Recommended Indicators of Estuarine Water Quality for Georgia

Joan Sheldon and Merryl Alber

Dept. of Marine Sciences
University of Georgia
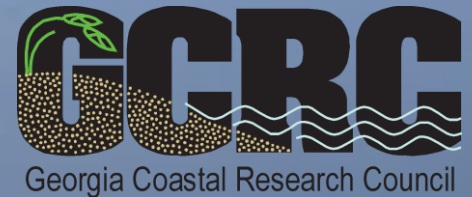Athens, Georgia

jsheldon@uga.edu

Photo courtesy W. Sheldon

Recommended Indicators for Georgia

The Condition of Georgia's Coastal Waters:

Development and Analysis of Water Quality Indicators

Joan E. Sheldon and Merryl Alber

Georgia Coastal Research Council
Dept. of Marine Sciences
University of Georgia
Athens, GA 30602

Technical Report

GEORGIA
DEPARTMENT OF NATURAL RESOURCES
COASTAL RESOURCES DIVISION

NOAA
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
U.S. DEPARTMENT OF COMMERCE

GCRC
Georgia Coastal Research Council

Table of Contents

http://www.gcrc.uga.edu/Research/sheldon_indicators.html

NOAA

EFFECTS OF NUTRIENT
ENRICHMENT IN THE
NATION'S ESTUARIES:
A Decade of Change

National Estuarine Eutrophication
Assessment Update

EPA et al.

National Coastal
Condition Report III

Eutrophic symptoms

Few symptoms occur at more than minimal levels.

Symptoms occur episodically and/or over a small to medium area.

Symptoms occur less regularly and/or over a medium area.

Symptoms occur less regularly and/or over a medium to extensive area.

Symptoms occur periodically or persistently and/or over an extensive area.

N, residence time

Influencing factors
(loads and susceptibility)

chlorophyll *a*
macroalgae
DO
SAV loss
HABs

Runoff
Sewage effluent

Phytoplankton Bloom
thrives on nutrients

Dissolved Oxygen
from wave action
and photosynthesis

Dissolved Oxygen
trapped in the upper,
lower-salinity layer

Lower-density
surface water

Dead
material
settles

Decomposition

Higher-density
bottom water

Dissolved Oxygen used up
by microorganism respiration

HYPOXIA

Nutrients
released by bottom sediments

Fish will avoid
hypoxia if possible

Dissolved Oxygen consumed

Shellfish
and other
benthic
organisms
unable
to escape
hypoxia

Decomposition of organic
matter in sediments

DIN
DIP
chlorophyll *a*
DO
water clarity

EPA-Mandated Numeric Nutrient Criteria

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

"To be effective, nutrient criteria should address *causal* (both nitrogen and phosphorus) and *response* (chlorophyll-*a* and transparency) variables for all waters that contribute nutrient loadings to our waterways."

MEMORANDUM

SUBJECT: Nutrient Pollution and Numeric Water Quality Standards

FROM: Benjamin H. Grumbles
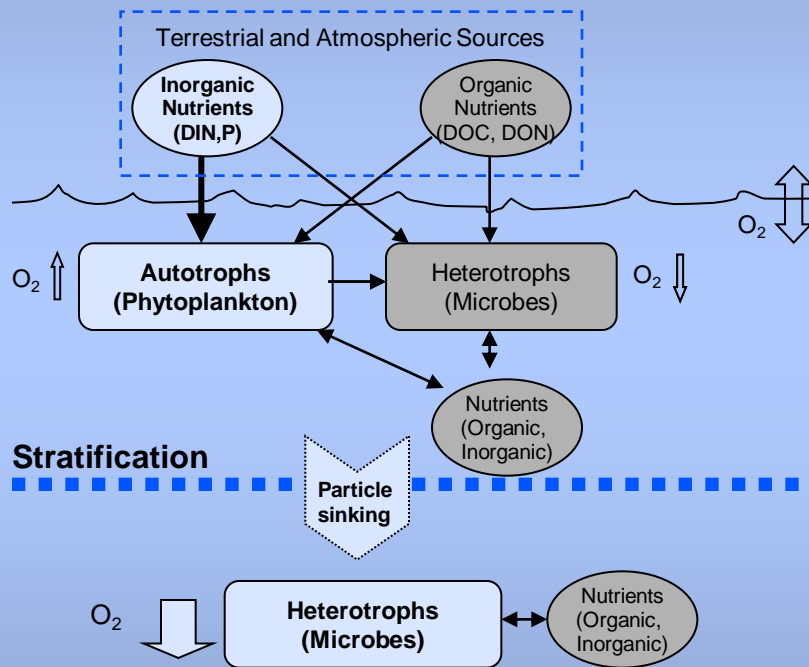   Assistant Administrator

TO:

"As always, States, Territories and authorized Tribes have the flexibility to address nutrient pollution using a subset of or alternatives to these parameters if they are shown to be scientifically defensible and protective of designated uses."

This memo provides a national update on the development of numeric nutrient water quality standards and describes EPA's commitment to accelerating the pace for progress. EPA published
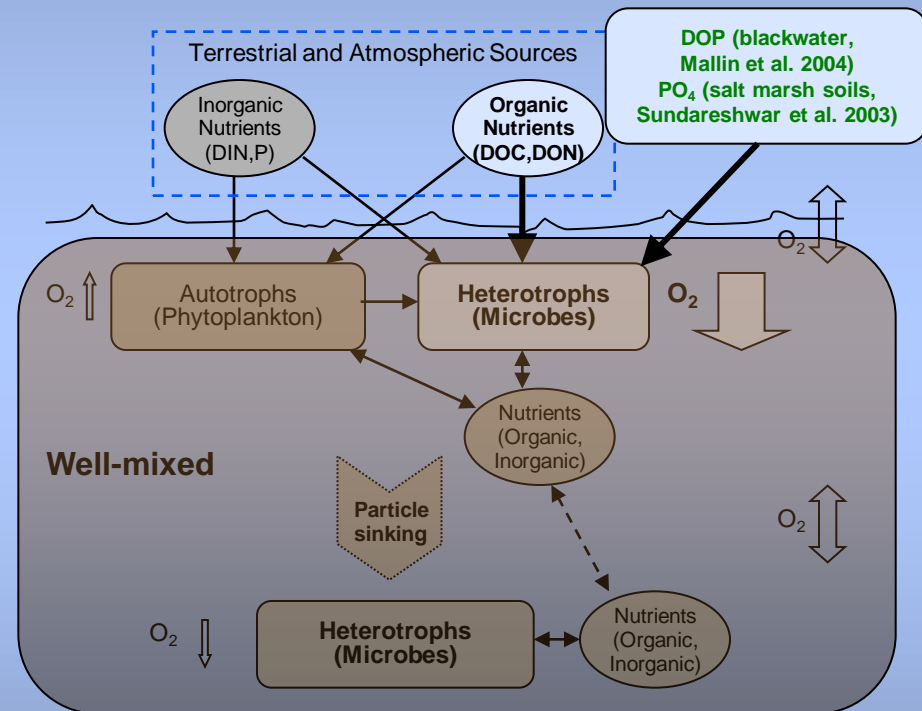
Eutrophication in Coastal Georgia

phytoplankton-mediated pathway in stratified water

Terrestrial and Atmospheric Sources

Inorganic Nutrients (DIN,P)

Organic Nutrients (DOC, DON)

O_2

Autotrophs (Phytoplankton)

Heterotrophs (Microbes)

O_2

O_2

Nutrients (Organic, Inorganic)

Stratification

Particle sinking

O_2

Heterotrophs (Microbes)

Nutrients (Organic, Inorganic)

Generally too turbid for SAV

microbially mediated pathway in unstratified water

DOP (blackwater, Mallin et al. 2004) PO_4 (salt marsh soils, Sundareshwar et al. 2003)

Terrestrial and Atmospheric Sources

Inorganic Nutrients (DIN,P)

Organic Nutrients (DOC,DON)

O_2

Autotrophs (Phytoplankton)

Heterotrophs (Microbes)

O_2

O_2

Nutrients (Organic, Inorganic)

Well-mixed

Particle sinking

O_2

Heterotrophs (Microbes)

Nutrients (Organic, Inorganic)

Light levels could affect the balance between nutrient uptake by autotrophs and heterotrophs.

Modified from Verity et al. 2006

What should we measure?

phytoplankton-mediated pathway in stratified water
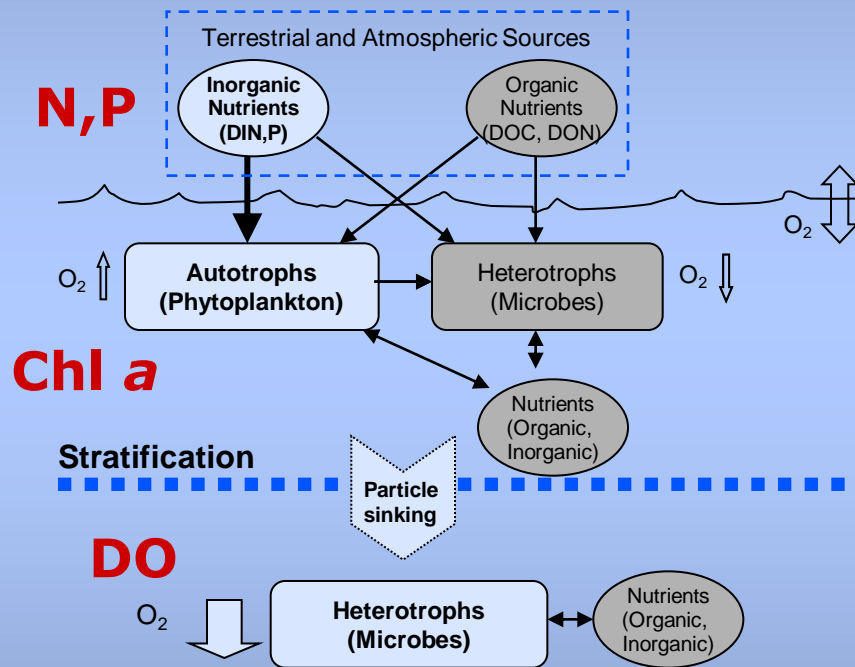
microbially mediated pathway in unstratified water
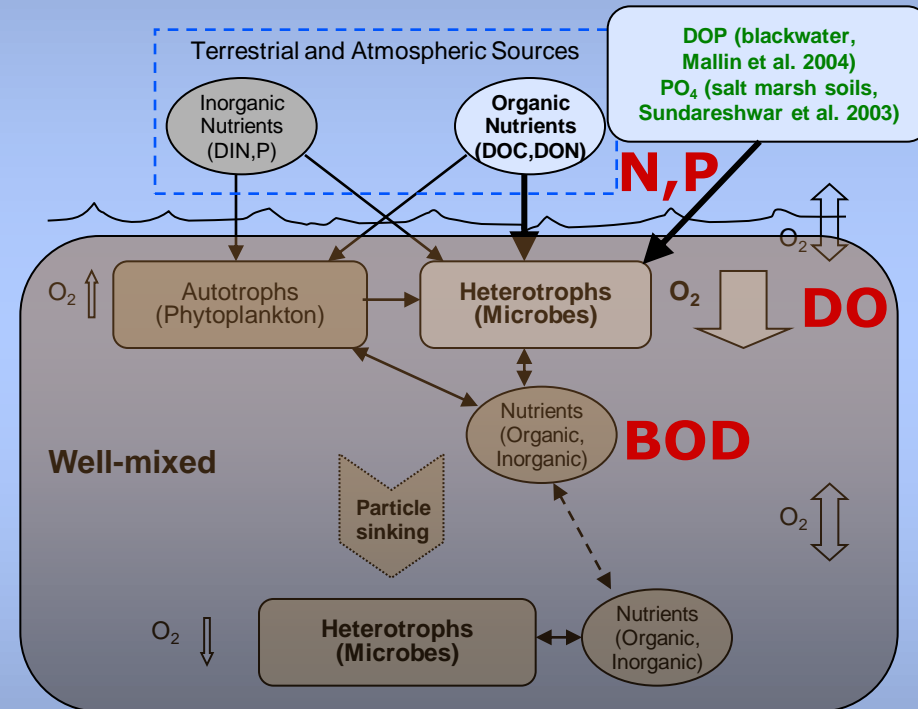
Recommended Indicators for Georgia

"Early warning" indicators of potentially poor water quality

1. Nitrogen

2. Phosphorus

3. Chlorophyll *a*

4. Transparency

5. Biochemical oxygen demand (BOD)

"Immediate" indicators of poor water quality

6. Dissolved oxygen

7. pH

Ancillary data

Water temperature

Salinity

Specific conductance

Criteria

🟢 **Good**

🟡 **Fair**

🔴 **Poor**

TDN, TDP

Encompass fractions used by phytoplankton and microbes

Recommended by 2 panels of experts as best if financial resources are limited (Bricker et al. 1999, 2007; DiDonato, in press)

Follow NEEA (Bricker et al. 1999) until local models developed

Criteria

TDN, mg L^{-1}

🟢 **Good** TDN $\leq$ 0.1

🟡 **Fair** 0.1 < TDN $\leq$ 1.0

🔴 **Poor** TDN > 1.0

Metrics

Annual median

Criteria

TDP, mg L^{-1}

🟢 **Good** TDP $\leq$ 0.01

🟡 **Fair** 0.01 < TDP $\leq$ 0.1

🔴 **Poor** TDP > 0.1

Metrics

Annual median

General indicator of algal biomass

In Georgia

Seagrass shading not an issue…

But what levels may lead to hypoxia via bloom degradation?

Need local data/models

In the meantime, national studies (NEEA, NCCR) are in good agreement based on expert judgment
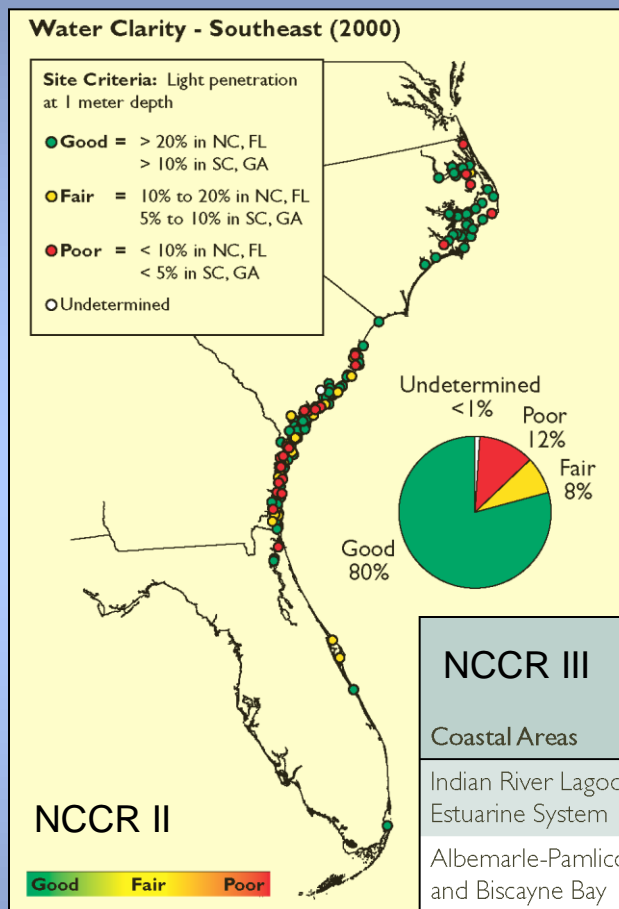

Criteria

Chlorophyll *a*, μg L^{-1}

🟢 **Good** Chl $\leq$ 5

🟡 **Fair**   5 < Chl $\leq$ 20

🔴 **Poor** Chl > 20

Metrics

Annual maximum

Annual median

High light transmission requirements of seagrass are not applicable to (and probably not achievable in) Georgia waters.

Criteria

% transmission at 1m
(or Secchi equivalents)

🟢 **Good** Trans ≥ 10

🟡 **Fair** 5 ≤ Trans < 10

🔴 **Poor** Trans < 5

Metrics

Annual median

Water Clarity - Southeast (2000)

Site Criteria: Light penetration at 1 meter depth

- **Good** = > 20% in NC, FL
  > 10% in SC, GA
- **Fair** = 10% to 20% in NC, FL
  5% to 10% in SC, GA
- **Poor** = < 10% in NC, FL
  < 5% in SC, GA
- Undetermined

Undetermined <1%
Poor 12%
Fair 8%
Good 80%

NCCR II

Good Fair Poor

NCCR III Coastal Areas	Criteria for a Poor Rating (Percentage of Ambient Light that Reaches 1 Meter in Depth)
Indian River Lagoon Estuarine System	< 20%
Albemarle-Pamlico and Biscayne Bay estuarine systems	< 10%
All Remaining Southeast Coast estuarine systems	< 5%

Measure the potential for microbially mediated hypoxia

5-day BOD is traditional, for more labile substances

20-day BOD may also be informative (Mallin et al. 2006), especially for slowly flushed systems
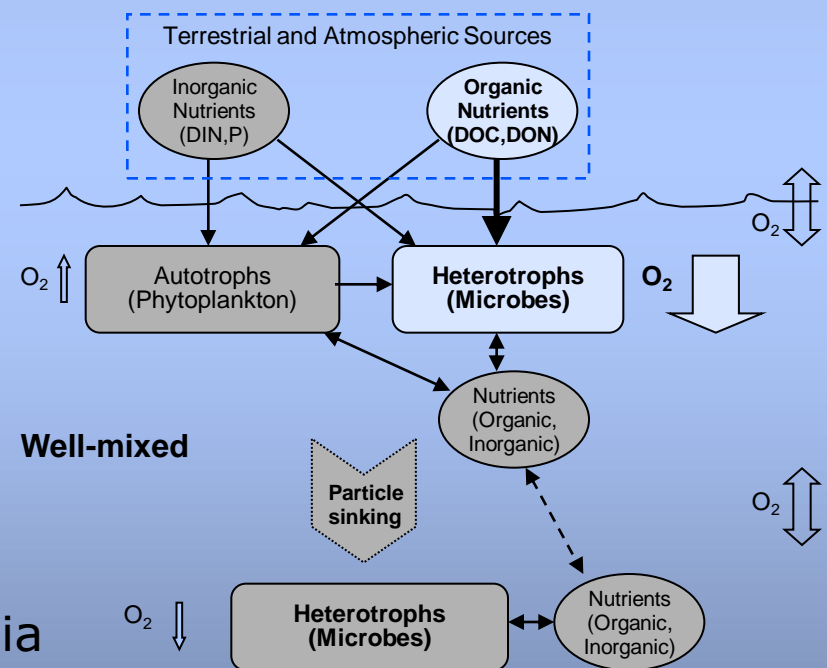
Criteria have been developed for exogenous *loads*, not in-estuary *concentrations*
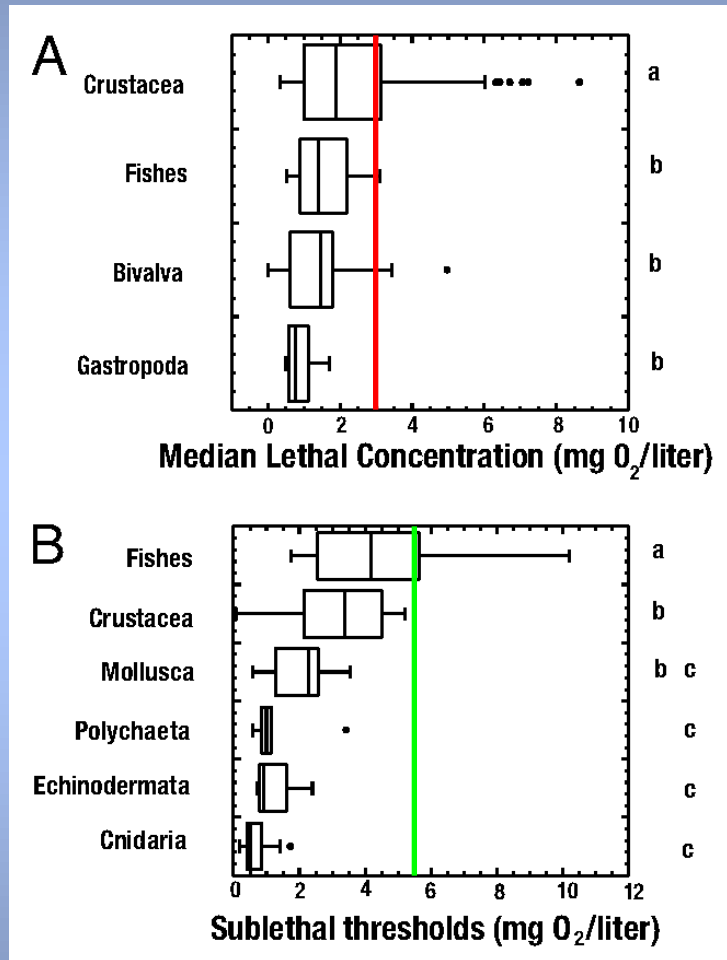
Recommendations for GA:

Measure BOD_5, BOD_{20}

Relate to subsequent DO minima

Develop criteria for avoiding hypoxia

Terrestrial and Atmospheric Sources

Inorganic Nutrients (DIN,P)

Organic Nutrients (DOC,DON)

O_2

O_2

Autotrophs (Phytoplankton)

Heterotrophs (Microbes)

O_2

Nutrients (Organic, Inorganic)

Well-mixed

Particle sinking

O_2

O_2

Heterotrophs (Microbes)

Nutrients (Organic, Inorganic)

Criteria

Surface water, daytime, mg L^{-1}

- 🟢 **Good** DO $\geq$ 5.5
- 🟡 **Fair** $3 \leq$ DO < 5.5
- 🔴 **Poor** DO < 3

Metrics

Annual minimum

Annual median

Estuaries experience potentially stress-inducing pH changes in spite of the buffer capacity of seawater and the fact that "normal" pH varies from one location to another.

ΔpH ≤ 0.5 units tolerated well by many organisms

    (but ⬆ ventilation in sharks)
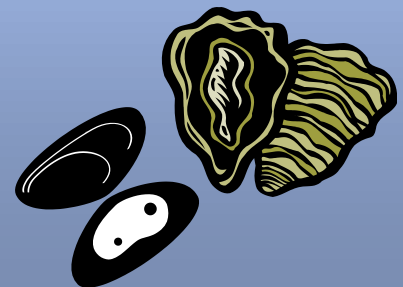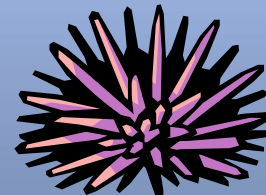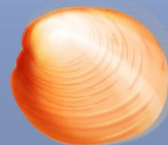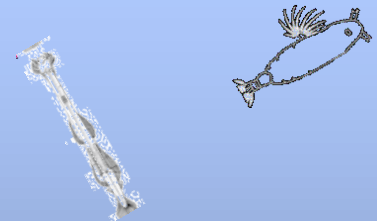
ΔpH ≥ 1 (pH decreases usually of concern)

    metabolic stress due to internal pH compensation
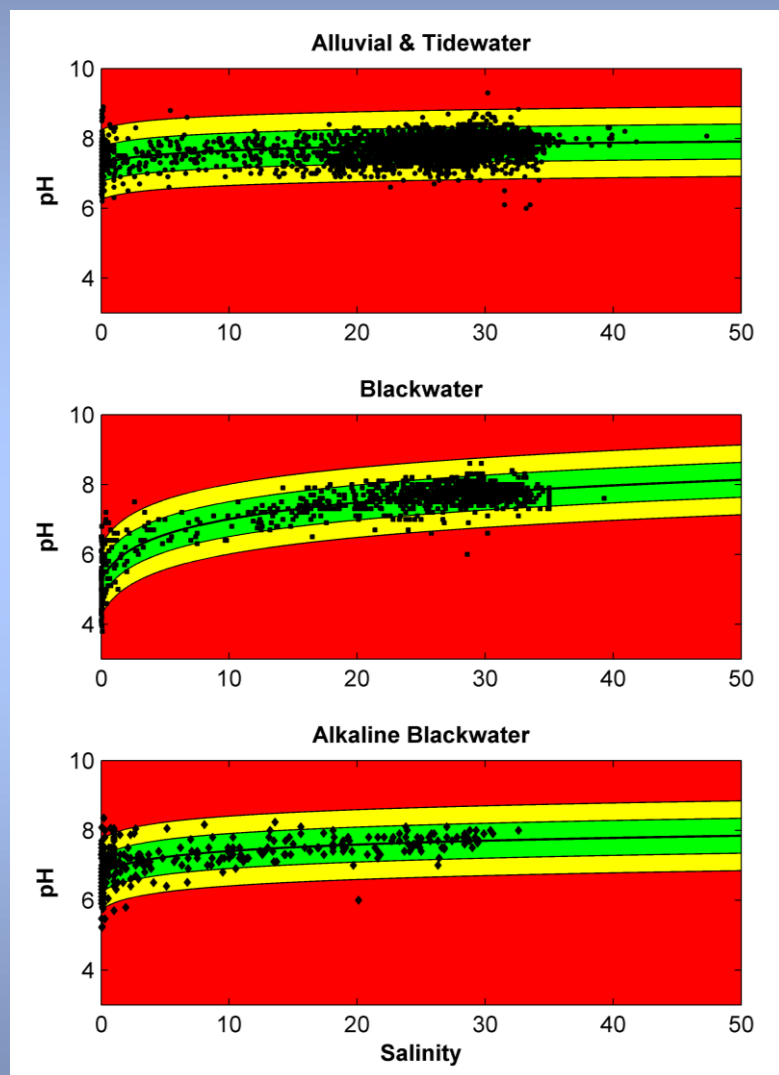
    inability of some larvae to compensate

    ⬇ calcification / ⬆ shell dissolution

    ⬇growth, reproductive potential, survival

(Knutzen 1981; Fabry et al. 2008)

Criteria

$$\Delta pH = pH_{sample} - E(pH_{(estuary\ type, salinity)})$$

🟢 **Good** $\Delta pH \leq 0.5$

🟡 **Fair** $0.5 < \Delta pH \leq 1$

🔴 **Poor** $\Delta pH > 1$

Metrics

Annual minimum pH / maximum change

Annual median

Summarizes Status for N, P, DO, pH

http://www.gcrc.uga.edu/Research/sheldon_indicators.html

Georgia Coastal Water Quality
2000 - 2006

Acknowledgments

Photo courtesy SkIO Photo Gallery