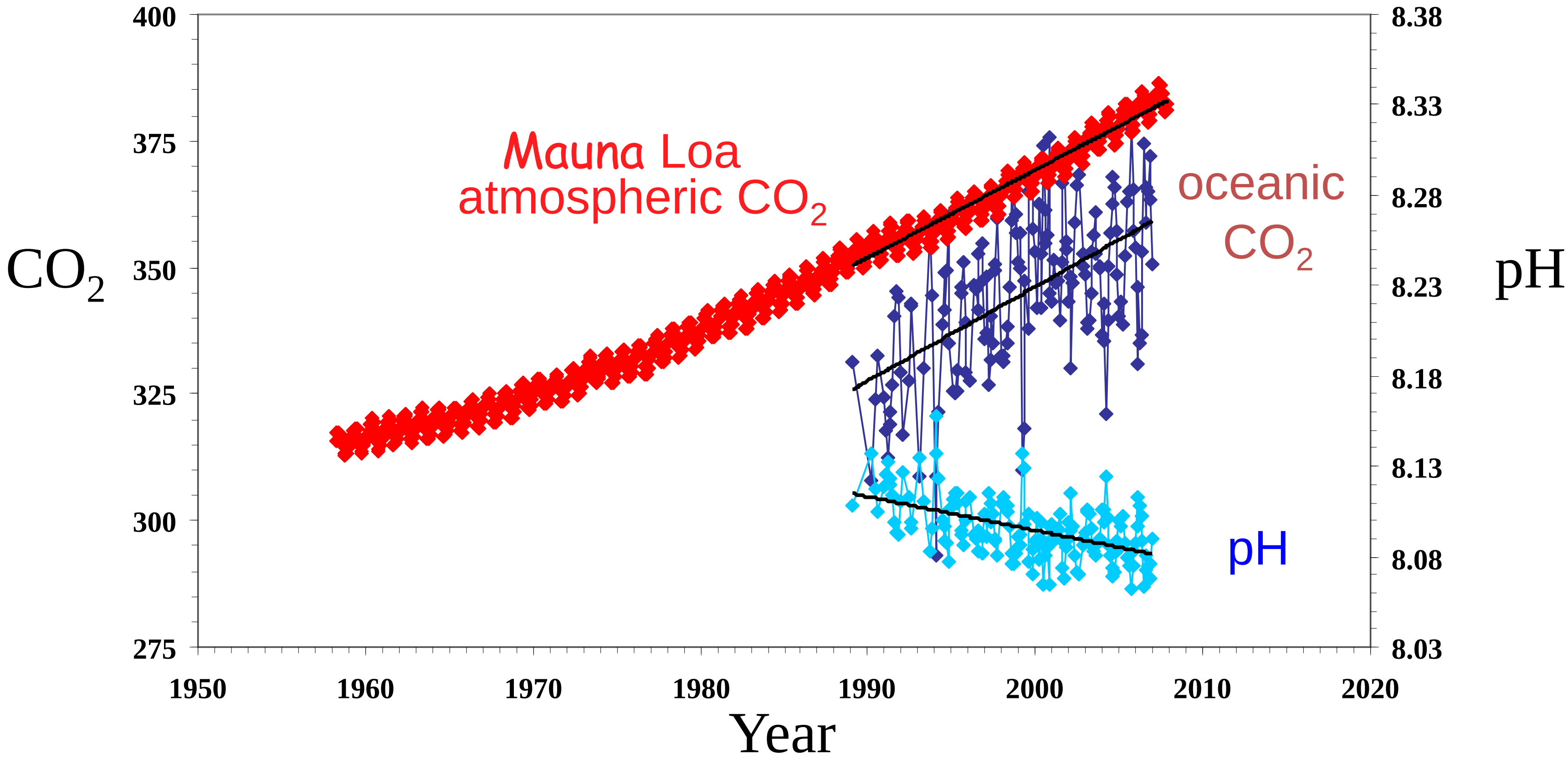
Increasing CO_2 and Ocean Acidification

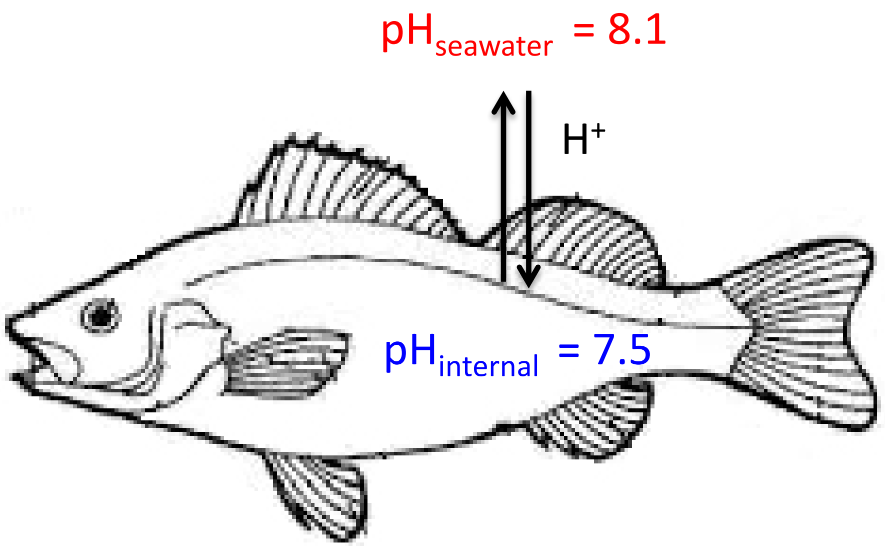
$$CO_2 + H_2O \longrightarrow HCO_3^- + H^+$$

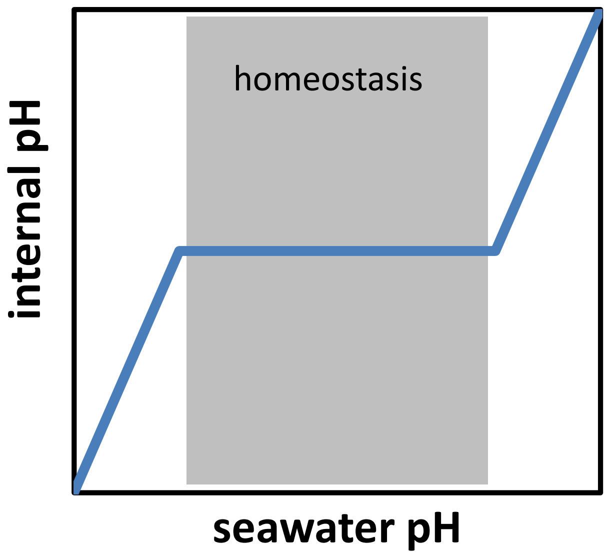


At 1000 ppm CO_2, pH ~7.7

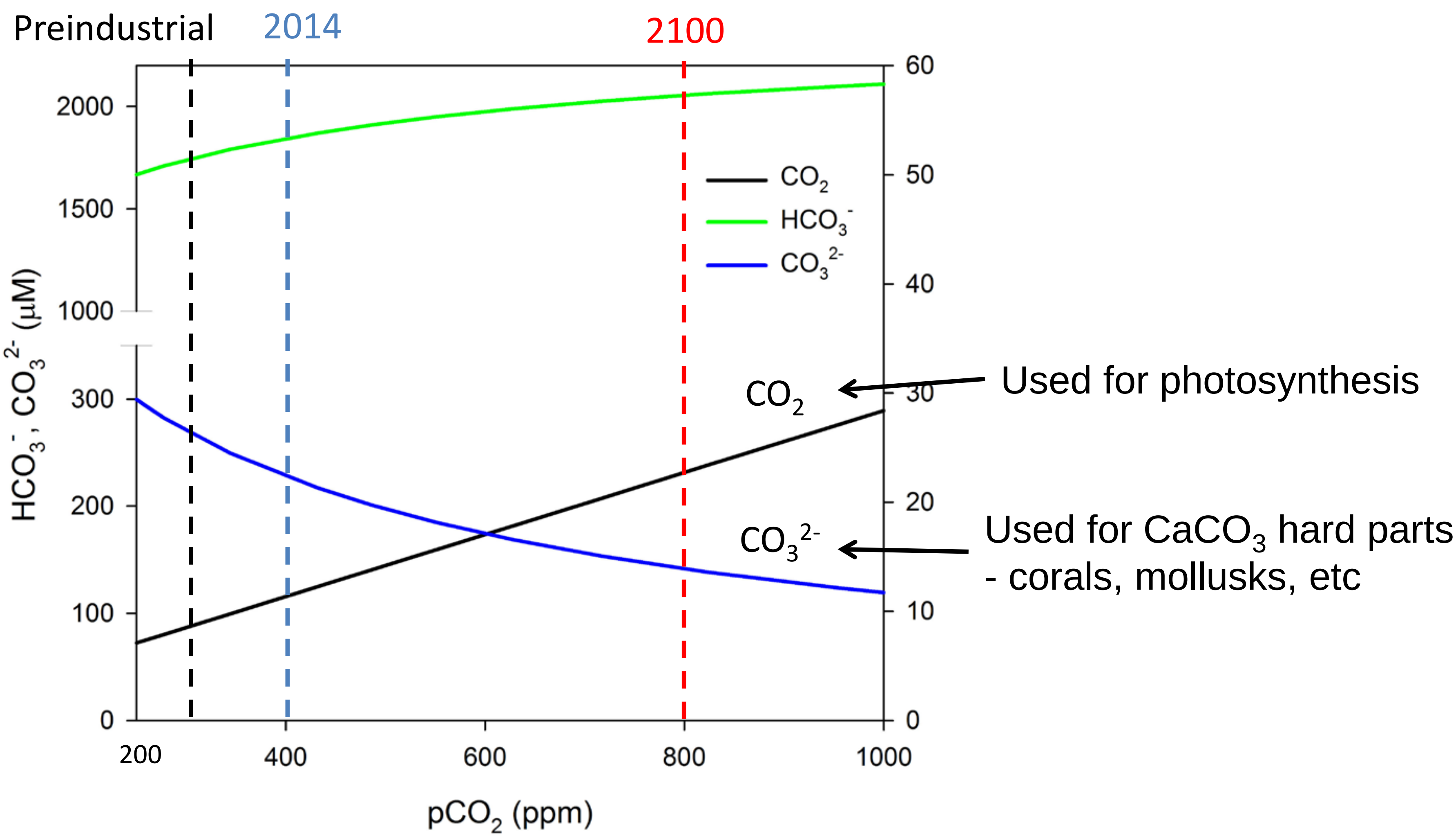
Feely et al. 2008

pH and Acid-Base Balance

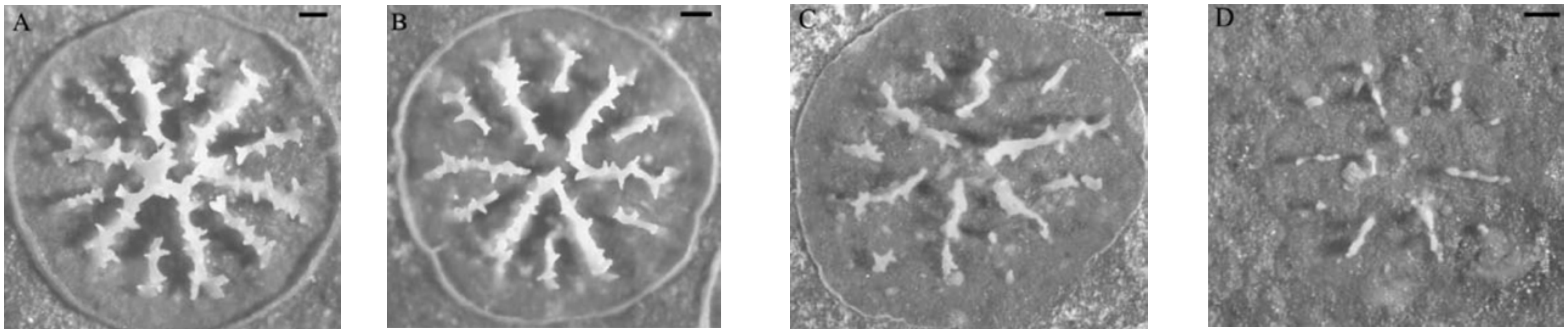




Changes in Inorganic Carbon Distribution



Effects of OA on Calcification



Today
$[CO_3^{2-}]$=320 μM

~ 2100
$[CO_3^{2-}]$=140

~2300
$[CO_3^{2-}]$=80

$[CO_3^{2-}]$=20

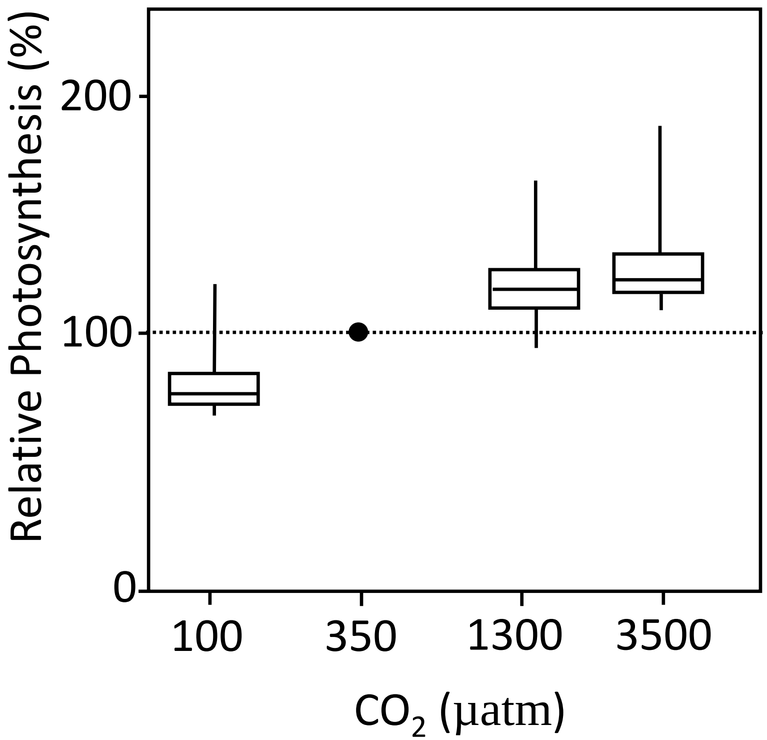
Cohen et al. 2009

Favia fragum

C. Vernon

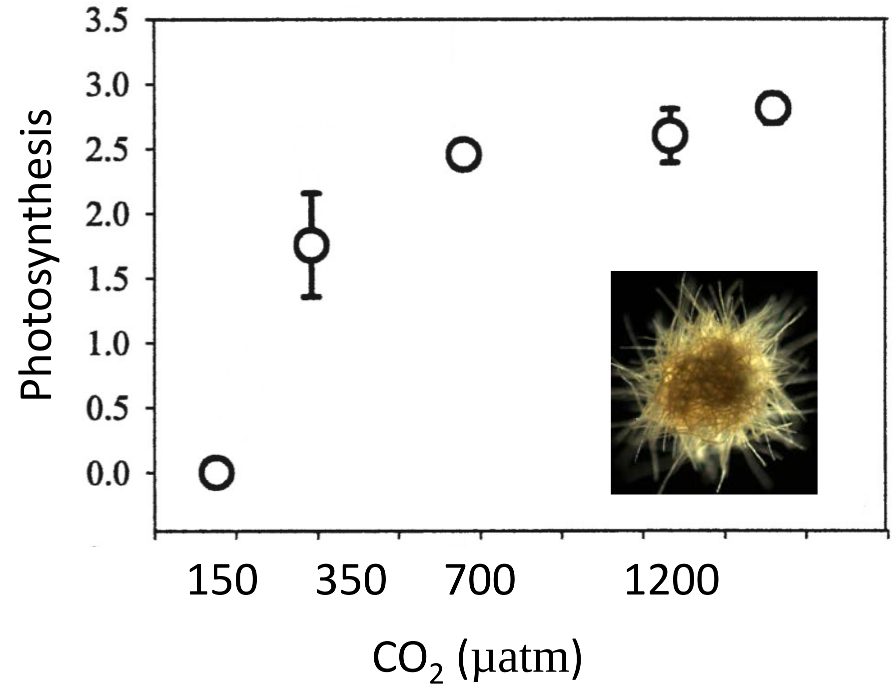
Effects of CO_2 on photosynthesis

Natural Assemblages



Hein and Sand-Jensen 1997

Trichodesmium



Hutchins et al. 2008

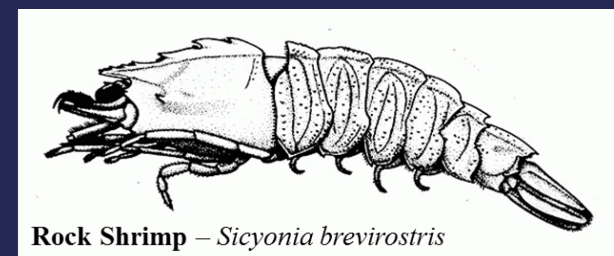
Ocean Acidification in Relationship to Southeast Atlantic Fisheries

GEORGIA
DEPARTMENT OF NATURAL RESOURCES
COASTAL RESOURCES DIVISION

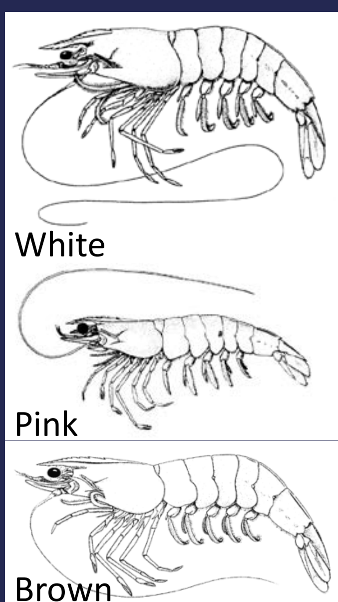
Patrick Geer, Chief of Marine Fisheries
Georgia Department of Natural Resources
SOCON August 18, 2015

Fisheries Possibly Impacted by Lower pH

Spiny Lobster



Cannonball Jellyfish

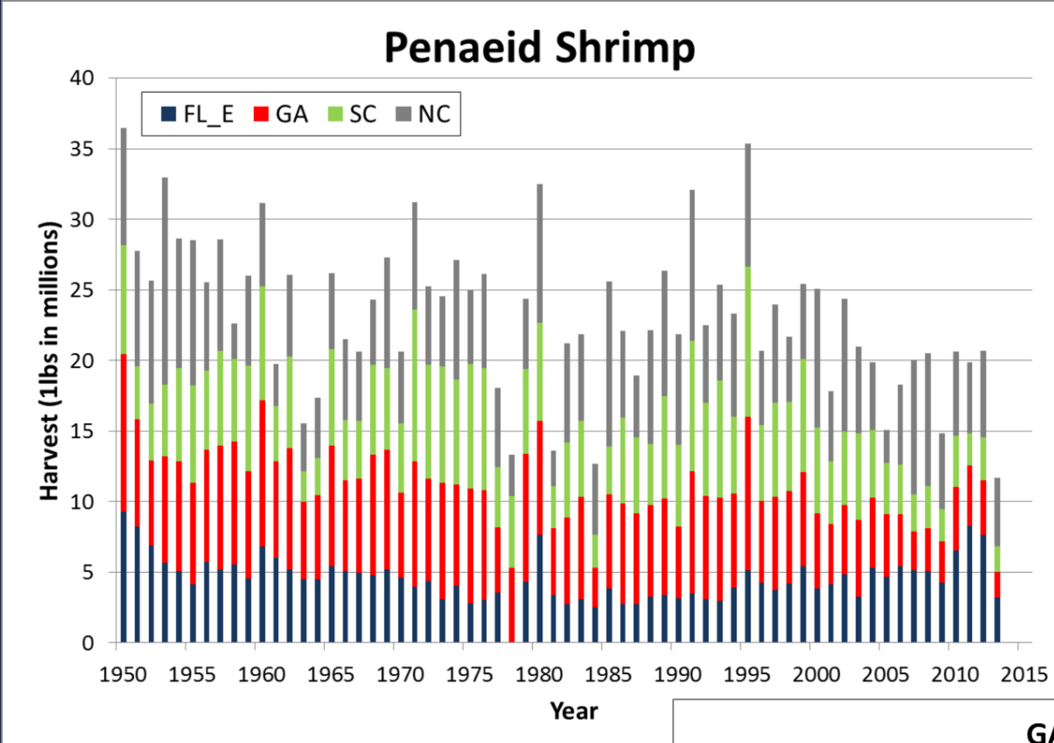


Average Annual Commercial Harvest by State Top 15 Species 2009-2013 (in millions of lb)

Rank	NC	SC	GA	FL - East	Total
1	CRAB, BLUE 27.066	CRAB, BLUE 4.711	CRAB, BLUE 3.310	SHRIMP, WHITE 4.303	CRAB, BLUE 37.673
2	CROAKER, ATLANTIC 4.707	SHRIMP, WHITE 2.156	SHRIMP, WHITE 2.918	MACKEREL, SPANISH 2.889	SHRIMP, WHITE 10.930
3	SHRIMP, BROWN 3.654	SWORDFISH 0.520	SHELLFISH 1.486	MACKEREL, KING AND CERO 2.858	SWORDFISH 2.321
4	SHARK, SPINY DOGFISH 2.285	SHRIMP, BROWN 0.449	JELLYFISH 0.949	CRAB, BLUE 2.587	SHRIMP, BROWN 5.743
5	FLOUNDER, SUMMER 2.131	SHRIMP, MARINE, OTHER 0.399	SHRIMP, BROWN 0.557	SHRIMP, ROCK 1.495	SHRIMP, MARINE, OTHER 0.872
6	BLUEFISH 1.878	OYSTER, EASTERN 0.343	SHRIMP, MARINE, OTHER 0.137	MULLET, STRIPED (LIZA) 1.322	OYSTER, EASTERN 1.108
7	FLOUNDER, SOUTHERN 1.833	SNAPPER, VERMILION 0.317	FINFISHES, UNC GENERAL 0.096	SHRIMP, BROWN 1.083	SNAPPER, VERMILION 0.924
8	MULLET, STRIPED (LIZA) 1.761	SHAD, AMERICAN 0.280	CLAM, QUAHOG 0.093	SWORDFISH 1.021	SHAD, AMERICAN 0.528
9	MENHADEN 1.589	FINFISHES, UNC GENERAL 0.175	CRAB, BLUE, PEELER 0.043	CRAB, DEEPSEA GOLDEN 0.648	FINFISHES, UNC GENERAL 0.375
10	SHRIMP, WHITE 1.555	GAG 0.146	SHAD, AMERICAN 0.027	SHRIMP, PINK 0.595	GAG 0.463
11	SHARK, SMOOTH DOGFISH 1.168	SEA BASS, BLACK 0.129	OYSTER, EASTERN 0.022	SHRIMP, ROYAL RED 0.588	SEA BASS, BLACK 0.585
12	MACKEREL, SPANISH 0.856	CLAM, NORTHERN QUAHOG 0.126	FINFISHES, UNC FOR FOOD 0.016	AMBERJACK, GREATER 0.443	CLAM, NORTHERN QUAHOG 0.126
13	SWORDFISH 0.780	SCAMP 0.114	CRAB, BLUE, SOFT 0.016	TILEFISH, GOLDEN 0.420	SCAMP 0.188
14	SPOT 0.755	LEATHERJACKETS 0.098	SNAILS (CONCHS) 0.016	LOBSTER, CARIBBEAN SPINY 0.416	LEATHERJACKETS 0.381
15	OYSTER, EASTERN 0.688	DOLPHINFISH 0.093	CRAB, FLORIDA STONE CLAWS 0.009	KING WHITING 0.338	DOLPHINFISH 0.623

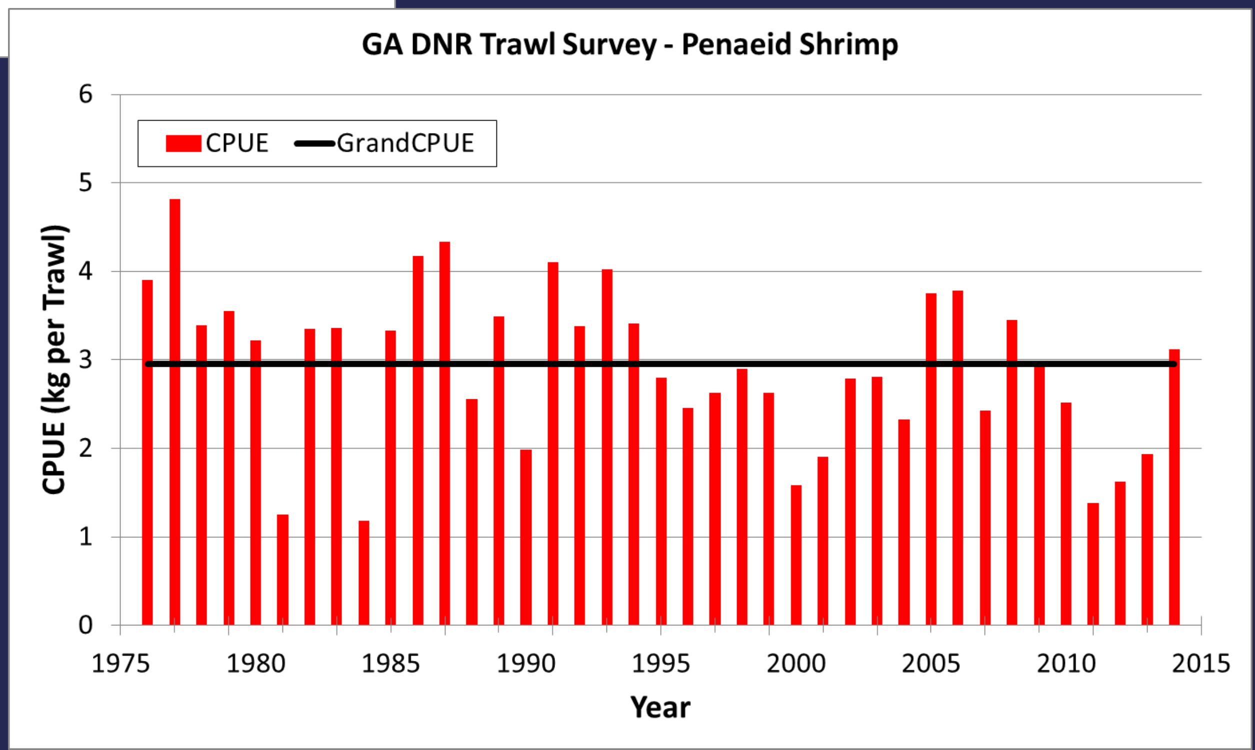
Harvest by State

Source: NMFS



Research Surveys

Source: GADNR



Penaeid Shrimp

1. Spawning offshore (May – June).

2. Eggs hatch within 24 hrs.

3. Naupli develop thru 5 stages – 2 days.

4. Protozoea develop thru 3 stages over 7 days

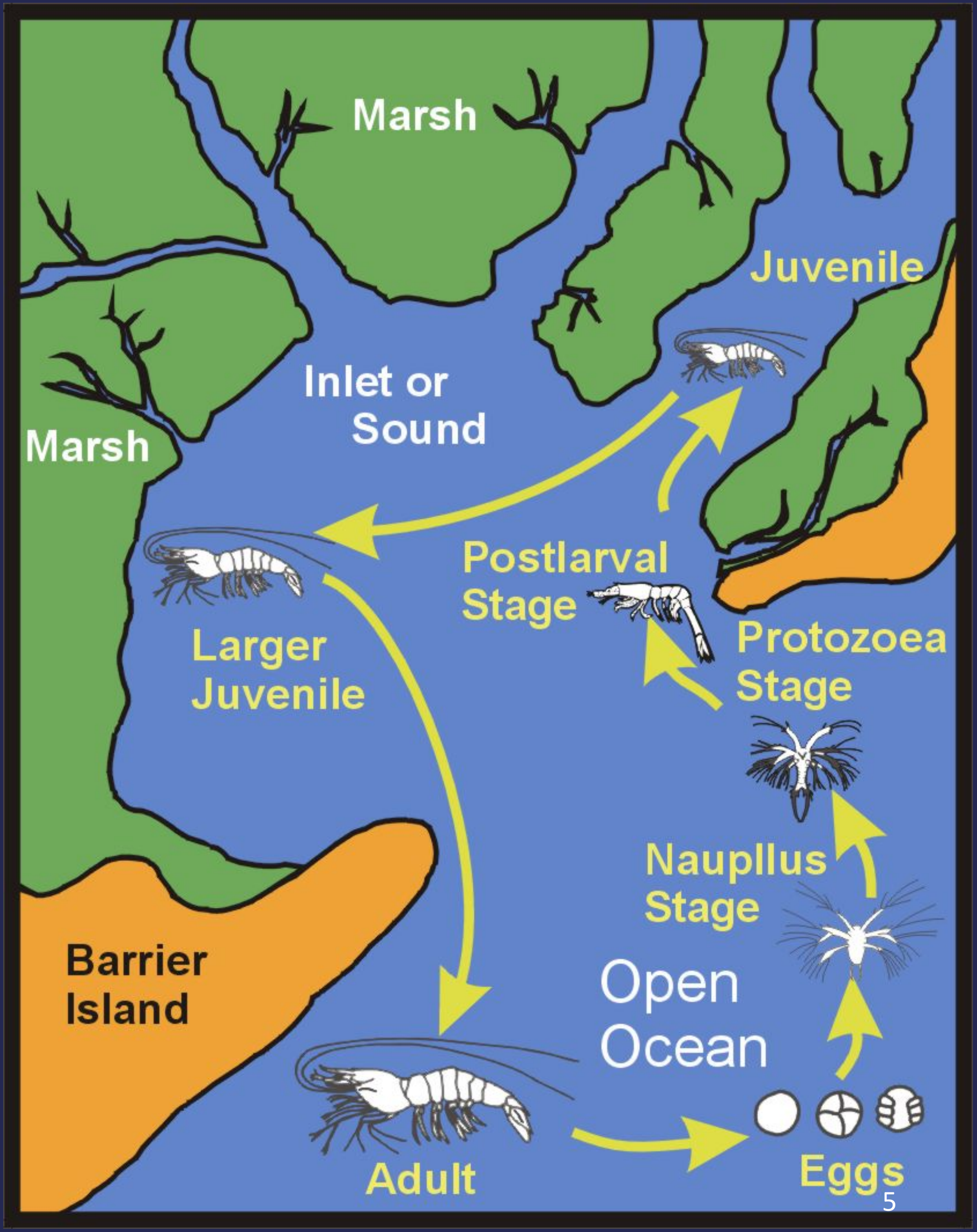
5. Mysis has 3 stages

6. Postlarva (2 stages) rides flood tides up into the creeks.

7. Juveniles grow quickly and move into the sounds as they grow.

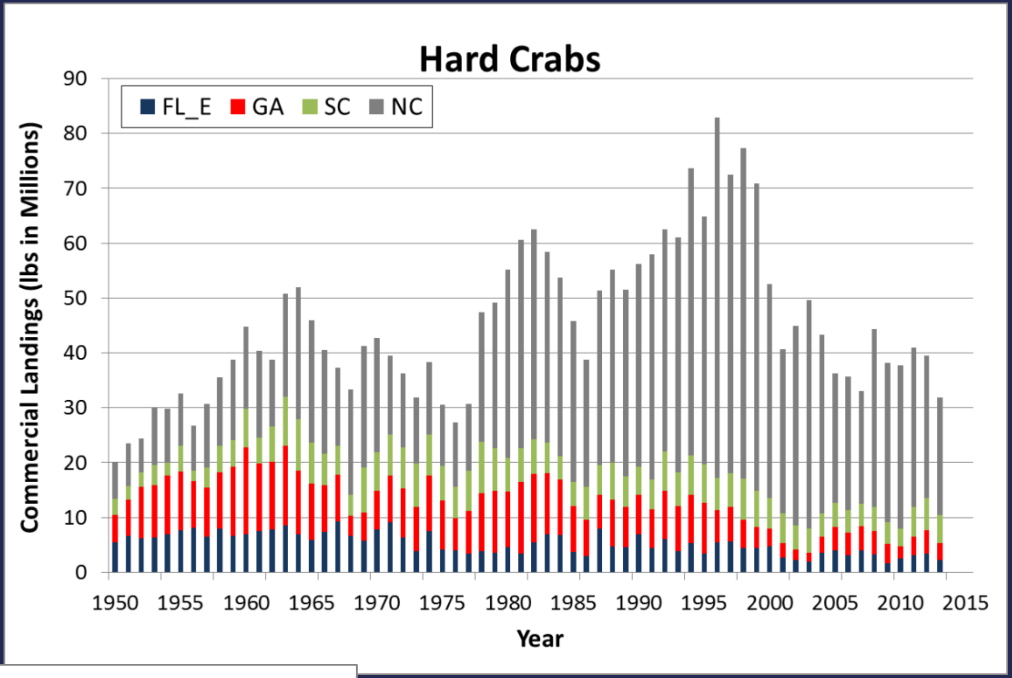
8. Adults migrate offshore to spawn

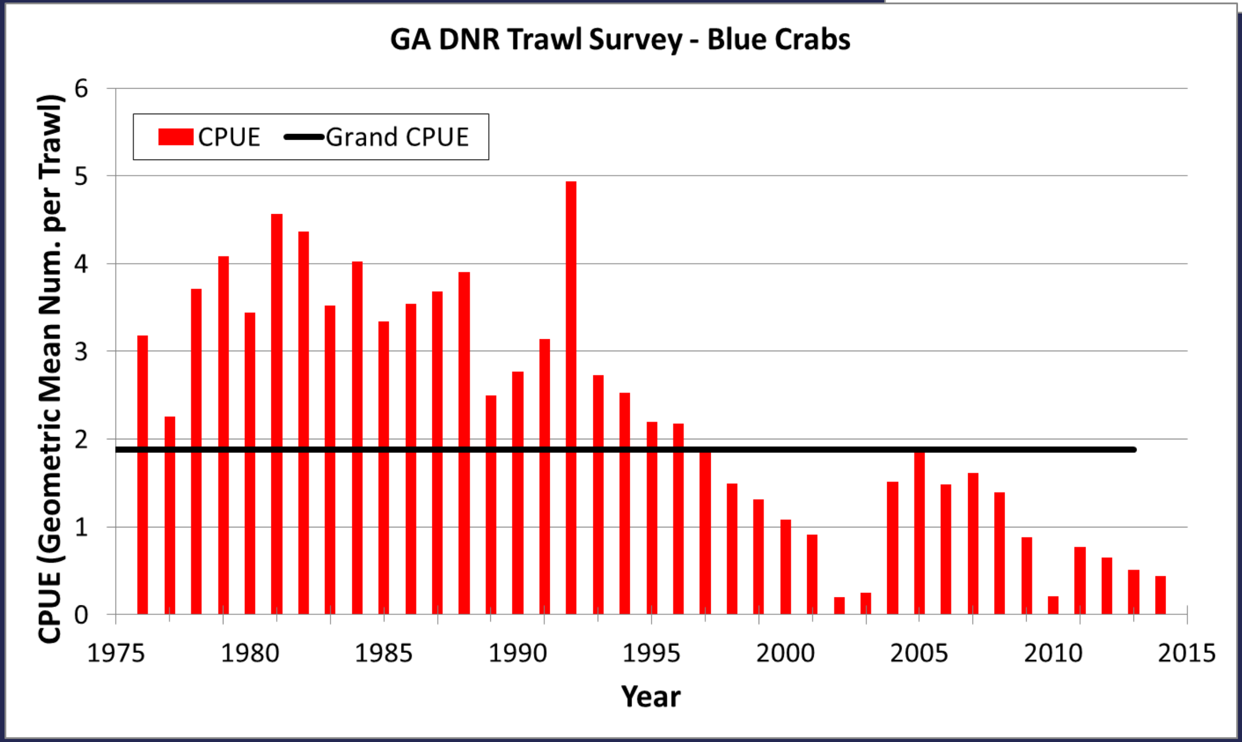
Total Life Cycle: 6-8 months
30-45 days in ocean



Harvest by State

Source: NMFS

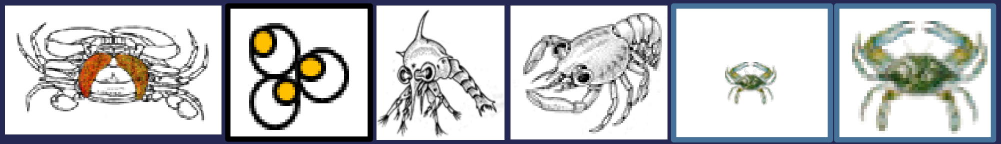




Research Surveys

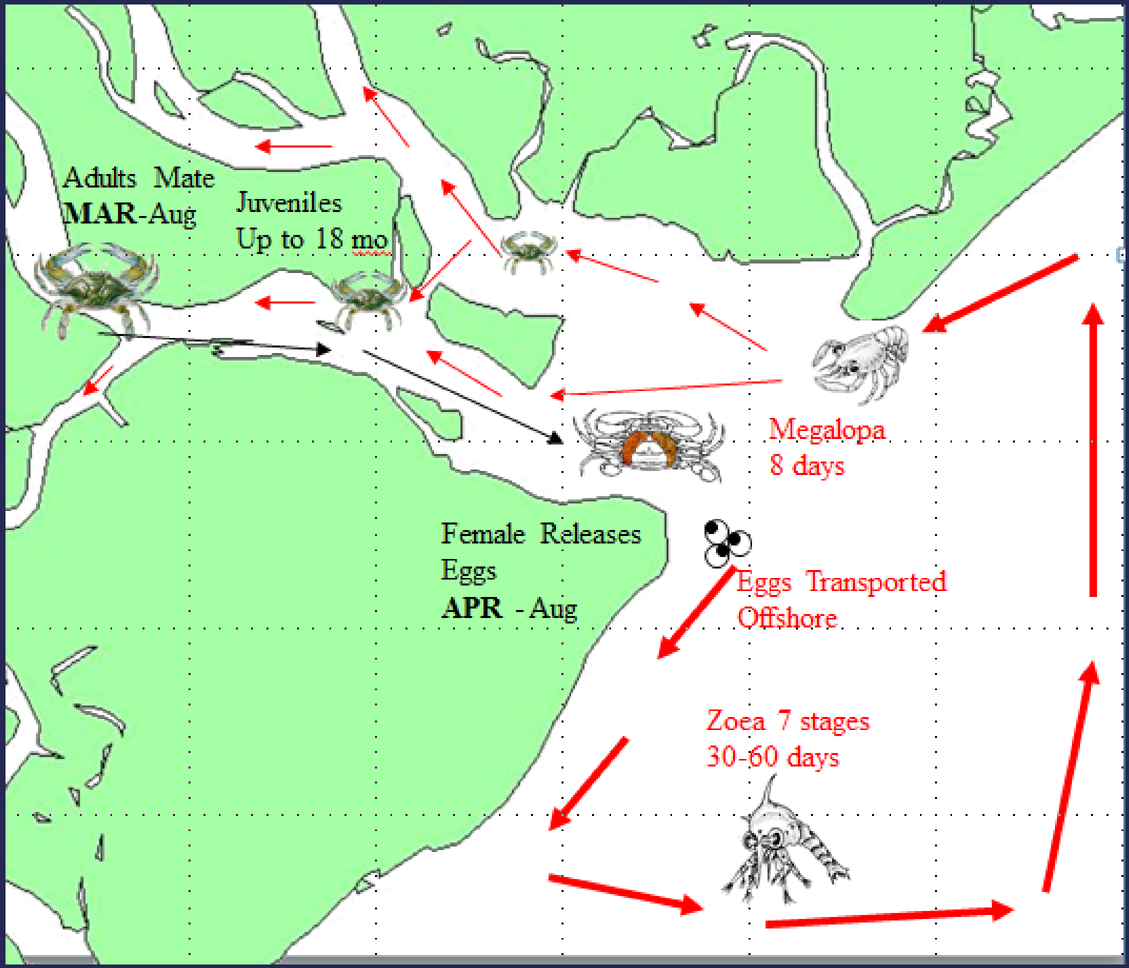
Source: GADNR

Blue Crab Life Cycle



- Mate upriver MARCH – August
- Females migrate down river carrying egg mass – 2 weeks
- Eggs are released in clean, high saline waters in ocean
- Larvae go through two stages and 8 molts and are transported back to the estuary.
- Larvae settle and juveniles migrates into the marshes

Total Life cycle: 1.5-3 years
35-70 days in ocean



Potential Impacts of Ocean Acidification

- Greater with calcifying ($CaCO_3$) organisms (mollusks, echinoderms, crustacean)
- Marine organisms typically more at risk than estuarine species, slow growing, less mobile species more susceptible
- Early life stages (eggs and larvae) may be at highest risk
- Generalized Impacts of lower pH
  - Calcification
  - Growth
  - Reproduction
  - RECRUITMENT
  - Survivability / Mortality

Specific Impacts on Crustaceans

- Not consistent across the phylum.

- Calcification: Increases
  - lobsters , crabs, and shrimp create thicker shells
  - BUT…. This has a metabolic cost in the long term
  - Reduced condition index – less meat, less value to fishery

- Growth: Decreased
  - Longer inter-molt period
  - Smaller growth increment
  - Prolonged period of ecdysis (soft-shelled)

- Reproduction
  - Smaller at maturity – less fecund

Specific Impacts on Crustaceans pg2

- Recruitment: Reduced
  - Eggs and larvae development compromised
    - slower growth

- Survivability/Mortality:
    - Smaller size - more vulnerable to predators
    - Predators not satiated – eat more

- Changes in the plankton community:
  - Food quality and quantity (copepods, amphipods)
  - Timing – match/mismatch
  - Predation – other zooplankton and high order species

Questions

Amanda Hurst

Management Implications of OA for Fisheries, and a question

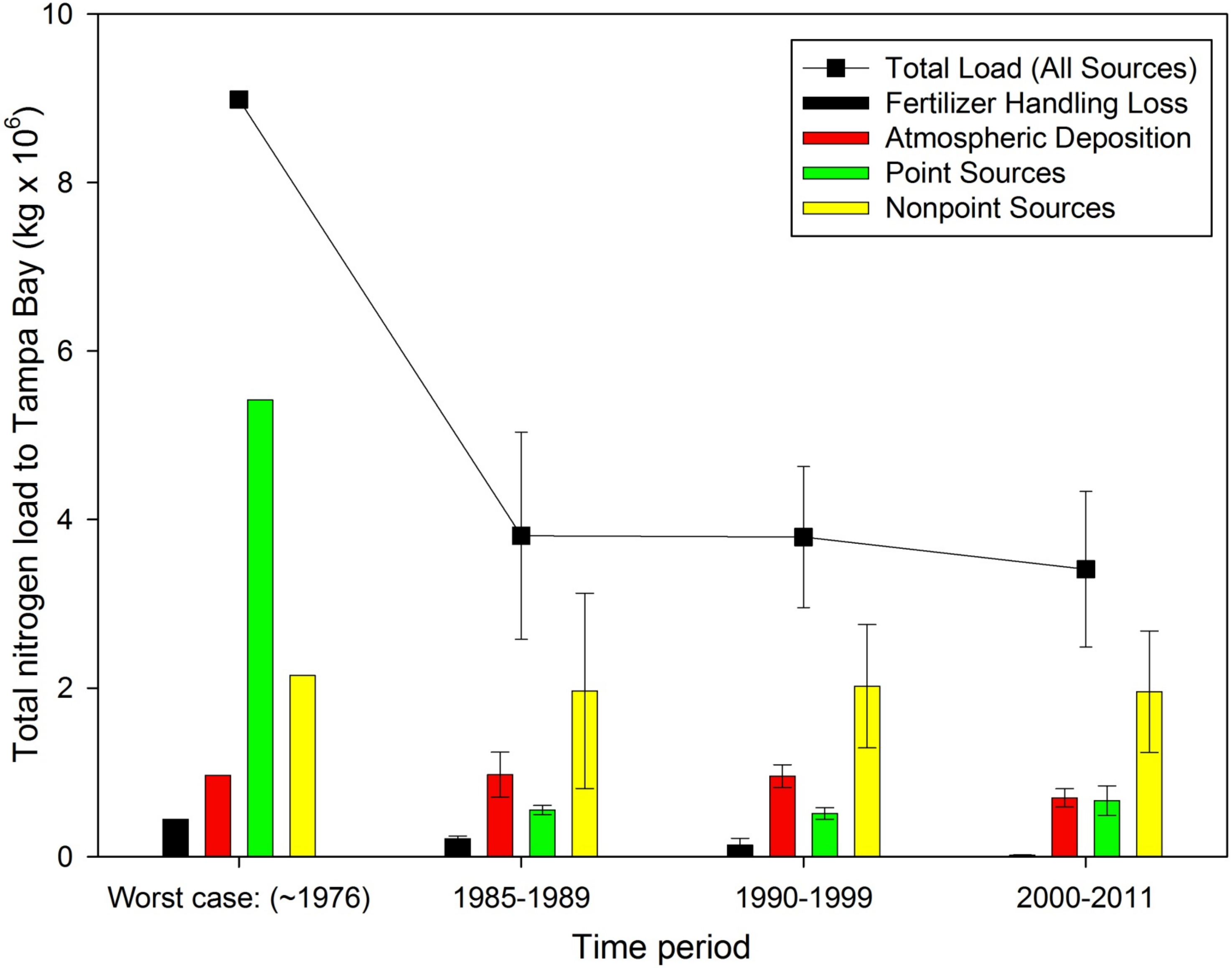
Identified OA management issues include:

- Shellfish, crustaceans, corals – impacts on larval development and shell production
- Fish- Potential secondary impact from reduced food organisms

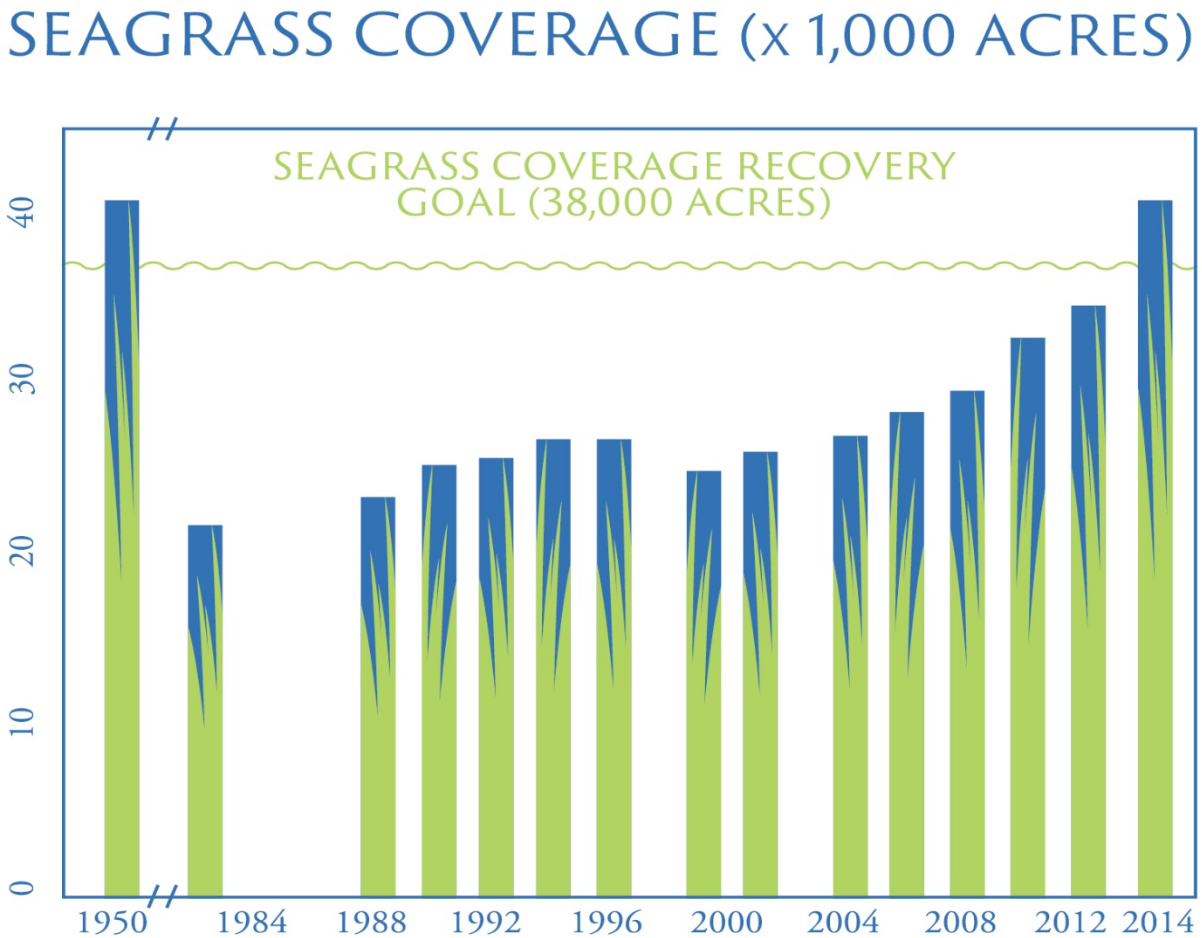
The question:

Can water quality improvements and seagrass recovery assist in providing 'OA refugia' in estuaries?

Tampa Bay nitrogen load decreased by 50%

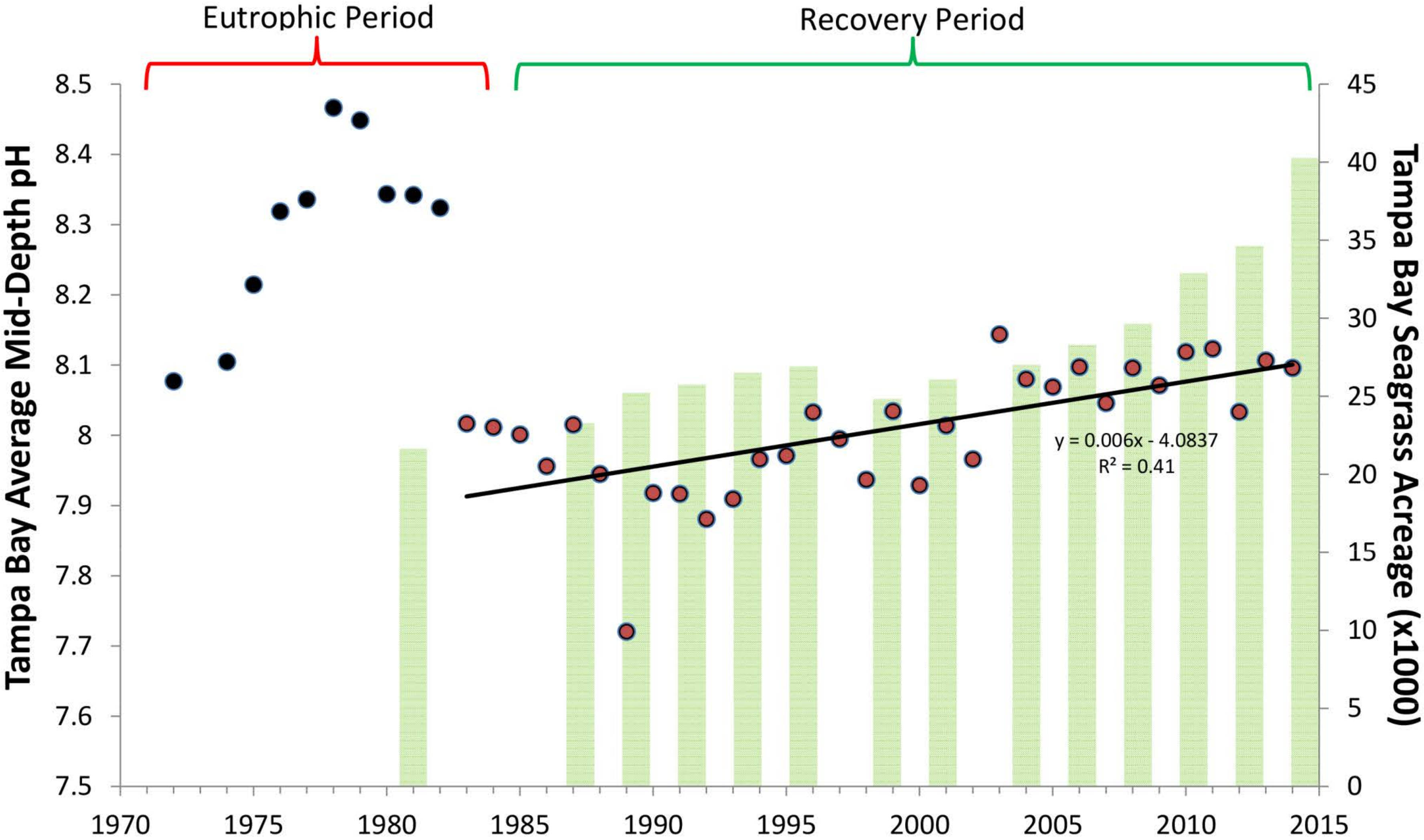


Seagrass Recovery Goal Met

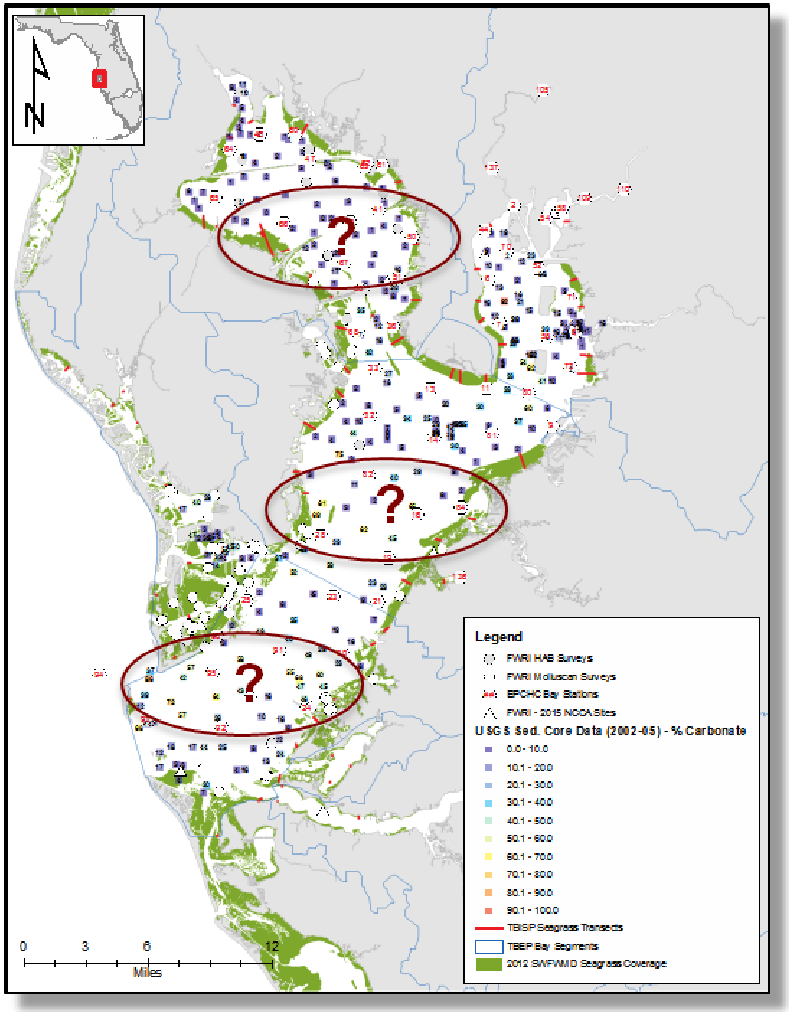


Data: SWFWMD

Long-term pH measurements indicate increases with seagrass recovery



Tampa Bay OA Monitoring Collaboration



LOCAL: Water quality

Environmental Protection Commission of Hills. County

100 fixed long-term water quality stations (1972-present)

REGIONAL: Seagrass extent

Southwest Florida WMD

Aerial surveys every 2 years (1982-present)

STATE: Molluscs, HABs, Fish

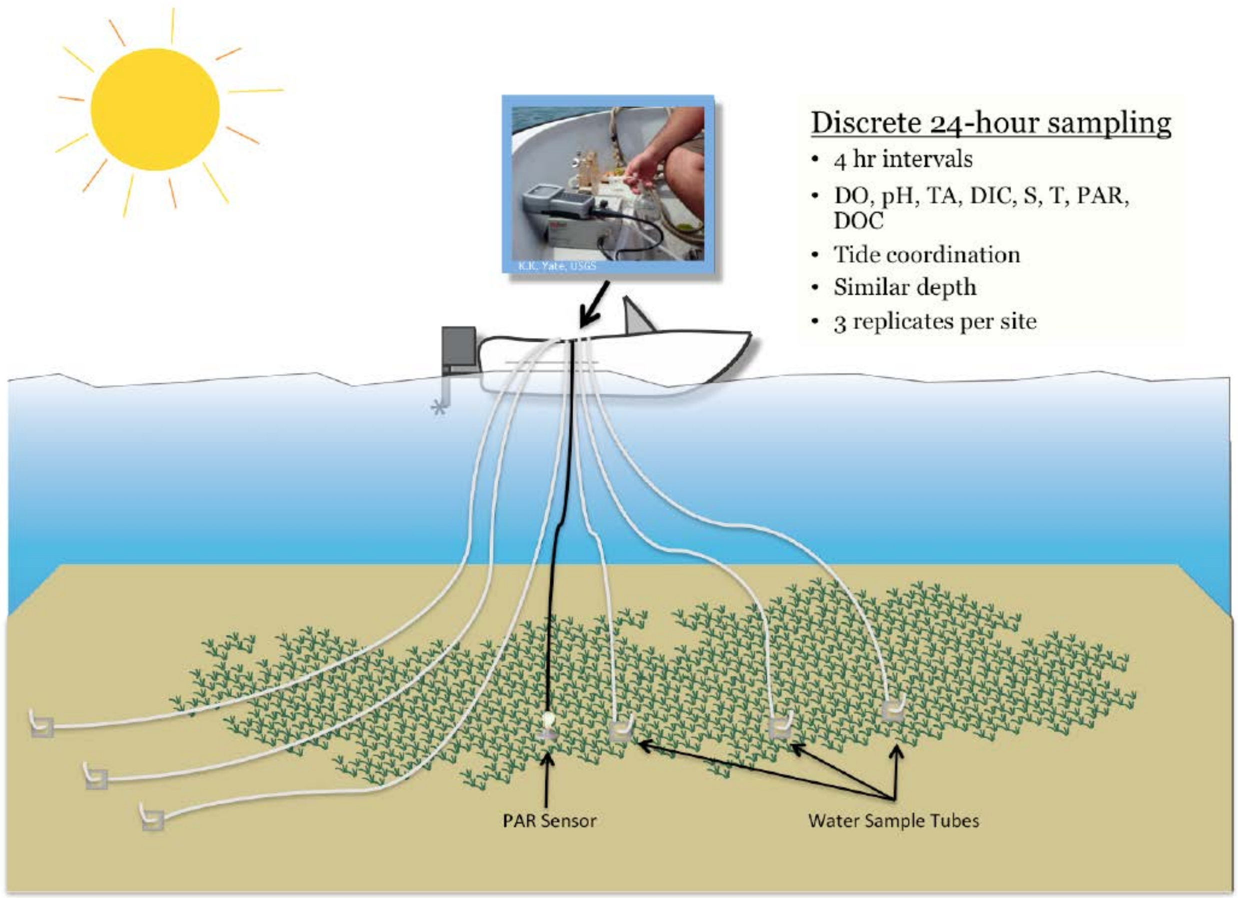
Florida Fish and Wildlife Conservation Commission

Random sites 1990-present

FEDERAL: Sediment cores

USGS (2002-2005)

Ongoing Research



USGS, FWRI, TBEP examining the role of seagrass beds in elevating pH and carbonate mineral saturation state in Tampa Bay

Ocean Acidification

the Southeastern Bivalve Industry

Defining the bivalve industry in the Southeast U.S.

the number of hatcheries by state South of Virginia

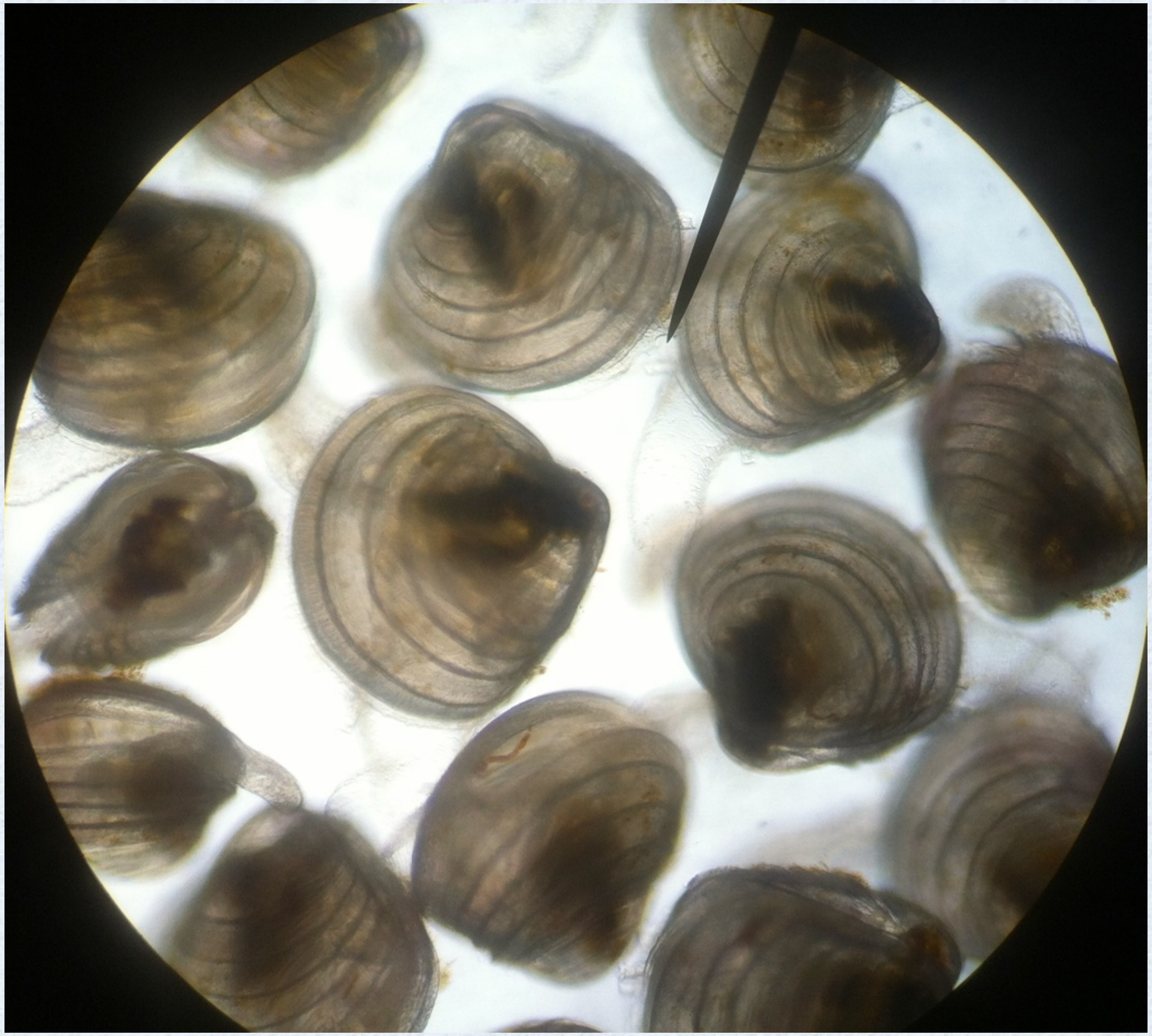
1- Louisiana
1- Alabama
8- Florida
1- Georgia
1- South Carolina

regional industry in regards to Ocean Acidification?

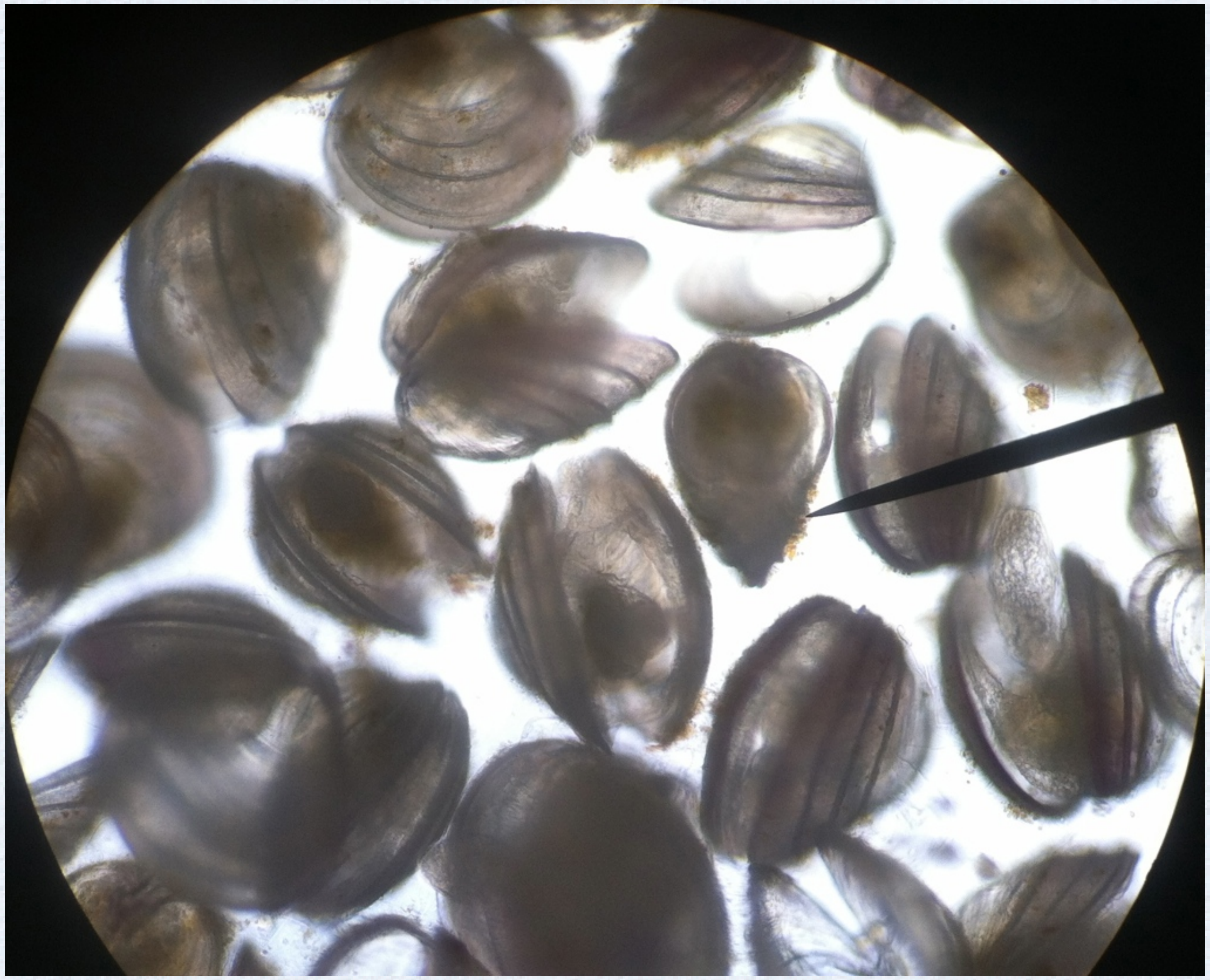
What do we know?

Have we done any testing?

What is planned?



looking at Ocean Acidification?

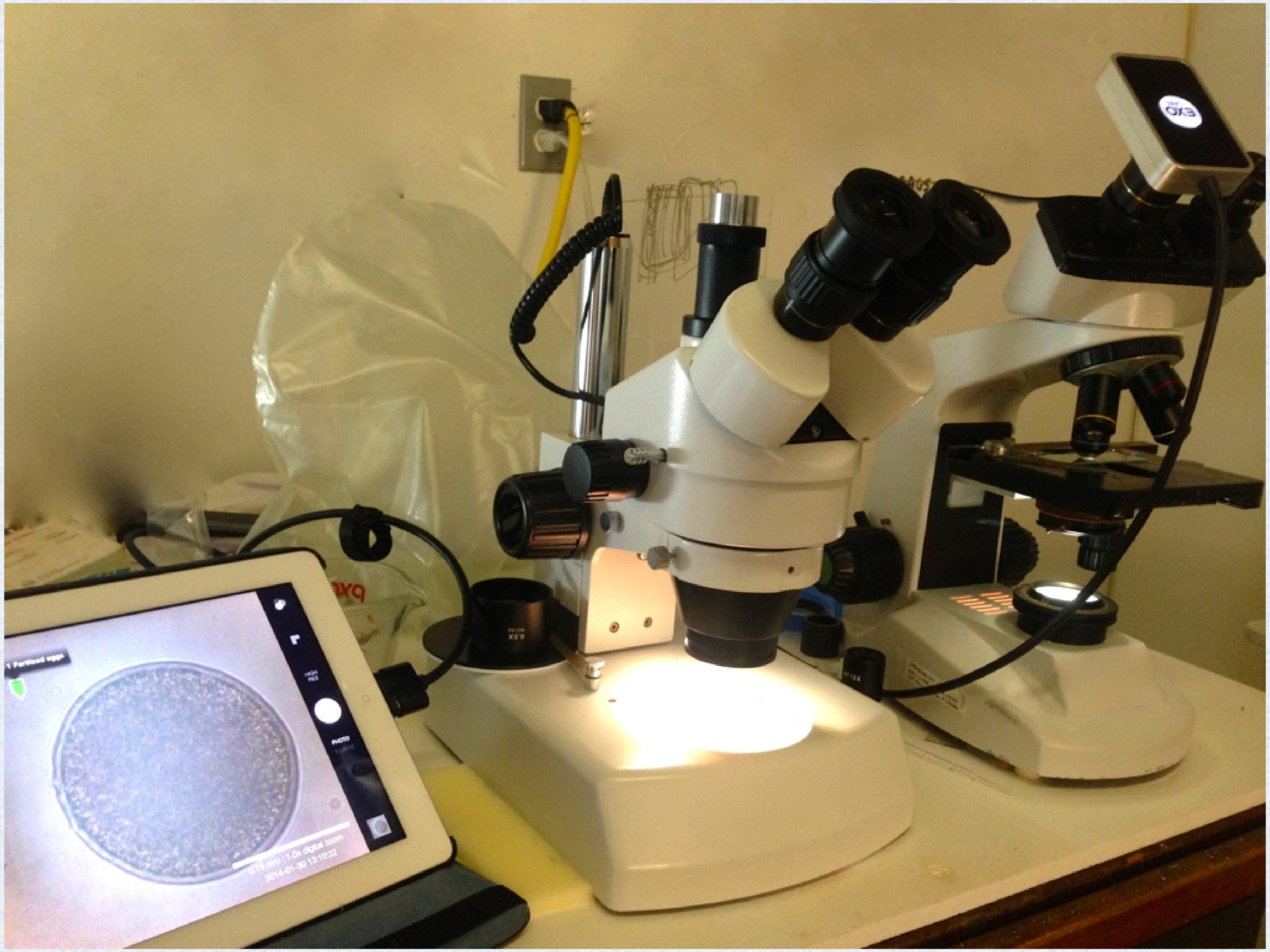


- It has been a defined problem with hatcheries in other regions

- Economically the bivalve industry in the Southeastern U.S. is worth 100’s of millions of dollars.

- Bivalve larvae along with other sensitive invertebrates represent the Canary in the Coal Mine

History of unknown diseases and mortality in bivalves



What are other regions in the world doing?

What should we be doing?