Eutrophication in the US and Elsewhere:
NOAA's National Estuarine Eutrophication Assessment

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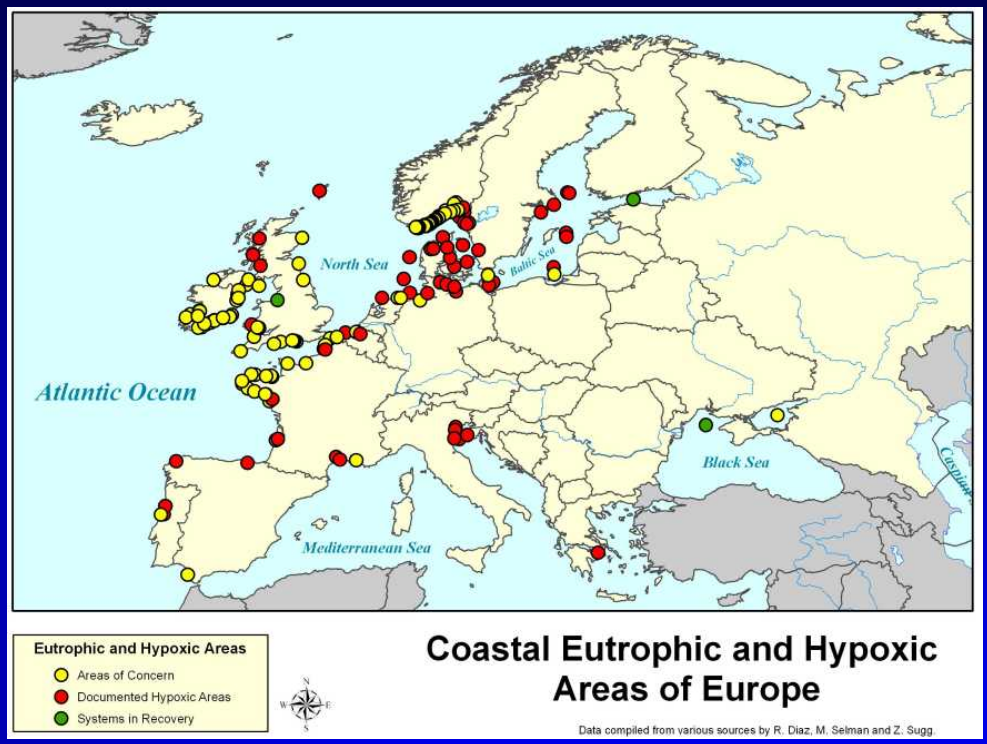
http://www.eutro.org
http://www.eutro.us

National and International Partners

Picture yourself here?!

Global Context and Guiding Legislation for Nutrient Issues

- **US** *Clean Water Act of 1972, US Harmful Algal Bloom and Hypoxia Research and Control Act of 1998*
- **EU** *Water Framework Directive 2000, older generation directives: Urban WasteWater Treatment Directive and Nitrates Directive, Marine Strategy Framework Directive 2008*
- **PRC** *Environmental Protection Law 1989, Law on Prevention and Control of Water Pollution 1996, Marine Environmental Protection Law of 2000*

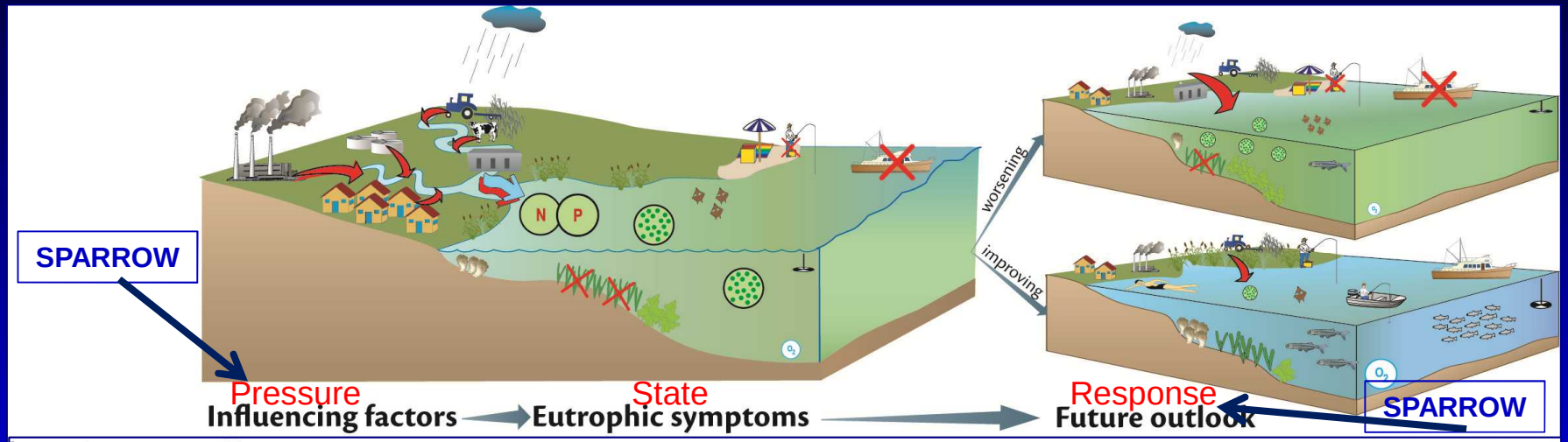


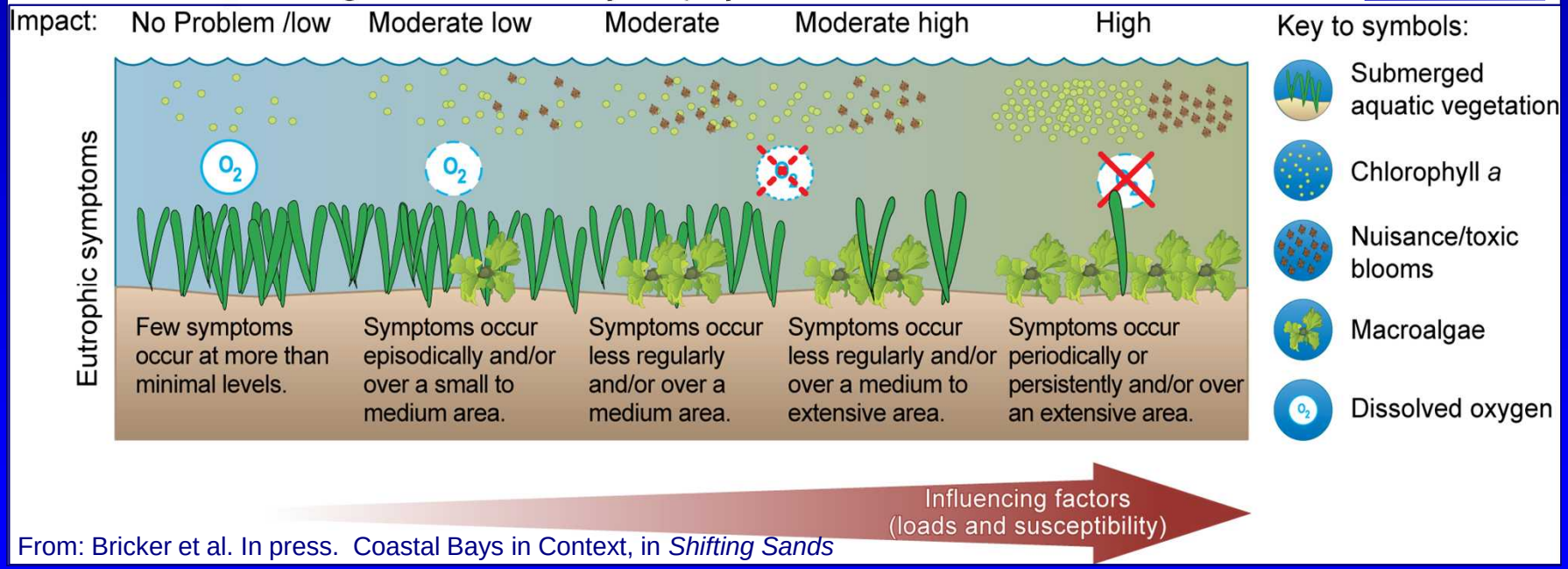
Diaz, R.J. and R. Rosenberg. 2008. Spreading dead zones and consequences for marine ecosystems. Science 321:926-928

- **Eutrophication** is a significant problem worldwide (US, EU, China, Japan, Australia and elsewhere)

ASSETS Eutrophication Assessment Components

科学问题 – 评估方法和成分





From: Bricker et al. In press. Coastal Bays in Context, in *Shifting Sands*

http://www.eutro.us http://www.eutro.org/register

What does eutrophication look like? Where is it?

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Qingdao, China

Key Aspects of NEEA/ASSETS approach

The NEEA approach may be divided into three parts:

- ✓ **Division of estuaries into homogeneous areas**
  - **Tidal freshwater (<0.5 psu)**
  - **Mixing zone (0.5-25 psu)**
  - **Seawater zone (>25 psu)**
- ✓ **Evaluation of data completeness and reliability**
  - Spatial and temporal quality of datasets (completeness)
  - Confidence in results (sampling and analytical reliability)
- ✓ **Application of indices**

State: Eutrophic Condition index (Chl, macroalgae, HABs, DO, SAV loss)

Pressure: Influencing Factors index (susceptibility + nutrient load)

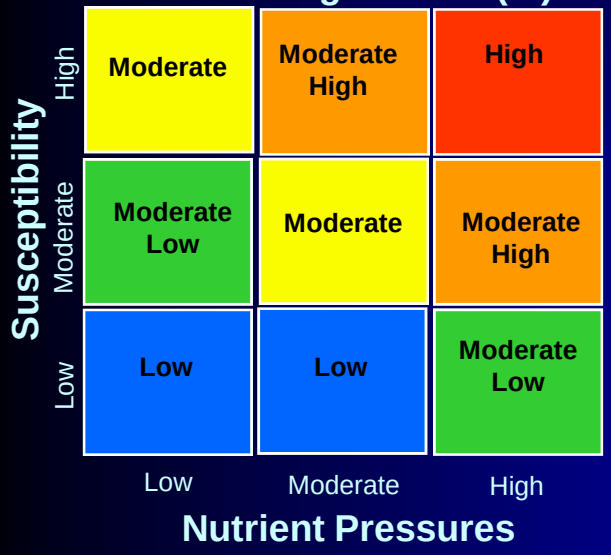
Response: Future Outlook index (susceptibility + future nutrient load)

Guide for management, research, monitoring

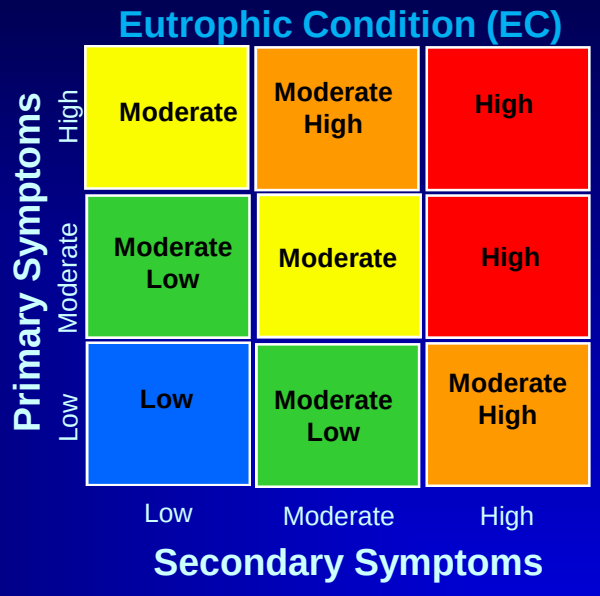
Pressure - State - Response:

Influencing Factors + Eutrophic Condition + Future Outlook → ASSETS

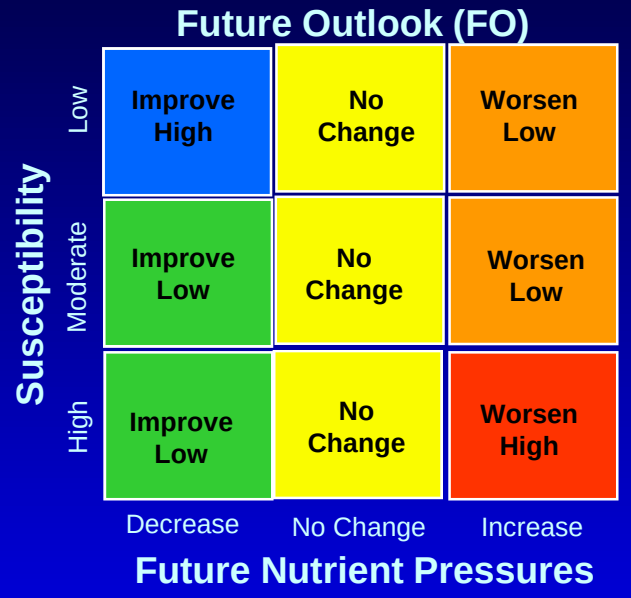
Influencing Factors (IF)



Eutrophic Condition (EC)



Future Outlook (FO)



Susceptibility
dilution & flushing

\+

Nutrient Inputs
land based or oceanic

SPARROW

Primary Symptoms
Chloropyll a
Macroalgae

\+

Secondary Symptoms
Dissolved Oxygen
Nuisance/toxic blooms
SAV change in spatial coverage

Susceptibility natural processing

Nutrient pressure expected changes in load

SPARROW?

IF + EC + FO = ASSETS

Influencing Factors - Pressures

Natural processing through flushing (tidal action, FW inflow) and dilution (volume FW /system volume)

+

Land-based* and oceanic nutrient loads

* For most US coastal water bodies, land based sources are much greater than oceanic sources

Land-based loads are calculated from river flow x concentration or by models such as *USGS SPARROW*.

SPARROW model estimates were used in the 1999 report, future updates of the NEEA?!

NOTE: Meaningful interpretation of load-response relationships (and resultant management recommendations) are dependent on concurrence of timeframe of load estimates and water quality assessment

Influencing Factors from NEEA 1999

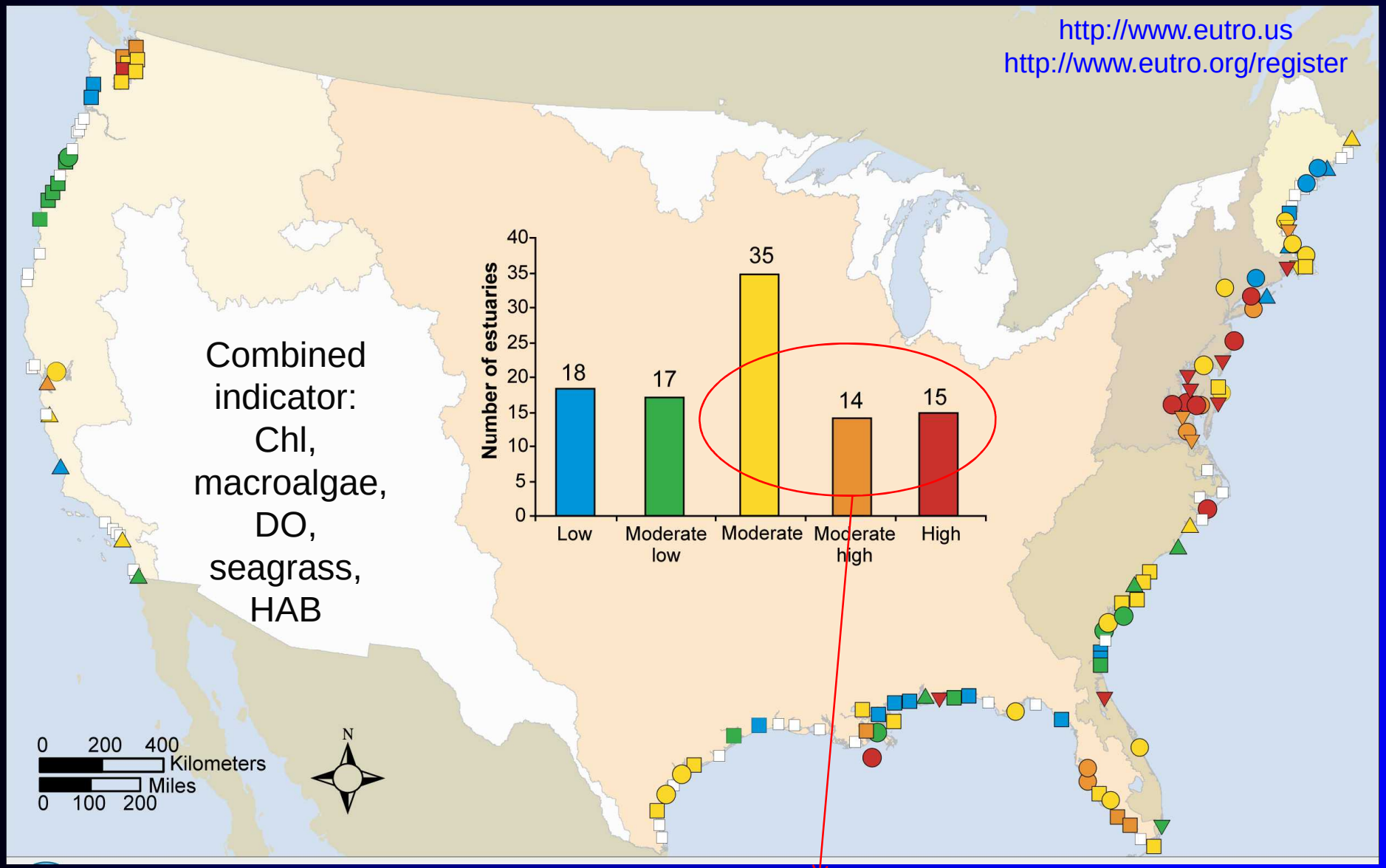
Region No. systems	Human Influence Mod – High (% systems)	>50% NPS (% M – H systems)	Primary NPS from Ag* (% >50% NPS systems)
No. Atlantic (18)	33	78	0
Mid Atlantic (22)	100	91	60
So. Atlantic (22)	81	100	81
Gulf of Mexico (38)	95	100	85
Pacific (39)	82	89	50
US Total (139)**	68	92	56
Portugal (10)	30	89	67
China (4)	75	?	?

US from SPARROW model estimates base year 1987, PT from Ferreira et al 2003

**for US: >30% though most are >70% from ag, for PT: ag is most significant nonpt source*

****Early 2000s: 44 of 64 (~70%) systems evaluated had moderate to high influencing factors***

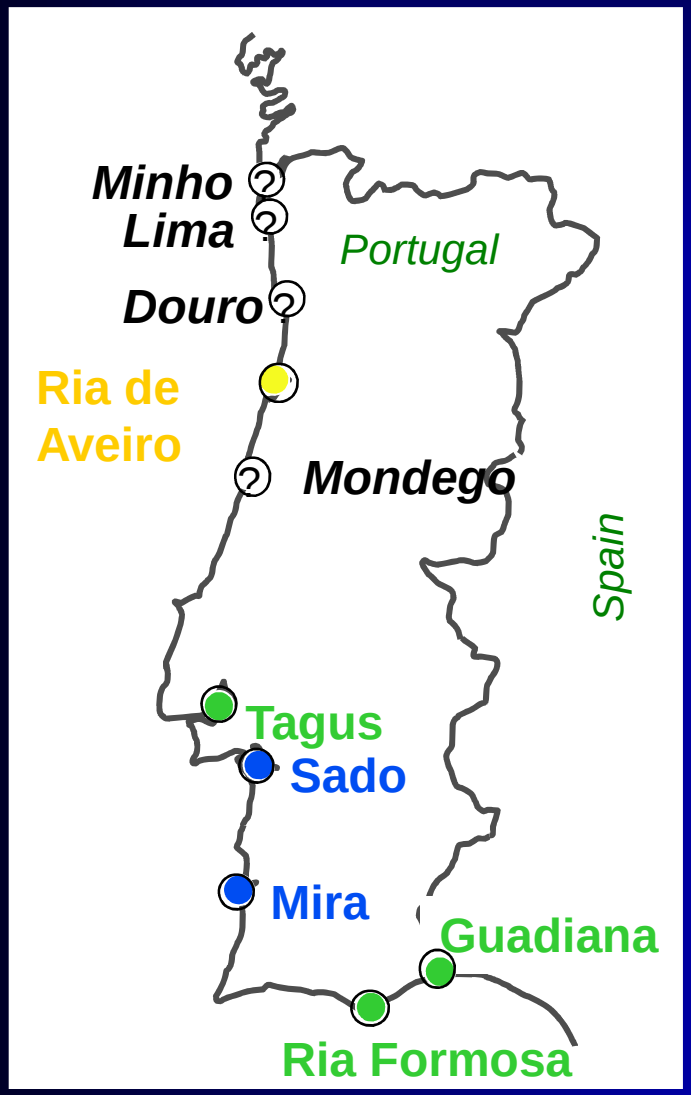
Overall Eutrophic Condition



65% of assessed systems M to H eutrophication, same in early1990s

Overall Eutrophic Condition

- *Unknown*
- High
- Moderate High
- Moderate
- Moderate Low
- Low

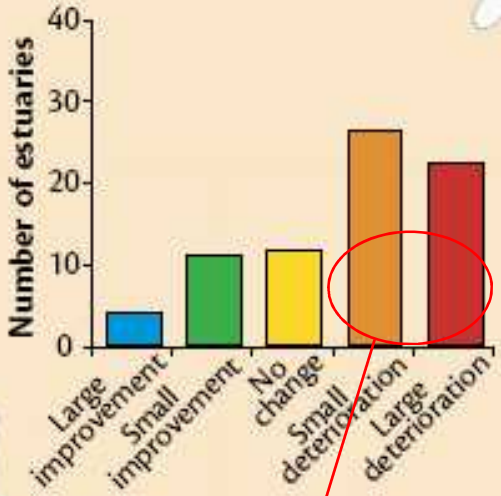


Future Outlook

http://www.eutro.us
http://www.eutro.org/register

What will happen next?

Tells us how can we improve and protect water quality?



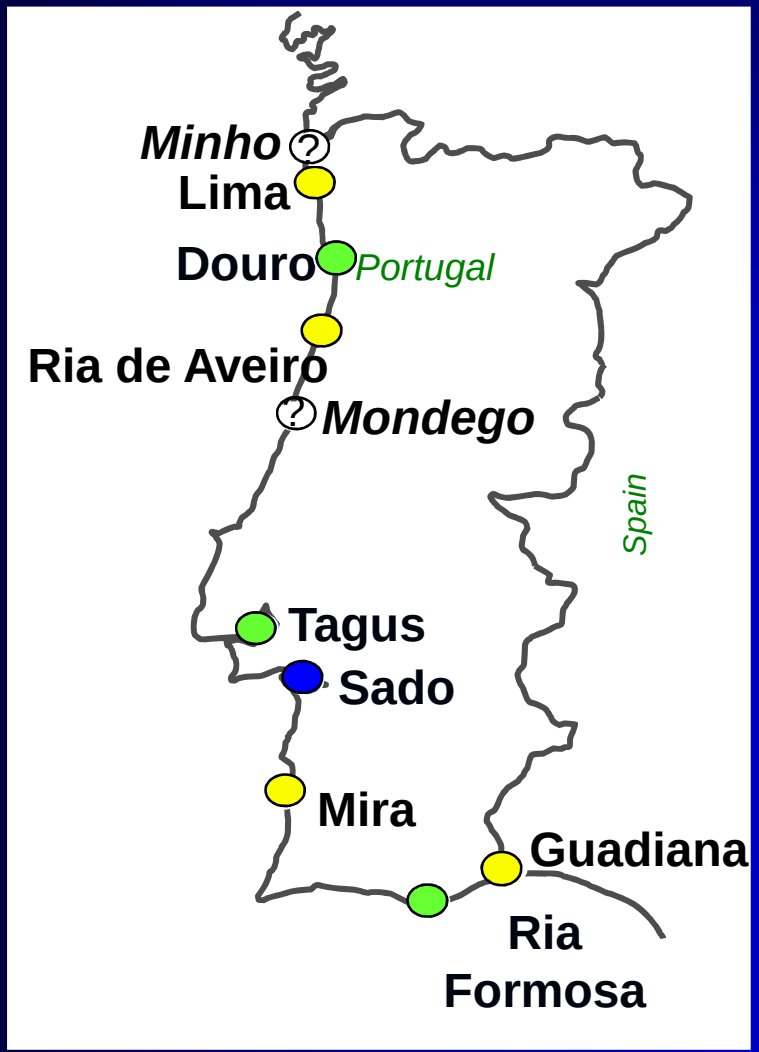
0 200 400 Kilometers
0 100 200 Miles

N

65% (71% in 1990s) assessed systems – worsen
20% (7% in 1990s) assessed systems - improve

Future Outlook

Unknown	No Change
Worsen High	Improve Low
Worsen Low	Improve High



Changes 1990s – 2000s

Analysis was possible for 58 of 141 US systems

Improved: 13 systems (9%) assessed surface area

Worsened: 13 systems (14%) assessed area

Remained the same: 32 systems (77% assessed area)

Due to management efforts, primarily point source

Due to population increase and associated activities

Aquaculture and Eutrophication

Why? A response to diminishing benefit for economic costs of further improvements to traditional management measures

Shellfish Aquaculture and Eutrophication: An "In-the water" nutrient management measure

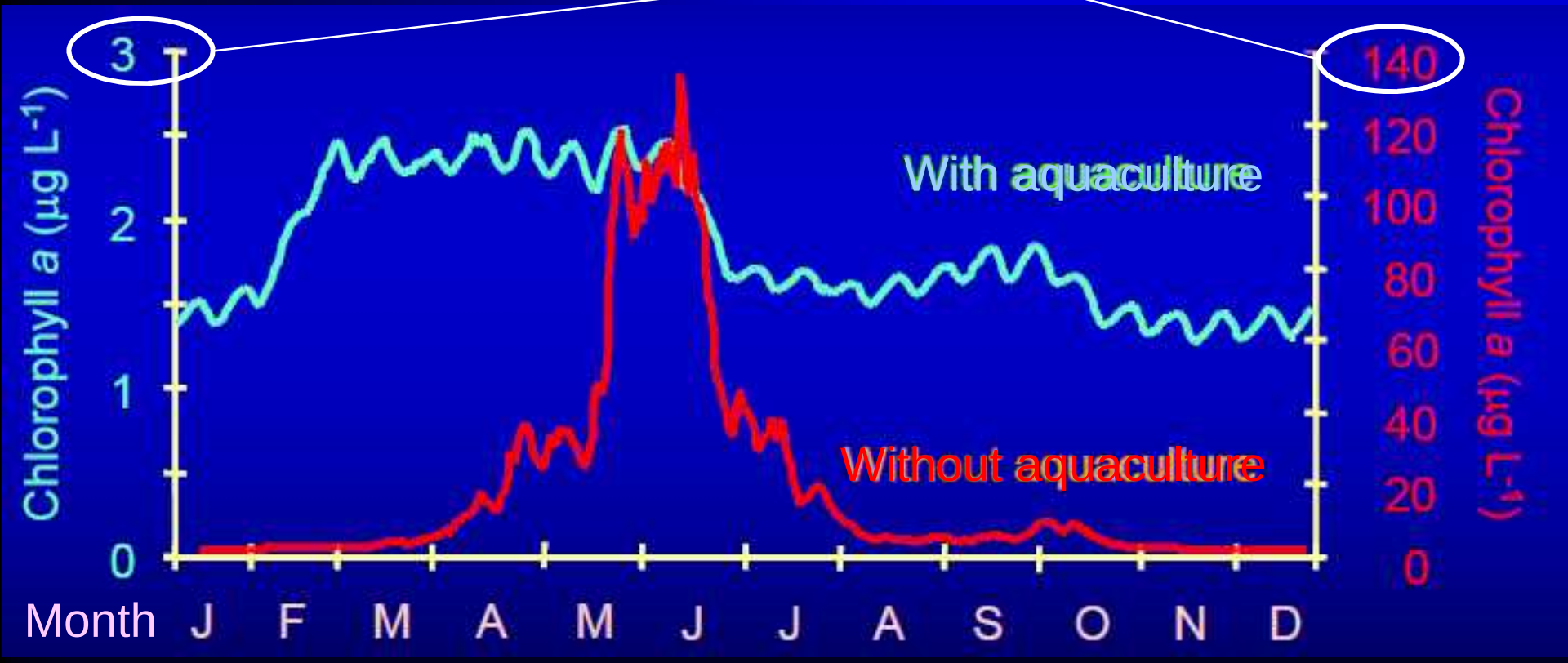
How does bioextraction work?

- Cultivation and harvest of shellfish and macroalgae
- Nutrients are taken up directly (seaweed) or indirectly (shellfish, via plankton, organic detritus)
- Removal of biomass removes nutrients from the ecosystem
- Removal of primary eutrophication symptoms reduces secondary symptoms by (i) improving water clarity, restores SAV; (ii) limiting D.O. loss from decomposition of organic matter
- Shellfish farmers can negotiate nutrient credits to offset loading from land, and be included in the trading program

“Bioextraction” of nutrients (Sanggou Bay, China)

Nutrients → phytoplankton → clams and oysters
remove fattened oysters clams, you also remove nutrients

Chlorophyll concentrations are 50X less with aquaculture!



(From: Sustainable Options for People, Catchment and Aquatic Resources (SPEAR) http://www.biaoqiang.org/)

“Bioextraction” in Long Island Sound, NY

What? How important is the removal of nutrients by shellfish compared to nutrient inputs?

How? Mathematical models simulate growth of shellfish, removal of nitrogen from the water through filtration.

Amount removed by shellfish is compared to inputs, and removal through traditional management.

American Oyster
Crassostrea virginica

Northern Quahog
Mercenaria mercenaria

Ribbed Mussel
Geukensia demissa

Modeling Bioextraction

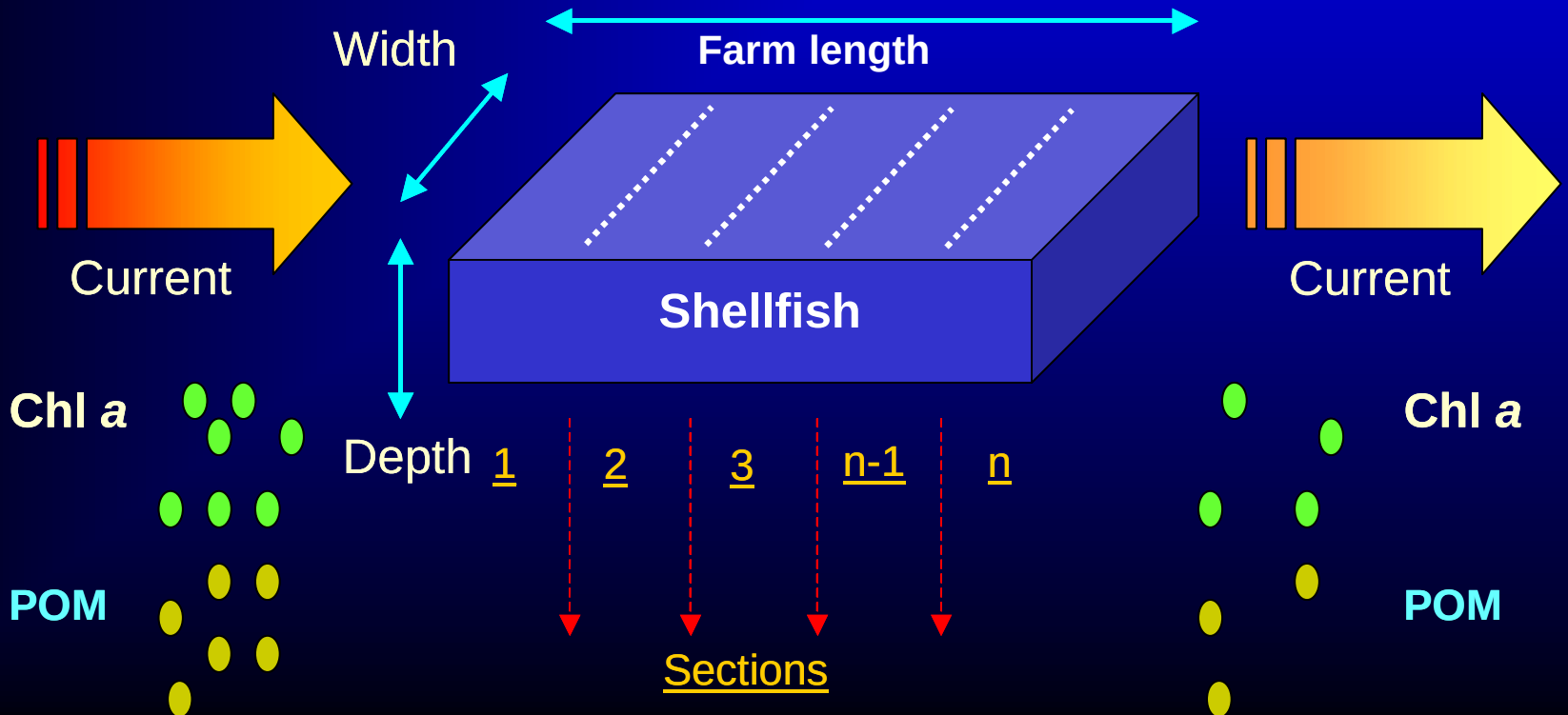
Aquaculture model (FARM)
Farm Aquaculture Resource Management model

Evaluates shellfish growth

+

Eutrophication model (ASSETS)
Assessment of Estuarine Trophic Status

evaluates farm water-quality footprint



What did we find in Long Island Sound?

Preliminary results

- 4.8 tons N removed in one 10 hectare farm*, equal to nutrient removal by traditional measures for ~1,500 people

- Chlorophyll reduced, DO stayed the same

- Aquaculture beds in ~30% LIS area would remove equivalent of present N load (now only ~3% of area is cultivated)

- Farmer income increased 2-5% for nutrient treatment

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*how big is that?
20 soccer or field hockey fields, 19 football fields or 18 lacrosse fields

Summary and Conclusions

National Estuarine Eutrophication Assessment –

- Significant nutrient related impact in 65% of US estuaries, little change from early 1990s – early 2000s
- Continued management is needed
- Periodic assessment updates to evaluate success – ***SPARROW loads are needed for meaningful assessment***
- Innovative management needed as further reductions become economically unsupportable

Use of shellfish aquaculture as management measure-

- Promising solution to nutrient issues, complementary to land-based nutrient load reductions
- Provides shellfish product, income for shellfish farmers
- Caveat: marine spatial planning
- Stay tuned!

Additional information 未来工作 方向

http://www.eutro.org

http://www.eutro.cn

http://www.eutro.us

http://www.ccma.nos.noaa.gov

Try the models yourself:

FARM www.farmscale.org

ASSETS www.eutro.org/register

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