Climate Change and the Ecology of Chesapeake Bay and Oceanside

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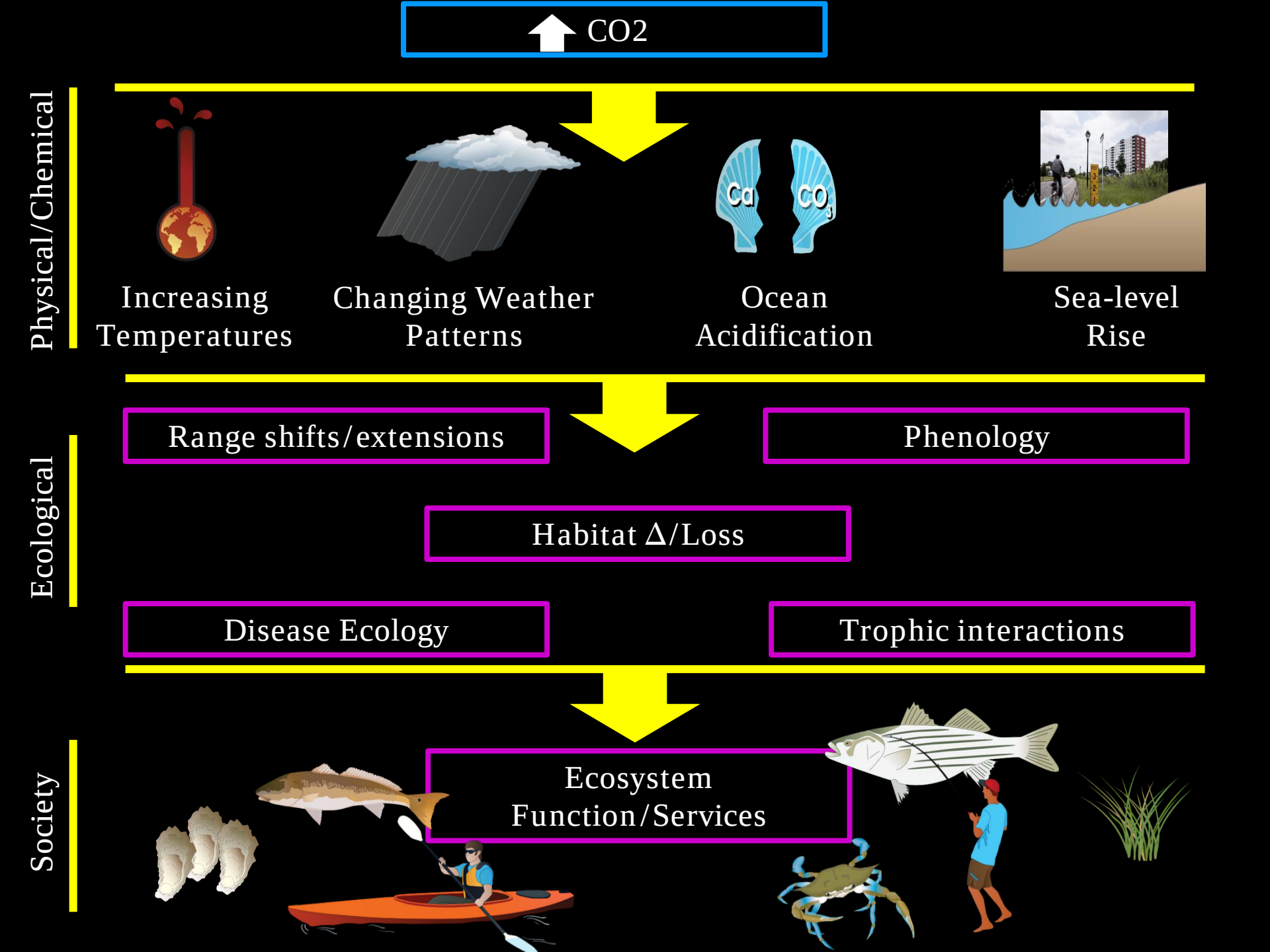
CO2
Physical/Chemical
Increasing Temperatures
Changing Weather Patterns
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Ecological
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Habitat Δ/Loss
Disease Ecology
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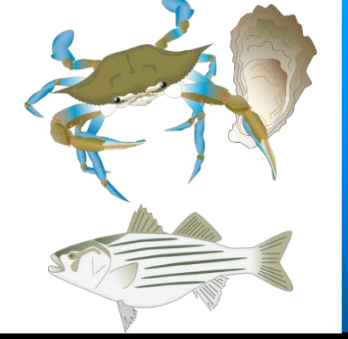
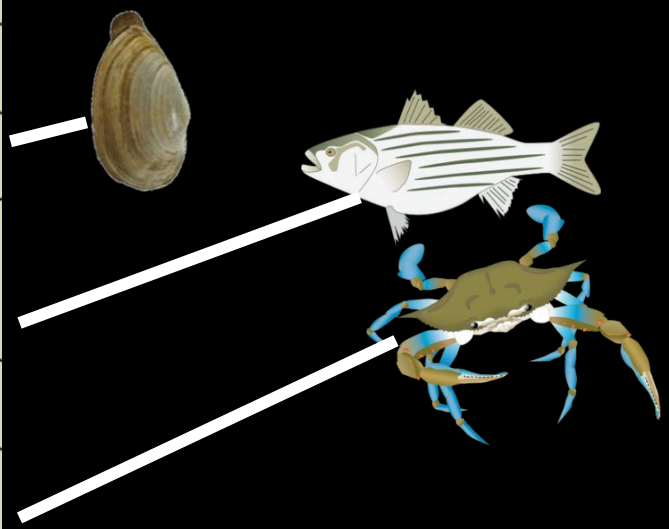


Prognostication

SPECIES	LIKELY TREND	CLIMATE CHANGE IMPACTS IN CHESAPEAKE BAY
Winter flounder	●	Water temperatures could exceed habitable range.
Soft-shelled clam	●	Water temperatures could exceed habitable range.
Rockfish	●	Water temperatures could reach near the upper limit of habitable range and also conducive to outbreaks of mycobacterial infections.
Atlantic sturgeon	●	Water temperatures could reach near the upper limit of habitable range.
Blue crab	●	Declining eelgrass habitat with rising sea level and exacerbated eutrophi-cation.
Atlantic menhaden	●	Warmer water more conducive to mycobacterial infections.
Eastern oyster	●	Warmer water more conducive to Dermo and MSX.
Brown shrimp	●	Warmer water more favorable.
Southern flounder	●	Warmer water more favorable.
Black drum	●	Warmer water more favorable.
Grouper	●	Warmer water more favorable.
Spotted seatrout	●	Warmer water more favorable.



Climate change will likely have negative effects for cooler-water species and positive effects for more southern, warmer water species. We are already seeing this in the Bay. For instance, trawl surveys report increasing frequency of brown shrimp.

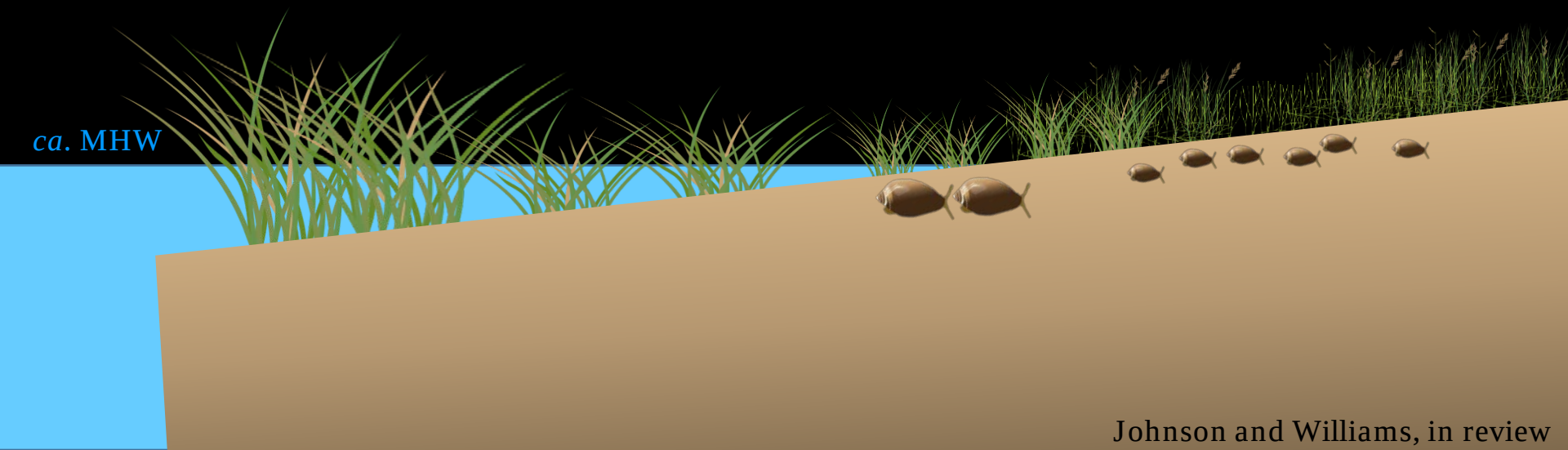
Glick et al. 2007 – National Wildlife Federation

While many studies focus on commercially important species, it is important to consider impacts on other species as well. For instance, the coffee-bean snail, *Melampus bidentatus*, is a common snail found in marshes from Nova Scotia to Florida to east Texas. It can be 50-70% of the total standing stock biomass of benthic invertebrates. That's a lot of biomass and potential prey energy that may be affected by climate change, specifically, sea-level rise.

Johnson 2011 - *Marine Ecology Progress Series*

Sea-level rise

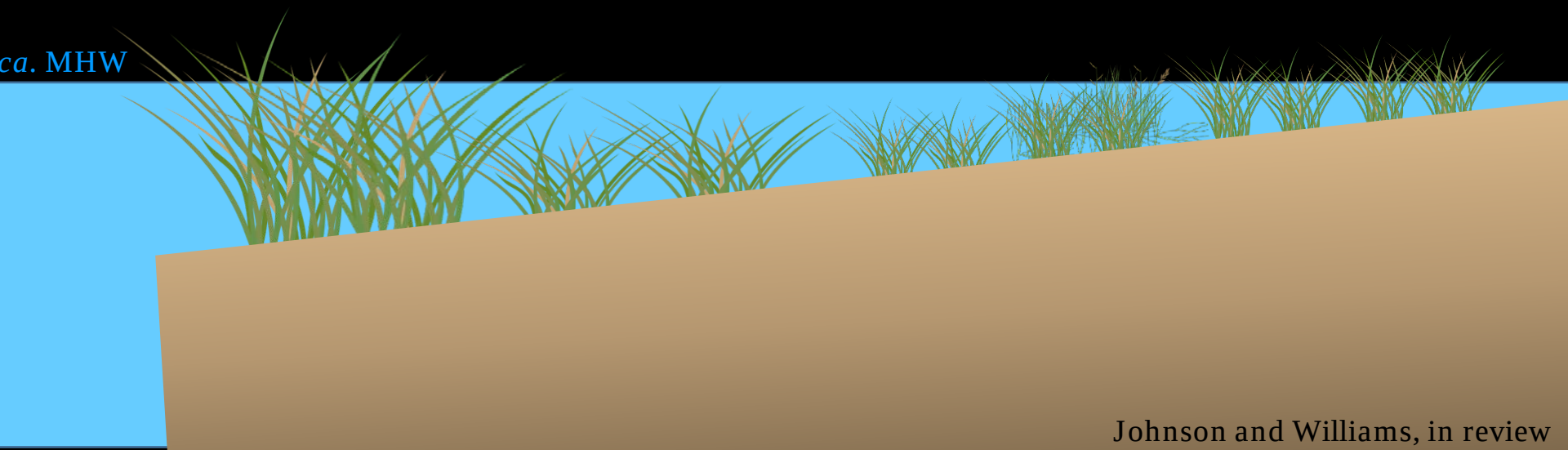
Salt marshes have distinct zonation patterns with flood tolerant species such as *Spartina alterniflora* in the low marsh and flood-intolerant species such as *S. patens* restricted to the high marsh. My lab has found that there is a clear pattern in coffee-bean snails, with juveniles restricted to high-marsh habitats. Our transplant studies show that juveniles experience significant mortality outside of the high marsh habitats, suggesting that the high-marsh is critical for persistence of this species.



Johnson and Williams, in review

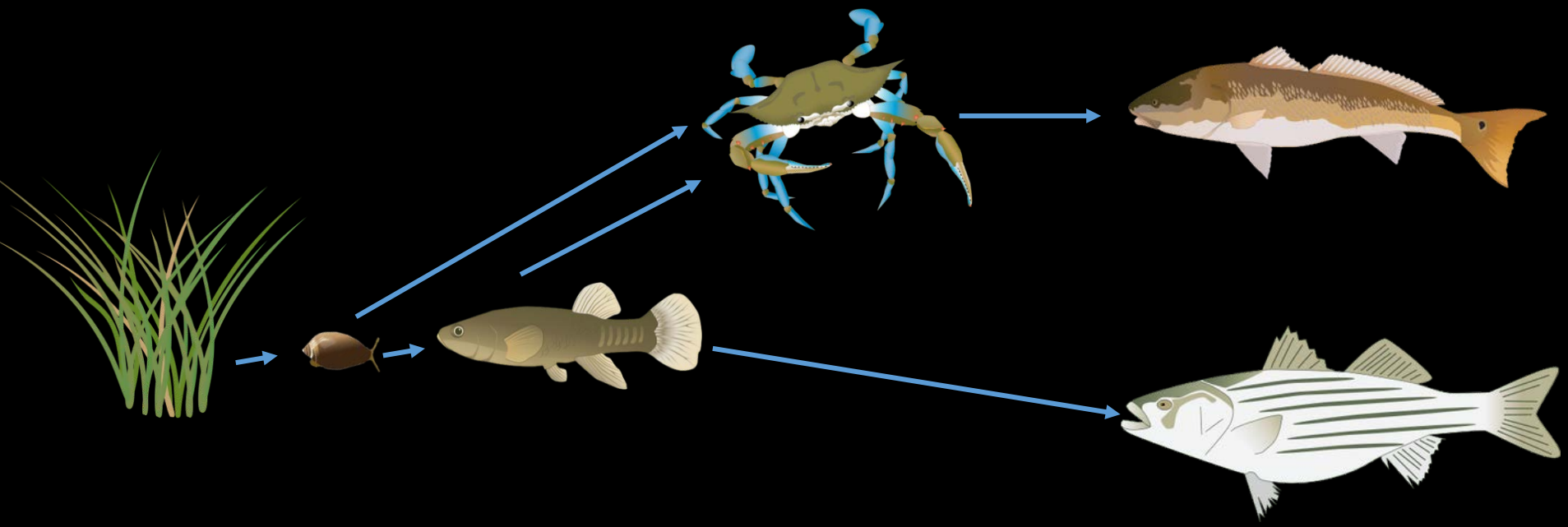
Sea-level rise

As sea-level rises, the prediction is that the high marsh will be displaced by flood tolerant species. Complete loss of the high marsh may result in local extinction of this abundant snail and other species that rely on this habitat.



Johnson and Williams, in review

No Wetlands, No Seafood



While the redfish and the rockfish may not directly consume the coffee-bean snail, the snail does represent an important link between salt marsh production and the production of these fishes. Thus, the loss of this snail and other prey species associated with the high marsh may lead to negative impacts on higher trophic levels (e.g., redfish).

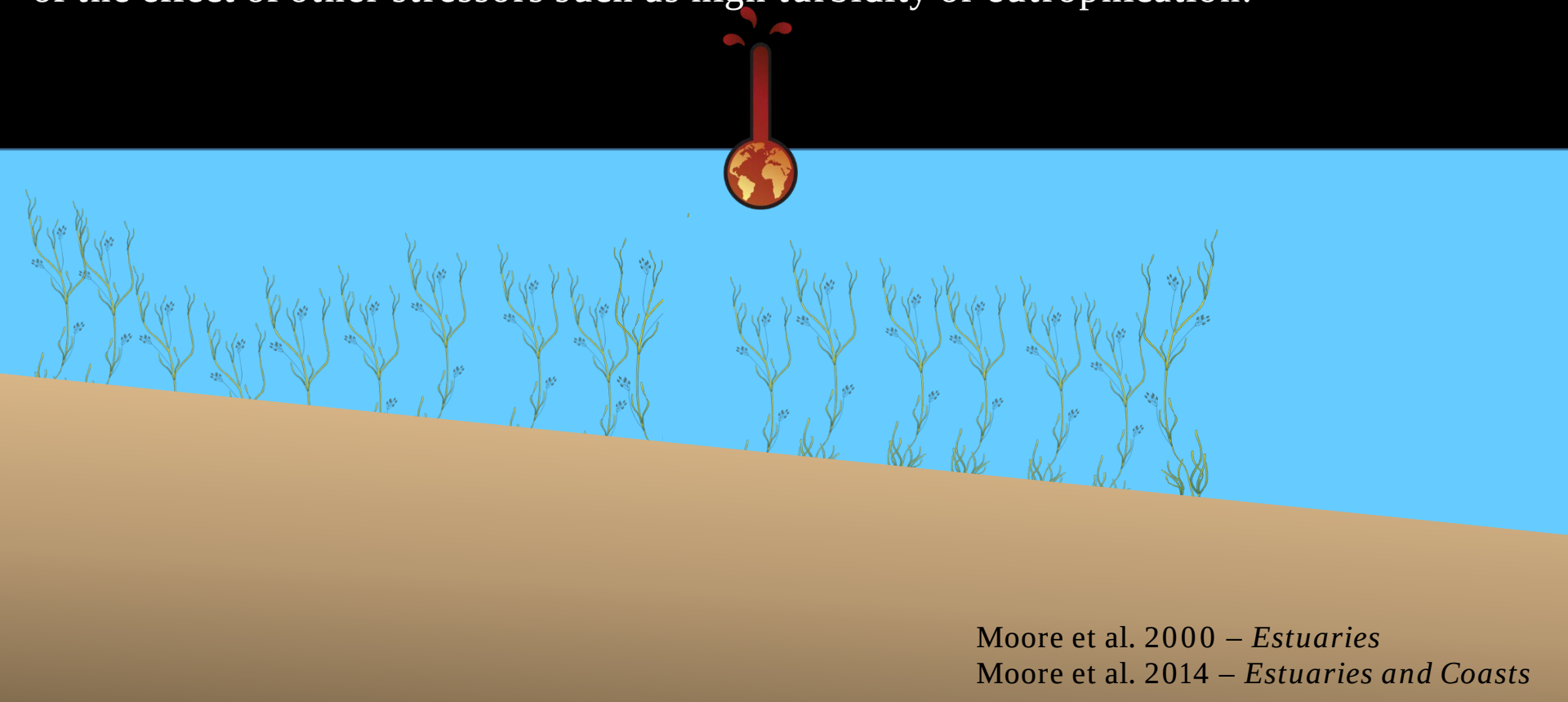
Submerged aquatic vegetation

Moving to the subtidal, we have two main seagrass species, with widgeongrass (*Ruppia*) in shallower water and eelgrass (*Zostera*) in deeper water.

Moore et al. 2000 – *Estuaries*
Moore et al. 2014 – *Estuaries and Coasts*

Submerged aquatic vegetation

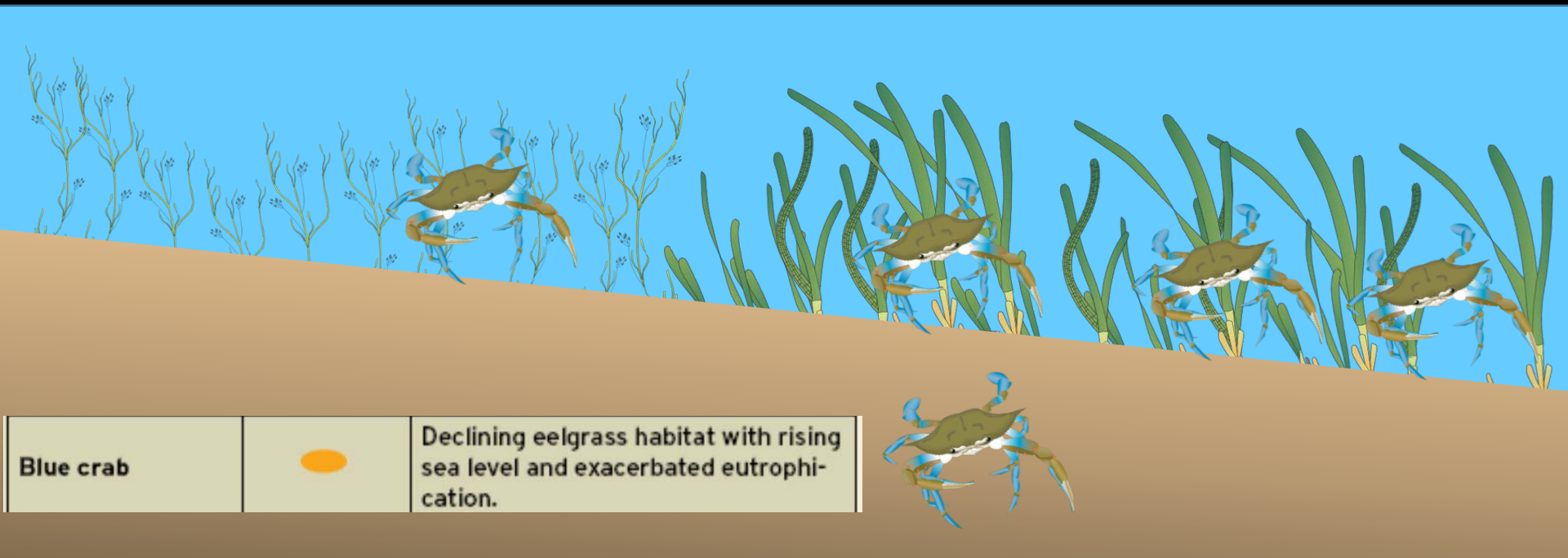
Temperature increases have been shown to lead to eelgrass loss; which can then be replaced by widgeon grass (to a certain depth). This is temperature effect is independent of the effect of other stressors such as high turbidity or eutrophication.



Moore et al. 2000 – *Estuaries*
Moore et al. 2014 – *Estuaries and Coasts*

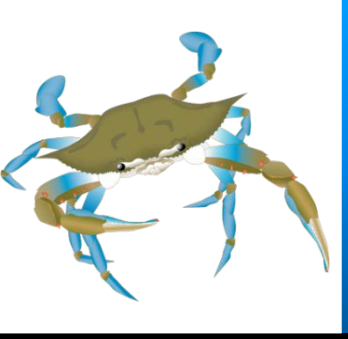
Can Ruppia grow crabs?

While we have success in restoring eelgrass on the eastern shore, it is likely in certain areas, particularly the lower Bay, we will lose eelgrass. As we do, how will the replacement habitat serve us? For example, is widgeongrass (*Ruppia*) a suitable habitat for blue crabs relative to eelgrass?



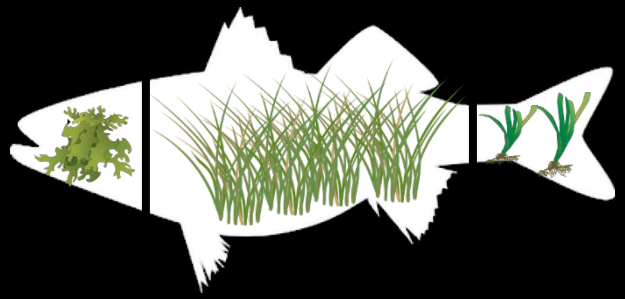
What is the ecological function of altered habitats?

More generally, we recognize that coastal habitats are changing whether you're in the Bay or Oceanside. The question is, how well will these changed habitats function or provide ecosystem services such as food provisioning, carbon storage, storm protection, or beauty?

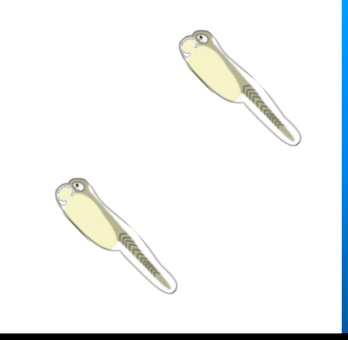


What plant is this crab?

Another critical question is to understand where animals are getting their energy. A crab may be found in the seagrass but some of its energy may have ultimately come from a salt marsh. But what percentage? We know that habitats such as salt marshes and seagrasses are critical to many species, but we don't know where these species are ultimately getting their energy or how much each habitat contributes. Because all of our carbon ultimately comes from a plant, we can use techniques such as stable isotopes to identify which habitats are critical to producing species of interests to help prioritize conservation efforts and to understanding how that energy relationship may change over time with changing habitats.

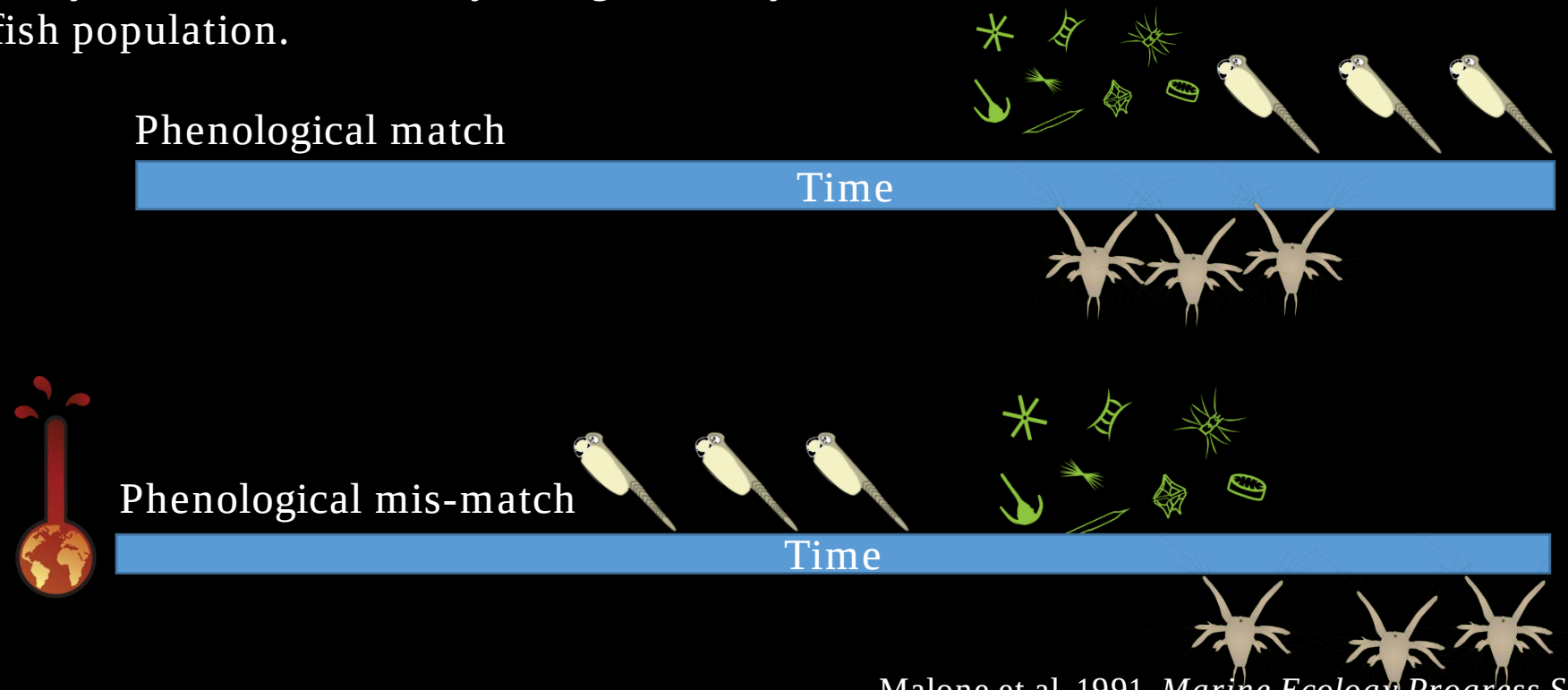


Where are species getting their energy?



Phenological mis-match

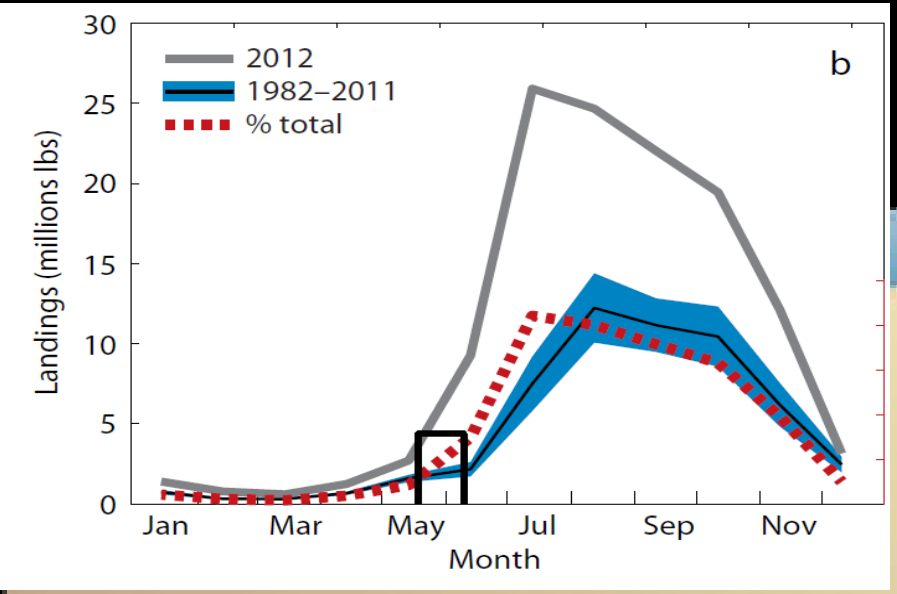
In terrestrial ecosystems we have seen phenological mis-matches between the arrival of migratory species or the emergence of local juveniles and their food, which can lead to significant population declines. The same may occur in our coastal systems. For instance, if fish larvae emerge ahead of a spring plankton bloom because of higher temperatures or delayed freshet, there may be significantly less food available and thus, a decrease in that fish population.



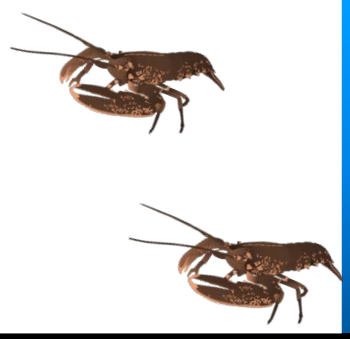
Malone et al. 1991. *Marine Ecology Progress Series*

Phenology and trophic interactions

A New England case study: 2012 was an ocean heat wave for the Gulf of Maine (1.3°C higher than average of previous two decades). Lobsters moved inshore 3 weeks earlier tha year and molted faster, which meant they got to market size sooner. The consequence was record landings in 2012 relative to previous decades.



Mills et al. 2015, *Oceanography*



A glut in the market

While catching more lobsters seems like a good thing, it flooded the market. As a result, lobsterman were getting up to 70% lower ex-vessel prices for their lobsters relative to previous years. This meant lobstermen had to catch more lobsters to compensate, but it was hard to offset the cost of fuel and bait whose prices did not decline.

This is an example of how the ecology of an ecosystem can drive the economy of communities.

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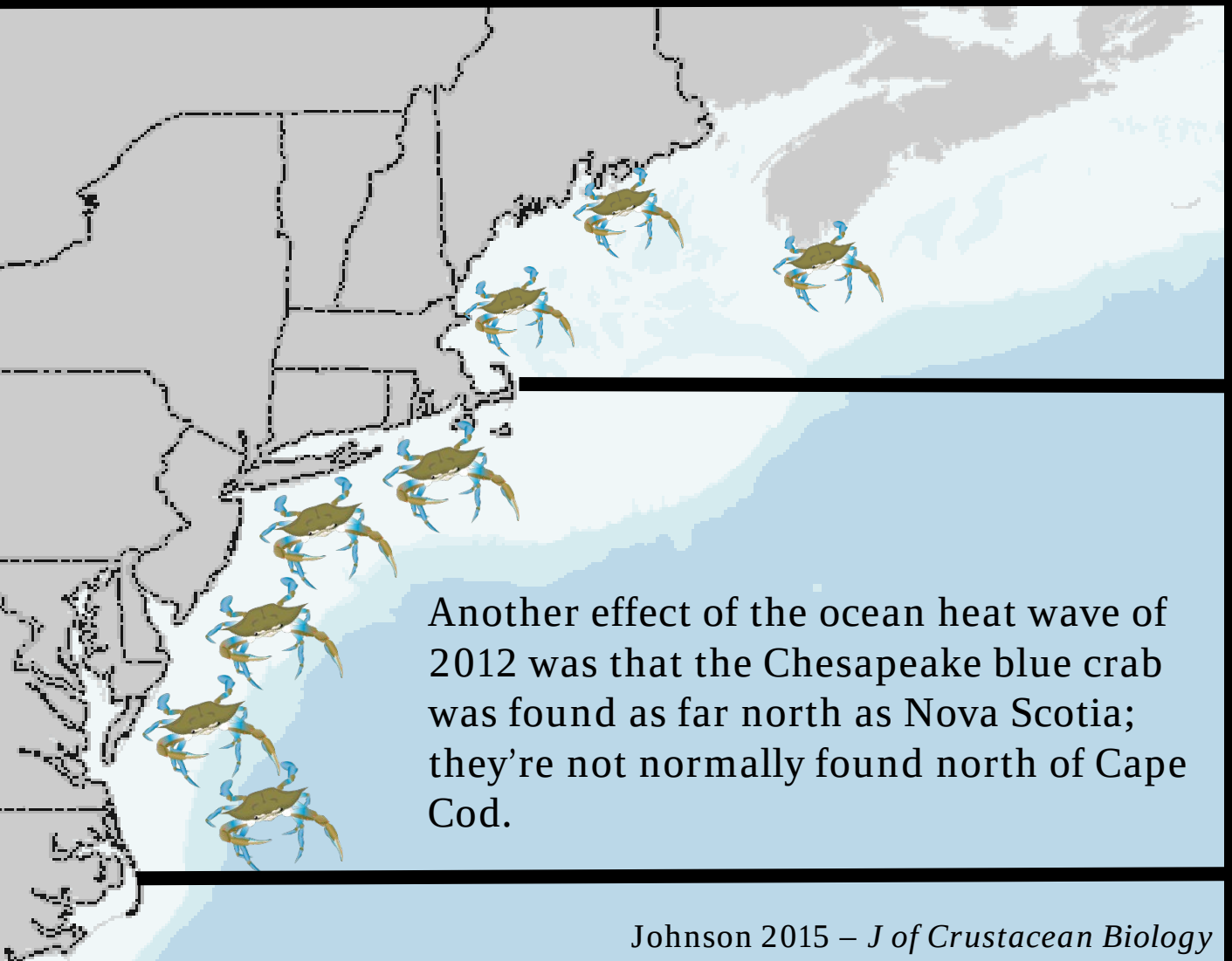
2012 Maine lobster catch increases by 18 million pounds, but price continues to decline

Bangordailynews.com

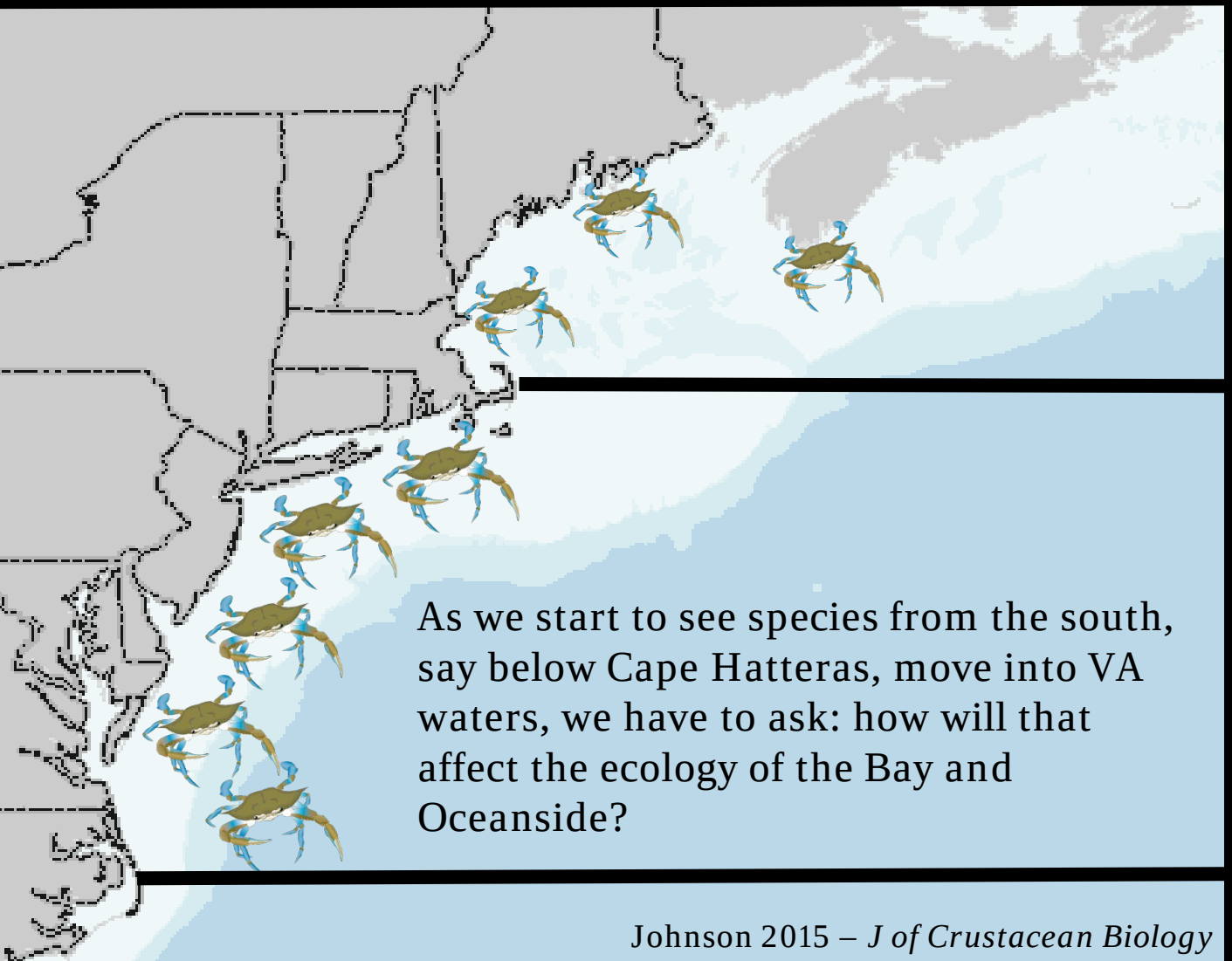
Range Shifts/Extensions



Another effect of the ocean heat wave of 2012 was that the Chesapeake blue crab was found as far north as Nova Scotia; they're not normally found north of Cape Cod.

Johnson 2015 – *J of Crustacean Biology*

Range Shifts/Extensions

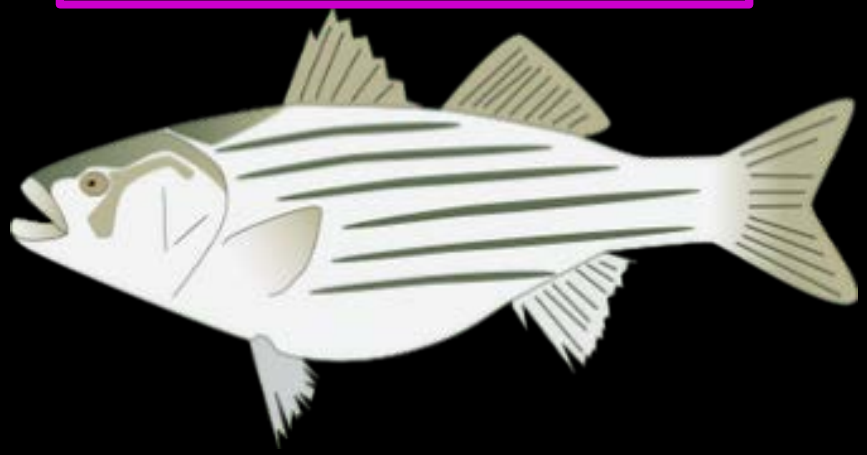


As we start to see species from the south, say below Cape Hatteras, move into VA waters, we have to ask: how will that affect the ecology of the Bay and Oceanside?

Johnson 2015 – *J of Crustacean Biology*

Phenology

How will changes in phenology and distribution influence trophic interactions?



Knowledge gaps in the face of a changing climate

Ecosystem functioning of altered habitats?

Habitat-energy use of target species?

Ecological consequence of phenological and range shifts?

Multiple stressors?

References and credits

Photograph of sea-level rise courtesy of *NYTimes*, all other photos copyright David Samuel Johnson unless otherwise stated

Vector images courtesy of the Integrated and Application Network of the University of Maryland Center of Environmental Science, www.ian.umces.edu and Lauren Huey (*Melampus bidentatus*)

Glick , P., A. Staudt, D. Inkley 2007. The Chesapeake Bay and Global Warming: A paradise lost for hunters, anglers and outdoor enthusiasts? National Wildlife Federation

Johnson, D.S. 2011. High-marsh invertebrates are susceptible to eutrophication. *Marine Ecology Progress Series, 438:143-152*.

Johnson, D.S. 2014. Fiddler on the Roof: A northern range extension for the marsh fiddler crab *Uca pugnax*. *Journal of Crustacean Biology* 34:671-673.

Johnson, D.S. 2015. The savory swimmer swims north: A northern range extension for the blue crab, *Callinectes sapdius*? *Journal of Crustacean Biology* 35:105-110.

Johnson, D.S. and B. L. Williams. In review. Habitat loss may lead to extinction of ontogenetic niche specialist.

Malone, T. C., H. W. Ducklow, E. R. Peele, and S. E. Pike. 1991. Picoplankton carbon flux in Chesapeake Bay, *Mar. Ecol. Prog. Ser.*, 78: 11–22.

Mills, K.E., A.J. Pershing, C.J. Brown, Y. Chen, F.-S. Chiang, D.S. Holland, S. Lehuta, J.A. Nye, J.C. Sun, A.C. Thomas, and R.A. Wahle. 2013. Fisheries management in a changing climate: Lessons from the 2012 ocean heat wave in the Northwest Atlantic. Oceanography 26(2):191–195, http://dx.doi.org/10.5670/oceanog.2013.27.

Moore, K. A., D. J. Wilcox, and R. J. Orth. 2000. Analysis of the abundance of submersed aquatic vegetation communities in the Chesapeake Bay, *Estuaries*, 23: 115–127.

Moore, K.A., Shields, E.C. & Parrish, D.B. Estuaries and Coasts (2014) 37: 20. doi:10.1007/s12237-013-9667-3

Pyke, C. R., R. G. Najjar, M. B. Adams, D. Breitburg, M. Kemp, C. Hershner, R. Howarth, M. Mulholland, M. Paolisso, D. Secor, K. Sellner, D. Wardrop, and R. Wood. 2008. Climate Change and the Chesapeake Bay: State-of-the-Science Review and Recommendations. A Report from the Chesapeake Bay Program Science and Technical Advisory Committee (STAC), Annapolis, MD. 59 pp.

Sullivan, B. K., D. Van Keuren, and M. Clancy. 2001. Timing and size of blooms of the ctenophore *Mnemiopsis leidyi* in relation to temperature in Narragansett Bay, R.I., *Hydrobiologia*, 451: 113–120.