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EPA Tools and Resources Webinar Coastal Nutrient Management: Research Update

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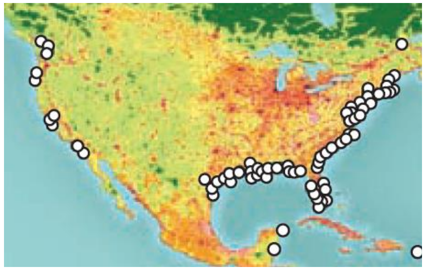
Nutrient pollution is pervasive in US coastal waters

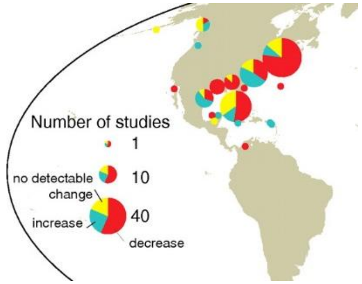
- Documented on every coastline of the contiguous US, plus Hawaii, Puerto Rico and other US territories
- Impacts aquatic life, human health, aesthetic value
- Sources to coastal waters are both local and upstream in larger watersheds
- Public interest grows and fades surrounding notable events, stakeholders more strongly engaged

Widespread Impacts include Hypoxia, Seagrass Loss and Harmful Algal Blooms

Low dissolved oxygen in coastal waters



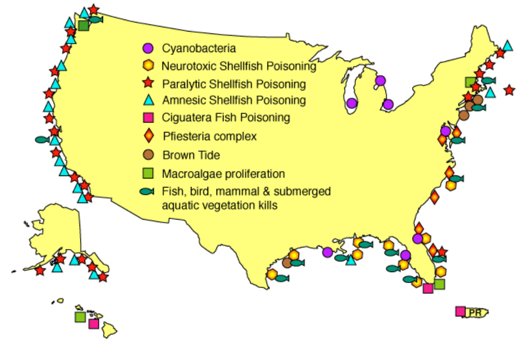
Diaz et al. 2008



Waycott et al. 2009

Documented seagrass declines outnumber few examples of recovery

And harmful and toxic algal blooms also are widespread

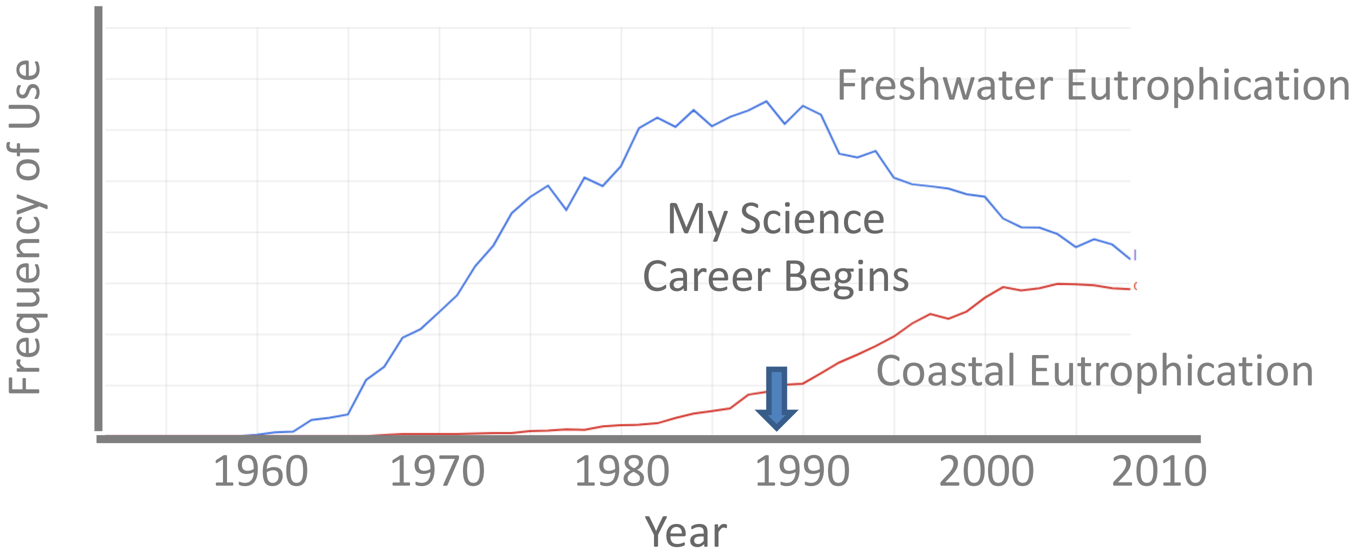


Source: WHOI/NOAA The Harmful Algae Page

Causes and effects related to nutrient pollution are understood

- Nutrient pollution comes from point sources and non-point sources, including stormwater run-off, agriculture and air-deposition
- Nutrient effects include hypoxia, harmful algal blooms, seagrass loss, and food web changes
- Decades of research have outlined key ecological processes and responses involved

Focus on coastal eutrophication increased around 1980, drawing on lakes research



Relative frequency of references to “Freshwater Eutrophication” and “Coastal Eutrophication” in books, as shown by Google NGRAM viewer

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Nutrient-related conceptual models often well-developed

Conceptual diagram illustrating the key features and threats to the Indian River Lagoon ecosystem of the east coast of Florida,. When healthy, the Indian River Lagoon Is a extremely complex, highly diverse, and very productive ecosystem. However, decades of human development have impacted water quality through polluted groundwater, and wastewater and stormwater discharges. As a result, all areas of the Lagoon are suffering from polluted water, seagrass losses, algal blooms, and fish kills, and marine, tourism, and real estate-based industries are at risk.

Diagram courtesy of the Integration and Application Network (ian.umces.edu), University of Maryland Center for Environmental Science. Source: Marine Resource Council, *Assessing the Health of the Indian River Lagoon* newsletter, IAN Press, October 2016.

Diagram from *Assessing the Health of the Indian River Lagoon* (Integration and Application Network - ian.umces.edu) illustrates that management agencies have strong conceptual understanding

We often know these:

- Social and Economic Drivers
- Sources of Loads
- Ecological Processes
- Modulating Factors
- Aquatic Life Effects

States use understanding of nutrient issues as they implement regulatory controls

- **Regulatory nutrient management** occurs under:
    - Clean Water Act (CWA)
    - Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA, as amended)
    - Endangered Species Act
- **CWA programs** include water quality standards and total maximum daily loads (TMDLs), among others
- **National Estuary Program (NEP) is a non-regulatory CWA program** that addresses coastal nutrient issues

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States establish their policy priorities and preferred management approaches

- These states' goals often lead to science questions
- This presentation is focused on how EPA ORD has addressed some of these science questions to help states

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EPA's nutrients strategy involves cooperative engagement with states and tribes

- **EPA supports policy development through collaboration and cooperation** in a variety of contexts
- **Involves EPA program and regional offices, often with ORD support**
- **Direct interactions with state**s, and via working groups and watershed-focused entities
- **Collaborative approach** reflects challenging, complex and at time site-specific solutions to coastal nutrient pollution challenges

States still face challenges implementing regulatory controls to manage nutrients

Example challenges:

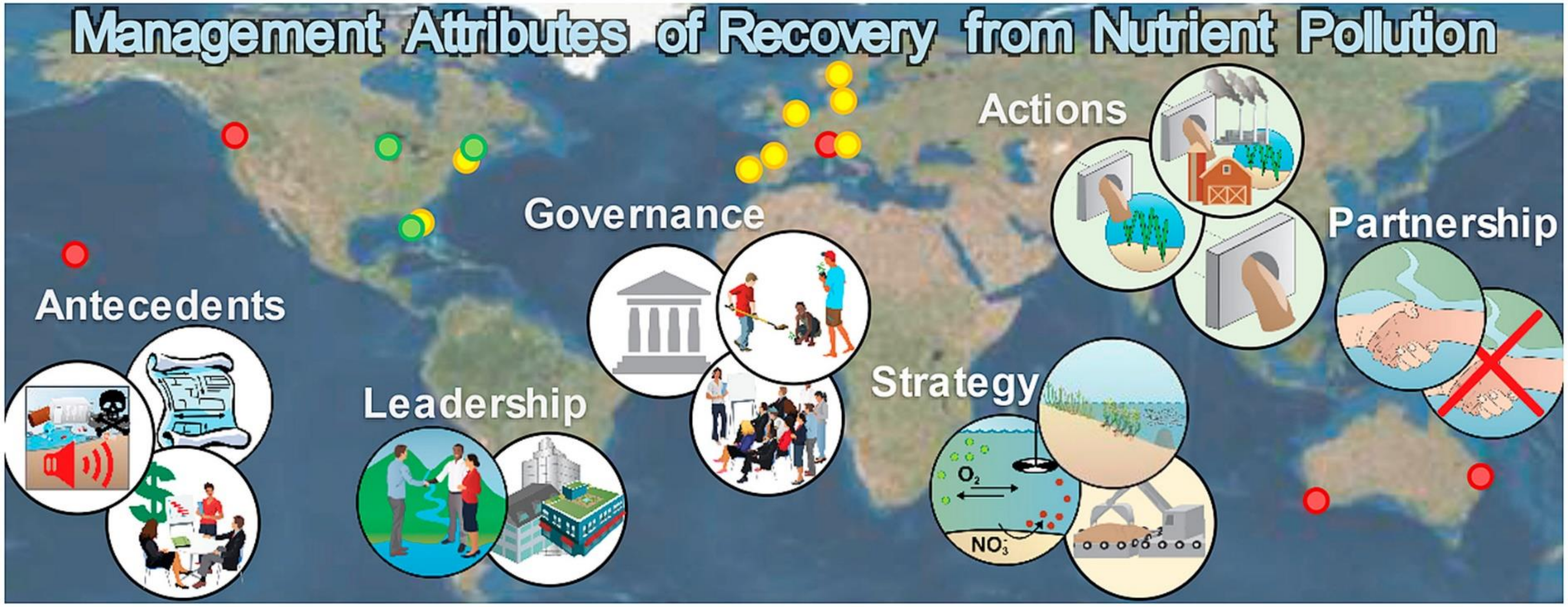
- Sustaining effective management programs build around socially and economically-resonant nutrient-sensitive endpoints
- Identifying analytical methods that address management questions at scale using available data
- Addressing temporal and spatial complexity
- Addressing responses behind the mean response … when nutrients change event frequency, severity or probability (e.g., low oxygen, algal blooms)

Some examples of ORD tech support …

Case studies illustrate cooperation and collaboration to address technical challenges

State(s)	Issue/Challenge Addressed
Multiple	Evaluating characteristics of 17 successful nutrient management programs
Florida	Applying seagrass as an aquatic life use endpoint to nutrient criteria setting
Georgia, South Carolina	Ecosystem metabolism as an aquatic life endpoint for marsh-dominated estuaries
Texas	Dissolved oxygen (DO) in metabolically-active estuaries .. Quantifying and comparing and contrasting oxygen regimes using continuous DO time-series
California	Understanding how eutrophication modulates probability of adverse water quality events in a nutrient-resilient estuary

Examples of successful management action can provide insight into successful strategies



Gross, C. and J. D. Hagy, 3rd (2017). Attributes of successful actions to restore lakes and estuaries degraded by nutrient pollution. Journal of Environmental Management 187: 122-136 (https://doi.org/10.1016/j.jenvman.2016.11.018)

Examples of successful management action can provide insight into successful strategies

Antecedents
- Public Crisis
- Government Mandate
- Existing Networks with Funding Incentives

Governance
- Command and Control
- Top-Down Collaboration
- Bottom-Up Collaboration

Strategy
- Ecological Goal
- Load/Concentration Targets
- Single Set of Actions

Actions
- Point Sources
- Point Sources + Active Restoration
- Comprehensive Nutrient Load Reductions

Leadership
- Watershed Coordinator
- Multiple Agencies

Goals Achieved
- Goals Achieved
- Partially Recovered
- Declined after partial recovery

Gross, C. and J. D. Hagy, 3rd (2017). Attributes of successful actions to restore lakes and estuaries degraded by nutrient pollution. Journal of Environmental Management 187: 122-136 (https://doi.org/10.1016/j.jenvman.2016.11.018)

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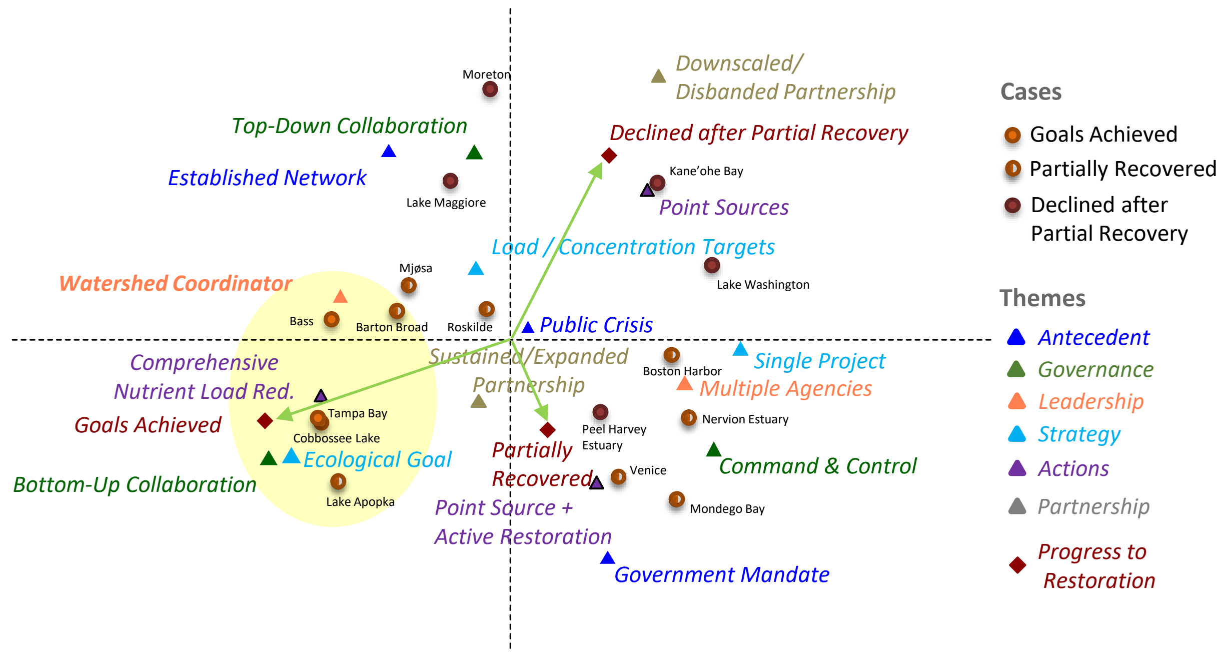
Achievement of policy goals associated with four policy attributes

(1) **Leadership** by dedicated watershed management agency

(2) **Governance** through bottom-up collaboration

(3) **Numeric targets** based on an ecological goal

(4) **Comprehensive nutrient loading reductions**



Multiple Correspondence Analysis shows characteristics linked to "Goals Achieved" (Yellow Area)

Gross, C. and J. D. Hagy, 3rd (2017). Attributes of successful actions to restore lakes and estuaries degraded by nutrient pollution. Journal of Environmental Management 187: 122-136 (https://doi.org/10.1016/j.jenvman.2016.11.018)

In Florida estuaries, seagrass habitat is key nutrient-sensitive aquatic life use

- Seagrass habitats in Florida have been impacted by nutrient pollution
- Effective management in Florida has restored seagrass in some estuaries
- What scientific “links” are needed to tie nutrient management to a seagrass endpoint?

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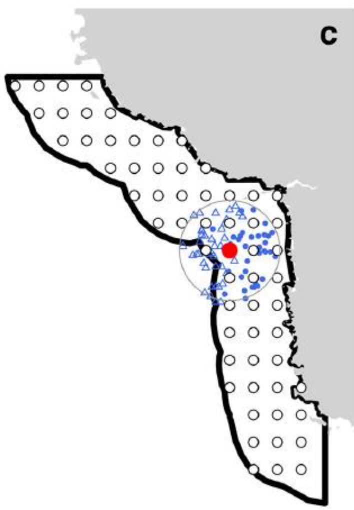
Seagrass protection and restoration provides logical path for setting nutrient targets

1. Depth to which seagrass grew in the past → 2. Light needed for seagrass to grow → 3. Max chl-a not blocking too much light → 4. Max nitrogen associated with attaining chl-a target

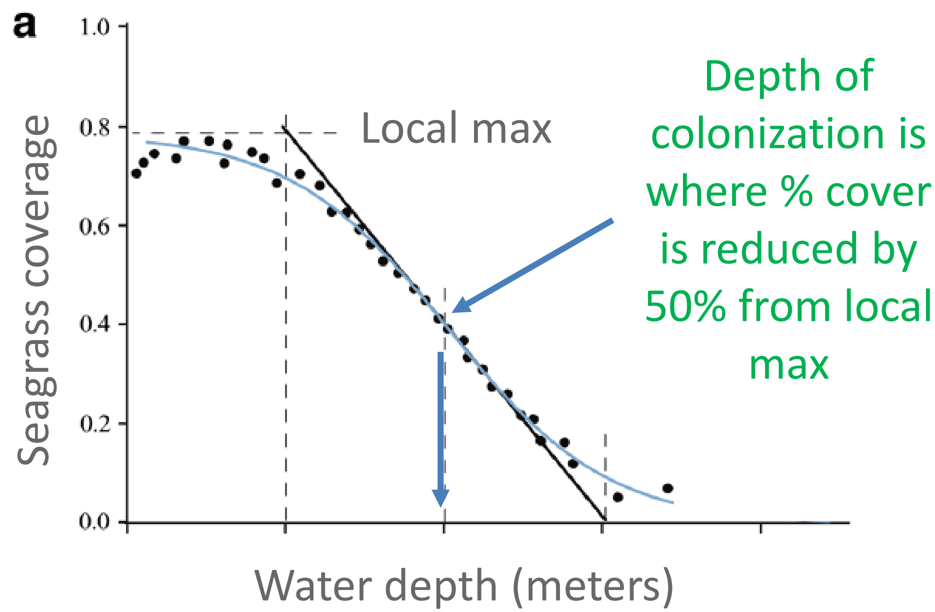
Each box is associated with science questions associated with quantifying estimates. ORD research addressed box #1 and #2

Beck, M. W., J. D. Hagy and C. Le (2017). Quantifying Seagrass Light Requirements Using an Algorithm to Spatially Resolve Depth of Colonization. Estuaries and Coasts 41(2): 592-610 (https://doi.org/10.1007/s12237-017-0287-1)

Combining maps of water depth and seagrass coverage enables mapping how deep seagrass grows



Automate selection of data from local area

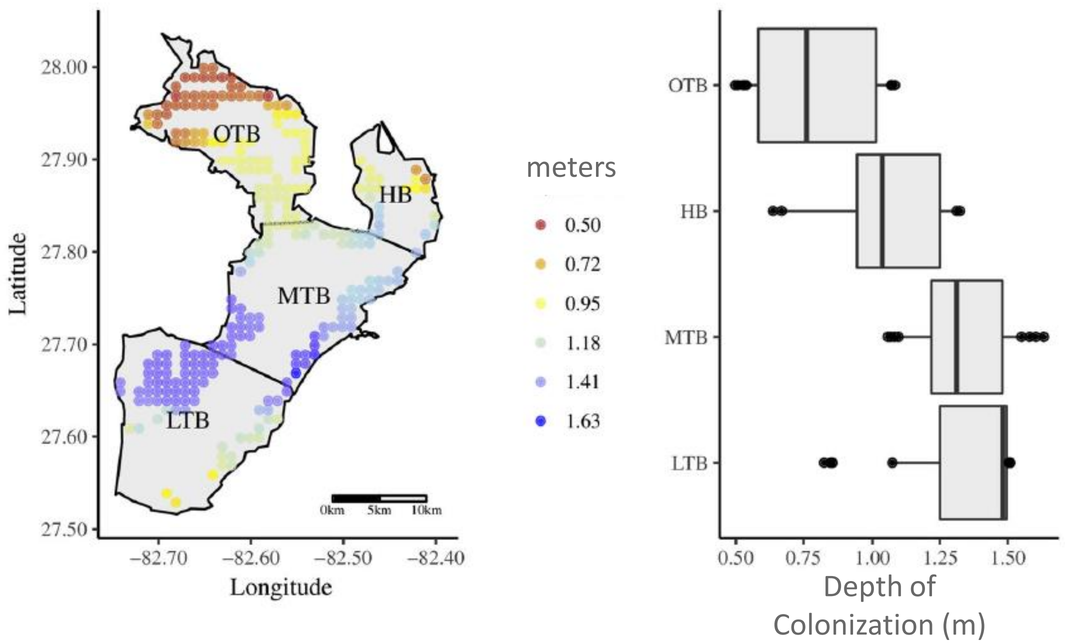


Computer script quickly generates thousands of estimates

Beck, M. W., J. D. Hagy and C. Le (2017). Quantifying Seagrass Light Requirements Using an Algorithm to Spatially Resolve Depth of Colonization. Estuaries and Coasts 41(2): 592-610 (https://doi.org/10.1007/s12237-017-0287-1)

Analysis resolves variations in seagrass depth of colonization within management units

Seagrass Depth of Colonization in Tampa Bay

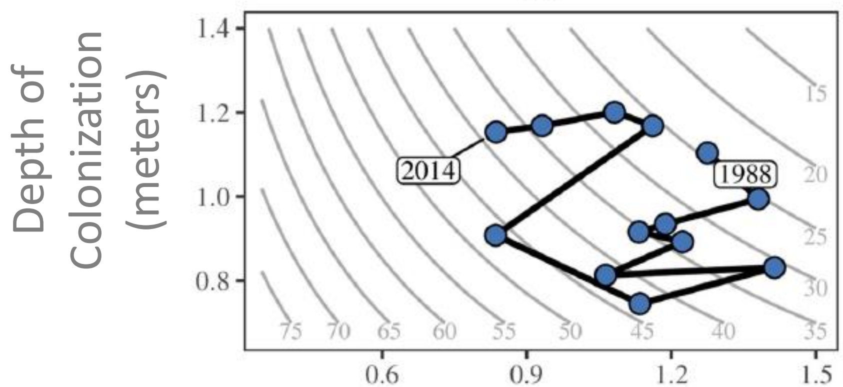


- Seagrass depth of colonization is mapped among and within water body segments
- Can be used to evaluate responses to management including relationships to light availability

Beck, M. W., J. D. Hagy and C. Le (2017). Quantifying Seagrass Light Requirements Using an Algorithm to Spatially Resolve Depth of Colonization. Estuaries and Coasts 41(2): 592-610 (https://doi.org/10.1007/s12237-017-0287-1)

Analysis resolved changes in light available to seagrass during Tampa Bay's seagrass recovery

Contours of % light at depth of colonization



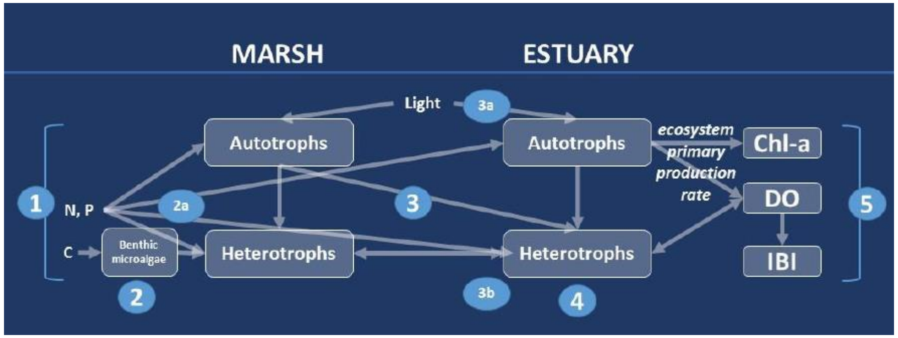
Light Attenuation
(= 1/water clarity)

- Automated analysis provided new insights using existing data
- Describes ecological changes during 20+ year seagrass recovery
- Recovery dynamic could be observed in other estuaries … informs management expectation

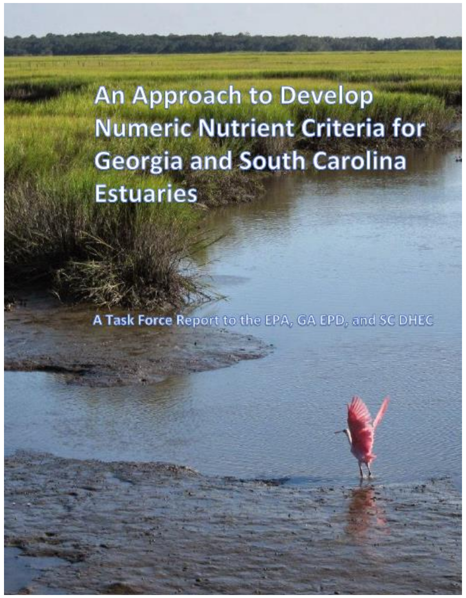
Beck, M. W., J. D. Hagy and C. Le (2017). Quantifying Seagrass Light Requirements Using an Algorithm to Spatially Resolve Depth of Colonization. Estuaries and Coasts 41(2): 592-610 (https://doi.org/10.1007/s12237-017-0287-1)

Spatial and temporal variability in low DO a key challenge for southern estuaries

- **Georgia and South Carolina** – Ecosystem metabolism and day-to-night DO variability are a potential endpoint for nutrient management
- **Florida and Texas** – One issue is distinguishing natural DO patterns from anthropogenic impacts



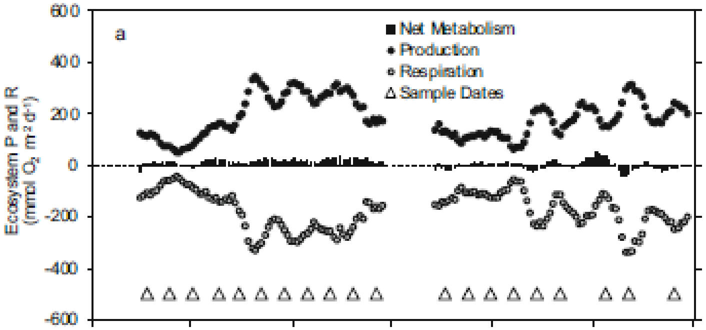
Links between nutrients and endpoints

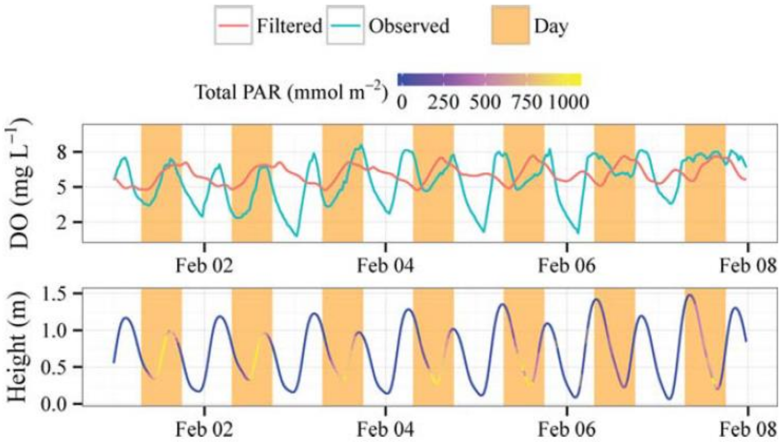


GASCET. 2015. An Approach to Develop Numeric Nutrient Criteria for Georgia and South Carolina Estuaries. A Task Force Report to EPA, GA EPD, and SC DHEC. (https://tinyurl.com/rhngsrc)

Use increasingly-available continuous DO time series to quantify metabolism

Use **“open-water” methods** to estimate metabolic rates and set targets for average rates -> measure of “trophic status” (Murrell et al. 2017)





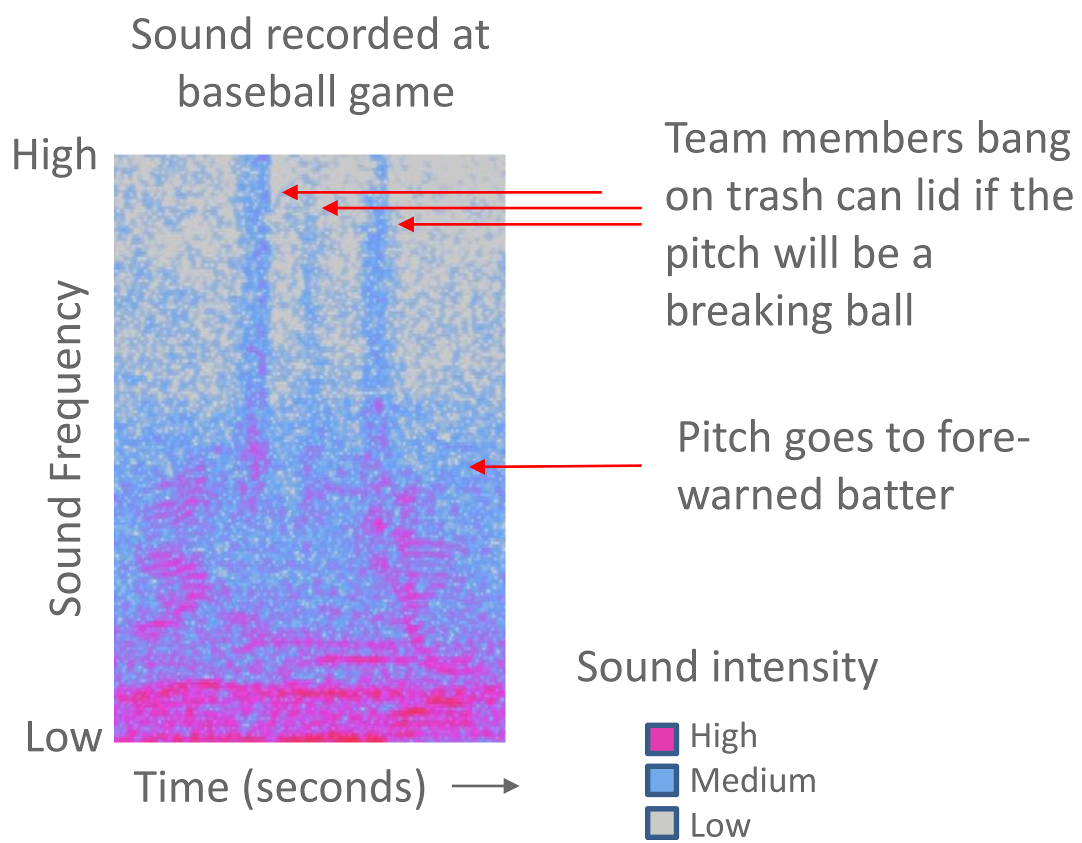
Use **tidal data** to help remove distortion of DO time series caused by tides and improve metabolism estimates
(Beck et al. 2015)

Beck, M. W., J. D. Hagy and M. C. Murrell (2015). Improving estimates of ecosystem metabolism by reducing effects of tidal advection on dissolved oxygen time series. Limnology and Oceanography: Methods 13(12): 731-745. (https://doi.org/10.1002/lom3.10062)

The value of detailed data and sophisticated analysis – a baseball story

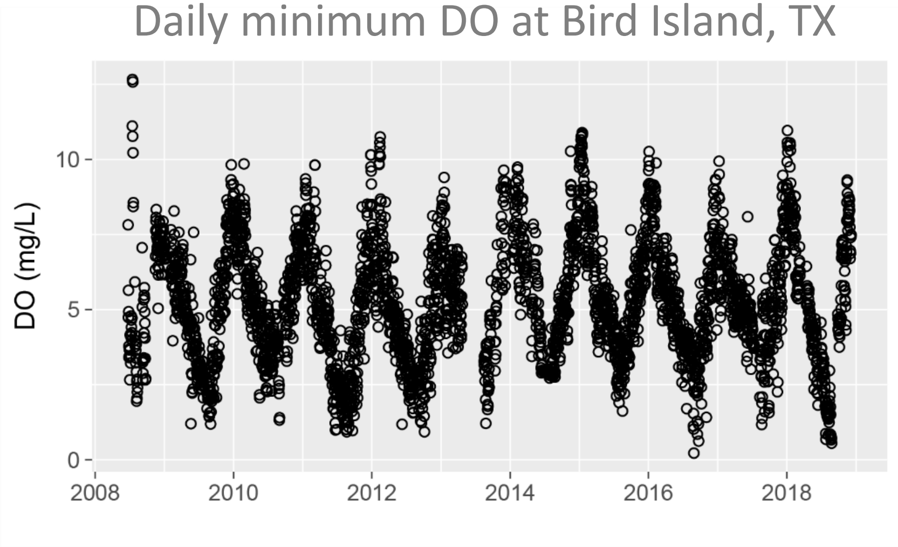
Houston Astros observe catcher's "signs" using video camera feed …

Use "audio signals" to tell batter if pitcher throwing off-speed



<u>Take-home message</u>: With the right data and analysis, previously subtle effects can become much more obvious… we can do that with water quality

10-year DO time series in Upper Laguna Madre, TX records 42,000 warm-season oxygen measurements on 1,800 separate days



Increasingly available continuous data allow for detailed analysis

With detailed data and computer-based analysis:

- Quantify DO dynamics in detail
- Estimate variability and uncertainty
- Compare "reference condition" to new data

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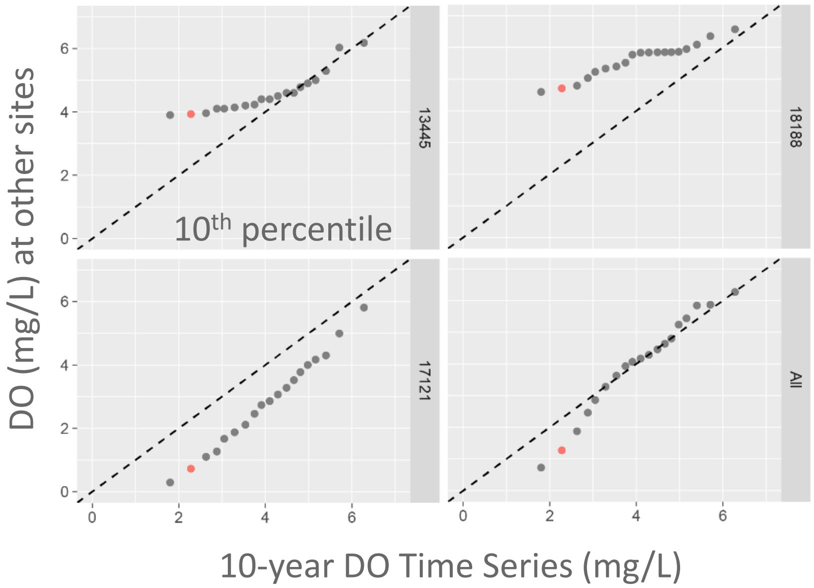
Quantile-Quantile Plots contrast new data with reference distribution



- Each point represents a quantile (5th, 10th, … 95th percentile) of BOTH the reference DO data (x-axis) and another side (y-axis).
- Provides sensitive way of comparing distributions

Detailed analysis methods are useful and can be better tied to biological effects

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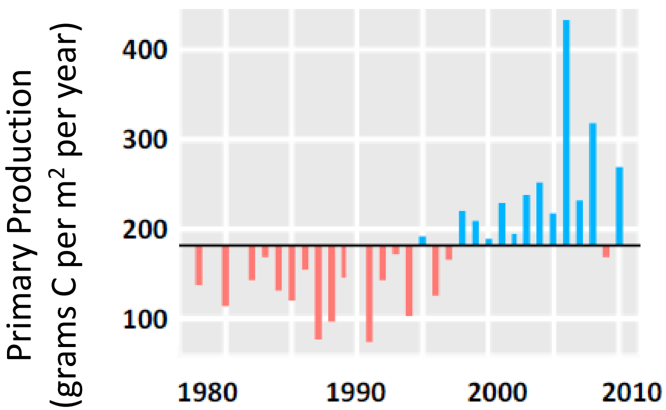
San Francisco Bay receives high nutrient inputs, but resists usual impacts … until recently



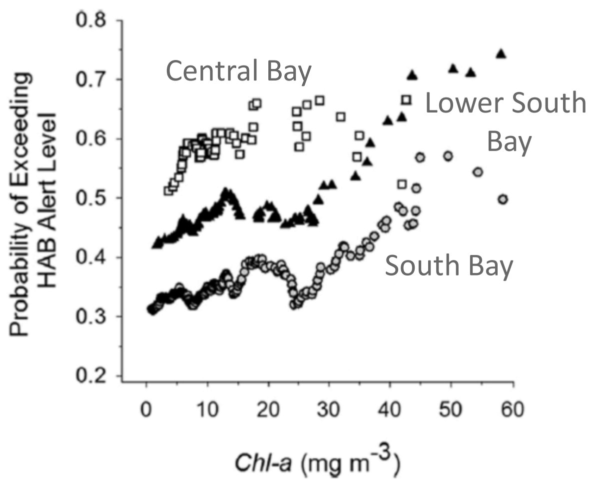
(Cloern and Jassby 2012, as shown in Sutula and Senn 2017)

- **What are effective ways to quantify ecological changes?**
- **How can these be used to set water quality thresholds or goals for management?**

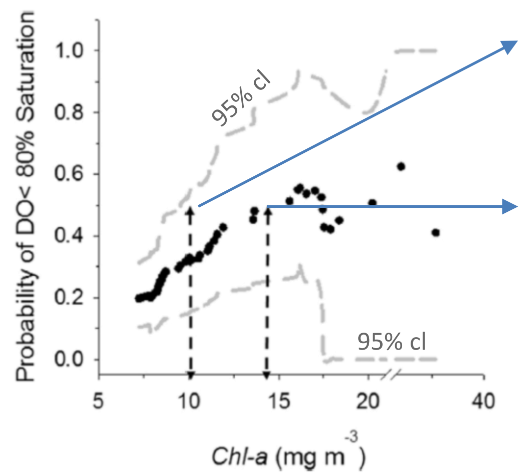
Sutula, M., et al. (2017). Novel analyses of long-term data provide a scientific basis for chlorophyll-a thresholds in San Francisco Bay. Estuarine, Coastal and Shelf Science **197**: 107-118. (https://doi.org/10.1016/j.ecss.2017.07.009)

Quantify conditional likelihood of adverse water quality condition, rather than mean response

Chl-a vs. HABs



Chl-a vs. Low Oxygen



When chl-a<10, DO<80% saturation *at most* 50% of the time.

When chl-a<14, DO<80% saturation *on average* 50% of the time.

The probability of low DO and HAB events can be related to chlorophyll-a, even though mean DO concentration and HABs cell counts do not correlate with chlorophyll-a

Sutula, M., et al. (2017). Novel analyses of long-term data provide a scientific basis for chlorophyll-a thresholds in San Francisco Bay. Estuarine, Coastal and Shelf Science **197**: 107-118. (https://doi.org/10.1016/j.ecss.2017.07.009)

EPA Collaboration Supports Solutions to address Nutrient Pollution

- **Collaboration approach has supported nutrient management for coastal marine ecosystems in a variety of states**
- Research illustrates **new methods and approaches** that capitalize on new kinds of data and computer-based analysis and may be broadly relevant to nutrient policy development
  - Improved quantification of aquatic life endpoints
  - Better understanding of relationship to risk and uncertainty
  - Improved understanding of spatial and temporal variability
- **ORD collaboration brings experience derived from solving analogous problems in a variety of locations**, while also considering local issues and concerns, local ecology, and to utilize local data and expertise

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