VIMS Center for Coastal Climate Change

"From the Shenandoahs to the Shelf"

Climate Change and Plankton Communities: Disruptions at the Base of the Food Web

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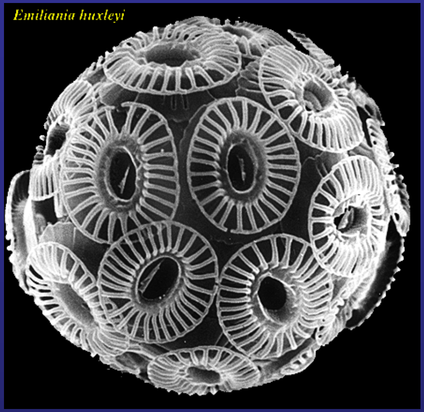
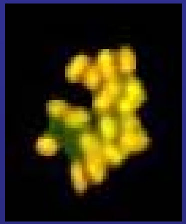
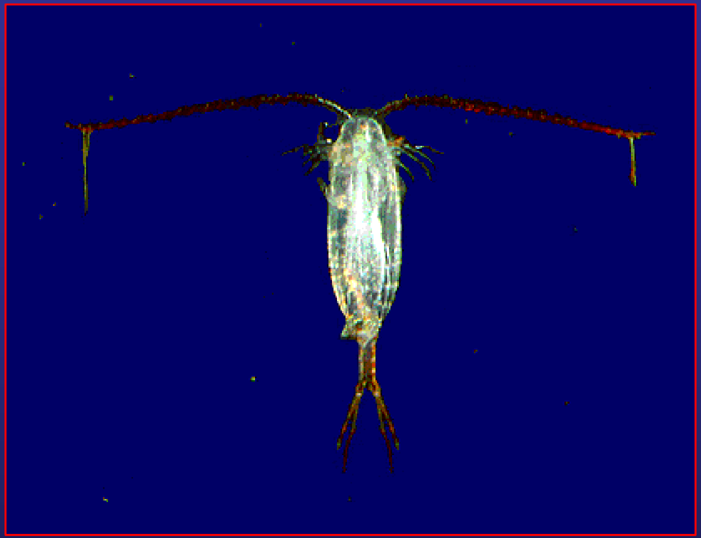
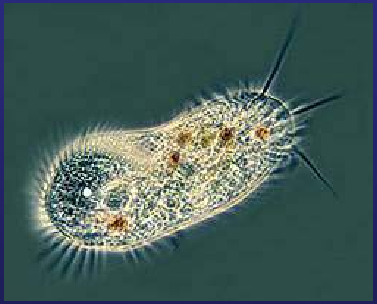
Plankton

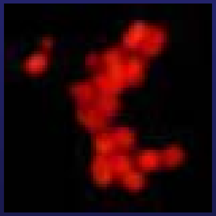
The base of estuarine food webs

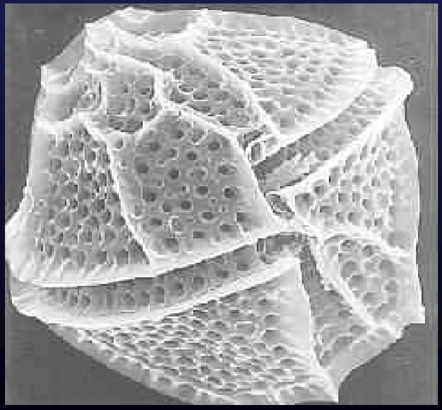


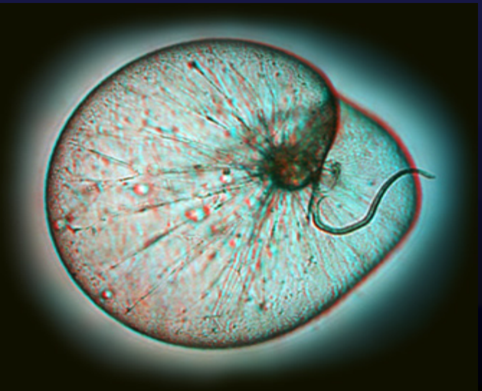












Predicted Environmental Changes as a Result of a Changing Climate

Direct Impacts

• Increased carbon dioxide concentrations in both atmosphere and estuary

• Increased temperatures

Indirect impacts

• Increased fresh-water inputs

• Increased nutrient inputs and altered ratios

• Altered frequency of episodic events (floods, draughts, harmful algal blooms)

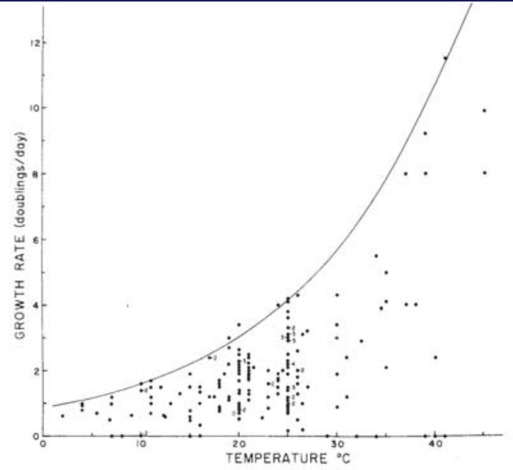
Impact of Environment Changes

Temperature

In general, microbial growth is an exponential function of temperature; hence as temperature increases, we would expect growth rate to increase; impacts on standings stocks less certain

CO_2

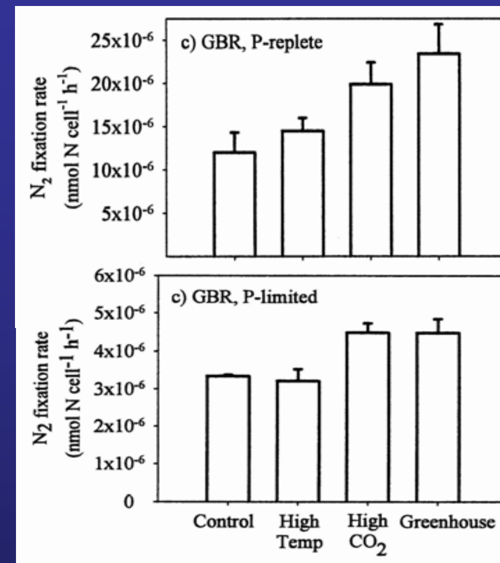
Impacts of elevated CO_2 concentrations (and lowered pH) in estuaries unknown

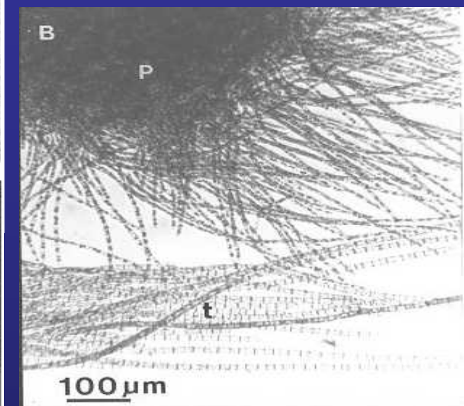


Eppley, 1972

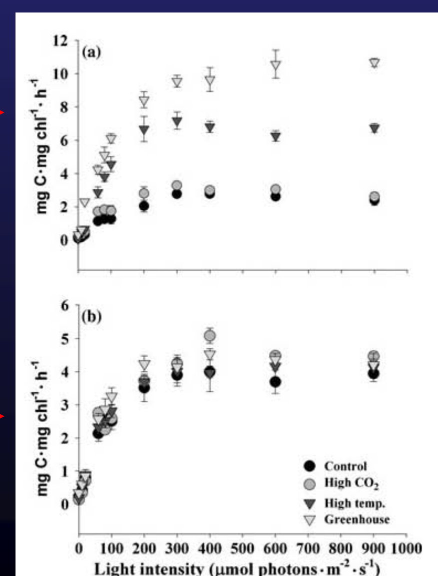
Direct Impacts of Increased CO_2 Levels

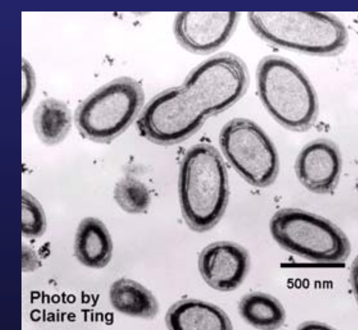
1. Effects on *Trichodesmium*, a critical N_2 fixer, show that high CO_2 levels stimulate nitrogen fixation and is independent of PO_4; temperature has little effects (Hutchins et al., 2007)



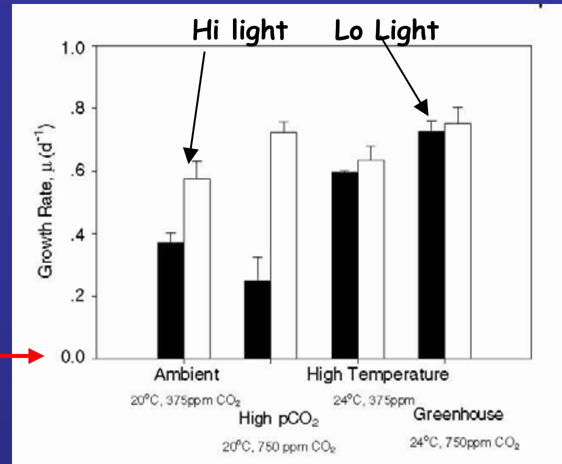


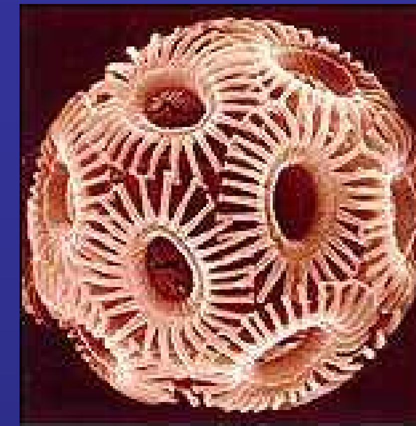
2. *Synnechococcus*, a unicellular cyanobacterium, responded positively to increased temperatures, and also increased its photosynthesis; *Prochlorococcus* responded only weakly (Fu et al., 2007)



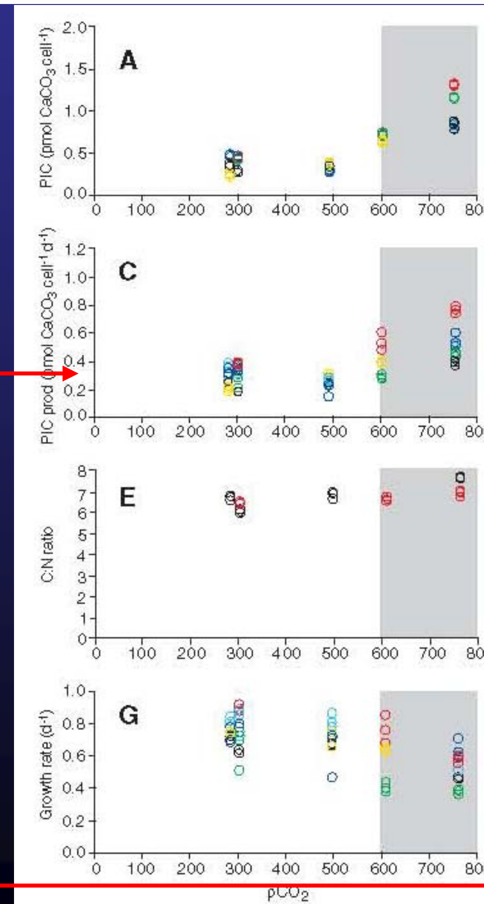


3. Growth rate of *Emiliana* increased under both elevated T and CO_2 conditions (Feng et al., 2008)

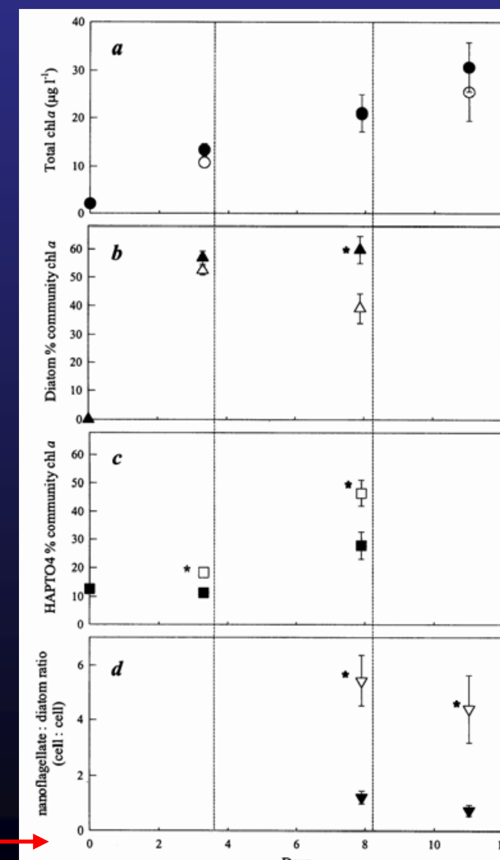




4. A separate study showed that mass of individuals increases in a high-CO_2 environment, but that the growth rate decreases (Inglesias-Rodriguez et al., 2008)



5. Many algae use CO_2 as a carbon source in photosynthesis; others use HCO_3 and have physiological means to convert bicarbonate to CO_2; taxa shift as a function of CO_2 (Tortell et al., 2002)

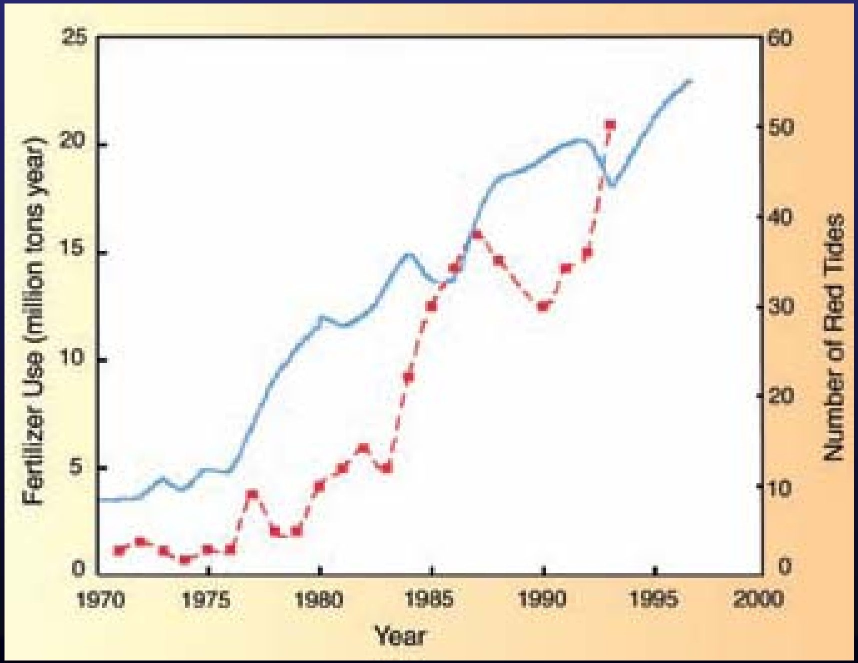


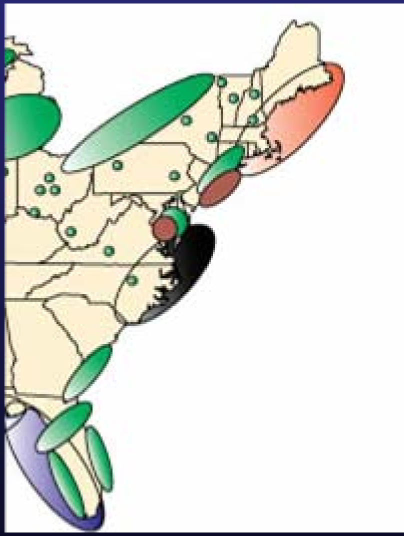
Conclusions

Temperature and CO_2 increases will alter growth rates of plankton, but perhaps more importantly, alter the seasonal patterns and composition in ways that at present cannot be adequately predicted

Indirect Impacts of Climate Change: Generation of Harmful Algal Blooms

While there is no clear causal relationship between increased nutrients and the formation of harmful algal blooms, HABS have increased dramatically in the past three decades, coincident with cultural eutrophication



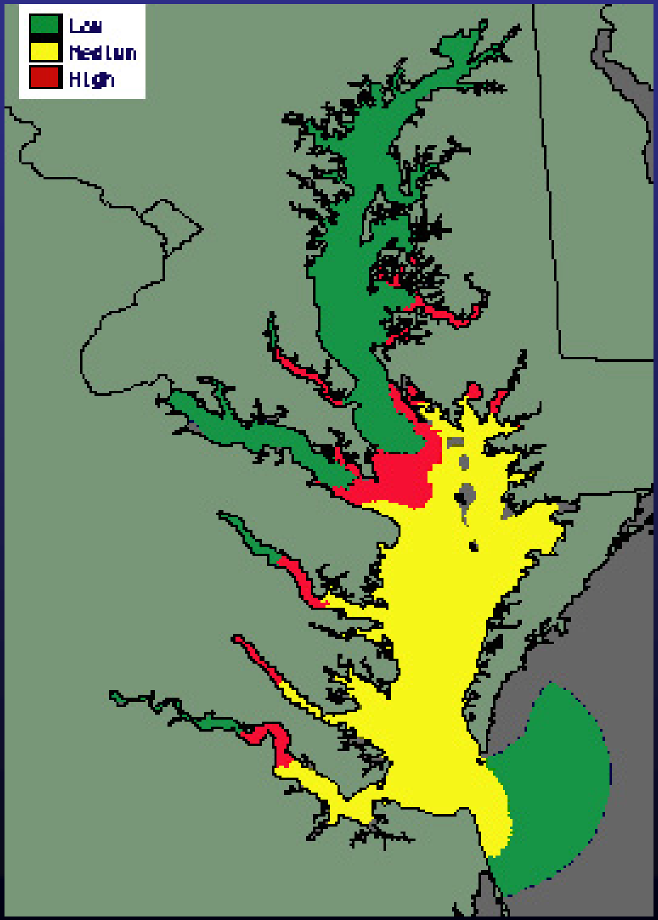


Black = *Karlodinium, Pfisteria*
Green = *Karenia*
Brown = brown tides

HARNESS, 2006

HABs and the Chesapeake Bay

Have been observed for decades, but their intensity and distribution have been markedly increasing in the past decade

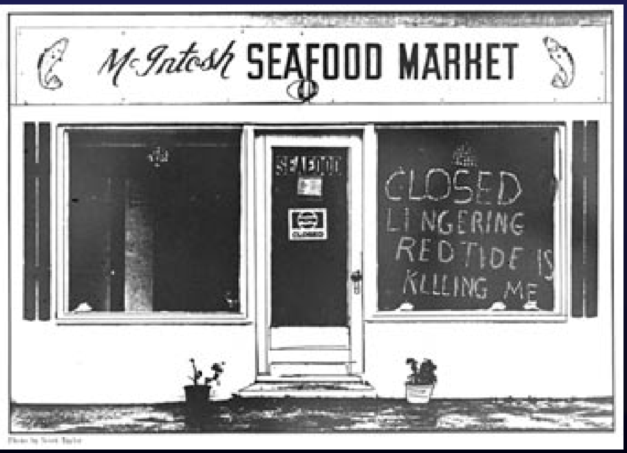


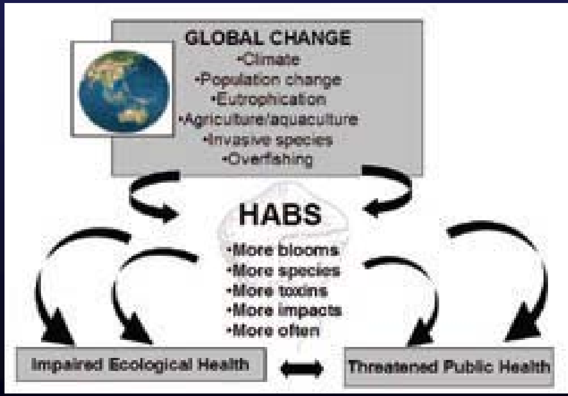
HAB nowcast model for *Karenia* (Chris Brown, MD)

http://155.206.18.162/cbay_hab/

Impacts of HABs in Chesapeake Bay

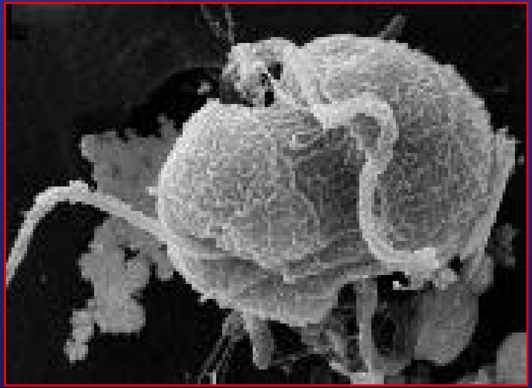
- Large increase in biomass results in decline of available light for seagrasses
- Eventual death of bloom causes hypoxic or anoxic events both in benthos and water column
- Replacement of other phytoplankton that are food items for zoopolankton, larvae, and higher trophic levels; hence, alteration of food webs
- Concentration by benthic filter feeders and closure of shellfish industry, including aquaculture, due to human health impacts





Impacts of HABs in Chesapeake Bay

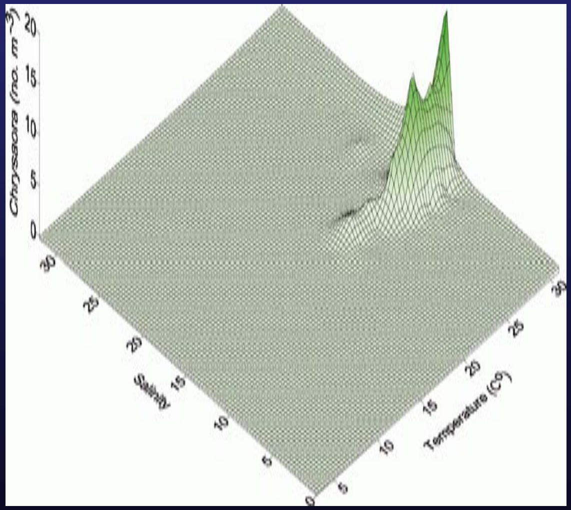
One extreme example was the large *Pfisteria* blooms that occurred in the upper Chesapeake Bay, which caused human health issues and severe economic losses (estimated to be $43 million dollars, not including the losses in tourism, recreational fisheries, and increased costs of monitoring)

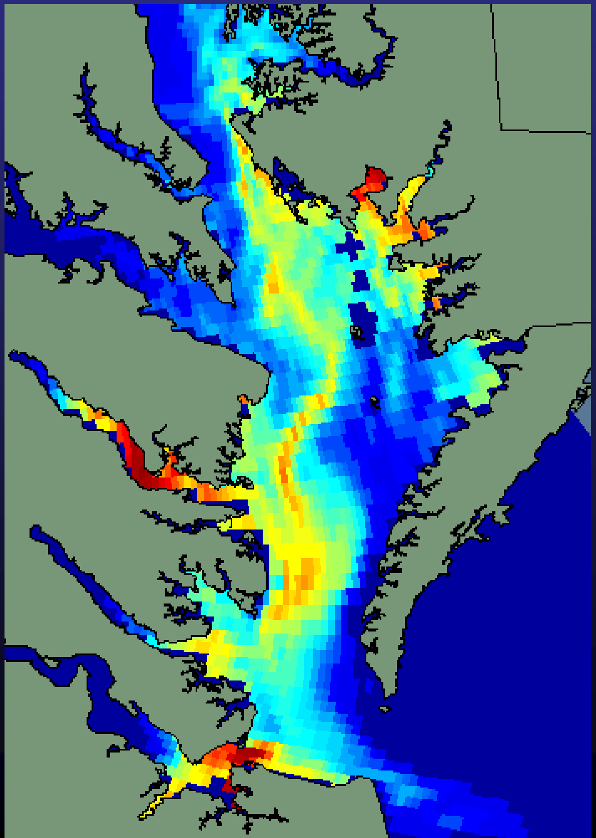


Other examples include mahogany tides in the lower Bay and brown tides in the upper Bay

Indirect Impacts of Climate Change: Alteration of Food Webs

In recent decades the growth and distribution of sea nettles (*Chrysaora quinquecirrha*), a noxious, stinging jellyfish, has received a great deal of attention. A model has been developed that uses the known narrow limits of temperature and salinity for sea nettles to predict their distribution.

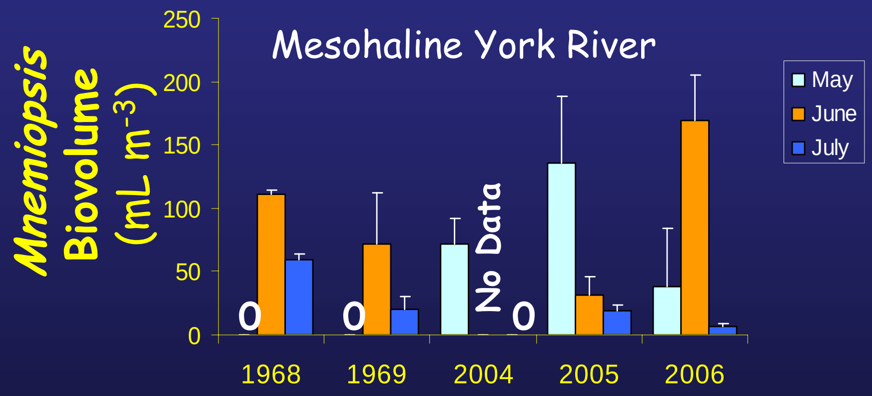


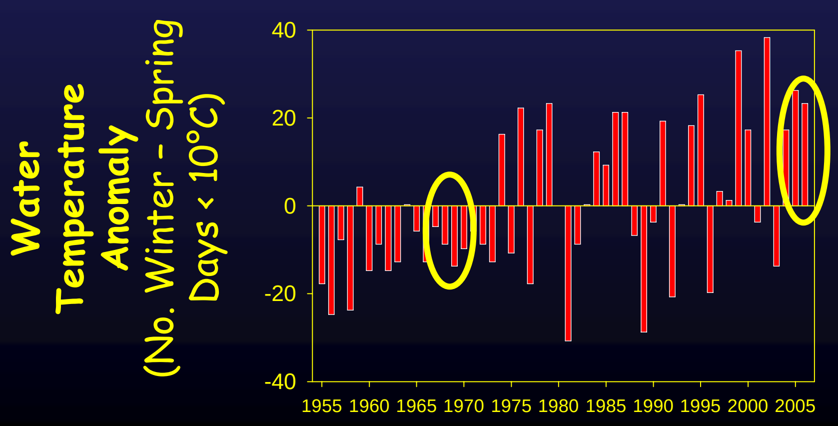


http://155.206.18.162/seanettles/

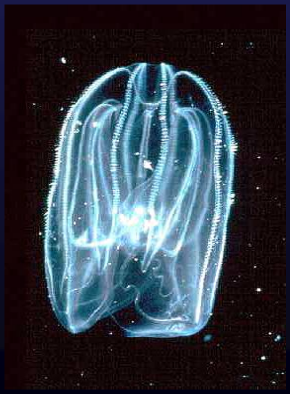
Indirect Impacts of Climate Change: Alteration of Food Webs

Sea nettles swim and feed continuously, harvesting larger particles that include copepods, invertebrate larvae, ctenophores, minnows, bay anchovy eggs, and mosquito larvae.
Given the large amount they ingest, they can substantially alter the food webs and prey composition within the Bay.





Similarly, ctenophores have apparently increased in numbers as temperatures have increased in York River (Condon & Steinberg, 2008)



Summary

• Direct climatic alterations will change not only the abundance of plankton, but the composition, with unknown consequences to the Bay's food web

• Interactive effects of environmental variables are large, and the effects vary by species

• HABs will likely continue to increase with time, with severe attendant socioeconomic and human health impacts

• Zooplankton communities will continue to change, and have significant impacts on water clarity and commercially important species

•Timing of natural events will be altered, with large, albeit poorly constrained, impacts on estuarine and coastal food webs

Recommendations

It is recommended that the Commonwealth initiate studies to investigate the influence of changing climatic factors, both direct (temperature, CO_2, pH) and indirect (nutrients, salinity, composition of plankton, biotic interactions within plankton) on the plankton community in order to reliably predict and respond to the changes that will occur in the coming years, in order to mitigate the human and economic impacts of these changes.