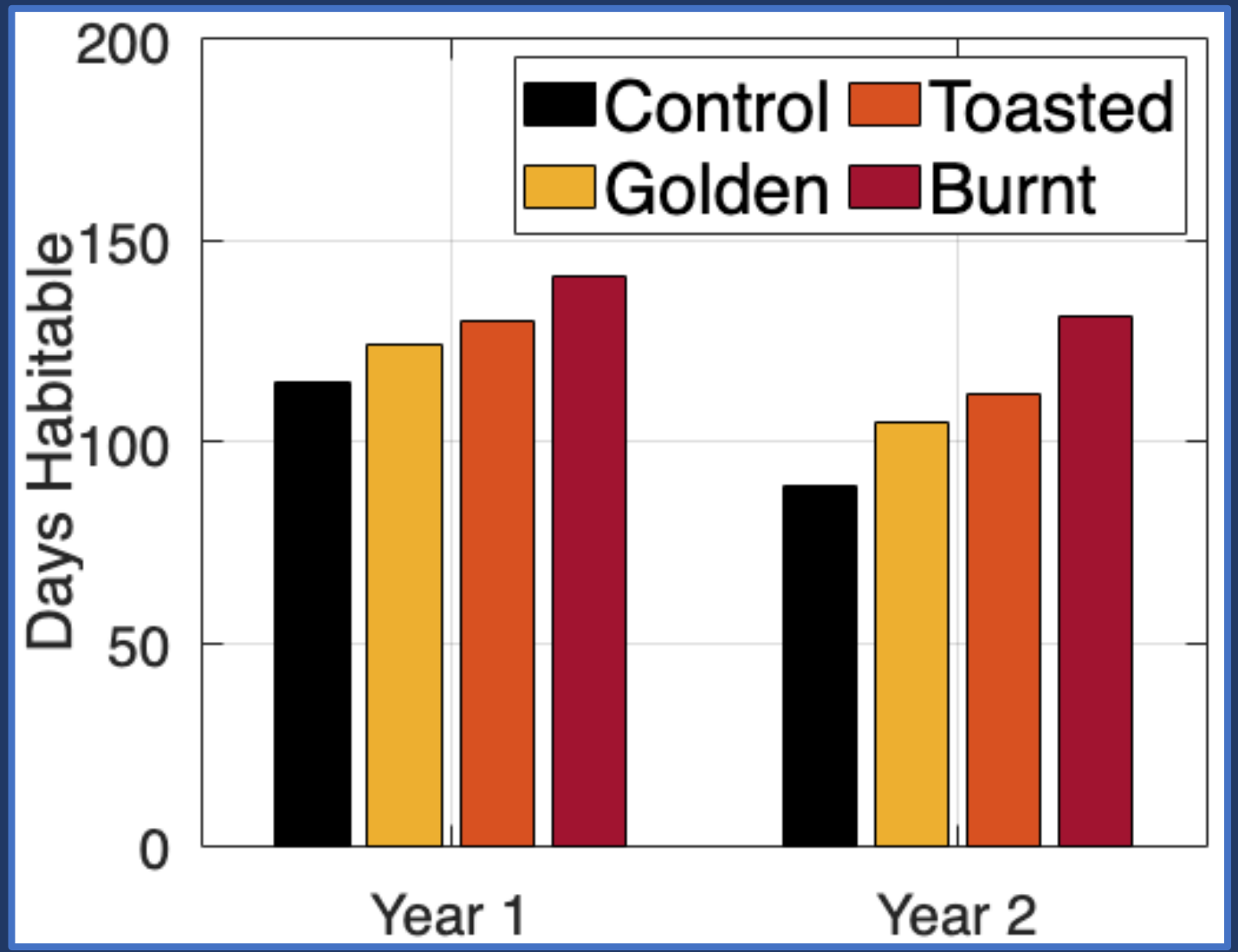
- Days habitable defined as days with > 50% of the Bay's bottom area projecting Growth > 0

- This can vary from year to year by up to a month



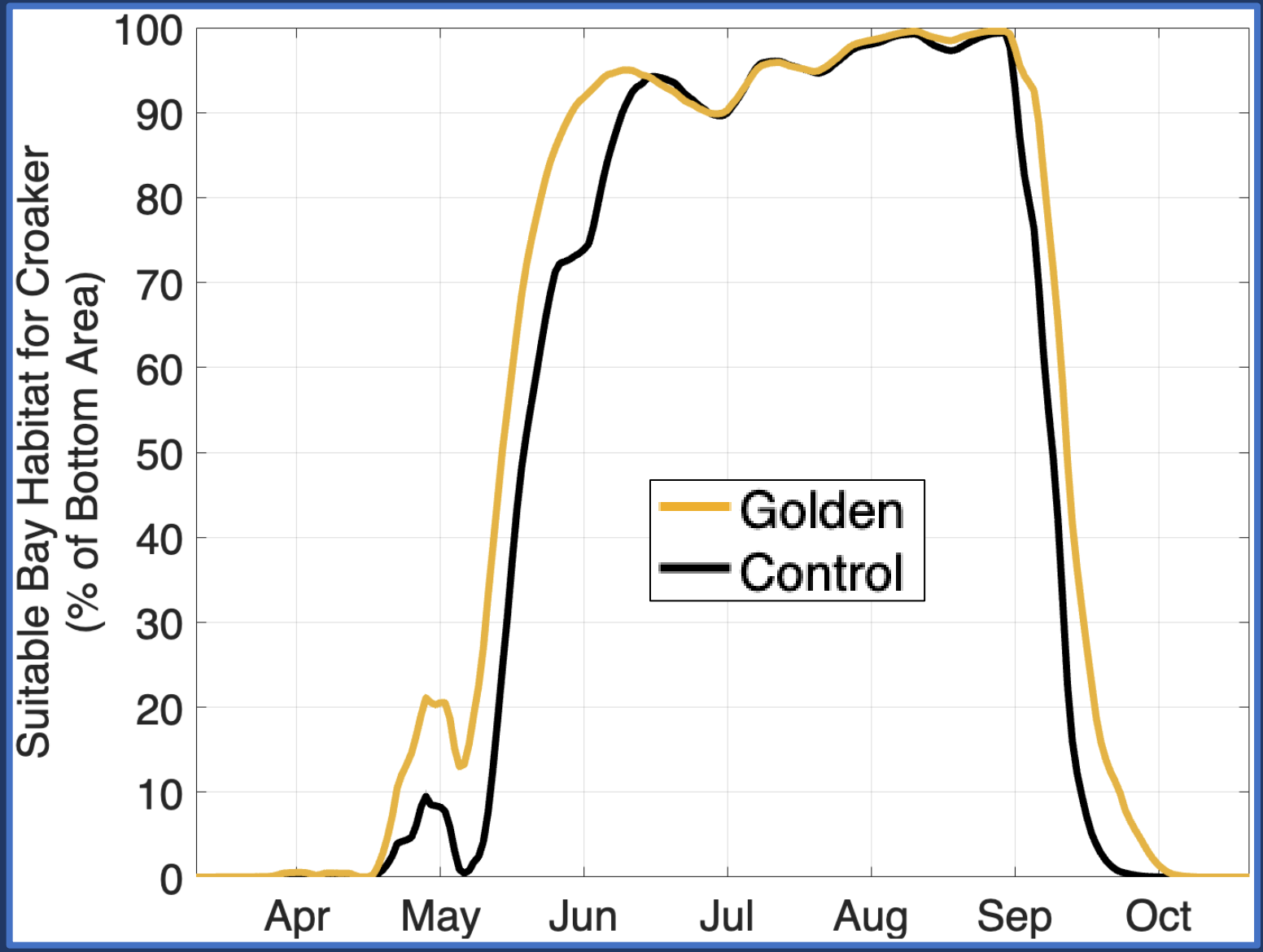
Warming increases the # days suitable for Croaker growth

- Days habitable defined as days with > 50% of the Bay's bottom area projecting Growth > 0
- Croaker is a climate winner, in each future projection warming increases the days habitable (~3 weeks)
- Choice of ESM and choice of emissions scenario are equally impactful to days habitable (~1-6 weeks)



Warming causes habitability to start earlier and end later

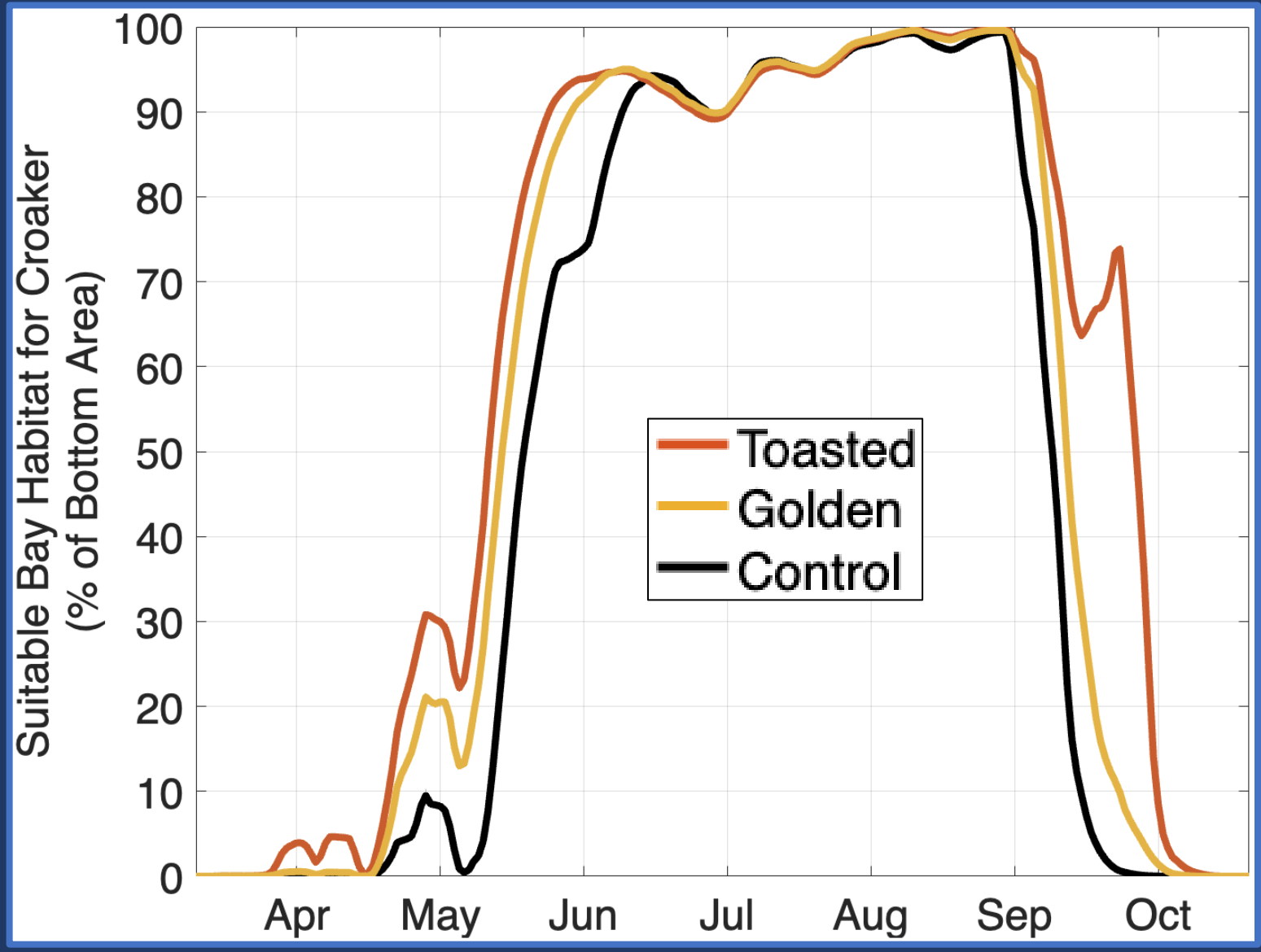
- Climate change increases duration of suitable habitat in the Bay, due to warmer temperatures in both spring and fall



Choice of ESM and emissions are equally important

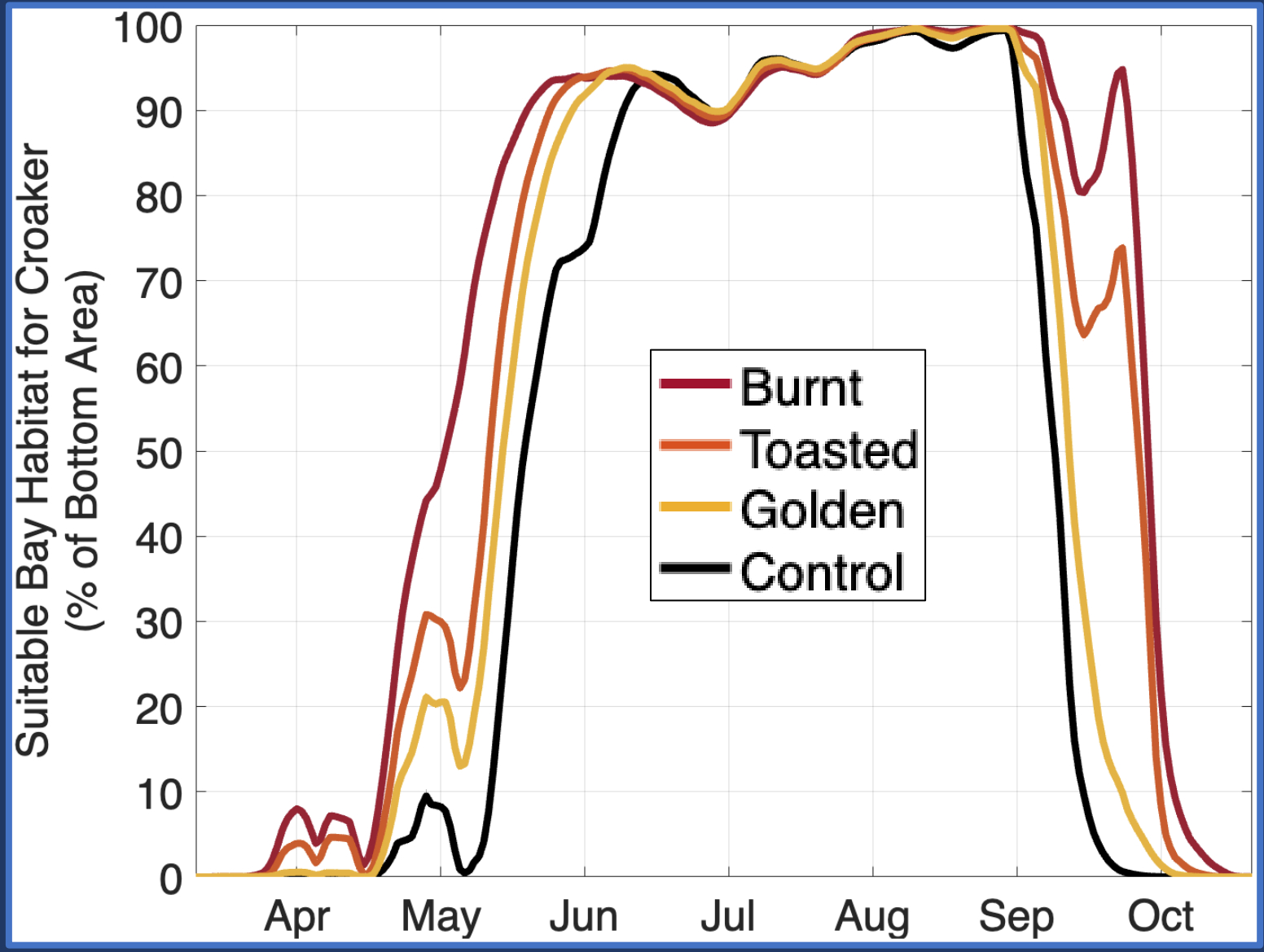
- Climate change increases duration of suitable habitat in the Bay, due to warmer temperatures in both spring and fall

- With a slightly warmer ESM, Croaker's habitable window is longer (~3 weeks)



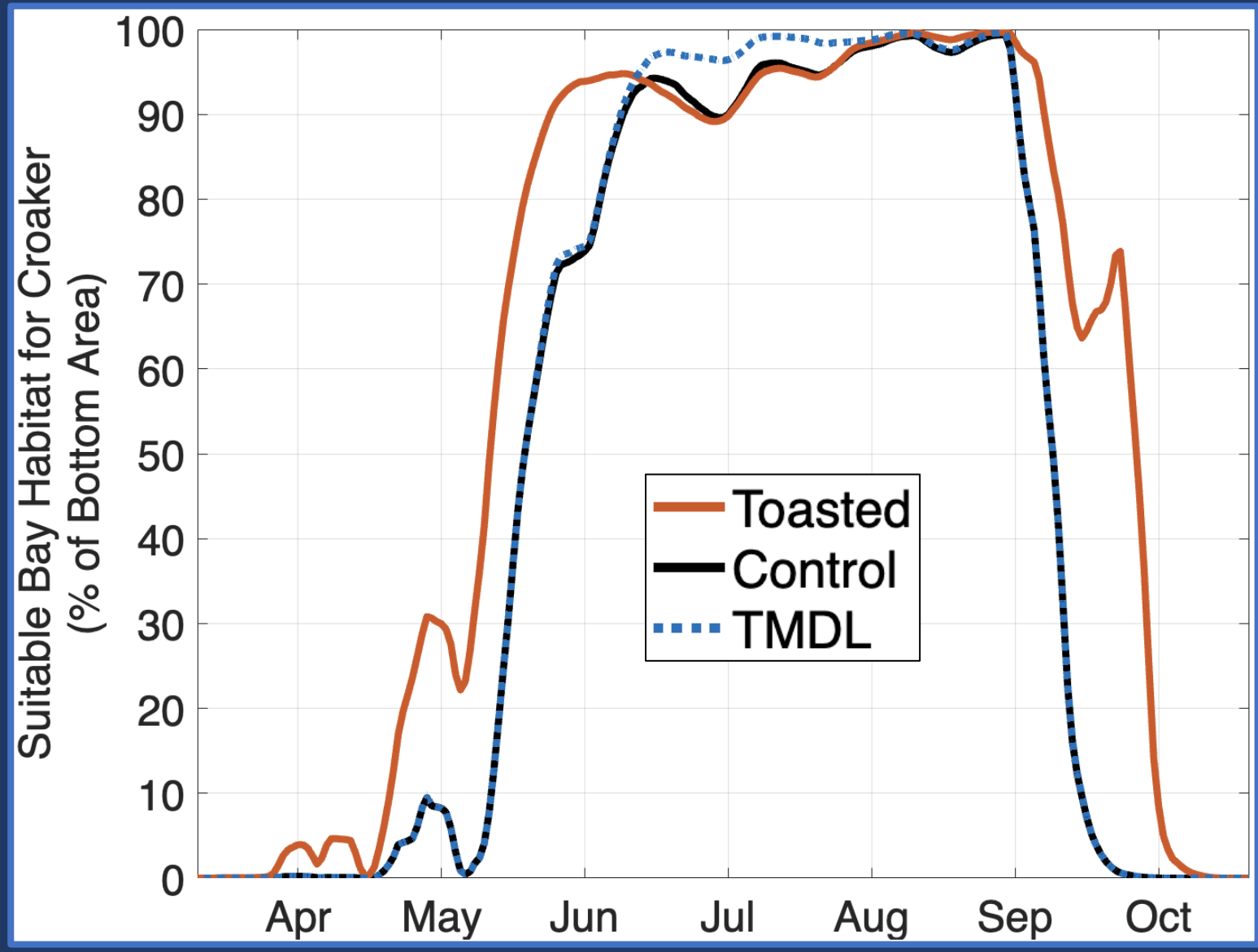
Choice of ESM and emissions are equally important

- Climate change increases duration of suitable habitat in the Bay, due to warmer temperatures in both spring and fall
- With a slightly warmer ESM, Croaker's habitable window is longer (~3 weeks)
- With more emissions, the window is even longer (~5-6 weeks)



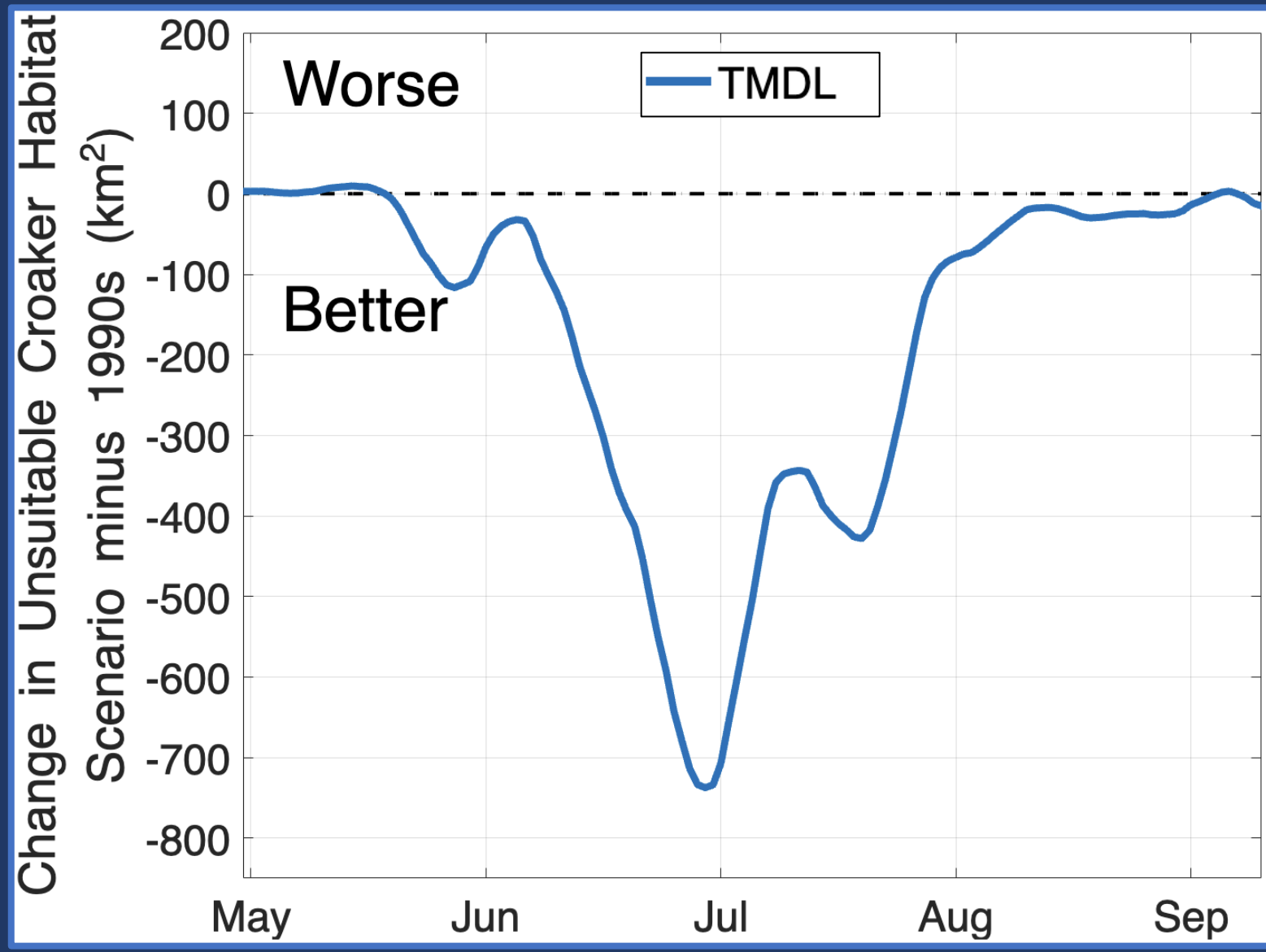
Nutrient load reductions improve summer conditions

- While nutrient reductions would not impact duration, they would improve summer conditions, via improved bottom O_2
- Meanwhile, warming would slightly decrease summer suitable area, via decreased bottom O_2



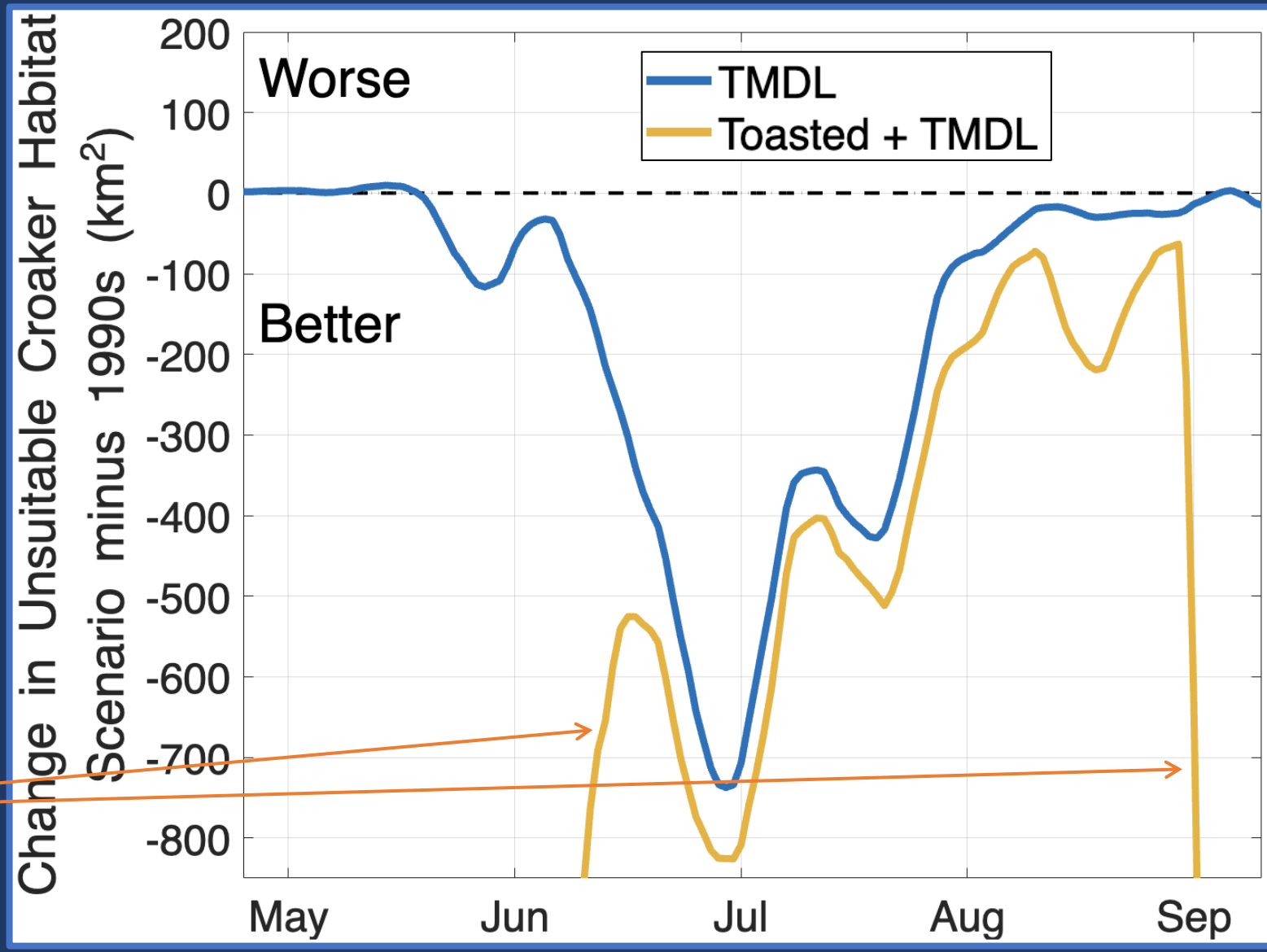
TMDL + Climate Change further reduces summertime unsuitable habitat

- *TMDL reduces unsuitable habitat* area (by as much as 700 km^2 or 11.8 Manhattans)



TMDL + Climate Change further reduces summertime unsuitable habitat

- *TMDL reduces unsuitable habitat* area (by as much as 700 km^2 or 11.8 Manhattans)
- *TMDL + warming reduces unsuitable habitat* area *in summer* by an additional ~100 km^2 than TMDL alone



These descending tails show the increased suitable habitat duration due to temperature and do not reflect impacts of O_2 changes

Conclusions

Climate change:

- Could allow for longer durations (~3 weeks), in the 2070s compared to the 1990s, of suitable Croaker habitat within the Bay

Uncertainties:

- Choice of both ESM & emissions have large impact on duration of Croaker habitat (1-6 weeks)

Nutrient Reductions:

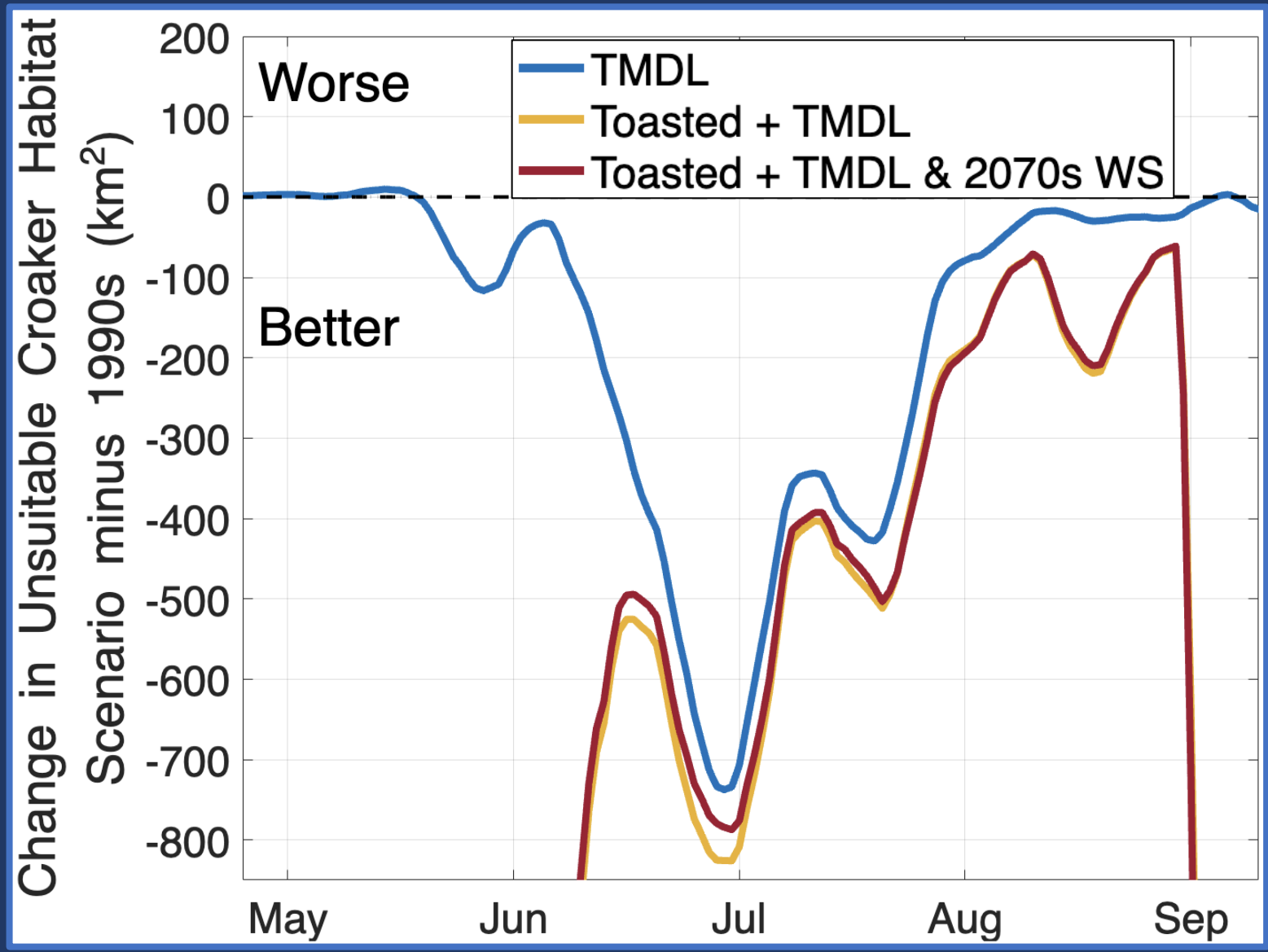
- Reduces unsuitable Chesapeake Bay bottom area for Croaker, by as much as 700 km^2 or 11.8 Manhattans, from 1990s conditions

Combination of climate change and nutrient reductions:

- With nutrient reductions climate change can reduce unsuitable Chesapeake Bay summertime bottom area for Croaker by an additional 100 km^2

Impact of climate change over the watershed is small

- *TMDL reduces unsuitable habitat* area (by as much as 700 km^2 or 11.8 Manhattans)
- *TMDL + warming reduces unsuitable habitat* area *in summer* by an additional ~100 km^2 than TMDL alone
- Climate change, just over the watershed, increases nutrient loading very slightly, thus increases unsuitable habitat



Future Work

Longer experiments:

- Results today only included two years of similar hydrologic conditions
- Longer experiments (10 years) will allow analysis of interannual (wet/dry) variability

Six future climate scenarios:

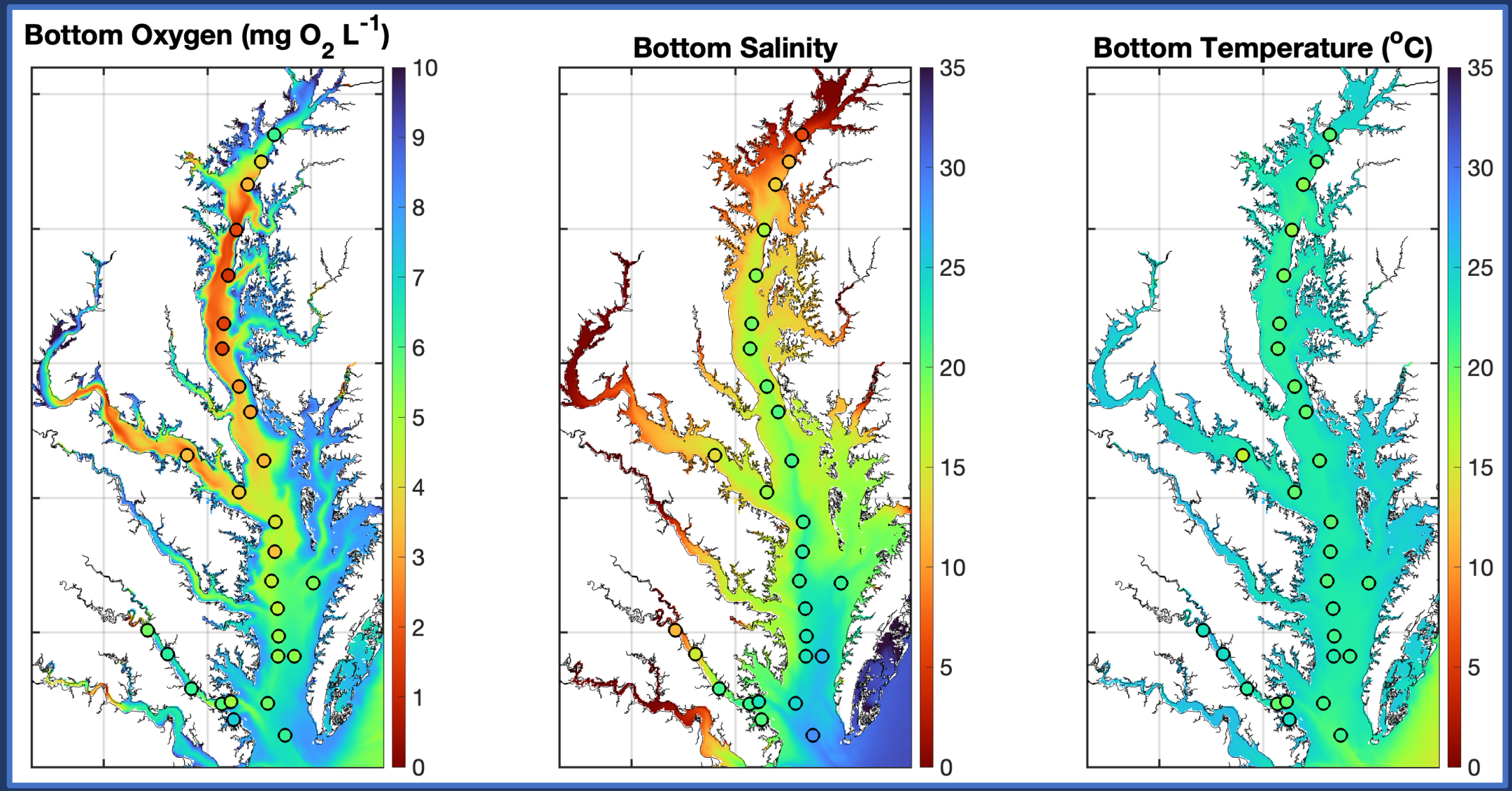
- Final experiments will include all six combinations of three ESMs and two SPPs

Additional habitat suitability models:

- While Croaker is an important species, it is the first of five species that our group has constructed physiologically-based models for

Extra Slides

Model Skill: Temperature, Salinity and Oxygen



Averaged 1991 & 1992, May – September

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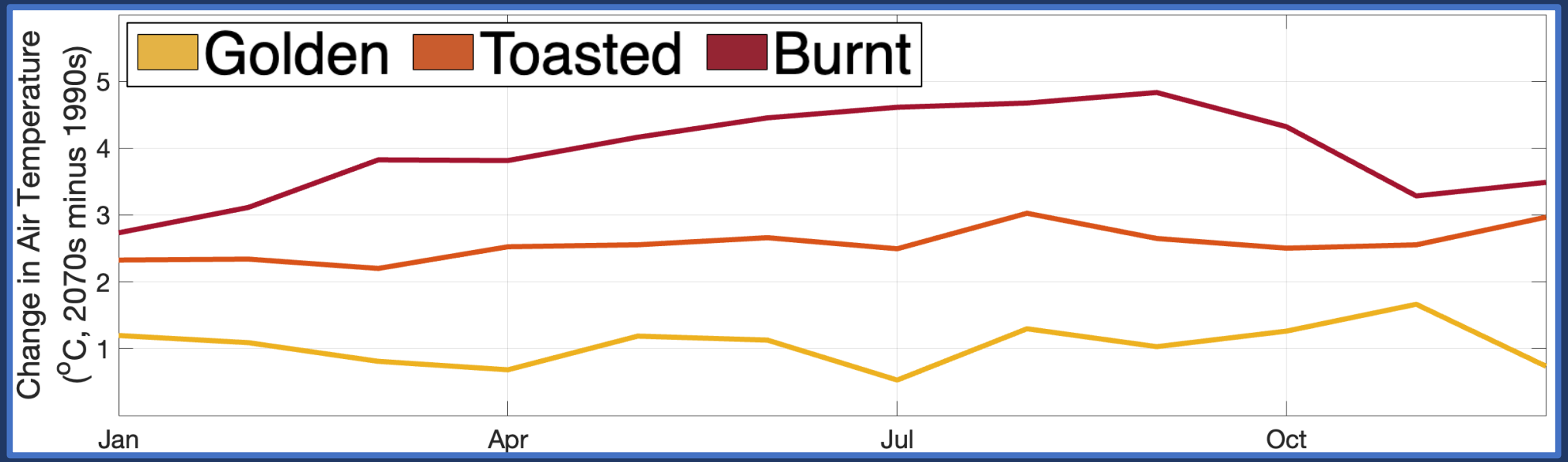

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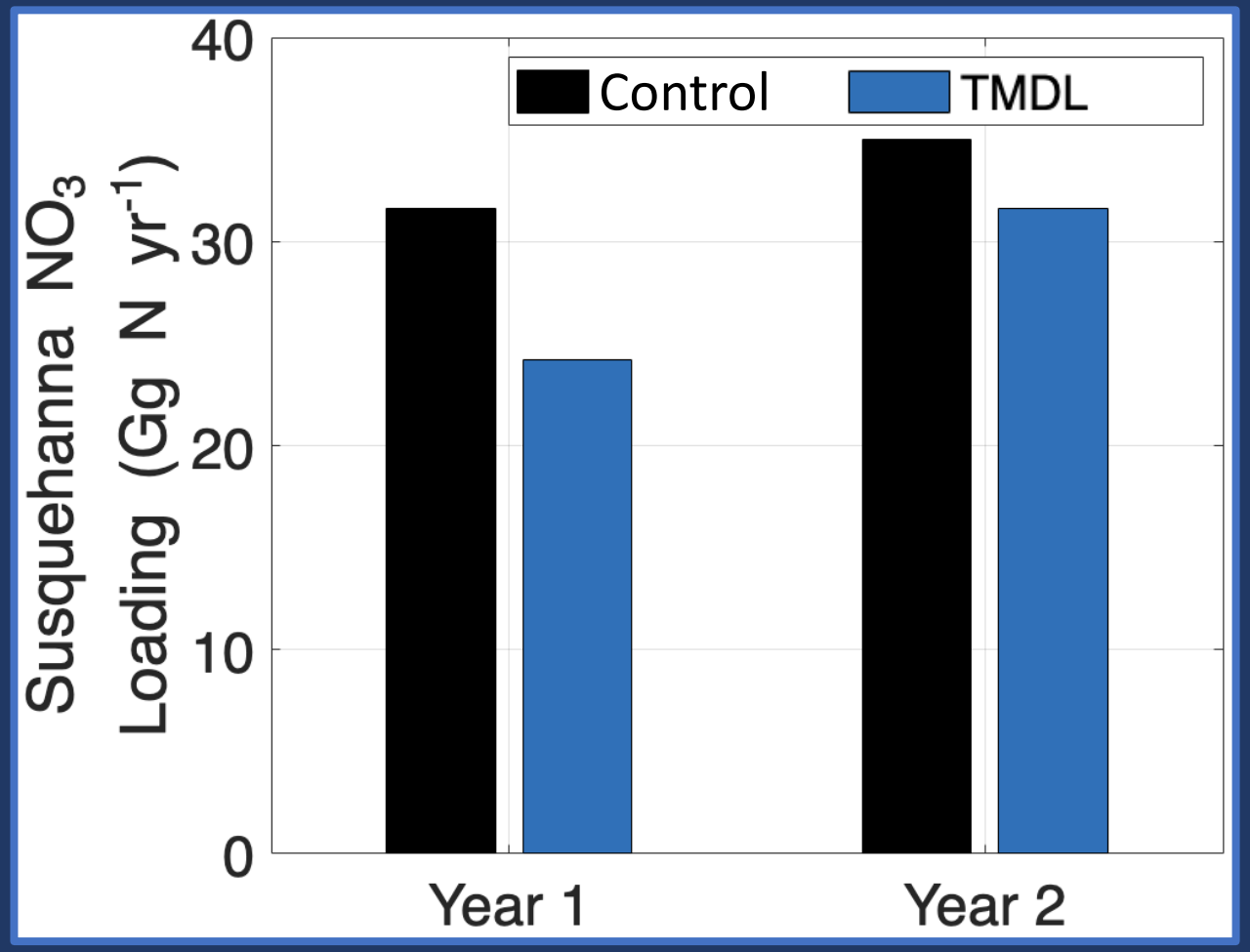
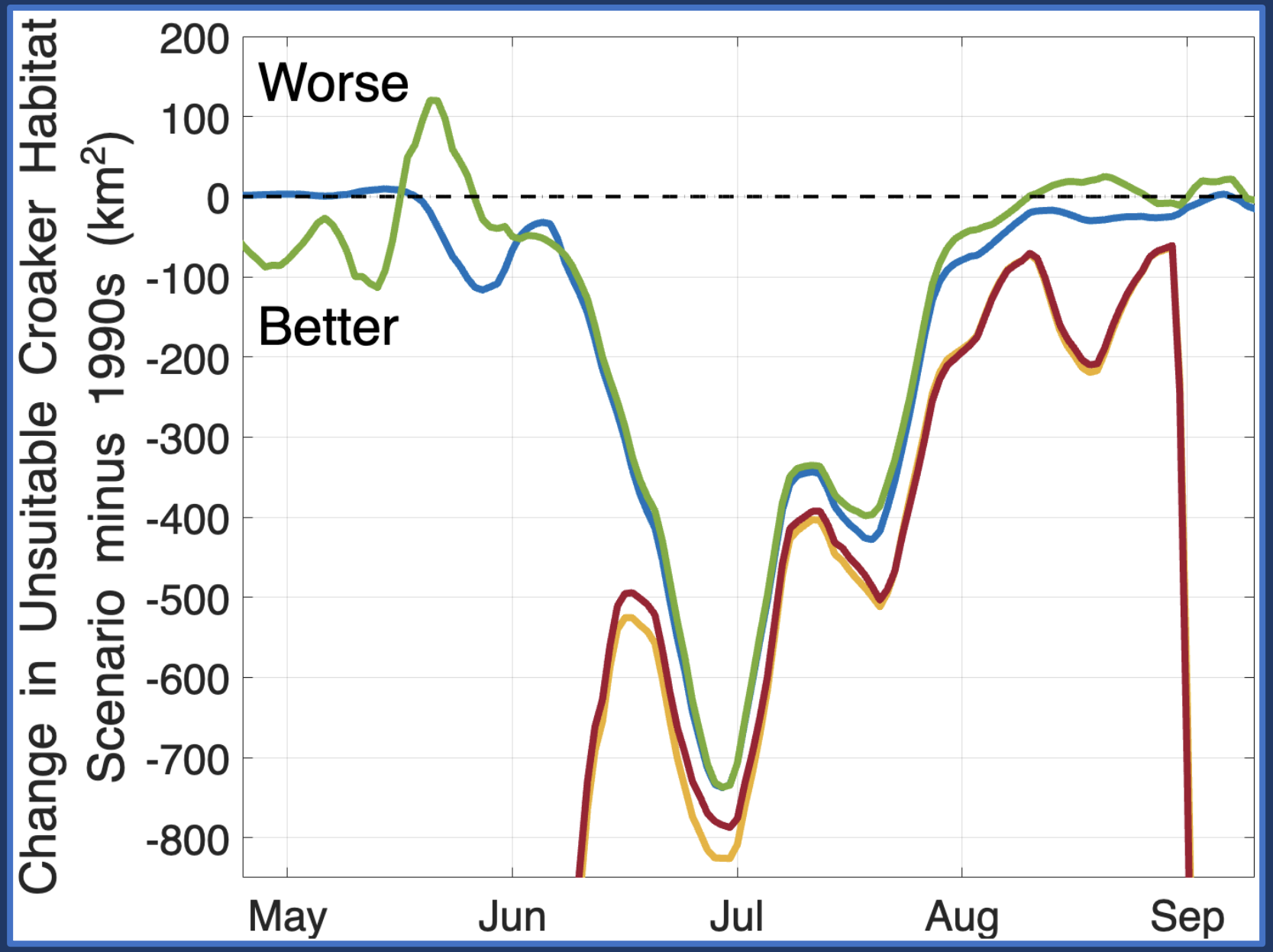
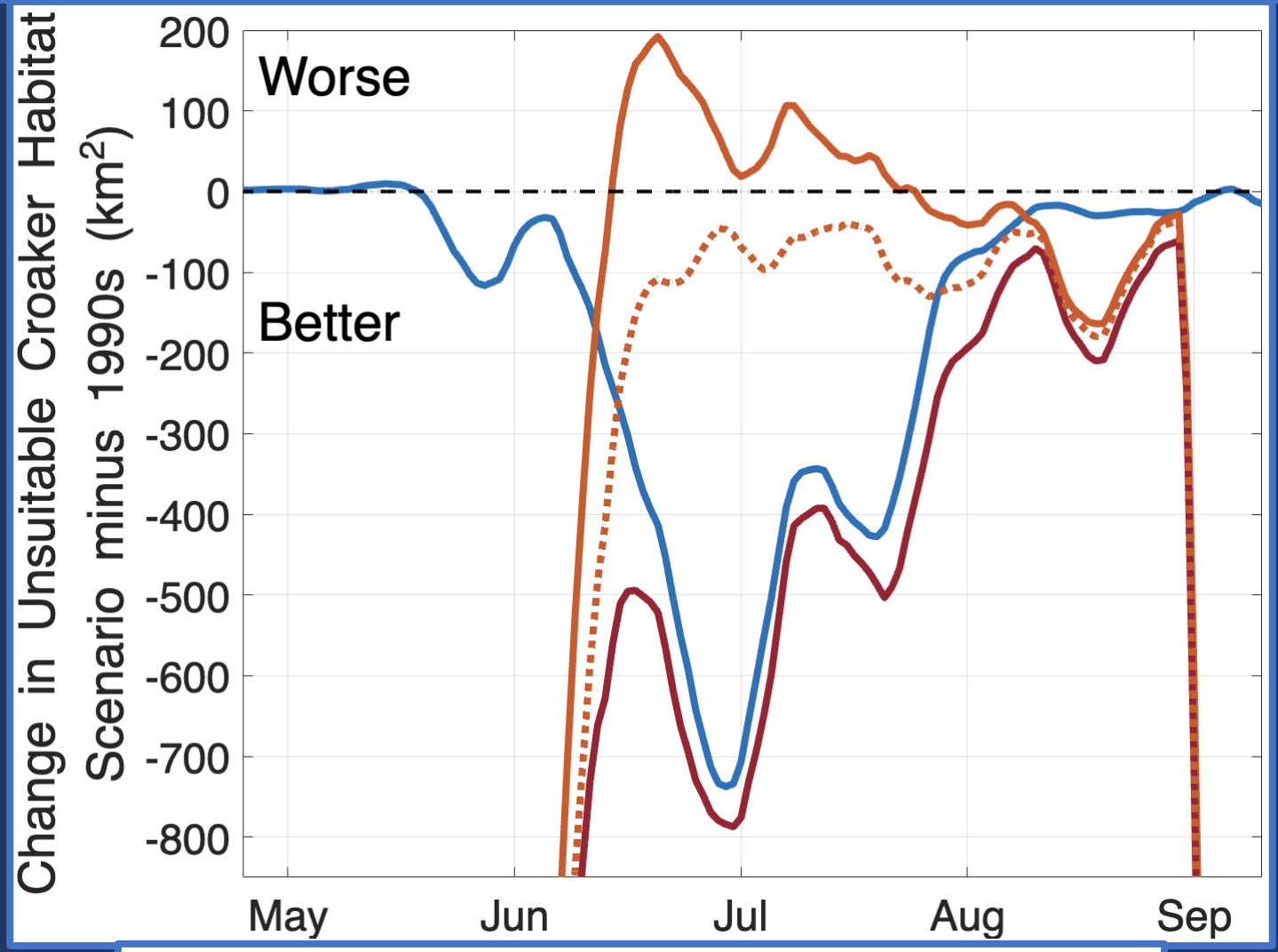


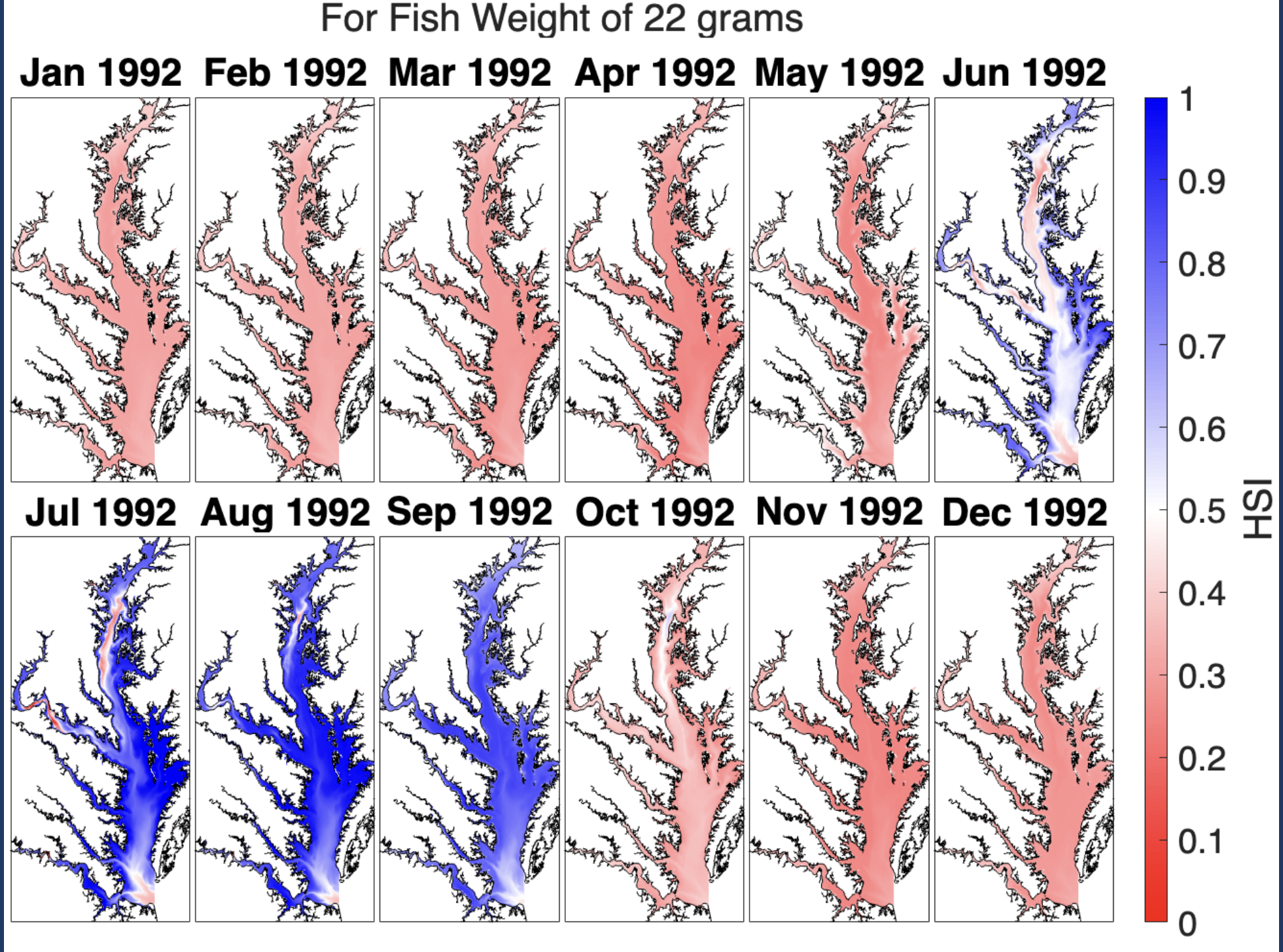
Impact of climate change over the watershed is small



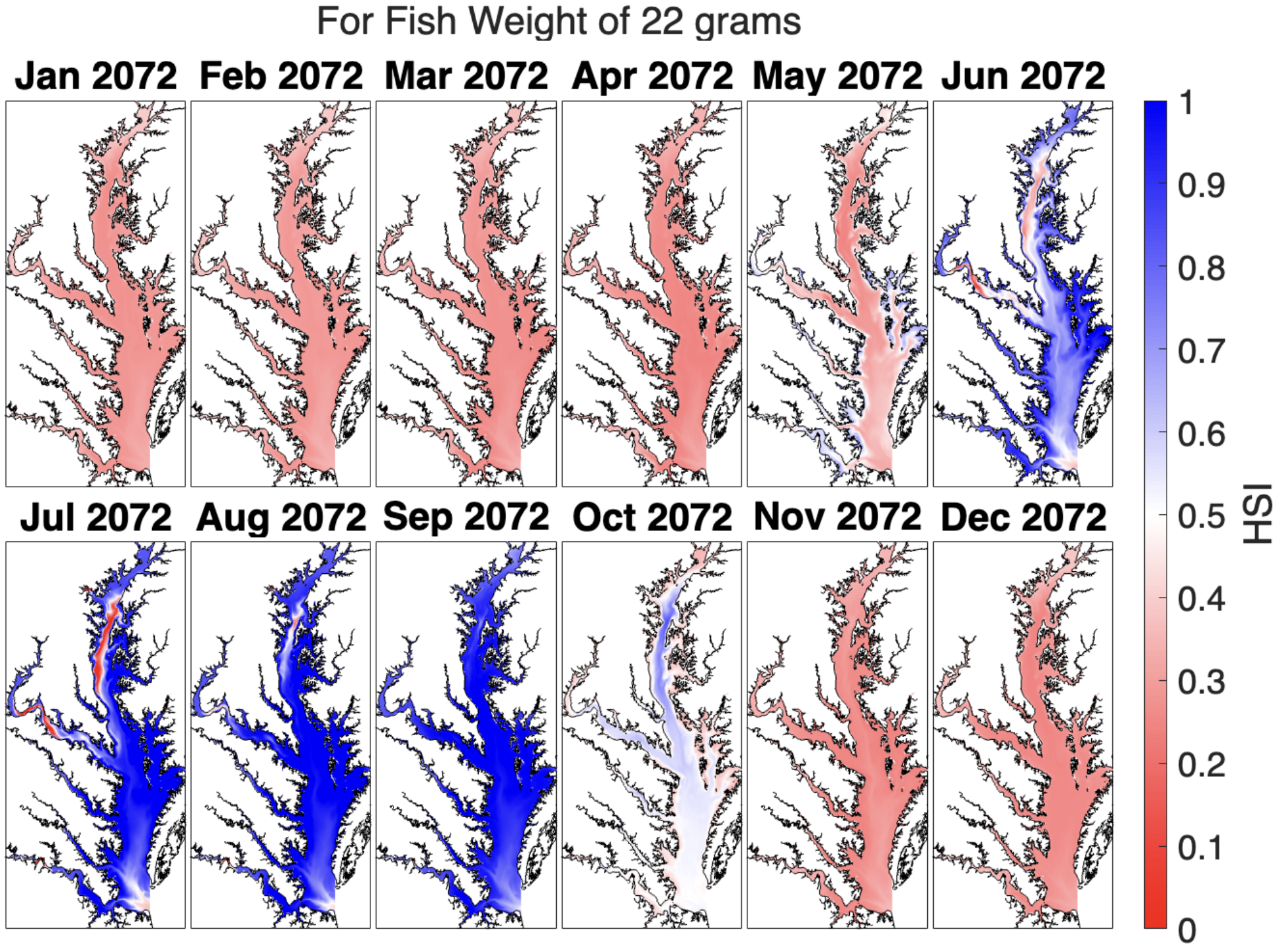
Impact of climate change is dependent on TMDL



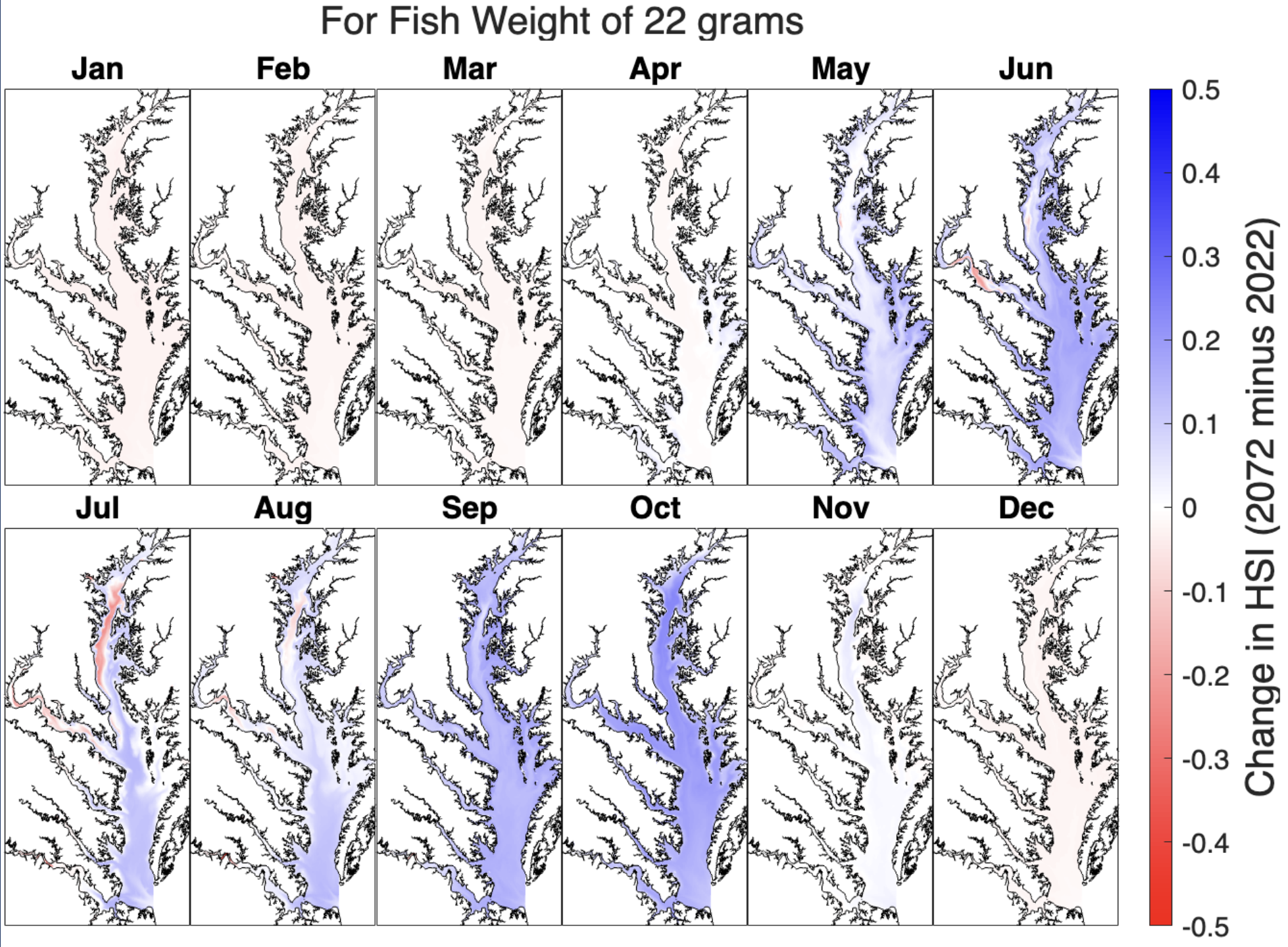
Control Run


For Fish Weight of 22 grams
Jan 1992
Feb 1992
Mar 1992
Apr 1992
May 1992
Jun 1992
Jul 1992
Aug 1992
Sep 1992
Oct 1992
Nov 1992
Dec 1992
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
HSI

Toasted Run


For Fish Weight of 22 grams
Jan 2072
Feb 2072
Mar 2072
Apr 2072
May 2072
Jun 2072
Jul 2072
Aug 2072
Sep 2072
Oct 2072
Nov 2072
Dec 2072
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
HSI

Toasted minus Control



HSI < 0.5 w/ warming
HSI > 0.5 w/ warming
HSI < 0.5 in both
HSI > 0.5 in both

Toasted minus Control