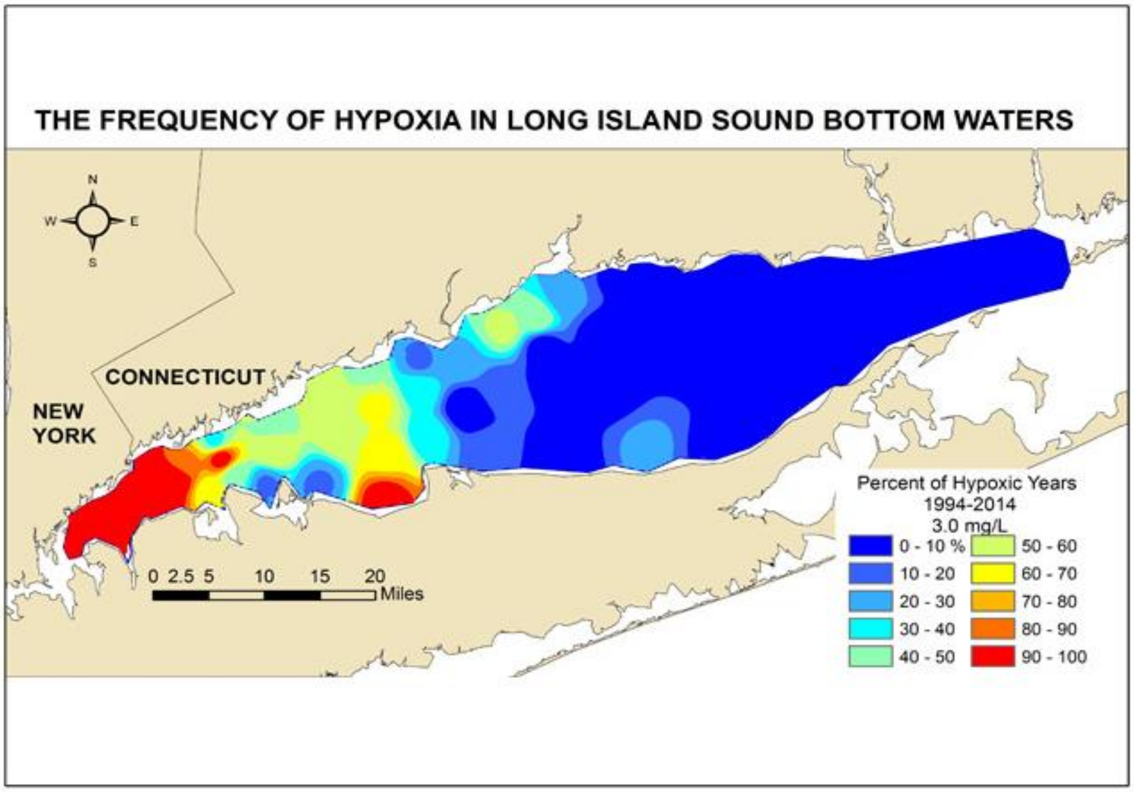
Proceedings of the 2015 Long Island Sound Water Quality Workshop



July 14 & 15, 2015

University of Connecticut's Avery Point Campus, Groton, Connecticut

Compiled By:

Jason Krumholz, Ph.D., NOAA Liaison to the Long Island Sound Study

Emily Bird, Environmental Analyst, NEIWPCC

Thank you, workshop partners!

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EXECUTIVE SUMMARY

The workshop was held on July 14-15 2015 at the University of Connecticut's Avery Point Campus. The workshop was co-hosted by the EPA Long Island Sound Study (LISS) and the Connecticut Institute for Resilience and Climate Adaptability (CIRCA), organized by the New England Interstate Water Pollution Control Commission (NEIWPCC), and funded by an interagency agreement (DW13923994) awarded by the USEPA to NOAA in partnership with the LISS, along with contributions from CIRCA and SeaBird Coastal. The formal agenda for the workshop can be found in Appendix B.

Through a variety of open oral and poster sessions, panel discussions, breakout sessions, and a keynote presentation from Ed Sherwood at the Tampa Bay Estuary Program, the workshop explored a set of overarching questions (see appendix C) intended to help guide conversation and focus discussion on the goals of the LISS program. The first day focused on monitoring, with topics such as future directions for the program, incorporation of new technologies, and application of monitoring data to management and intersystem comparison. The second day focused on ecosystem modeling, with discussion topics centered around the application of monitoring data to modeling, and next directions for the LISS program, but also modeling management scenarios (e.g., climate change, pollutant reduction), and a survey of modeling approaches from other programs.

In total, 74 attendees participated in the workshop, representing 37 different organizations (See Appendix A). The participant group was very broad, bringing expertise from federal and state government agencies, as well as academic institutions, non-profits, and environmental consulting agencies from throughout the region and beyond (MA, RI, CT, NY, NH, NJ, DE, FL).

While the overarching conclusion is that the "open sound" monitoring program is very robust, there are areas for incremental improvement. Continuing efforts to expand buoy coverage, both in terms of spatial frequency (adding buoys) and by adding sensors to existing buoys will improve our ability to estimate hypoxia, and understand its short temporal scale impacts.

In order to better monitor our progress towards CCMP goals and targets, additional attention needs to be paid to water quality monitoring in the embayments of LIS, either by expanding the existing efforts into the embayments, or, more likely, through organizing a central collaborative which assists local groups (many of which already exist) in collecting, Q/A'ing, storing, and sharing environmental data. Storage and sharing of data is also a concern for the "open sound" monitoring program, as access for synthetic and collaborative research is cumbersome and limited.

With respect to modeling, there are a wide range of potential approaches for further work. In the absence of a single robust model, an ensemble modeling approach should be considered, either using a hybrid or nested modeling approach, or by employing a suite of models or a Bayesian approach to better constrain uncertainty. In order to better support modeling, and improve parameterization of existing models, increased field measurements of benthic fluxes and carbon: chlorophyll ratios are needed, as these parameters are both highly sensitive, highly variable, and poorly understood.

The following several pages constitute an "extended executive summary" which breaks down the main points of workshop discussion and preliminary conclusions by topic area, with suggested next steps to accomplish stated goals.

SUMMARY OF CONCLUSIONS BY THEME AREA

Ongoing Open Water Monitoring Program

One of the primary goals of the workshop coming in was to discuss next directions for the existing LIS sponsored "open water" monitoring program, currently conducted by CTDEEP and IEC/NEIWPCC. While there was substantial discussion on this topic, the general consensus was that this program is at an appropriate spatial and temporal scale, and operating reasonably efficiently. Recent efforts by the water quality workgroup to streamline reporting, add nutrient sampling to the IEC/NEIWPCC cruises, and pilot test an in-situ primary productivity sensor are taking the program in the right direction. While there remain opportunities for incremental improvements in efficiency, and the program should continue to seek out and capitalize on these chances, the program is both effective and efficient, and given limited resources, our focus should be on improving our resolution in embayments and our ability to track progress toward CCMP targets.

Potential Action Items:

- Continue investigating avenues for improved efficiency through collaboration and new or improved cost effective sample collection and analysis techniques.
- Continue efforts aimed at streamlining data synthesis and reporting.

Shifting Sources/Alternate Focuses of Monitoring

The theme of adapting to a changing environment was pervasive in virtually all of the sessions. The major ways in which this theme expressed itself in discussion dealt with understanding and adapting to climate change, and evolving our monitoring program to better detect changes in anthropogenic loading. With respect to changing climate, key discussion points included things like detecting and understanding the impact of acidification, and the ecological importance of the combined stressors of temperature change, eutrophication, and acidification, which have been shown to be additive. Also, understanding the impact of short term eutrophication induced acidification, something that LIS is moving towards with increased in-situ sensor capacity in WLIS. A common problem throughout similar programs is the difficulty in trying to draw conclusions from sporadic (monthly/bimonthly) sampling of parameters with high spatial and temporal variability both seasonally and interannually. With respect to changing sources, as we dial back on WWTP load, other sources become more important, necessitating a greater understanding of embayment dynamics, non-point source loads, and higher nearshore resolution.

Potential Action Items:

- Increase use of in-situ monitoring to improve understanding of short timescale events and variability.
- Improve coverage in embayments and understanding of localized impacts of loading from various sources on eutrophication in the nearshore environment.

Alternate Endpoints

There was general agreement throughout the workshop that hypoxia is a difficult endpoint to use for management efforts. Spatial and temporal extent of hypoxia are prone to high inter annual variability, and are strongly influenced by forcing factors which are outside of management control (e.g., wind & weather patterns, temperature, stratification). Our understanding of the interplay of these factors, and the linkages between nitrogen reduction and reduced hypoxia, remains course. As such, some discussion was given to the use of alternate endpoints (e.g., setting management targets for a given chlorophyll level or eelgrass coverage goal rather than hypoxic extent) for the management of coastal eutrophication.

A successful example of this management strategy was demonstrated in Tampa Bay by keynote speaker Ed Sherwood from the Tampa Bay Estuary Program (TBEP). The data parameters necessary to implement this approach in Long Island Sound are all currently being collected by LISS and partner organizations, and/or calculations that can be collected within existing capacity. Furthermore, the framework for an approach like this has already been laid by the LISS funded eelgrass suitability modeling work conducted by Vaudrey and colleagues. However, the spatial resolution used by TBEP to establish spatially variable threshold chlorophyll levels supportive of eelgrass, and monitor for enforcement would require substantial additional nearshore monitoring capacity (TBEP station density is approximately 6X the CTDEEP station density), and the adaptive management framework used by TBEP which bases regulatory action on achievement of ecosystem targets would require substantial effort to implement.

Some concern was expressed that "walking away" from current hypoxia extent based management efforts which were central the original 1994 CCMP and remain a major issue in the 2015 CCMP revision, would be perceived as failure, and that this strategy should be used as a complement to, rather than a replacement for, a management strategy focused on reducing hypoxia.

Potential Action Items:

- Increase embayment and nearshore monitoring resolution in support of eelgrass based endpoints (e.g., chlorophyll a, water clarity).
- Refine localized estimates of the relationship between nitrogen loading, chlorophyll concentration, and light penetration.

Lag Times

Lag times were discussed in context of both modeled and observed responses of the ecosystem to changes in nutrient loading. Hypothesized causes range from large amounts of nutrients stored in marine sediments, to groundwater transfer time, to ecological buffering capacity, and the cause, extent and duration of a time lag is likely to be variable based on local conditions. Though groundwater is not thought to be a large source of nitrogen to LIS "writ large", it may be locally important. Regardless, this can be a confounding factor in determining system response and managing adaptively, and should be taken into consideration when setting goals, and communicating anticipated results to the general public and media. Observed lag times in other estuarine systems have ranged from <1 year, to approximately 10 years or even higher in cases with high load and long transit times of groundwater, (e.g., some areas of Cape Cod). While the causal relationships contributing to this range of observations are not well understood, some influencing factors may include residence time, duration and extent of anthropogenic load prior to remediation, sediment type, watershed size and composition, and factors influencing stratification (temperature, depth, freshwater load, etc.). Observed lag duration is also dependent on the chosen response variable with some (e.g., water column nutrient concentration) responding more quickly, and others (hypoxia, community composition, etc.) taking much longer.

Potential Action Items:

- Improve our understanding of sediment/water column nutrient interactions and potential changes in these rates in response to changes in nutrient load.
- Incorporate uncertainty into management targets and communication strategies.
- Select for management targets with generally shorter lag times.

Embayments

Understanding the dynamics of embayments and other nearshore systems is critical to understanding and managing response to eutrophication and reversal. While the formal LIS sponsored monitoring program does not include an embayment component, there are several local groups collecting water quality data in the LIS embayments, some funded by LIS Futures Fund. Some efforts are underway to categorize and understand these data collected by these groups, but no formal coordination effort between programs exists, though pilot projects are underway to establish a framework. Establishing a centrally co-ordinated embayment monitoring effort for LIS is essential if the focus of the monitoring program is to incorporate an alternate or supplemental chlorophyll/eelgrass endpoint regieme, and regardless, would be beneficial to support CCMP targets for coastal habitat and eelgrass restoration.

Improved understanding of the factors dictating embayment eutrophication are also essential to understanding the response of embayment systems to eutrophication and reversal. This includes continuation of ongoing efforts to understand the partitioning of nutrient and pollutant loading to various embayments, as well as monitoring and modeling efforts to understand the parameters influencing susceptibility of embayments to stratification and hypoxia, including circulation, watershed land use, and nutrient loading.

Potential Action Items:

- Implement a co-ordinated, standardized and potentially centrally funded embayment monitoring program with established protocols, sampling parameters, and frequencies.
- Enhance the coverage, frequency, and quality of embayment water quality data in support of CCMP goals and targets.
- Integrate and centralize data storage and management for “main” and embayment water quality programs, to facilitate synthetic research and data analysis towards the development of effective management strategies.

Modeling Needs

The next steps for the program with respect to modeling are somewhat less clear than for many of the other key topic areas. Existing shortfalls in the LISS modeling program center around the inability of SWEM to reproduce realistic oxygen conditions in western LIS under realistic mixing conditions, likely due at least in part to underestimation of stratification and or primary production, leading to insufficient flux of organic matter to the benthos, and therefore, either underestimating benthic oxygen demand or overestimating resupply (or both). The cause of this discrepancy is unclear, though possible hypotheses include lack of spatial resolution in the model, inaccurate parameterization of benthic fluxes and/or carbon:chlorophyll ratios, and/or unrealistic simulation of algal kinetics.

A wide range of alternative modeling approaches were explored, ranging from high resolution embayment efforts which place emphasis on circulation, and potentially implicate advection of problematic water masses from embayments as a mechanism for hypoxia formation in Narragansett Bay, to hybrid biophysical models, to modular and Baysian approaches.

It is important to note that each of these approaches has relative strengths and weaknesses, and that an ensemble approach, which utilizes the strengths and weaknesses of multiple modeling efforts appears to be the best way around this problem, and will also help with the quantification of uncertainty- a major issue in ecosystem modeling. An example of this was (inadvertently) presented when two models of Narragansett Bay (Kincaid and Brush/Vaudrey) explored the same question of what happens to primary production when sewage effluent concentration is reduced from 16 mg/L (secondary treated) to 8, 5, and 3 mg/L (various common break points for treatment plant efficiency, with the latter being Limit of Technology). Both models saw similar improvement in reduction from 16 mg/L to 8, but one model showed dramatic reduction between the 8 mg/L and 5 mg/L cases, while the other showed little difference between the 8, 5, and 3 mg/l scenarios. The ensemble approach in this case, at the very least identifies this concentration range as an area of high uncertainty worthy of further investigation. Ensemble based modeling is frequently used in other fields with high levels of uncertainty (e.g., weather forecasting), but is not without its caveats. Chief among these is that in a limited budget climate, financially supporting multiple modeling efforts may not be practical (one “good” model is better than several “bad” ones), and/or may come at the cost of other efforts.

Potential Future Approaches (distinguished from action items as these are relatively mutually exclusive):

- Continue refining parameter estimation in SWEM and/or switch to running SWEM with a higher resolution physical model.
- Switch to a single hybrid or modular model design (e.g., FVCOM, GOTM, FABM, EcoGEM)
- Employ an ensemble modeling approach in addition to/in lieu of SWEM.

Monitoring to Support Modeling

A recurring theme throughout the discussion of the second day was what monitoring or research should be prioritized in order to improve our estimation of model parameters in LIS, and therefore, our ability to model ecosystem response to changes nutrient loading. Although there are many avenues to explore with respect to model parameterization, a few areas stood out in discussion.

The first is the parameterization of benthic fluxes. Understanding the flux of nutrients into and out of the sediment is critical to virtually any modeling approach. This includes not only fluxes of nutrients and organic matter into and out of long term benthic storage in the sediments, but also active transformation processes which occur in the sediments, such as denitrification. These processes can change the bioavailability of nutrients and contribute to whether the sediments are a net source or sink of nutrients to the water column. There are no good recent estimates of benthic fluxes from LIS, and existing estimates do not have good spatial or seasonal resolution. Recent work from Narragansett Bay suggests that these parameters are highly spatially and seasonally variable, and may be changing in response to climate change and/or eutrophication reversal. **Three ongoing LIS research grants are investigating various aspects of benthic pelagic coupling, and should provide a great deal of insight on this topic.**

The second area is the ratio between carbon and chlorophyll (C:Chl). Since most models express biomass in units of carbon, but most field measurements of production are in units of chlorophyll, it is necessary to convert between the two in order to ground truth and calibrate models. Changes in the C:Chl ratio determine how much carbon is fluxed to the benthos in the model (and therefore respired, creating oxygen demand). While most models use standard assumptions regarding C:Chl, typically fixed values, the limited field data on this topic show it to be highly variable both spatially and temporally. SWEM, on the other hand, allows this parameter to vary, but frequently returns predicted C:Chl ratios nearly a full order of magnitude outside the "conventional" range of expected values. In sensitivity analyses of both SWEM and other modeling approaches (e.g., EcoGEM), modeled production is highly sensitive to changes in C:Chl ratio. Literature on the topic also indicates that C:Chl ratios may be changing as plankton assemblages shift in response to changing climate. This creates a "perfect storm" parameter which is highly important, highly variable, poorly understood, and potentially changing. Efforts to refine parameterization of this ratio should be prioritized.

A third area to explore would be to collect additional data on circulation and flow in nearshore and embayment areas, using technologies such as ADCP (mounted or towed) or SeaHorse current meters. Model investigation of embayment dynamics in Narrangansett Bay (Kincaid) implicates embayment flow structure in formation and advection of hypoxic water and/or plankton blooms which can influence system wide dynamics. If this were shown to be true in LIS as well, it places even more focus on gaining a greater understanding of the role our embayments play in our continued efforts to improve water quality in LIS

Potential Action Items

- Improve spatial resolution of flow data in nearshore (e.g., embayment) areas.
- Continue work to improve and constrain our estimates of benthic fluxes and benthic/pelagic coupling.
- Collect field data on C:Chl ratios to better constrain the spatial and temporal variability in this parameter.

Data Sharing, Communication and Collaboration

LISS does an excellent job of communicating scientific data to general audiences, both through the LISS website and environmental indicators programs, through internal efforts such as *Sound Health, Protection and Progress*, teacher workshops, and Report cards, and through collaborations with partner organizations (e.g., Save the Sound, Harbor Watch, etc.). However, our ability to synthesize data across multiple sources (e.g., CTDEEP, NEIWPCC/IEC, USGS, academic institutions, embayment monitoring programs), and participate in regional and national collaborations is limited by the lack of easy access to properly QA'ed, uniformly stored, and formatted data. While some efforts have been made in the past to tackle aspects of this problem (e.g., LIS Sentinel Monitoring data clearinghouse effort, unification of the CTDEEP and NEIWPCC/IEC annual water quality monitoring report), a central data repository remains elusive, and should be a priority to maximize effectiveness of underway and planned projects such as the report card, advanced water quality instrumentation projects funded by NERACOOS and EPA, and any future embayment monitoring collaborative. Improving access to data for researchers outside our region will also help to ensure that our data are used in synthetic research, which may help reveal additional insights into how to improve our ability to adaptively manage water quality

Potential Action Items

- Implement a central data repository for water quality data.
- Eliminate barriers to participation in centralized data collection, storage and quality control initiatives.
- Increase regional and national access and usage of LIS water quality data.

SESSION SUMMARIES: DAY 1 | Tuesday, July 14, 2015

Essential Questions for Day 1

- How can Long Island Sound Study (LISS) improve the efficiency and effectiveness of its monitoring program?
- What techniques and tools should we be considering as the LISS's monitoring program evolves?

INTRODUCTION TO THE WORKSHOP – *Mark Tedesco, USEPA Long Island Sound Office*

States developed TMDL for nitrogen reduction. The base load represents the total loading in 1990. The TMDL will be achieved in 2017. We are 90% to the goal. Mark showed a graph of where we could go (Limit of Technology) and what once was (Pastoral) and a map of the frequency of hypoxia.

Questions Mark Posed: Are we seeing changes in the system due to N reductions? Where will the program move in the future? Is it a wait and see? What will the eutrophication impacts be?

- Major goals that have been established
  - Measure the effectiveness of the management actions and programs implemented under the CCMP
  - To be able to use that information. Provide essential information that can be used to redirect and refocus the CCMP during implementation
  - Inform and facilitate research and modeling efforts
- Desired attributes
  - Have clear goals articulated as questions
  - Include only what is needed so that the likelihood of being sustained during difficult budget times will be enhanced (this is hard to do). Are there things that we are doing that are non-essential?
  - Where can we use citizen monitoring programs? We don't have the resources to monitor everywhere, all the time. We can create partnerships.
  - Maintain support and make a long-term commitment, one designed to answer key questions and to test key hypotheses.
  - Take advantage of new technologies and methodologies as they become available
  - Pay attention to data management, synthesis, analysis, integration, and transformation into information as to data collection.
  - Develop products to communicate. Develop and sustain a rich array of informational products that are carefully tailored to the special needs and interests of different constituencies
- We want to use this information to effect budget decisions. The LISS CCMP is being updated. Look at the results of this workshop to see if the investments we made in monitoring/modeling are the right investments.

INTRODUCTION TO THE CURRENT LISS MONITORING PROGRAM – *Jason Krumholz, NOAA*

Review the present status of Monitoring Program

- We have a very extensive Open Water monitoring program
  - Sampling stations Increase east to west
  - CTDEEP and NEIWPCC/IEC both have monitoring programs
  - Programs are focused on detecting and quantifying extent of hypoxia
- Boat surveys are supplemented by buoy network and tributary monitoring
- No formal embayment monitoring program but several programs run by nonprofits and community groups, some of which are funded through LISFF grants

Hypoxia Map- Summer of 2014 DEEP Survey and IEC Survey

- We have pretty good resolution (every two weeks in the summer)
- We can look at timing and duration and how it has changed. No clear pattern in terms of changes in the temporal window, but we see hypoxia in July and August every year
- We can look at hot spots, frequency, duration
- We can look at habitat loss due to hypoxia (Biomass Area Depletion Days index)

Potential Issues:

- Inter-annual variability is quite high
  - General downward trend, but inter-annual variability is very high in area and duration
  - Estimation of area/duration remains difficult. We use buoys but, buoys are less spatially dense
  - Link between manageable actions and hypoxia is complex
  - Wind direction, Storm events, effects of temperature

Central Workshop Questions:

- Can the monitoring program detect changes in hypoxia and water quality parameters that contribute to hypoxia? What do we need to add/subtract?
  - Is the monitoring program adequate to consider other endpoints?
  - Eelgrass and chlorophyll
- Difficult question----What patterns and conclusions from the open water monitoring program can, or cannot, be applied to embayments and near shore areas?
  - Some embayments follow the pattern of west to east but some do not
- LISS report card – Water quality improves west to east. There was good data density to categorize sound into 5 regions. We had to slightly adapt some of our cut points and thresholds based on what Chesapeake has used…can we do that?
  - Embayment report cards- parameters between the two are different
  - What we can learn from the report card?
  - What is the purpose of the report card?
- How can we improve the efficiency of our monitoring program?
- What techniques and tools should we be considering as our monitoring program evolves?
  - Can we drop some things off as our program evolves to keep costs down?

PANEL DISCUSSION: Where Are We Now and Where Are We Going? Status of Water Quality Monitoring in Long Island Sound – Panelists: *Robin Jaxhi, IEC District-NEIWPCC, Chris Bellucci, CTDEEP, John Mullaney, USGS, Jim O'Donnell, UConn/CIRCA*

Introductions from the Panelists:

Robin Jaxhi, IEC District-NEIWPCC: since 1991 (25th year), they have been monitoring western LIS and analyze samples in-house, with the exception of nutrients (working on getting equipment to do this in-house). They would like to have a coordinated LIS report with CTDEEP.

Jim O'Donnell, UConn/CIRCA: Since 2004, he's been operating the buoys in open LIS. In the western LIS, trying to understand hypoxia with funding from NOAA. They set up the ArtG buoy a few years ago to see improvements of hypoxia too.

Chris Bellucci, CTDEEP: 17 sites that they do monthly monitoring in LIS. They produce the DO in LIS bottom waters maps (hypoxia). They collect physical and chemical parameters. They also collect biological information (plankton). They participate in EPA's National Coastal Condition Assessment (NCCA) survey that is conducted every 5 years. They are setting up an embayment pilot project, to begin in 2016-2017: the goal of the project is to establish a tiered monitoring program for near-shore coastal samplings that can be performed by volunteer monitors to help assess the health of LIS embayments. They also do collaboration with guest researchers aboard the *RV Dempsey* (there's already an established network for freshwater tributaries, but not much for coastal areas).

John Mullaney, USGS: Conduct tributary monitoring in cooperation with CTDEEP. Sampling goes back to 1970s. Most coastal sites are monitored monthly. Sampling for nutrients, ions, trace metals, salinity, etc. Long-term data set that will allow for some trend analysis. They are seeing some changes in stream flow over the past 30 years. For example, can see changes in total nitrogen in the Quinnipiac River after a wastewater treatment plant (WWTP) was upgraded. There is not a lot of data to see if NPS changes affect change of nutrients in the rivers.

1. **What are the goals of your monitoring? Are you meeting them?**

   Chris, CTDEEP: Nitrogen, TMDL, Clean Water Act mandates that they monitor and assess the waters of the State. There are reductions in loads from WWTPs. Yes, they are meeting the goals in regarding TMDL and monitoring and assessing the waters of CT. They would like to do more embayment-intensive monitoring.

   John, USGS: Tied with work of CTDEEP. Their work is also tied in with the National Coastal Assessment program. They have kept a strong data set that can be used for trends, etc. Some missing data from what happens during storm events. They are able to keep up with trends.

   Jim, UConn: Yes, they are meeting their goals. But, are they able to detect a change in hypoxia in western LIS? No. To detect the change in hypoxia, need to be able to detect a 10% change, which is difficult. Are they making measurements that they really need? Need to resolve the variability due to slow and infrequent sampling. Bob Wilson showed that the direction of the wind over LIS affects the area of hypoxia. They were not able to detect a 10% change. Need to consider this when working in embayments.

   Robin, IEC: Do a comparison over time, comparing nutrients and DO. They would like to identify trends over time and compare this year vs. last year. They would like to do a coordinated report with CTDEEP. They would like to get their nutrient analyzer.

2. **Do you see changes with nutrient loading reductions?**
   a. **Can we answer this question at the scale (space and time) that we're monitoring?**
   b. **If not, what are next steps and what data are needed?**

   Robin, IEC: They just started sampling nutrients last year, but will continue sampling this year and moving forward. They have information on oxygen and do a comparison over time.

Jim, UConn: There are decadal scale variations in LIS due to weather patterns. What they need to do is note changes that are not from year-to-year, but need decades of information to see if our actions are making a difference.

John, USGS: They have seen reductions in nutrients from wastewater, but difficult to see how management actions can have an impact on waters. Moving forward, they need to continue monitoring.

Chris, CTDEEP: Can we make the network better to help reduce variability? What is good enough and can we afford it?

3. **Are you using, sharing, and synthesizing the data effectively? How can storage, access, and distribution be improved?**

(Skipped answering this question and went straight to taking audience questions-)

Question from the audience: Is there inter-comparison of the sampling going on? Are there common protocols regarding analyzing nutrients and collecting data?

Chris, CTDEEP: They try to do with IEC, but need to analyze the data to answer this question.

Robin, IEC: Sends out report every week of their data. She communicates with Katie O'Brien-Clayton, CTDEEP.

Jim, UConn: They share data with CTDEEP and make sure there aren't any errors.

John, USGS: Use USGS national protocols, but do not align with CTDEEP because they don't do the same kind of monitoring.

Question from the audience: Is there a metric that we can conceive that is a little more robust in the face of this variability? For example, do we know if primary productivity in western LIS is directly related to nitrogen concentrations?

Jim, UConn: (1.) Oxygen concentrations are regulated. There's a need to measure it to assess if conditions are being violated or not. (2.) The magnitude of the variability was not appreciated until 2008/2009. (3.) What should you measure that's more robust? There are technical challenges that need to be overcome to sustain productivity near the surface and bottom of the water column. Technical developments won't happen for a few years to measure the rates of restoration and production – this will help us determine more reliable actions.

Question from the audience: How much funds would you need to make the data less variable?

Jim, UConn: Take the buoy stations and multiply by them by at least 4 or 10 (a lot). Currently, it's about $1 million a year. Need at least $5-$10 million a year.

Chris, CTDEEP: Multiply it by 4. So, $4 million a year.

Question from the audience: How do you work towards collecting more reliable data? Is there an amount of phytoplankton that would mean that we reached a 'clean' condition?

Chris, CTDEEP: They started collecting phytoplankton data to see how it correlates with other data. There is no perfect metric or organism to look at to evaluate if we're reaching our goals.

Jim, UConn: People are trying to develop technologies to do just so.

Question from the audience: Is the data set determining conclusions regarding management actions in respect to area and duration of hypoxia?

Jim, UConn: We could not have detected if there was a reduction in 30%.

Question from the audience (Paul Stacey): Monitoring nitrogen has not made much difference in management decisions. So, do we need to look into Clean Water Act of looking at biological, chemical, and physical integrity condition? Need to understand biocondition assessment where it makes a difference.

John, USGS: This is a tricky question. He's seeing something with that in regard to phosphorus management. Not sure how the biological conditions of our streams to relate to LIS?

Lorraine Holdridge, NYSDEC: Not able to really focus on the causes of hypoxia by looking strictly at biology, need a more holistic approach.

Question from the audience (Jim Latimer): How well is the integration of CTDEEP and USGS data?

Chris, CTDEEP: Data is managed separately. But, it can be synthesized with USGS to put them together.

John, USGS: Data is available on their website. National USGS is trying to make data more available.

Question from the audience: What kinds of discussions have you had in the frequency of monitoring, from east to west?

Jim, UConn: He thinks that resources are available, just need to be re-allocated. Need to make tough choices and decide what is essential. Nitrogen has been reduced, but cannot detect a reduction of hypoxia. Need to keep eastern LIS measurements to help understand the links between them. So, don't change frequency.

Comment from the audience (K. Lwiza): Regarding the number of stations you need, need to concentrate a few stations in areas where there is a lot of variability. USGS stations need to be synchronized with CTDEEP open water/coastal sampling.

John, USGS: Sampling has not been tied with sampling of LIS. This is something to consider for a more continuous data set moving forward. There haven't been many linkages between changes in rivers compared to the changes in LIS.

Jim, UConn: All these things (data management) can be fixed down the road. There is just not enough adequate data that is persistent for decades.

Comment from the audience (Mark Tedesco): In regard to assessing eutrophication impairments, are there other impairments that we should monitor in the open or near-shore waters? And, how do they merge back with watershed management? Are there other approaches to complement the DO focus that could inform decisions on a watershed and community level?

Concluding remarks:

Robin, IEC: LIS is her main responsibility at IEC and would like to coordinate with others.

Jim, UConn: The level of funding for CTDEEP has been flat for a decade. Need to consider how to do it right.

John, USGS: There needs to be an evolution towards change and variability moving forward. Need to keep continue collecting data the existing data and expand upon it.

Chris, CTDEEP: Need to explore monitoring benthic invertebrates, eelgrass, etc.

KEYNOTE SEMINAR: Alternatives to Oxygen Based Criteria in Estuarine Eutrophication Assessment – *Edward Sherwood, Tampa Bay Estuary Program*

- How can Long Island Sound Study (LISS) improve the efficiency and effectiveness of its monitoring program?
- What techniques and tools should we be considering as the LISS's monitoring program evolves?

Developments of Estuarine Recovery Targets for Tampa Bay – Ed Sherwood

- Growth in state is exponential, leading decline in resources, sea grasses were declined and people began to consider the area "dead"
- Citizens in the community wanted to change → Tampa Bay's first kick start
- Began with 53 fixed stations throughout Tampa bay, now have over 354 in watershed, monitored on quarterly basis
- 1990 began a program to ensure the different monitoring programs that have been developed bring comparable data
  - be able to define areas and still working on defining others so that the monitoring can be the same through out

What Citizens Wanted?

- Back to conditions growing up circa 1950, pristine conditions where sea grass would come back and grow
- Citizens realized they had impacts in 1950, can't turn back to what it used to be
- Recognition that they wouldn't get back all of the acres that they had, goal to get back 95% levels of what was observed in the 1950s
- Watershed used for multiples uses, urban, agriculture, mining (agriculture and phosphate mining)
- Bay nutrient limited, nitrogen was a problem, had to be the core of the restoration
  - Had to manage the nitrogen in the area

Light Conditions?

- More clear water in the area the sea grasses growing at different heights, and different depth limits
- Had to focus on the water quality for the sea grasses
- Need to active 20.5% of the light where the sea grasses grow, if they can deal with the light targets they establish than they can get sea grasses to grow back in the area
- Moving targets were made from simple ideas that would lead to an outcome

Steps:

- Loading-monitoring or measuring data, not using any watershed models for this
- Looked at various labs of nitrogen levels and chlorophyll relations
- Restore sea grass →end goal
- Relationships between light (Secchi disks), specific light at different depths
- Look at turbidity and color at target depths
  - Targets weren't formalized to being with were formalized later on
  - "hold the line" viable option as sea grass extent was improving
  - trying to reduce in the 1970s
- Formation of the Nitrogen Management Consortium (Tampa Bay NMC)
  - Reduce loads in nitrogen in Tampa bay
  - Partnership between public and private partners
  - Exceeding the goals with this partnerships they have formed
  - Lowers values of chlorophyll that is what would tried to be achieved to continue to maintain and grown sea grass in the bay
  - Ahead of the game of for the targets in Tampa Bay, which were adopted in 2002, as of now they are slightly higher

Management Framework

- Come up with green, yellow, red response towards the areas of observed water quality; be able to convey to the people in the towns
  - Note: This "Report Card" like mechanism ties conditions to actions. Can we tie management actions to the LIS report card in this way?
- Began operating under volunteers, it wasn't until 2009 that they NMC developed TN load allocations

- Regulatory steps are not required as of 2009
  - Triggered with Chl-a become above thresholds for 2 straight years
  - Developed tracking tools
- Online action data base, any projects that have to do with nitrogen can be entered into the data base – can show what they have done in the past and what is needed currently
- Flexible tool
- Can enter own data

Summary

- Reduce nitrogen loads →reduce chlorophyll→increase water clarity →sea grass recover
- Checking to see how the loads are doing every 5 years
- Been able to monitor the sea grasses every 2 years to determine the sea grass extent that is observed in the bay

Has It Worked?

- Yes
- About a third of what they had in the 1970s,
- Significant load reductions in the water shed since the 1970s,
- Been able to reduce the nitrogen
- Drastic reductions in chlorophyll over the years
- Water clarity has improved
- Sea grass as of now has exceeds the goal originally had, back to the more pristine condition
- Positive feedback
  - 930 acres/year, received the news in march 2015 that they had exceed the goal

Sustaining Success

- Population is going to increase, will continue to work on the loads to maintain the stability of the bay with more people coming
- Need to maintain the goals in the future
- Maintain partnerships
- Long-term monitoring
- Target resources identified
- Seen by citizens and scientists that wanted to help regain the sea grass in the area
- Able to use multiple tools to help get the
- Looking for the best interest in all parties and recovery in Tampa bay want to be realistic
- Ongoing assessment and adjustment throughout if needed if not able to maintain the goals
- Restoring sea grass is good and beneficial to the area

Questions and Answers:

Q: John Connolly, Anchor QEA: The sea grass was almost flat but now it is exponentially growing, do we know why that is happening? Is there too much sea grass and what is going to happen?

A: Wasn't until about 4-5 years, there was a lag, due to sediment memory in the Tampa Bay. No there cannot be too much sea grass, it would not be a bad thing, good for lots of ecologically benefits for fishes and other creatures in the area.

Q: William Wise, SEA Grant: Any active restoration efforts for sea grass? Is the sea grass coming back to the areas where they were before?
A: Yes there were active restorations projects, they have come back and exceeded what they were before, recovering more sea grass in the lower part of the bay than the first part of the bay as long as we can maintain the water quality then the sea grass should be able to exceed within the area

Q: Sima Ebbin, SEA Grant: Was there an increase in fisheries in the area of sea grasses?
A: Yes but can't be completely because of the Tampa Bay effort. There is variability and that you can in fact see a change within the area of sea grasses.

Q: Robert Hust CT DEEP: What are the typical waste water plant loading concentrations?
A: Chl-a thresholds were adopted as the restoration target and established in Tampa bay, able to get ahead of the curve since they were adopted by the state. All of the plants either had to move or they had to be reusable within. Tampa Bay saw a significant response. Plants were required to do it by 1980. Go to reuse or straight to aquafer.

Q: Mark Tedesco, EPA LISO: In terms of nutrient loading was to counteract the nonpoint sources, what is the portion that would lead to point sources?
A: Would drop about 90% primarily from domestic point sources.

BREAKOUT SESSIONS ON MONITORING APPROACHES

A. FUTURE DEVELOPMENTS IN MONITORING TECHNOLOGY – Moderators: *Jim O'Donnell and Mike Twardowski, Florida Atlantic University*

1. **How can emerging technologies improve our ability to meet CCMP monitoring goals?**
   Emerging technologies can improve the ability to detect changes in LIS. Also, it helps improve platforms that we use to make measurements as well as improves instruments that we use to make measurements.

2. **What developments should we have on the 5 year/10 year radar to follow/pilot/adapt?**
   More buoys; more ship surveys; more AUV deployments; incorporate drones capturing high-resolution spatial imagery of algal blooms; crowdsourcing in western LIS (a lot of measurements that are noisy will complement a few measurements that are very precise); develop a distributed network of low-cost instruments that can be used to get the spatial structure of the seafloor; and take measurements of the rates of oxygen demand and production.

3. **Are there other things we should be doing now (e.g. satellite data)?**

   Use more data to improve models and need to make sure that there is a need for more monitoring data from the modeling community. Also, there is a need to focus on more process experiments: get more information on benthic cycling, understand the carbon budget more effectively, and understand that an ecosystem structure is necessary to link nutrients with oxygen (zooplankton, plankton).

4. **Does augmenting our program with automated in situ sensors potentially change the design of our ship based survey program? If not, what additional things do we gain?**
   No strong feeling about changing the ship program. Instead, focus on having more technologies to improve the accuracy and improve the instrumentation.

BREAKOUT SESSION RAW NOTES:

Mike - Working with NERACOOS on project with Jim O'Donnell. Putting in an *in situ* nitrate, ammonia, and phosphate sensors in 4 buoy locations for the top 2-3 meters of water surface and they're sampling every hour to account for tidal variability. Data is transmitted via cell phone and goes straight to website.

Mike - For each parameter, it depends on the space, time, hydrodynamics, biology, etc. Autonomous vehicles (AUV) could be used, but they're costly.

Jim – need a network of stations to define the boundary of hypoxia in western LIS. Maybe have an autonomous vehicle to explore where hypoxia is happening.

Melanie – Need to consider wind blowing over the Sound and how it affects hypoxia and tilting of the oxycline in the North-South direction.

Why do we care about hypoxia in LIS? Reducing hypoxic areas will give us more fish and shellfish.

Higher frequency variability. CTDEEP only goes out during the day and provides a nonsynoptic view.

Mike – instead of more buoys and ship surveys, why not deploy AUVs?

Jim - The data needs to be collected to detect trends (oxygen, nitrogen, carbon, phosphorus, biology – chlorophyll a, R, productivity, plankton, zooplankton, fish) and explain processes. You might not need as complete a survey to get this.

Tim Visel – need to consider benthic flux of nitrogen (biochemical process). Jim said that we need to monitor benthic areas too to understand this process further.

Look at high resolution spatial imagery to see algal blooms. Also, you can use drones to do this.

Jim - Two or three year campaign of data collection will improve modeling. Model doesn't really work and needs more measurements to make it better.

Work with lobstermen to put temperature sensors on lobster pots in LIS.

Glider (AUV) was deployed in eastern LIS in 2014 for about a month.

CTDEEP is collecting chlorophyll data

Tim – can we come up with a new monitoring regime? Jim – Good idea to use proxies to get information (e.g., looking at wind direction/weather data).

Tim – Look at long-term climate patterns. Is anyone looking at that? No.

<u>Survey</u> (to help us understand the extent of hypoxia)

- Oxygen
- Nitrogen
- Carbon
- Phosphorus
- Biology (Chlorophyll a, Respiration, Productivity, Plankton, Zooplankton, Fish)

<u>Experiments</u>

- Benthic demand/cycling
- Gas exchange
- Carbon budget
- New productivity model (light, temperature)
- Zooplankton
- Bacteria
- Phytoplankton

Technologies

- Ship surveys (more accurate measurements)
- AUV surveys
- More buoys
- Satellite imagery
- Crowdsourcing in western LIS (a lot of measurements that are noisy will complement a few measurements that are very precise)

B. APPLICATION OF MONITORING DATA TO MANAGEMENT AND DECISION MAKING – Moderators*: Peter Moore, MARACOOS and Paul Stacey, Great Bay National Estuarine Research Reserve*

Opening of breakout placed emphasis placed on how each part of the equation crosses borders: monitoring informs science, informs policy, informs management, and informs public engagement and back again.

1. Do we have a good summary of what the data are telling us, and is it influencing decision-making?

- Knowledge has to be transferred into action, challenges, how, variability and how is that handled?
- Some pushback on the question – good summary on the data, not sure exactly what it is telling us because of variability. Small samples, discrete sampling times means good summary of the data, but stops there…
  - What do you need to do to figure it out for next steps to make more sense of the data?
  - Strategically placed locations for monitoring between sampling periods, better understanding of variability? Too much time between samples
  - Continuous readings would help to fill in the blanks
  - Reactions:
    - Hard to say you have too much data, but is the data we have been integrated to understand the actual ecological effects that the data is supporting?
    - Hard to get to that point, limit on resources for monitoring, hard to gather data everywhere all the time – <u>so how do we determine what is good enough? If not, why not?</u>
    - Is monitoring for a standard a good and effective way to regulate?
- Do we have sufficient data and are we looking at the right parameters? We are becoming clearer on what we need to know, but don't have good summary for the data we do have.
- How the data is used to influence decision-maker is highly variable and depends on who the audience is? Local, state, federal? All depends, different needs.
- Good summaries on the data are there, can look at gradients effectively, have definitely improved, and can tell what has changed, but…
  - Don't necessarily know how those systems have changed over time specifically because of variability
  - Need more data, time, or we need to think differently about parameters to be able to assess other impairment end points
  - How will we know we fixed it?
- Struggling with this notion, see's different types of decision making at play
  - Motivations for decision – economic outcomes, ecosystem outcomes can be different. Informs the understanding of the problem
  - What we need to know and the level that we need to know depends on the decision we are making
  - Precision vs. Accuracy: Precision ability to measure something repeatedly and get same answer, accuracy is precise, but may be wrong answer, targeted at wrong question
- How do you align monitoring data to hit the points above??
- Nutrients become difficult because if you cut, you may constrain productivity, but you don't want to go the other way because eutrophication – how do you manage??

- Questions today have focused on the program focusing on hypoxia, and what can you do to manage it?
    - But also question today is hypoxia what we should be focusing on?
        - Importance as endpoint not likely to change, but should we look at other indicators/sources? Likely yes.
        - Limited set of options in terms of management, funding
        - Important not to decide between, but realize that monitoring may inform different outcomes
    - Are there other indicators that could/should be looking at? What are they?
        - Data is compartmentalized, not compared across other indicators
        - Lots of linear relationships, but maybe need to understand interactions between these entities to better inform decision
- Still need to answer what is good enough? Hard to move ahead if this hasn't been answered.
- Question about whether or not we know what the data are actually telling us? Do we understand the data we have?
    - One decision has already been based on existing data (N TMDL), how do we take next steps?
- Decisions have already been made on monitoring data – other questions asked might be how do we know when we're done?
- What are the co-benefits of decisions?

2. **Are we producing diverse informational products that reach diverse audiences?**

3. **How can the "Report Card" on LIS water quality be improved?**

4. **How can we better use our monitoring data to set individualized thresholds/cut points for ecosystem condition analysis?**

- TBEP has eelgrass, CBEP has blue crabs, what is the thing in LISS that people care about??? Could be lobsters? Commercial fishery? Rallying critter or champion could help efforts and garner attention and influence
    - Targeted ecosystem biological monitoring?
        - Pushback says this is more of a public relations tool, not a water quality indicator
    - Selling good indicators helps community connect with issue
- Monitoring data to explain ecosystem based indicators
- Need for a baseline to help explain improvements
    - Real need for data sharing amongst entities
    - Long-term data to better understand relationships
- Data-based vs. societal based – do we want to get back to a certain place?
- Do indicator species have any bearing on what you're trying to explain?
    - Real need to understand that relationship
    - Connections have to be made, can't just pick indicators
    - So, is eelgrass the appropriate indicator?
- DO isn't sexy, but sold the program. Must be able to say something about return on investment at the end of the day.
    - How do these decisions affect economics?
    - Can you credibly tie DO back to management actions?

5. **How can uncertainty be characterized in adaptive management?**

- Can be shown in fisheries management – you never really know because things move, time scale is a problem
- Are we using best science available to make best decisions we can?
- How long are we willing to wait to know you made the right decision?

    - How do you go to people in the community with non-concrete results and ask them to continue to change? Impose more regulation?

6. **Should we remain solely focused on oxygen or can our monitoring programs be used to evaluate alternate endpoints?**

7. **If we wanted to set nutrient reduction goals to meet an eelgrass target, is our current monitoring program adequate to do so?**

C. APPLICATION OF MONITORING DATA TO INTERSYSTEM COMPARISON AND SYNTHESIS – Moderators: *Jim Latimer, USEPA Office of Research and Development*

Introduction (Jim presented a few slides to introduce the topic):

- Intersystem comparison- looking across space and time.
  - By looking at more than one system of similar type and trying to draw conclusions you can gain insights to how systems respond (i.e. looking at nitrogen loading to eelgrass extent).
  - Get a characterization of the watershed and characterizing the waterbody itself.
- Data we can use to make intersystem comparisons and to synthesize it.
  - Variables: impervious surface, land use types, stream order, lakes, etc. probably will only use a small subset of these variables.
  - Data collecting: getting data from 15-20 sources (some better QA/QCed than others)
- Example: N load conceptual model. We were able to calculate how much N goes into the system. From that, we have N loading and eelgrass extent. As you increase the N loading you see a threshold of eelgrass extent.
- Embayment monitoring and citizen science is written into the new LISS CCMP

1. **What lessons are most and least transferable between systems?** *(lessons in terms of how the systems work)*

    - Land use association- How do we monitor change?
      - With push in Green Infrastructure do you see these starts to break down?
      - Density vs. usage
      - Land side needs to be tweaked
      - Flow pattern changes
    - Air shed and atmospheric deposition can also impact the system
    - Larger systems beyond embayments
    - Self-contained trend (benthic index)
    - Cross system comparison is using a screening process
      - Say you have a system that you can measure N load but is too warm for eelgrass to grow
    - Transferability
      - you can't compare a macro tidal estuary to a micro tidal estuary
      - monitoring frequency (timing), when to sample (pre knowledge) and sharing or transferring that knowledge (only measuring DO in summer months because that is when hypoxia occurs)
    - Classification variables
    - Groundwater vs. surface water load

2. **What parameters are most applicable to intersystem comparison?**

    a. ***What data are critical for comparing nearshore and embayment areas within the Sound and interactions with the open Sound?***

        - These can be broken down to Dependent variables and Explanatory variables

Explanatory variables:

- Salinity exchange
    - by knowing salinity you can get the exchange (fresh water/open water)
- Septic load
    - Importance of septic to N load between embayments and LIS proper is highly variable
    - When you look at LIS proper, we don't look at septic as a main N source to manage. But, it can be a major source in any given embayment (this is the whole point of Jaime Vaudrey' s research)
- Surface water temperature
    - Between the Sound and embayments
    - Stratification
- Wind Direction
- Tidal range
- Depth
- Land use
- Precipitation
- Population density
- Impervious cover

Dependent Variables:

- Chlorophyll a
    - We tend to have chlorophyll a thresholds (NCA threshold of 20) across systems- is that appropriate?
    - How do you define a chlorophyll a level that is bad?
    - This is a metric that is transferable
- Water clarity
- Flora/Faunal abundance
- DO
- pH
- Residence time

Nitrogen is a state variable

Patchiness
- Embayments are very small patches
- Due to geology (glaciers)
- Variability of embayments
    - Characterized the shoreline of CT and came up with 12,000 different segments using 6 variables

b. Can embayment "report cards" help summarize and communicate the conclusions?

Yes:
- it is a strong outreach document and allows you to track progress which is very valuable
- Score separately on loading vs. susceptibility
- Report card is good but it needs to provide some education of what the scores actually mean

No:
- Lack of consistency between embayments
- Identifying core variables
- Does it adjust shifting baselines?
- You are assigning value to things that don't implicitly have value
- Biological condition gradient

- interesting concept, doesn't establish thresholds
- Metric for impaired vs. pristine
- The public focuses on the grade, not the variable you are grading
- Modern baseline might help the situation
- The grade should be based on where we want that variable to be
    - Then does consistency matter?
        - Human health indicators – beaches, bacteria levels should be considered

3. What are the most interesting things we've learned from synthetic analysis of monitoring data, and how does this help us monitor and manage more effectively?

- Linkages to watershed development and expressions of eutrophication
- Nutrient trends are going down
- What is changing? What is not?
    - Which characteristics are changing with climate change and which are seasonally variable?
- Lag-time
    - System response
    - Management response?
        - Do you wait to see response?
        - use Models
- We did not achieve TMDL goal.
    - We are at 90% right now.
- We don't know much about what is happening in the embayments

4. What patterns and conclusions from the open water monitoring program can and cannot be applied to embayments and near shore areas?

Cannot Apply

- East/west gradient does not seem to apply
    - Eelgrass does
- Loading ratio assumptions (point and non-point source)
- Top-down, bottom-up
- Physics matters – how the water moves
- Introduction:
- Intersystem comparison- looking across space and time.
    - By looking at more than one system of similar type and trying to draw conclusions you can gain insights to how systems respond. (i.e., looking at nitrogen loading to eelgrass extent). Getting a characterization of the watershed and characterizing the waterbody itself.
- What kinds of data we can use to make intersystem comparisons and to synthesize it.
- Presentation Jim gave in South Carolina
    - New CCMP- embayment monitoring and citizen science is written into CCMP
    - N load conceptual model
    - Study systems in new England
    - Characterized land use
    - We were able to calculate how much N goes into the system
    - From that, we have N loading and eelgrass extent.
    - As you increase the N loading you see a threshold of eelgrass extent
    - New study: land use, how many lakes in the system, etc.
    - Data collecting: getting from 15-20 sources (some better QA'd then others)
    - Variables: impervious surface, land us types, stream order, lakes, etc., probably will only use a small subset of these variables.

    - Sites and drivers will be filtered out at the end.
    - BHQ: benthic habitat quality
    - Studying 98 systems
    - We have existing data on N and P loading
    - Preliminary results: High population levels, higher response in chlorophyll.

5. **What lessons are most and least transferable between systems? (lessons in terms of how systems work)**

    - Land use association- How do we monitor change?
        - With push in Green Infrastructure do you see these starts to break down?
        - Density vs. usage
        - Land side needs to be tweaked
        - Flow pattern changes
    - Air shed and atmospheric deposition can also impact system
    - Larger systems beyond embayments
    - Self-contained trend (benthic index)
    - Cross system comparison is using a screening process
        - Say you have a system that you can is too warm for eelgrass to grow
    - Transferability- you can't compare a macro tidal estuary to a micro tidal estuary
    - Transferability- monitoring frequency (timing) when to sample (pre knowledge) sharing or transferring that knowledge (only measuring DO in summer months because that is when hypoxia occurs)
    - Classification variables
    - Groundwater vs. surface water load

6. **What parameters are most applicable to intersystem comparison?**

    - Two main groups – explanatory and ecosystem response
    - Salinity exchange
        - by knowing salinity you can get the exchange (fresh water/open water)
    - Septic load
        - Importance of septic to N load between embayments and LIS proper is highly variable
        - When you look at LIS proper, we don't look at septic as a main N source to manage. But, it can be a major source in any given embayment (whole point of Jaime's research)
    - Patchiness/heterogeneity
        - Embayments shorelines are heterogeneous
        - Due to geology (glaciers)
        - Variability of embayments: Characterizing shoreline of CT (came up with 12,000 segments using 6 variables)
    - Surface water temperature
        - Between the Sound and embayments
        - Stratification
    - Tidal range
    - Flora/Faunal abundance
    - Chlorophyll a
        - We tend to have chlorophyll a thresholds (NCA threshold of 20) across systems- is that appropriate?
        - How do you define a chlorophyll a level that is bad?
        - This is a metric that is transferable
    - Wind direction
    - Water clarity

- Temp,
- DO, salinity, pH
- Residence time
- Depth
- These can be broken down to Dependent variables and explanatory variables.

RECONVENE AND REPORT OUT ON BREAKOUT SESSIONS – *Facilitated by Jason Krumholz*

PANEL DISCUSSION: Evaluating the Success of Monitoring Programs – Panelists: *Rachel Jakuba, Buzzards Bay Coalition, Edward Sherwood, Paul Stacey, Mark Tedesco*

1. **From the breakout session reports, what conclusions resonate from your own experience in monitoring your systems?**
2. **How do you evaluate whether your program is meeting established criteria for success?**
   - Once you lose funding, you're gone – never going to come back once you lose funding, so you need to keep collecting the data to be able to make decisions. Success is continuing to be funded.
   - Discussion is usually around making the case to increase monitoring – but just maintaining the current level of funding is critical, especially with tight budgets
     - Need to make the clear statements as to why this is critical
   - Two things for Buzzards Bay in terms of what they get out of data collected:
     - Utilized by state, federal agencies in regulations/decisions – that's a success for the program
       - Keeping a QAPP has been critical to getting MassDEP and EPA to use the data
         - **a.** Collaboration with UMASS Dartmouth
     - Engagement: rate of returning volunteers, hits on the data section of the website
   - Paul: criteria for success are impairment-driven. We don't do anything until there is an impairment, at which point it may be too late to do anything
     - Guide acceptable social, economic, environmental outcomes in a sustainable way, at the local level
   - Maintaining WQ and nutrient loads at a level that will allow sustained eelgrass growth (protecting what we already have) – but this can still use a criteria approach, with an endpoint/threshold
   - LIS is difficult: focus is not on eelgrass beds, but on hypoxia and sewage treatment plants
     - LIS still needs NPS, SW improvements before success can be declared, not just point-source
3. **How can we improve our ability to self-evaluate and manage adaptively?**
   - Rachel: example of treatment plant discharging through GW – reduced concentrations in discharge, but still no changes in algae growth
     - Here is where they can use adaptive management – hit loading goal, but how long until the WQ and ecosystem changes/recovery? That can be a test system to understand how long it might take for other systems
     - NPS work is just getting started, progress will likely be slow – need to determine which of the suite of options will make the biggest difference, then hope to get that to a bigger scale
     - Lorraine: was the expectation of fewer algae made clear to the public?
       - Public was told that it was going to get worse before it gets better. They were told to wait 7-10 years, but that isn't bearing out 10 years later. They thought there would be a response.
         - **a.** For surface discharges, there was more success, but not for the GW discharge (even though it was 70% of the load initially)
       - Where is the balance on waiting vs. continuing to push for further reductions?
         - **b.** Using models to inform existing/current loads, lock in permit discharge levels
           - **1.** Treatment plant permit was up for renewal: appealed the permit, saying it wouldn't meet the load – negotiated a modified permit with the town and EPA

        i. Other things the town could do to meet the TMDL

    c. Hit other sources: project funded by EPA through CZM – $200,000 to upgrade 200 septic systems with a list of tech that should meet 12 mg/L or less, offered the funds to homeowners
    d. So close to achieving results (theoretically) – motivation to have an extra push to get it over the hump

- Paul doesn't think adaptive mgmt. has been implemented effectively anywhere.
  - Variability: measuring change is difficult (can't figure out what works best).
  - Doing some things and seeing what works vs. doing everything we can as quickly as possible (LIS needs to do the latter)
    - Phasing is still valid, just harder to pick certain approaches over others
  - 7-10 years is a long time to be patient – especially if there are other current practices/standards that might be causing other loads to increase. Need to be realistic about how new BMPs are being tested while current practices are still in place
    - Another Question for Rachel: Could you do a crude meta-analysis of what, in a range of other examples, has shown response to decreased nutrient loading? And what were the changes (and how long did they take)?
    a. Most models don't build in a lag if there is expected to be a <10 year lag
    b. Paul: watershed models are good enough to determine what equilibrium systems would be like.
        i. That shouldn't cause us to wait before managing systems, though
    c. What is it about certain systems that make them respond more or less quickly? Understanding that would help in terms of setting expectations for stakeholders
    d. For Buzzards, recent study has shown that the relationship between Chl and N is changing over time: more chl is coming per N, so limits that were set previously may not be good enough now
- Adaptive management will be important when you get to the threshold, and then you can review and see what else needs to be done

- Mark: adaptive mgmt. works on different scales:
  - Can still learn from specific pilot projects
  - Using monitoring data: Tampa went down to 3 mg/L, and also had some zero discharge from St. Petersburg. Even then, there was a decade before the data showed a major change. Need to give the system the time it needs to respond, patience is needed. Need to make sure we are learning, taking the right lessons.
  - CT Fund for the Environment sent a petition on the TMDL to EPA, arguing that the existing TMDL would not achieve standards based on CCMP – more needs to be done now. There are legal vehicles that could be used to push further nutrient reductions
- Tampa Bay: if you build it, they will come
  - Vs. Mississippi River hypoxia, which had direct implications on the various fisheries. That's the next step: what are the implications of improved hypoxia conditions in W. LIS?
    What are the next steps that people should be looking forward to following all of their investments?

    Focus on progress, even if it could take a really long time to "get there"

4. **How do we evaluate whether our current designs are sufficient to understand near shore & embayment patterns?**
   - Ed: good tool to engage citizens, local municipalities – they can know what's happening in their backyard
     - Collect just a little bit of data to inform local citizens of trends and baselines
     - Can at the same time address gaps in the overall monitoring system

- Enhances their need and want to support protection for those areas – they know that what they do affects their lifestyle, their local area
- Mark: How many near shore sites existed that could be monitored, and are they reflective of overall health?
  - Those areas are not always reflective of the overall health –
- Some of the monitoring was very specific to catching specific polluters, showing their specific impacts to local WQ
- Hard to get away from a 40-year dataset, without that funding, it would be hard to know much

- Rachel: Buzzards has been very focused on embayments – helpful for seeing decreases, changes/successes for local municipalities
- Paul: Near shore monitoring has been neglected in LIS, but it is valuable.
  - Strong link between how we develop/manage the land and the problems in the receiving waters. Everywhere we look there are ways to manage better. Monitoring can help force that better

Paul Stacey

- Paul was at CT working on N mgmt. for LIS
  - Now working at NH on Great Bay – firestorm of nutrient controversy; high costs, how do we know that the numbers are right? Are there other things to do?
  - List of inconvenient truths
    - Management is impairment-drive. Nutrient don't behave like traditional pollutants (natural variability, difficult of monitoring, not a threshold pollutant)
    - Nutrient limits are often not obtainable, especially for large waterbodies with many jurisdictions, especially for NPS
    - Adaptive management is a great term, but by the time you've monitored enough to determine changes, the stressors have changed. It's important, flexible, but very difficult
- Positive:
  - Look at new CCMP fact sheet: progressed from focusing on N pollution to a more holistic view of the issues and the way forward. Paul hears that in the talks today

Rachel Jakuba

- Scientist for Buzzards Bay
- Tracking nutrients, DO for 24 years
- Two goals: track trends and changes over time, engage citizens (citizen scientists)
- Two-pronged approach
  - Citizen scientists trained every year (130 volunteers, 800 over the course of the years) – heavily focused on embayments, due to volunteers who can sample from the dock
    - Go out every 5 days (20x per summer)
    - 4 times a summer they do whole water samples to collect the suite of parameter data
    - Has been able to track trends over time: listing waters, establishing TMDLs, high volume of data
    - How program is designed: purposefully bias DO (6-9am), and Nutrients (last 3 hours of an outgoing tide to bias for the nutrients coming off of the land)

Mark Tedesco

- Reminder that this session has covered all of what we *have* been able to achieve over the past 20 years – now we know that hypoxia does happen, and where. Has opened peoples' eyes to the extent of the problem
- Only through buoy programs that we understand shorter-term variability, effects of weather patterns and weather events – now we have a more subtle understanding of the system and its various controlling factors
  - Understand what controls the respiration rate

- Monitoring program is serving its purpose to help direct research (e.g., sediment oxygen demand and fluxes)
- Big question (in addition to improving our ability to understand mechanisms of hypoxia): Are there additional understanding of more localized impacts of eutrophication / nutrient inputs
  - Scale is one of the great challenges, and the diversity from east-west
    - Focus on bi-state, western LIS
      - **a.** Doesn't help towns farther east in making decisions on how they should manage their local water quality
      - **b.** We should make LIS issues local, so that communities agree to make expensive upgrades

Edward Sherwood

- As an outsider: we're selling ourselves short on how much we understand about LIS
  - We have a lot more data than a lot of areas in the US
- Lacking: closing that loop – are N load reductions implemented having an effect on hypoxia?
  - Progress is a selling point for continued investments
- Might just need to be patient and wait for the ecosystem to start seeing improvements

Open Discussion

- John Connolly: Success evaluation is comparing to other areas, but they don't necessarily have the same problem. However, Mississippi has the same problem. To what extent is LIS taking advantage of Mississippi River efforts (how they're using monitoring, data to evaluate their progress)?
  - Mark: Gulf project has pursued ensemble monitoring approach to refine nutrient reduction requirements – a range of different modeling approaches.
    - They have also gotten multiple agencies involved and taking a lead, which has been helpful
    - Topic for discussion tomorrow
    - Much bigger watershed, driven by Ag – how do you get a farmer in Iowa to care about the Gulf of Mexico?
    - N flux information is valuable, positive – we have not had a reduction in tributary loads, but that's mainly due to higher rain flow – the management is actually working, even if it doesn't seem so
      - **a.** However, rain flow may be changing over time, so normalizing with an expectation of previous expectations for rain flow may not be valuable (due to potential increases in rain from Climate Change)
- R1 LIS coordinator until 2002: Served on the management committee for other estuary programs
  - Over the past 35 years, fantastic progress is being made
  - We've seen reductions in point source, and ecosystem responses – significant accomplishment – if we can continue to make incremental progress on NPS, we should see more progress
  - Population growth and impervious surface: any correlation between load reductions, pop growth, impervious surface changes, and rainfall

SESSION SUMMARIES: DAY 2 | Wednesday, July 15, 2015

Essential Questions for Day 2

- What are the next steps in LIS eutrophication modeling?
- What is the monitoring needed to support improved modeling?

RECAP OF DAY 1 AND DAY 2 OBJECTIVES – *Jason Krumholz*

- Other sources are going to be important and models are mainly use currently
- Turing down the point sources
- Linkages between nitrogen loading and hypoxia are difficult to establish and model can help us understand tem
    - Modeling a good approach to look at them
    - Explore monitoring and modeling and how we can improve on them
- Paradox of patience vs. precautionary principle
    - Takes time, can't expect an immediate response but don't want to wait 10 years →models can help bridge that gap
- Great need for models to help us bridge them together

Overarching Questions

- What are the next steps for the modeling program?
    - Improving existing models
    - Develop alternate hypoxia based approaches
    - Modeling other eutrophication endpoint
- Should alternative approaches supersede of complement them?
- What are the data gaps and what data do we need to be collecting to continue to improve modeling hypoxia? Alternative endpoint different parameters? More spatial or temperate coverage?
- How can we better incorporate anticipated future ecosystems dynamics and changing climate into our models?
    - Different approaches? Simulations? More/better data?
- What is the most effective way to accomplish this?

STATUS OF LISS ECOSYSTEM MODELING EFFORTS – *Jim O'Donnell*

- Two kinds of models
    - Budget kind of model (geochemist→understanding the big budgets (oxygen, carbon))
    - Predicting what is going to happen (i.e. oxygen) how much and how long is it going to take?
- Water column respiration had been estimated to be about 8-20 Moles/m^3/day
- Seasonal decline rate is much less than the bottom water by a factor of 10
- Horizontal or vertical transport had to be compensated
- Wanted to know if the transport would be horizontal of vertical
- Benthic oxygen depend along the LIS
    - Bigger in the summer, half in the spring
- Respiration is underestimated relative to the LISICOS
    - Pynocline waters around 20
    - Closer to the surface 20
    - Not consistent with what was found before
    - Begins with 5 O^2 concentrations in July but in September it gets low
    - Rapid decreases were observed

- Going down during the periods with the seasonal trends →seasonal mixing and CDT = R
- Don't need any mixing with but mixing has to do something with it to

- Transport it about 40, horizontal transport is about the same
- Eddy diffusivity
  - Low levels of mixing at the pynocline
- Seasonal trend over 100 days is the difference is between the distance flux and the transportation flux
  - Slight deviations of mixing, can explains how the wind and the movement of oxygen

<u>SWEM</u>

- Created over a periods of 15 year
- Based on geographical representation, simulated
  - Shows velocity, temperature, etc.
- Each box they use the equation mentioned previously
- Found with initial hydrodynamics lowest O^2 values were around 4
- Transport mixing, turbulent flux
- When using this couldn't get the hypoxia →argued that the numbers were to big so adjusted which allowed to get the oxygen level down to the right area
- 125 parameters that are involved
- Looked at production of the models and concentration of O^2
  - Observed actual buoy data, which was different than what they had estimated with SWEM
- Suggested that the production in the model was too low compared to what it was actual
- Changed to extract the data
- Concluded that got low O^2 in the model was that the production, respiration and the mixing were too low, explored it with a few changes to try and improve it
- Years later tried to make the bio part better than what it was before

<u>Scientific Questions</u>

- Funded more work to be able to understand the magnitude and variability
- Don't understand why the data Kremer came up with was so important
  - What are the mechanisms controlling the magnitude and variability of respiration rate?
  - Is there seasonal variation in the benthic respiration?

<u>What's Next?</u>

- Modular model
- More than one or two people would be able to use, that people in the future would be able to use, simple and can be changed.
- Have competing biological, chemical, physical that can be changed and adjusted,
- NPZ model?
- Higher model that has to do with kinetics?
- Need to know the plankton community first before going ahead
- Instead of just funding a single PI, need experts and professional scientists that would be able to assist in the making of a model
- Suggestions on how to break it up
  - Production, respirations, benthic cycling (nitrogen, oxygen, etc.)
  - Mixing (difference between respiration and vertical transport?)
  - Data sharing and analysis code sharing (try and make the solutions to be offering to the wider community, that other people can use it that aren't experts can be able to use it, broader range of scientists, writing programs that are accessible through excel, mat lab)

Question and Answer:

Mark Altabet

Q: Didn't talk about air sea exchange, is it important?
A: We need to increase the gas exchange a little bit, model was not sensitive to those variables, surface concentration was low in the model before 2012, didn't make much difference in the hypoxia, did increase the gas exchange in the winter

John Connolly

Q: SWEM model is spatially crude in LIS averaging going on vertically and horizontally, data is being controlled. How much average it is being impacted?
A: Data resolution that we have is being assessed, only about 20 points in the LIS not a lot of data for hypoxia, lateral variations for bathymetry could have an impact on the vertical flux in the ocean, LIS is quite steep where that would be sustainable transport, but there is not a lot, probably about 10x the amount, going forward there would be higher resolutions to help,

How much is physics vs. biological?

Focused on the more basics

Craig Tobias

Q: In the model is it just in the benthic respiration?
Jim: Carbon budget is just as important as the oxygen budget but we don't have a clear idea of how much carbon is being imported into LIS, not very well measured.

What would you used to do to get better measurements?

Should find a better way to get the measurements.

PANEL DISCUSSION: Application of Monitoring to Modeling – Panelists: *Chris Kincaid, University of Rhode Island Graduate School of Oceanography, Jim O'Donnell, Robert Wilson, Stony Brook University*

Panel Discussion:

Robert Wilson, Stony Brook University: South Shore Lagoons of Long Island

Jim O'Donnell, UCONN: Group 1 Simulate Circulation, Transport, Wave Conditions Mostly Focused on the East of the LIS

Chris Kincaid, URI: Plate tectonics surface embayment's in the bay, conductivity in the bay, collect data throughout the Rhode Island

Robert: People at Texas A&M find it helpful to find a connection between hypoxia and a change in loading to help guide some numerical data, using the statistical conditions of hypoxia.

Jason: What data/research studies do we need to do a better at parameters the data?

Robert: A lot of high resolution in Smithtown bay, monitoring efforts in to do a better idea in density that would help, profiling instruments (vertical mixing), accommodating detailed vertical structures.

Jim: Profiling CTD in the sound, it is straight forward the maintenance that is costly

Chris: Benthic processes is quite strong, like the equations Jim showed in the presentation.

Jim: Assessment, multiple the restorations by 10 the water column is about 3 or 4 times more than the benthic demand, benthic demand and water quality demand depend on one another, need to get the water depth

Robert: No vertical mixing

Jim: Hypoxia in the sounds is low mixing, which is wrong, oxygen in LIS is strong and so is the respiration reason you are getting hypoxia is because there is a high respiration.

Chris: How important would it be to have the shallow systems nearby?

Jim: If there is respiration and the water depth is shallow it will be more controlled by the benthic flux, of oxygen do to benthic demand.

Chris: Light controls?

Robert: In Smithtown bay surface mixed layer, small pynocline, don't see much in the summer.

Jim: Dynamics of oxygen may be different in smaller bays.

Robert: you can see sharp front, and cross structural in the bottom

Jim: Higher oxygen off shore?

Robert: Strong oxygen gradient at the bottom, strong to bottoms mixing

Jason: How do we better develop modeling?

Question from Audience:

How is respiration represented well in the models? If it is not being done properly are we just putting in the best guess in the model?

Answer from Audience:

Put in an oxygen term that will look to two different ways. Putting in a respiration term is a not going to be a management tool.

Question from audience:

How do you work to have a better model?

Answer from audience:

Really understand what we have, don't know how to plug in the parameters into the model, simplest way is to prescribe rate that can then be linked to oxygen simplest to a more complicated one.

Jim O'Donnell?

Biggest assumption link between nitrogen loading and respiration is the most poorly defined

Question from audience:

Fixed respiration model. In LIS have hard time look at relationship between hypoxia and nitrogen loading, does it have long-term impacts. What long-term changes are due to the meteorology forcing changes?

Answer from audience? Or Jim O'Donnell?

That is what is going on in the Gulf of Mexico, see a correlation between the two?

Been a long standing issue has been river discharge or wind pattern, but that kind of model is not useful, won't give you a management tool. Need to find a model for respiration that it can relate to

Chris: to Edward

Q: Significant ground water is coming in. how important is ground water coming in?

Ground water is 5%, formulated models that have used ground water, but it is not important in the Tampa bay area as much as the east coast, north of the FL region there is a lot of springs in the area so there is input form the spring water and the ground water which is more important, so in that area the spring water and ground water is about 5%

Melanie Fewings to Chris

Q: Doing the models based on salinity?

A: Velocity based on water flow, using lines; there are residual rivers in the system, challenging.

Jason: Do we need to model dissolved oxygen in order to manage eutrophication or are there other approaches?

Jim: Because oxygen is so important to the organisms in the bottom, under represents the impact. Vertical structure is weak that has to be multiplied by 10, huge fraction of LIS, has a clear impact on fish and organisms; clean water acts calls for it.

Jason: Are there alternative approaches?

Robert: Trying to assess statistical loading changes and oxygen, trying to pull out the variability and looking at the liner and non-liner changes or bottom oxygen in the Mississippi bloom.

Jim: Link between eutrophication can find that without the dissolved oxygen, oxygen is not limiting the potential habitats, LIS there is, can't find a link between discharge and eutrophication without looking at oxygen.

Chris: Looking at wind changes, and track nitrogen in rivers and waste management strategies, look at differences at sizes of different blooms if you add oxygen then you would look at different parameters.

Jim: Don't model anything that is easy to measure oxygen is easy to measure relative to everything else, oxygen is a thing that should be measured, lots of data is hard to do, when you get it right the model is right.

Comment from Audience:

Water quality is the next thing that you would want to measure. In the future in terms of the long ecology multiyear stress, ocean acidification, temperature, salinity etc., for the future and the understanding of that is happening lowing towards the future. What phytoplankton are we going to turn on and off looking forwards? The organisms that we are seeing, food quality.

PRESENTATIONS ON ALTERNATIVE MODELING APPLICATIONS

A. Alternative Formulations and Modifications to SWEM – *Grant McCardell, UConn*

- Model considerations
  - Model complexity is different from model resolution
    - There can be box models that are complex, and there can be very simple models with high resolution
    - Increasing complexity allows for inclusion of important missing processes, adding processes of interests, BUT more difficult to code, tune, and validate
    - More complex models are more likely to get it right, but for the wrong reason – more likely to be poorly constrained or parameterized
    - Higher resolution: more computation expensive
  - Model objectives – need to know these
    - Heuristic purposes vs. prediction purposes
      1. Prediction: in theory, more complex=better "fit"
         a. In practice, model "calibration" is limited by data availability of additional systems you're trying to model
      2. Heuristic: simplest model that captures what you want to look at is best. Better to look at multiple simple models that a complex one that looks at multiple processes. Can combine simple models later on.
    - Parsimony is important for both types of purposes – the simpler solution is generally the correct one
      a. Improvement vs. Degrees of Freedom
- Alternative example: GEM
  - Modeling algae as having two types of carbon: one that grows and one that can store hydrocarbon – gives phytoplankton the ability to store carbon and release it once leaving the photic zone, able to draw Oxygen down quickly
    - Implemented as a 1-D surface model
  - How to incorporate into a 3-D model? Modular modeling
- Modular Models – need it to be scalable, device-independent (can be run on different machine, different program/language), Open Source, community development/input/output
  - FVCOM – hydrodynamic
    - 3-D Hydrodynamic model
    - What if there were no freshwater fluxes from East River WWTPs? Reduced freshwater at surface, increased mixing
      a. Increase in salinity, reduced stratification
  - GOTM – 1-D turbulence model
    - Can be used with real data, designed to be easily incorporated into a model – comes up with mixing rate
  - FABM – Flexible Aquatic Biogeochemical Model (New)
    - Can be used with GOTM and FVCOM
    - Works on a simple interface: you decide what you want to be included in your model, describe the linkages you want between boxes, it compiles and creates model you can run
    - Includes predefined building blocks to build a full-up model, or simpler models
      a. Can also make a unique model (e.g., 12 different types of diatoms)
- <u>Conclusion: complexity and resolution are not the same, heuristic models can be used to inform predictive models, parsimony is vital, multiple formulations should be pursued, modular design allows flexibility/cooperation, FVCOM/GOTM/FABM already combine with each other and could be used</u>

B. High Resolution Biophysical Modeling of RI Embayments – *Chris Kincaid*

- Presentation will talk about lessons learned from RI, how this could be applied to LIS
- Three areas: Providence Bay, Bristol Harbor, Greenwich Bay
  - Low oxygen in these 3 areas
- Three-legged stool: data, lab models, numerical models
- Data
  - Spatially detailed ADCP surveys (on the water getting a full tide cycle over various transects
    - Can determine de-tided flow
  - Moored ADCPs in key locations
  - Tilt current meters in key locations: low cost, good spatial/temporal covers
    - Placed in many location around the area – buoyant sticks that tilt over with current
    - Can track the current changes , such as a big flood event (gyre wasn't affected by the flood event, very persistent)
- Lab models
  - Representation of the Providence River, with shipping channel in shallow shoal (applied tidal range
  - Over 10-20 tide cycles, dyed areas do no exit the shoal – can track out the eddies at the interface of the shoal and the main channel
- Lab and data show a recirculation period
- High resolution grid model has been used (ROMS Model?) – need to determine flushing, age of water vs. oxygen
- Tracking temp, salt, and also different chemical dyes from different discharges – can all discharges up, or turn down different sources and see how that impacts the overall model
- Used tracers to track flushing rates (took 5-10 days to flush, despite previous studies saying that it should just be 1 day)
  - Really depends on whether the tracer is in the main flow or the eddy/gyre
- Greenwich Bay: similar data/modeling strategies
  - Strongly affected by the winds – cause individual, stable gyres
  - Just like Providence River, take the model and run a simulation for a period of the summer with different winds, see what happens. N-ward wind causes much higher retention, longer flushing times than other estimates have predicted (>15 days), E-ward winds lead to 4 day flushing times
- NPZD Model turned on in ROMS: total N, phytoplankton, zooplankton
  - Tracking multiple rivers, multiple WWTPs
  - Can look at surface N levels and how it leaves the river into different bays
  - Bloom tarts in certain bays/shallows, then moves north (and time progression matches data)
  - Is Greenwich Bay a catalyst for Bay-wide events?
- Important to ask what are the repeatable processes/events that are important (e.g., wind)
- Tested impact of changing different WWTP discharge levels
  - Reductions 5-0 mg/L imperceptible
- Tested Greenwich Bay as a "bad gallbladder" for the system
- Conclusion:
  - Stable, consistent gyres
  - Started looking at NPZD
  - Winds important to movement of plankton within the system
  - Greenwich Bay as hotspot (if you zero it out and run the model, it can have significant effects)

C. Lessons Learned From ECOGEM Modeling in Narragansett Bay and Potential Adaptation to Long Island Sound – *Mark Brush, Virginia Institute of Marine Science/Jason Krumholz/Jamie Vaudrey, UConn*

- Different GEM than the one Grant covered
- This project is part of the NOAA program
- Reduced complexity parsimonious ecological model to predict hypoxia in Narragansett Bay
- Advantage: the model is an Excel file, runs in MatLab, only 17 parameters
    - Available for direct use by managers, direct applicability
- 30 components (the bay is broken into segment boxes) – surface and bottom boxes
    - Run the model for a day, see where dyes move over the course of that day
        - Can use this to estimated Gross Exchange Metrics
        - Advantage: quick to run
        - Disadvantage: can only run for years where you already have ROMS data
- 17 constants and coefficients – very simple
    - Oxygen is not modeled, it is calculated stoichiometrically
    - Mixing/flushing done on a daily basis
- Based on empirical formulations of key rate processes
    - Robust relationships from studies across many ecosystems
- Since it uses formulations based on relationships from multiple systems, it is ideal for using in different systems
- For WWTPs, the N component for dischargers are added to the river additions that they are upstream of
- Skill Assessment: a box model predicts a box-wide daily average parameter – not directly comparable to field data
    - Large variability in survey data of oxygen data across the box – the average from the model will not capture this variability
        - Not expecting to see a "perfect skill" for this model
    - Also the data aren't being collected that often for some parameters
- Relative Operating Characteristic – ROC Curve – way to evaluate the skill of model
    - Goes from 0 (unskilled) – 1 (perfectly skilled)
        - < .5 is considered skilled
            a. Hit rate vs. false alarm rate over a range of thresholds
    - Overall skill for salinity is .97, which is very good
- Captures general trends
- ROC Skill for the whole model: O2, N, and CTD are good, Phyto not so great but still considered skilled
- Ran the model to see if the model was responsive to N reductions
    - Reduction in phytoplankton (slight)
    - No change in oxygen
    - There was a nitrogen reduction
    - <u>Observed reduction in Nitrogen inputs does not appear to be enough under these conditions to change the bay's condition</u>
        - What if the N reductions were ratcheted up to a reduction of ¾ of the WWTP flow? In this case, the model shows a substantial reduction in hypoxic
- Conclusion: Model suggests that more N reductions would be needed to see a noticeable effect
    - What EcoGEM cannot do: no new physical forces (effects of changes in river flow or stratification)
    - EcoGEM was good for providing bracketing (the model years were two ends of the spectrum)

   - What is needed to apply EcoGEM to LIS?
     - Physical exchange coefficient from ROMS or FVCOM
     - Benthic rates (flux of N, P, O2, including Denitrification)
     - Light (PAR) at surface, daily
     - C to N in sediment
     - C to chl (high variability)
- Question: Is the assumption that all respiration is aerobic?
   - Sensitive to PQ and RQ – there are benthic terms, but not sure if it is tweaked to account for that or if it is making an aerobic assumption – question for Jamie
- Question: Can you look at why there wasn't an effect on Oxygen? Maybe the N isn't limiting, the N is being exported farther down in the bay
- <u>Note: opposite conclusion regarding the reduction from 5 to 3 mg/L for WWTPs compared to previous talk</u>

D. Load Based Modeling Approaches in Embayments – *Holly Drinkuth, The Nature Conservancy*

- Holly's Role: work with managers/communities to drive action
   - Research recently conducted by TNC, and how it has been used to help communities better understand N loading
- TNC has experience with seagrass research, salt marshes, and shellfish restoration
   - Restoration efforts needed reductions in N to be successful
- A number of N load models have been conducted across areas in LIS
   - Can be used as an outreach tool, a way to engage communities
- Work started with Great South Bay in 2011
- Seagrass Research: sampling all across the CT/RI/MA coastline, 36 sites tested for genetic diversity and tolerance to a suite of stressors – nutrients and light levels were the biggest impacts
   - Wanted to take research to the next level and determine where the N was coming from (something that TNC could do something about)
     - In some areas, the N levels were above threshold for seagrass survival or stressing seagrass survival
   - Used a model that quantifies sources of N with relative ease, helps decision makers determine where to reduce N loads
- Simplicity of the model is part of its strength – can understand how to tailor it for local conditions
- Drawbacks: uses decadal averages
- Can apply to the model the atmospheric deposition and fertilizer rates for different land types (lawn, parks, Ag, etc.)
   - Assumptions about different wastewater types
- Inputs and parameters are relatively easily available, and there are also model enhancers to improve the model if available
- E.g., Peconic Estuary: graphical representation of where the loading is coming from, and from what sources
- Management applications: susceptibility of seagrass to nitrogen load
   - Look across subwatersheds, determine the necessary reductions to meet seagrass enabling conditions
   - Can use it to start the conversations about what are the options for reducing loads
- Is there ever not enough data?
   - Need parcel information, and information about residences – not always available in CT
- Communities will use this data, and also other information from past studies to make management decisions – it isn't meant to be its own policymaking tool

E. Does Consideration of Global or Regional Changes (in Climate) Alter Our Prediction of Ecosystem Response to Nutrient Abatement? – *Jason Grear, USEPA Office of Research and Development*

- Part of a broader national research program
- At the boundaries: changes in wind, sea surface temperature, precipitation and salinity, carbonate chemistry, DO, nutrients – focusing on salinity and carbonate chemistry
- Can we understand these internal characteristics through inverse modeling techniques and model comparison?
- Aragonite Saturation State – what shellfish need to construct their shells – already seeing conditions for issues with this in some areas in the Northeast
- Changes in precipitation patterns – changes freshwater coming into the system, which changes carbonate chemistry
- Huge ranges in changes in CO2 concentrations
- Tow data from 1998-2010 – are there changes over space or time? Same boxes used as EcoGEM
- Carbon:Chlorophyll ratios – determined by phytoplankton community structure
- Recent study exposed whole phyto communities to different CO2 concentrations – resulted in a shift in size composition of the community (shift to smaller cells for low and high CO2)
  - Each size class is affected differently by CO2
- Can look at data from narrabay.org – phyto species that are counted every week over many years, grouped by flagellate vs. myzozoa vs. ochrophyta – different patterns appear for each
- Which parameters in EcoGEM would be sensitive to climate? (may change annually or decadally)
  - Using a statistic test: AIC, Bayesian – rather than just based on goodness of fit, is the addition of a new parameter justified?
- Using Bayesian methods, one can walk through the parameter space using the EcoGEM model.
  - The speed of the model is really important since it needs to be run thousands of times
  - Output: comes up with a density range of carbon:chl ratios
  - Note: using a placeholder model, need to get the same exact versions of models to ensure that the results are comparable
- Future direction: would like to use correct initial conditions, boundary fluxes, both GEM and OBM-based exchanges
- Need a geospatial model of observations for better linkage to WQ model (parse out observation and process error)
- Why is carcon:chl a problem? Isn't carbon production the important part?
  - Because we don't have estimates of carbon production – chl is just indicator
  - <u>Need in-the-field measurements of carbon:chl, organic carbon</u>
    - But the detritus may get in the way
  - Should be trying to get cell counts, estimates of biovolumes, carbon contents to determine how much of the DOC is phytoplankton
    - Chl is a good indicator, but also changes based on light
- Comment: Data error is important – definition of skill is important
  - One problem has been the precision of DO – ship surveys need to be calibrated
    - Difference between the size of the model cell and the point measurement
- Data issue: noticed that the tidal flow was correct, but subtidal flow was off – net flow went to 0
  - Can try to get skill better for a given data set, but it could make the overall model worse – it depends so much on the data that were collected (more data can change understanding of the system significantly)
- A lot of hydrodynamic model take once-a-day coarse ecological measurements and try to parse them out to match the detailed model, or you take the physical observations and coarse them to the level of the ecological measurement scale
- If towns are using TNC-style tools, are the detailed models even necessary?

  - When ratepayers feel like they have been pushed to the limit, the definitive model may really let them know that a little bit more will make a difference – can be the needed pressure to make more changes – pressure for more defined, definitive predictions
- Discussion of the two Narragansett models, and why they ended up being differently
  - They are looking up vs. down the river
  - They are calculating WWTP loads differently

BREAKOUT SESSIONS ON MODELING APPLICATIONS

A. Model Parameterization Issues/Data Availability – Moderator: Dan Codiga, Massachusetts Water Resources Authority

B. Modeling Management Scenarios/Climate Change – Moderator: *Jim Fitzpatrick, HDR, Inc.*

BREAKOUT SESSIONS A AND B COMBINED

Jim Fitzpatrick Presentation: Brief Introduction on Models

- Water quality models primarily focus on eutrophication and sediment nutrients and there is a submodel for each
- Phytoplankton carbon/chlorophyll ratio in the water column is modeled
- Parameters that go into making models:
  - Phytoplankton (species composition, growth, respiration, grazing, settling rates, temp
  - effects, stoichiometry)
  - Nutrients (different forms, recycle rates, settling rates, bacterial loop)
  - Light attenuation: base + chl A + pom/dom + TSS
  - Reaeration: transfer of oxygen between air/water interface via wind/waves
  - Sediment oxygen demand/nutrient flux model: labile/refractory/"inert", diagenesis
  - rates, nitrification/denitrification rates, bioturbation, burial, partition coefficients
  - Loads: carbon, nitrogen, phosphorus, silica, labile/refractory
  - Boundaries

1. What model parameters are most in need of additional data?
   - Routine water chemistry data is available
   - Need more data/observations on: loading, primary production, respiration, nutrient flux, -zooplankton grazing, settling rates
   - *Continuous* monitoring
   - Sediment oxygen demand
   - Measure rates, not just concentrations

   Most Sensitive?
   Temperature (because of its impact on DO)

   Highest Uncertainty?

2. How do we improve the connection between monitoring and modeling?
   - Have multiple inter model comparisons (Gulf of Mexico as an example) rather than many models being developed without comparison.

- Shorter time scale stations would help constrain complex models are we at a point where we should consider new parameters or should we use historic and current data that exist? Create simpler comparison studies and models (Gulf of Mexico as an example).
  - **a.** next step would be to look at what kind of simpler models to develop
    - i. SWEM currently has 25 water column parameters, maybe tone it down and remove unnecessary parameters that complicate the model

Grant: Physical structure of the water column is important- important to get the physics correct in the hydrodynamic model.

Everything is based on mass balance.

$$dO/dt = [G_{max} (T,L,N) - R(T) - G_z(T) - V_s (1+R_n)]\ P$$

Question: What is the best data you have?

- We have the routine water chemistry – chlorophyll, POC, etc.
- Respiration
- Primary production
- Settling rates (not really)

Question: When you have old datasets what do you do/how do you relate them?

- Do you use old data or try to relate it to what is happening now?

Dan: Are we already at a point that the measurements already collected are doing so well that we would want to go out and use new parameters?

Grant: In WLIS, water column respiration drives the oxygen down.

What model parameters are most in need of additional data? Most Sensitive? Highest Uncertainty?

Key parameters:

- Primary production
- Respiration
- Nutrient flux
- Species composition
- Temperature effects
- Stoichiometry

How do we improve the connection between monitoring and modeling?

- Intensive shorter time scale observations would really help models like this.
- Comparing different models–have a multiple model comparison for LIS
- More progress can be made by reconfiguring the model
- Simplify the models:
  - How simple can you make a model to still be useful?
    - Maybe get rid of phosphorus?
- Gulf of Mexico is data limited so their models look much better. In LIS, we are testing a complicated model with relatively really good data quality.

1) **What have we learned from system comparison using models?**

2) **What are the most important considerations in applying models across systems?**

3) **How can we apply what we have learned to refine existing models, and how they are applied to management?**

C. Intersystem and System Comparison Using Models – *Moderator: Chris Kincaid*

1. **What future scenarios, such as climate change and land use and population changes, should we be considering to understand impacts on eutrophication?**

   Climate change forces include changes in temperature, changes in precipitation, changes in wind, and changes in atmospheric nitrogen deposition.

2. **What are the data needs for these scenarios?**

   Atmospheric nitrogen, land use changes, marsh changes, and groundwater inputs (groundwater recharge and discharge).

3. **How do we improve the feedback between model results and management?**

   Need climate scientists to help us improve our existing models to make them more useful for management. Land use managers need to know how they can improve land use in their communities to account for the changes that will occur with climate change (e.g., incorporating green infrastructure to help with groundwater recharge).

BREAKOUT SESSION RAW NOTES:

Holly Drinkuth – TNC is looking at CC impacts to habitats; looking at opportunity for salt marsh to migrate and look at resilience of salt marsh in regard to nitrogen loading.

Jason Krumholz – When we do modeling, we should consider changes in land use and changes in salt marsh.

Paul Stacey – Model needs to accommodate drivers and stressors.

John – Changes in freshwater flow and precipitation affect salinity; do we need to further reduce nitrogen loading to this system? How do we incorporate changes in precipitation and temperature that will happen in the future?

Eileen Keenan – How is climate change affect N in LIS? And therefore impact processes in LIS? How might modeling climate change lead to focusing our efforts not just on nitrogen, but on other stressors?

Chris Kincaid and Rob Hust – Wind is a big driver of N in LIS. Need to factor changes in our climate when thinking about management moving forward?

Lorraine Holdridge – What has been done and what continues to be done to continue the trend of the flow of freshwater entering LIS (from USGS freshwater)?

Jason Krumholz – Need to consider climate change when we're doing modeling.

Chris Kincaid – What are nonlinear effects of the watershed?

Rob Hust – CSOs have long-term control plans.

Jason Krumholz and Eileen Keenan - Look how climate change will affect the atmospheric deposition of nitrogen.

Lorraine Holdridge – Other land use and population change scenarios need to go into another land use model (not the SWEM model). Management options are going from the point sources to the nonpoint sources. Need to shift from WQ model to the land-based models.

Paul Stacey – Need to consider nutrient loading kinetics and temperature changes. Do you still have the same ecosystem once the climate changes?

Eileen Keenan – Need to refine what we're doing with modeling and monitoring as the management decisions are high cost. We need good data and good models to convince managers to spend money.

Lorraine Holdridge – We're hyper-focused on nitrogen, but there are other things that need funding too. We've been ignoring pharmaceuticals in the ecological system.

Eileen Keenan – What are our questions and what do we need to get the answers? Need to ask the important questions and figure out where to move forward.

Paul Stacey – What does the model provide and what can we do to make it better to answer climate change concerns in the future?

Jason Krumholz – WLIS is similar to RI in that changing nitrogen won't have a dramatic affect if nitrogen is removed.

Lorraine Holdridge – Do we know if the boundary conditions for the model need to be changed?

Eileen Keenan – What affect does the MS4 program have on the changes in nitrogen in LIS? Very minimal, if anything.

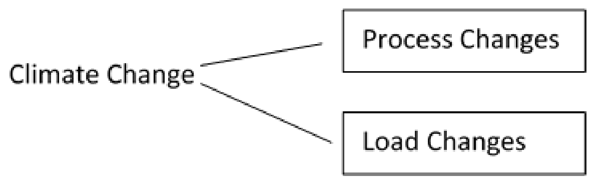
Group 4's top 4 findings: (1.) Find a way to incorporate climate change factors into our modeling. (2.) How have model boundary conditions (groundwater, atmospheric, ocean, etc.) and model parameters have changed since the 1978 paper? (3.) As point sources decrease in our models and nonpoint sources increases, need to incorporate NPS. (4.) How is LIS considering climate change processes, not just nitrogen?

Group 2's top 3 findings: (1.) Naturalizing our past and future development should be considered. (2.) Have the boundary conditions in western LIS changed? (3.) How do we communicate cost benefits to land use managers and the general public?

Group 1's top 3 findings: (1.) How do we allocate and manage point and nonpoint source conditions? (2.) Better assess watershed loading models. (3.) When it comes to climate change, there is some much uncertainty, so what do we do with it?

Group 3's top 4 findings: (1.) Climate change will impact our predictions and needs to become incorporated (population and land use changes also change). (2.) SWEM needs climate scientists to be involved. (3.) Disconnect in time scale between scientists and land use management decisions. (4.) Take advantage of things that already exist (people probably have already run temperature models on LIS).

Climate Change	Drivers
Seagrass changes Salt marsh migration Changes in temperature Wind speed/direction Changes in precipitation	Sea level N increase due to salt marsh collapse Changes in precipitation



Climate Forcings (changes in temperature, changes in precipitation, changes in wind, changes in atmospheric nitrogen deposition) → Watershed (land use, marsh changes) → Estuary

<u>Change in Oxygen</u> ~ [Lateral accretion] [Vertical mixing] [Respiration] [Benthic] [Production]
Change in Time

RECONVENE AND REPORT OUT ON BREAKOUT SESSIONS – *Facilitated by Jason Krumholz*

BREAKOUTS REGROUP

- Management Scenarios and Climate Change
  - 4 different subgroups each talked about the topic and came up with top three points
  - Must start incorporating climate change concerns into existing models – these parameters have changed and will change over time (temp, precipitation – changes in these need to be put into a model in terms of how they change over time)
    - Do they need to be reestimated?
  - "Naturalize systems" as a good management practice – these systems can handle changes in precipitation
    - <u>Green infrastructure changes the way we look at infrastructure/land use</u>
  - Communication of costs and benefits, and uncertainties, involved with models – need to be cautious in terms of how models are represented to stakeholders
    - Don't want to enable people who want to do nothing
  - Boundary conditions: use climate models (and work that has already been done for other modeling) to inform boundary conditions and assumptions
    - If we don't have this expertise, bring in experts that know climate models to give ranges in temperature/precipitation over different timescales
  - Understanding in PS and NPS loading – need to understand the impacts if NPS
  - Loading models: look at the entire watershed, not just the waterbody itself
  - Disconnect on time scales for which managers need information vs. timescale for running models, making predictions, collecting data
- Model parameterization/data availability, and intersystem comparison
  - Different ways that the model could be configured to explore improving the model, other than just collecting more data to pinpoint the model as it currently stands
  - There is a range of models, from simple to complex – complex ones become over parameterized

Theme recently to move towards simpler models with fewer parameters – can be a good complement to more complex models

Using multiple models can be beneficial – comparing one model to another for the same system can help you learn about each of them and how they are functioning

- e.g., at different spatial resolutions

  - It was recognized by the group that having multiple models working in a coordinated way (so that they can be compared) in a modular way would be better than having separate modeling groups that are doing their own thing, creating models that cannot be compared effectively
  - 25 variables for water column, 10 in sediment – could that be more parsimonious (cut out P)?
    - Over parameterization: gets diminished with longer time series, and with biological data
  - Instruments that can do continuous sampling for ammonium, nitrate – could we use these?
  - Importance of nutrient flux and sediment oxygen demand and sediment flux (we haven't had this in a while, potential data gap)
  - Going back and sampling loading more comprehensively – another potential data need
- Important to measure rates, not just concentrations (models are based on rates, not concentrations)
  - We're increasingly capable of measuring this, even if it is not easy
- Gap in time frame between need for management action vs. time for data to be processed and models to run and data – what can be done to streamline this process, minimize the gap?
  - That's just the reality – e.g., Chesapeake, revisiting TMDL every X years – adding more data, longer time record over time.
  - Simple statistical, empirical models can be run very quickly, may have more value for short time frame required from managers
  - The problem is trying to treat nutrients like a toxic contaminant – by the time there is impairment for nutrients, it's expensive or impossible to fix. However, there are still pockets of areas that could focus on preventing the problem rather than fixing it
    - Model can be tailored to look at coarse ecology – N can't managed on the timescale that a fine model would expect, but maybe we can rectify the model to do a better job of working with the coarse ecology as good science (can refine later as we get closer to the target) – benefits for an adaptive management approach
    - Don't want to get trapped in a "good science turnstile" where we are waiting until the science is good enough
  - When there are multiple loads and the benefits/costs are complicated to allocate, then something that's simple may not be adequate, may need a complicated system

Preliminary Synthesis of Workshop Results and Next Steps – *Facilitated by Mark Tedesco*

FINAL WRAP-UP

- Ended day 1 on an optimistic note: Ed Sherwood saying "you guys are doing pretty well! You have in place the overall targets for reductions, making good progress on meeting reductions, solid monitoring program, solid research programs"
  - TB is a success in nutrient management: part of the reason for their success is that they made commitments 35 years ago, took steps and put in place a program and modeled/monitored afterwards to further support management in the watershed
    - It was all on top of aggressive management/control of nutrients
- Today: modeling – we only really scratched the surface, but we need more interaction in terms of the types of decisions that managers are faced with and the kind of support that monitoring can/cannot provide in an adequate time frame - that helps us understand the scope of the modeling efforts we should undertake
- Remind ourselves of the decisions made based on earlier modeling, but the model was not used to get a magic number – it was used to strengthen the conviction that there was a connection between N and

hypoxia, but then the group went back and spoke with the decision makers to develop a plan with greatest benefits for the investments
    - How to maintain the reductions put in place back then?
        - And do we have to do more? Should there be additional WWTP upgrade requirements? What about NPS/septic systems?
            a. Different level of decisions we're facing now, and modeling can still help make these decisions
- One question we're always faced with: what effect do upstream states have? Importance of CT vs. East River
    - We need to be able to make the case, if we're going to make the case for aggressive action for upstream states to take more action that the CT River really does have a significant impact.
    - Need to have a response for those types of questions
- Chesapeake Bay has been at it for 35 years, far more resources – they haven't been able to show statistically significant improvements
    - Shows the challenge and the difficulty – even with more resources, it wouldn't lead automatically to a better condition for LIS
- Positive: much better understanding of the system, improvements, looking forward to pulling together the results of these discussions into practical steps for the program for LISS to take

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Thank you, workshop partners!

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APPENDIX A: Attendee List

Mark Altabet
SMAST
(508) 999-7622
maltabet@umassd.edu

Richard Balla
U.S. EPA Region 2
(212) 637-3788
balla.richard@epa.gov

Cassie Bauer
NYSDEC
(631) 444-0474
cassandra.bauer@dec.ny.gov

Chris Bellucci
CT DEEP
(860) 424-3735
christopher.bellucci@ct.gov

Emily Bird
NEIWPCC
(978) 349-2521
ebird@neiwpcc.org

Brett Branco
Brooklyn College
(718) 951-5000
bbranco@brooklyn.cuny.edu

Nikki Cantatore
Harbor Watch
(203) 557-4403
n.cantatore@earthplace.org

Dan Codiga
Massachusetts Water Resources Authority
(617) 788-4942
dan.codiga@mwra.com

Christine Comeau
Narragansett Bay Commission
(401) 461-8848
christine.comeau@narrabay.com

John Connolly
Anchor QEA
(201) 232-9857
jconnolly@anchorqea.com

Josh Cooper
Harbor Watch
(203) 557-8447
j.cooper@earthplace.org

Mel Cote
U.S. EPA Region 1
(617) 918-1553
cote.mel@epa.gov

Sarah Crosby
Harbor Watch
(203) 557-4403
s.crosby@earthplace.org

Charles de Quillfeldt
NYSDEC
(631) 444-0439
charles.dequillfeldt@dec.ny.gov

Philip DeGaetano
NEIWPCC
(518) 810-2531
philnps@aol.com

Lena DeSantis
Anchor QEA
(201) 571-0913
lmdesantis@anchorqea.com

Shelby Dillman
NERACOOS
(603) 988-5569
shelby@neracoos.org

Bryan Dore
U.S. EPA Region 1
(617) 915-1211
dore.bryan@epa.gov

Holly Drinkuth
TNC
(203) 568-6291
hdrinkuth@tnc.org

Lynn Dwyer
National Fish and Wildlife Foundation
(631) 621-3488
lynn.dwyer@nfwf.org

Melanie Fewings
University of Connecticut
(860) 405-9080
melanie.fewings@uconn.edu

Corinne Fitting
CT DEEP
(860) 424-3724
corinne.fitting@ct.gov

Jim Fitzpatrick
HDR Inc.
(201) 335-9362
jim.fitzpatrick@hdrinc.com

Peter Fraboni
Harbor Watch
(203) 557-4403
p.fraboni@earthplace.org

Julie Granger
University of Connecticut
(860) 405-9094
julie.granger@uconn.edu

Jennifer Halstead
Neracoos
(603) 312-7133
jen@neracoos.org

Lorraine Holdridge
NYSDEC
(578) 402-8121
lorraine.holdridge@dec.ny.gov

Penny Howell
CT DEEP Marine Fisheries
(860) 447-4307
penny.howell@ct.gov

Robert Hust
CT DEEP
(860) 424-3718
robert.hust@ct.gov

Rachel Jakuba
Buzzards Bay Coalition
(508) 999-6363
jakuba@savebuzzardsbay.org

Robin Jazxhi
NEIWPCC
(718) 982-3792
rjazxhi@iec-nynjct.org

Lwiza Kamazima
Stony Brook University
(631) 632-7309
kamazima.lwiza@stonybrook.edu

Jerome Keefe
U.S. EPA Region 1 Lab
(617) 918-8376
keefe.jerry@epa.gov

Eileen Keenan
Nelson, Pope & Voorhis
(631) 427-5665
ekeenan@nelsonpope.com

Kyla Kelly
NOAA
(860) 819-1567
kyla.kelly@noaa.gov

Tripp Killin
Jeniam Foundation
(203) 304-1762
tripp_killin@yahoo.com

Chris Kincaid
URI Graduate School of Oceanography
(401) 874-6571
kincaid@uri.edu

Jason Krumholz
NOAA
(401) 874-6011
jason.krumholz@noaa.gov

Elizabeth Lamoureux
Anchor QEA
(201) 571-0916
blamoureux@anchorqea.com

James Latimer
U.S. EPA ORD
(401) 782-3167
latimer.jim@epa.gov

Peter Linderoth
CFE/Save the Sound
(914) 381-3140
plinderoth@savethesound.org

Nora Lough
Narragansett Bay Commission
(401) 461-8848
nlough@narrabay.com

Kamazima Lwiza
Stony Brook University
(631) 632-7309
kamazima.lwiza@stonybrook.edu

Amy Mandelbaum
NY Sea Grant
(631) 632-8216
acb328@cornell.edu

Grant McCardell
University of Connecticut
(860) 405-9087
grant.mccardell@gmail.com

Eivy Monroy
Narragansett Bay Estuary Program
(401) 633-0551
eivy.monroy@nbep.org

Eliza Moore
Narragansett Bay Commission
(401) 461-8848
eliza.moore@narrabay.com

Peter Moore
MARACOOS
(302) 528-9773
moore@maracoos.org

Jon Morrison
U.S. Geological Survey
(860) 291-6761
jmorriso@usgs.gov

John Mullaney
USGS
(860) 291-6760
jmullane@usgs.gov

James O'Donnell
University of Connecticut
(860) 992-2499
odonnell@uconn.edu

Leah O'Neill
U.S. EPA Region 1
(617) 918-1633
oneill.leah@epa.gov

Mark Parker
CT DEEP
(860) 424-3276
mark.parker@ct.gov

Dan Peckham
NEIWPCC
(978) 323-7929
dpeckham@neiwpcc.org

Julie Rose
NOAA Fisheries Milford Laboratory
(203) 882-6544
julie.rose@noaa.gov

Courtney Schmidt
Narragansett Bay Estuary Program- NEIWPCC
(401) 633-0553
courtney.schmidt@nbep.org

Christopher Scott
NEIWPCC
(631) 852-5806
christopher.scott@suffolkcountyny.gov

Edward Sherwood
TBEP
(727) 893-2765
esherwood@tbep.org

Paul Stacey
Great Bay National Estuarine Research Reserve
(603) 294-0146
paul.stacey@wildlife.nh.gov

Allison Staniec
Uconn
(908) 279-3136
allison.staniec@uconn.edu

John Steinberg
Save the Sound
(203) 787-0646
jsteinberg@ctenvironment.org

Larry Swanson
Stony Brook University
(631) 632-8704
larry.swanson@stonybrook.edu

Mark Tedesco
U.S. EPA Long Island Sound Office
(203) 977-1542
tedesco.mark@epa.gov

Craig Tobias
UCONN
(860) 405-9140
craig.tobias@uconn.edu

Heidi Travers
RIDEM
(401) 222-4700
heidi.travers@dem.ri.gov

Michael Twardowski
Harbor Branch Oceanographic Institute, FAU
(401) 862-9067
mtwardowski@fau.edu

Tim Visel
Sound School
(203) 946-7106
tim.visel@new-haven.k12.ct.us

Penny Vlahos
University of Connecticut
(860) 235-5337
penny.vlahos@uconn.edu

Robert Wilson
SoMAS
(631) 632-8689
robert.wilson@stonybrook.edu

William Wise
New York Sea Grant
(631) 632-6905
william.wise@stonybrook.edu

APPENDIX B: Long Island Sound Water Quality Workshop Event Program

July 14 & 15, 2015

University of Connecticut's Avery Point Campus, Groton, Connecticut

Sessions held in Academic Building (ACB) Auditorium unless otherwise noted

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DAY 1 | TUESDAY, JULY 14, 2015

Essential Questions for Day 1

- How can Long Island Sound Study (LISS) improve the efficiency and effectiveness of its monitoring program?
- What techniques and tools should we be considering as the LISS's monitoring program evolves?

Agenda

8:30 Welcome, registration, and continental breakfast **(ACB Auditorium Lobby, 2nd Floor)**

9:00 Introduction to the workshop – *Mark Tedesco, USEPA Long Island Sound Office*

9:15 Introduction to the current LISS monitoring program – *Jason Krumholz, NOAA*

9:45 Panel Discussion: Where are we now and where are we going? Status of water quality monitoring in Long Island Sound – *Panelists: Robin Jaxhi, IEC District-NEIWPCC, Katie O'Brien- Clayton, CTDEEP, John Mullaney, USGS, Jim O'Donnell, UConn/CIRCA*

10:45 Fifteen minute break

11:00 Keynote Seminar: Alternatives to oxygen based criteria in estuarine eutrophication assessment – *Edward Sherwood, Tampa Bay Estuary Program*

12:00 **LUNCH (Branford House)**

1:00 Breakout sessions on monitoring approaches **(ACB Classrooms)**

A. Future developments in monitoring technology – *Moderators: Jim O'Donnell and Mike Twardowski, Florida Atlantic University* **(ACB, Room 303)**

B. Application of monitoring data to management and decision making – *Moderators: Peter Moore, MARACOOS and Paul Stacey, Great Bay National Estuarine Research Reserve* **(ACB, Room 304)**

C. Application of monitoring data to intersystem comparison and synthesis – *Moderators: Jim Latimer, USEPA Office of Research and Development* **(ACB, Room 311)**

2:30 Fifteen minute break

2:45 Reconvene and report out on breakout sessions – *Facilitated by Jason Krumholz*

3:30 Panel Discussion: Evaluating the success of monitoring programs – *Panelists: Rachel Jakuba, Buzzards Bay Coalition, Edward Sherwood, Paul Stacey, Mark Tedesco*

5:00 Afternoon workshop sessions adjourn

5:30 Evening Poster Reception and Social Sponsored by CIRCA and Sea-Bird Coastal

Day 2 | WEDNESDAY, JULY 15, 2015

Essential Questions for Day 2

- What are the next steps in LIS eutrophication modeling?
- What is the monitoring needed to support improved modeling?

Agenda

8:30 Welcome, registration, and continental breakfast **(ACB Auditorium Lobby, 2nd Floor)**

9:00 Recap of Day 1 and Day 2 objectives – *Jason Krumholz*

9:15 Status of LISS ecosystem modeling efforts – *Jim O'Donnell*

9:45 Panel Discussion: Application of monitoring to modeling – *Panelists: Chris Kincaid, University of Rhode Island Graduate School of Oceanography, Kamazima Lwiza, Stony Brook University, Jim O'Donnell*

10:45 Fifteen minute break

11:00 Presentations on alternative modeling applications (12 minutes each plus Q&A)

- Alternative formulations and modifications to SWEM – *Grant McCardell, UConn*
- High resolution biophysical modeling of RI embayments – *Chris Kincaid*
- Lessons learned from ECOGEM modeling in Narragansett Bay and potential adaptation to Long Island Sound – *Mark Brush, Virginia Institute of Marine Science/Jason Krumholz/Jamie Vaudrey, UConn*
- Load based modeling approaches in embayments – *Holly Drinkuth, The Nature Conservancy*

12:30 Lunch **(Branford House)**

1:30 Breakout sessions on modeling applications **(ACB Classrooms)**

A. Model parameterization issues/data availability – *Moderator: Kamazima Lwiza* **(ACB, Room 303)**
B. Modeling management scenarios/climate change – Moderator: Jim Fitzpatrick, HDR, Inc. **(ACB, Room 304)**
C. Intersystem and system comparison using models – *Moderator: Dan Codiga, Massachusetts Water Resources Authority and Chris Kincaid* **(ACB, Room 311)**

2:45 Fifteen minute break

3:00 Reconvene and report out on breakout sessions – *Facilitated by Jason Krumholz*

3:45 Preliminary synthesis of workshop results and next steps – *Facilitated by Mark Tedesco*

4:00 Adjourn

Thank you, workshop partners!

APPENDIX C: Overarching Questions for Workshop

DAY 1: Monitoring Overarching Questions

1. Can the monitoring program detect changes in hypoxia and contributing WQ parameters in response to nitrogen reductions? Do the data adequately support analyses and tools, i.e., models, to understand the causal relationships among these parameters?
   a. If not, what would need to be changed/added?
   b. If so, can anything be eliminated/reduced?
2. Is the current monitoring program adequate to consider other endpoints (e.g. eelgrass, chlorophyll) that relate to eutrophication impairments? If not, what would need to be added?
3. What patterns and conclusions from the open water monitoring program can and cannot be applied to embayments and nearshore areas?
4. How can LISS improve the efficiency and effectiveness of our monitoring program?
5. What techniques and tools should we be considering as our monitoring program evolves?

PANEL : Where Are We Now and Where are We Going? Status of Water Quality Monitoring in LIS

1. What are the goals of your monitoring? Are you meeting them?
2. Do you see changes with nutrient loading reductions?
   a. Can we answer this question at the scale (space and time) that we're monitoring?
   b. If not, what are next steps and what data are needed?
3. Are you using, sharing, and synthesizing the data effectively? How can storage, access, and distribution be improved?

BREAKOUT SESSION: Future Developments in Monitoring Technology

1. How can emerging technologies improve our ability to meet CCMP monitoring goals?
2. What developments should we have on the 5 year/10 year radar to follow/pilot/adapt?
3. Are there other things we should be doing now (e.g. satellite data)?
4. Does augmenting our program with automated in situ sensors potentially change the design of our ship based survey program? If not, what additional things do we gain?

BREAKOUT SESSION: Application of Monitoring Data to Management and Decision Making

1. Do we have a good summary of what the data are telling us, and is it influencing decision making?
   a. Are we producing diverse informational products that reach diverse audiences?
   b. How can the "Report Card" on LIS water quality be improved?
2. How can we better use our monitoring data to set individualized thresholds/cutpoints for ecosystem condition analysis?
3. How can uncertainty be characterized in adaptive management?
4. Should we remain solely focused on oxygen or can our monitoring programs be used evaluate alternate endpoints?
   a. If we wanted to set nutrient reduction goals to meet an eelgrass target, is our current monitoring program adequate to do so?

BREAKOUT SESSION: Application of Monitoring Data to Intersystem Comparison and Synthesis

1. What lessons are most and least transferable between systems?
2. What parameters are most applicable to intersystem comparison?
   a. What data are critical for comparing nearshore and embayment areas within the Sound and interactions with the open Sound?
      i. Can embayment "report cards" help summarize and communicate the conclusions?
3. What are the most interesting things we've learned from synthetic analysis of monitoring data, and how does this help us monitor and manage more effectively?
4. What patterns and conclusions from the open water monitoring program can and cannot be applied to embayments and nearshore areas?

PANEL DISCUSSION: Evaluating the Success of Monitoring Programs

1. From the breakout session reports, what conclusions resonate from your own experience in monitoring your systems?
2. How do you evaluate whether your program is meeting established criteria for success?
3. How can we improve our ability to self-evaluate and manage adaptively?
4. How do we evaluate whether our current designs are sufficient to understand nearshore & embayment patterns?

DAY 2: Modeling Overarching Questions

1. What are the next steps for the Long Island Sound Study water quality modeling program?
   a. How can we improve the predictive capacity of the existing LIS water quality model?
   b. Should we develop alternate hypoxia-based modeling tools?
   c. What would be needed to model other eutrophication endpoints, e.g. chlorophyll, water clarity, eelgrass?
      i. Should these efforts supersede or augment ongoing modeling work?
2. What are the existing data gaps, and what new data might help us improve our ability to model Long Island Sound?
3. How can we incorporate future ecosystem dynamics/climate into models?

PANEL DISCUSSION: Application of Monitoring to Modeling

1. What monitoring data or research studies are needed to support improved model parameterization (Models are only as good as the data that underlie them)?
2. How do we better model dissolved oxygen?
3. Do we need to model dissolved oxygen to manage eutrophication? Are there other approaches?

BREAKOUT SESSION: Model Parameterization Issues/Data Availability

1. What model parameters are most in need of additional data? Most Sensitive? Highest Uncertainty?
2. How do we improve the connection between monitoring and modeling?

BREAKOUT SESSION: Modeling Management Scenarios/Climate Change

1. What future scenarios, such as climate change and land use and population changes, should we be considering to understand impacts on eutrophication?
2. What are the data needs for these scenarios?
3. How do we improve the feedback between model results and management?

BREAKOUT SESSION: Intersystem and System Comparison Using Models

1. What have we learned from system comparison using models?
2. What are the most important considerations in applying models across systems?
3. How can we apply what we have learned to refine existing models, and how they are applied to management?