Science & Technical Advisory Committee
TEAMS Online Meeting
June 30, 2023 – Meeting Summary

In Attendance:
STAC Members: Jim Ammerman, Vincent Breslin, Chris Conroy, Carmela Cuomo, Kristin DeRosia-Banick, Melissa Duvall, Dianne Greenfield, Shauna Kamath, Robin Miller, Jim O'Donnell, Julie Rose, Paul Stacey, Kelly Streich, Mark Tedesco, Maria Tzortziou, Jamie Vaudrey, Penny Vlahos (Connecticut Co-chair), Nils Volkenborn, Emily Wilson

CAC Liaisons to STAC: Sarah Crosby (The Maritime Aquarium), Mickey Weiss (Project Oceanology)

Others: Zosia Baumann (U Conn), Chris Bellucci (CT DEEP), Jordan Bishop (NEIWPCC), Robert Burg (LISS/NEIWPCC), Finnian Cashel (EPA), Emma Coffey (CT DEEP), Emma Cross (SCSU), Lillit Genovesi (NYSG), Chris Gobler (Stony Brook U), Ashley Helton (U Conn), Steven Hohman (EPA), Sharon Kahara (U New Haven), Kristin Kraseski (NYSDEC/NEIWPCC), Jason Krumholz (U Conn), Ben Lawton (EPA/ORISE), Peter Linderoth (STS), Matt Lyman (CT DEEP), Emily Marquis (CT Bureau of Aquaculture), Esther Nelson (EPA), Beau Ranheim (NYCDEP), Jimena Beatriz Perez-Viscasillas (NYSG), Matthew Pruden (Cornell), Leonel Romero (U Conn), Luciana Santoferrara (Hofstra), Samara Scantlebury (NYSDEC), Nancy Seligson (CAC), Lane Smith (NYSG), Nikki Spiller (Harbor Watch), Kurt Stephenson (Virginia Tech), Alexa Sterling (EPA), Cayla Sullivan (EPA), Nikki Tachiki (EPA), Denice Wardrop (Chesapeake Research Consortium), Gregory Wilkerson (NYCDEP), Abagail Winter (CT DEEP), Kimarie Yap (IEC)

Introductions, Updates: Penny Vlahos, UCONN (STAC CT Co-Chair)
Jim Ammerman announced that the EPA LISS has recently released a notice to recruit an ORISE Fellow, a recent Masters or Doctoral graduate with a background in biogeochemistry and data analysis. The application deadline is August 18th, and the start date could be as early as September 2023. Melissa Duvall added that there were a variety of potential project options focused on water column plankton, modeling, and related efforts.

Proposal to Revise LIS 2015 CCMP: Mark Tedesco, EPA
Mark said that mainly wanted to provide background on the process and scope of the upcoming effort to revise the Comprehensive Conservation and Management Plan (CCMP). The CCMP (or the Plan) is required under our authorizing legislation and was first developed in 1994 and was completely restructured and revised in 2015. The 2015 Plan was anticipated to last for 20 years, had Ecosystem Targets to be achieved in 2035 and had built in updates every 5 years, including the recent 2020-2024 update. The 1994 Plan was organized around problems to be addressed, but the 2015 Plan was organized around management themes. The Themes were all broken down into Goals, Outcomes, Objectives, Strategies, and Implementation Actions (IAs). There were originally 136 IAs, which were slightly reduced to 133 in the latest revision. The four themes

include Clean Waters and Healthy Watersheds, Thriving Habitats and Abundant Wildlife, Sustainable and Resilient Communities, and Sound Science and Inclusive Management. The four themes will be continued in the revision as well as the three integrative principles (resiliency to climate change, long-term sustainability, and environmental justice). The Ecosystem Targets will have ten-year targets, maintaining the previous 2035 time set in 2015, and some Ecosystem Targets will probably be added or removed. Mark also noted that the program hopes to streamline the number of organizational levels in the plan, reduce the number of IAs to about 50, and strengthen the linkage between Ecosystem Targets and the Implementation Actions to simplify tracking and reporting.

While there will be a written version of the new CCMP for management use, a web-based story map with accessible language, imagery, and video will be developed for communication with the public. The program area will also be expanded beyond the current LIS drainage area in NY and CT to the entire watershed and the public review process will be used to get feedback on the adoption of a new program name and logo at the same time. Various committees of the LISS have been briefed on this plan and a final draft will be presented for approval at the July 20th Management Committee Meeting. The Policy Committee of Agency Heads and EPA Regional Administrators will also be briefed on this plan on July 13th.

Following approval by the Management Committee, a process will be developed with an 18-month timeline, including public comment on a draft plan, leading to the final draft by December 2024 and new CCMP adoption in early 2025. A detailed timeline and process for the CCMP revision, including roles and responsibilities, will be presented for approval at the October 18-19 Management Committee meeting. This meeting will also include presentation of an evaluation of the progress on the 2020-2024 Implementation Actions and a review of the strengths and weaknesses of the Ecosystem Targets, to provide the lessons learned for application to the new CCMP. Ultimately the process will culminate in 2025 with a new CCMP, name, and logo, following adoption by senior administrators and appointed and elected officials.

Discussion:
-Penny Vlahos asked about the completion time for the plan and Mark replied that it should be completed by December 2024, including allowing for a public comment and response period. Formal approval by senior administrators would go into 2025.
-Paul Stacey said the revised Ecosystem Targets should be S.M.A.R.T. (Specific, Measurable, Attainable, Realistic, and Timely).
-Penny Vlahos asked if there was room for "horizon scanning" or anticipating future threats and stressors, such as population and development. Mark replied that that was fundamental to addressing climate change and some other challenges, and that we should not just consider threats as they are today but also as they may be in the future. We have indicators that are important to follow as well as the Ecosystem Targets. Population and agricultural activities have not increased in the LIS watershed the way they have in some other systems, but we need to be able to plan for future scenarios, however challenging. Mark concluded by saying that they STAC's input will be very important when we get to discussions of the specific issues to be addressed.

Jim Ammerman introduced editors of a recent Chesapeake Bay Science and Technical Advisory Committee (STAC) report for the following presentation:

Achieving Water Quality Goals in the Chesapeake Bay: A Comprehensive Evaluation of System Response (CESR): Kurt Stephenson, VA TECH; Denice Wardrop, Penn State/Chesapeake Research Consortium

Denice started by addressing Jim Ammerman's question about the Chesapeake Research Consortium (CRC) which just celebrated its 50th anniversary, it is older than the Chesapeake Bay Program (CBP). It consists of the seven largest research institutions in the Chesapeake Bay Watershed (Johns Hopkins University, Old Dominion University, Penn State University, Smithsonian Environmental Research Center, Virginia Institute of Marine Science, Virginia Tech, and the University of Maryland). The CRC is supported by an EPA grant and has three major functions: 1. Administering and coordinating the STAC; 2. Administering an Environmental Management Career Development Program (EMCDP) with thirteen three-year entry level positions for environmental managers and scientists in the region; and 3. Acting as a connector between the larger academic community and the CBP.

Denice continued with a brief description of the CBP STAC, with consists of 38 volunteers from around the region, including 10 jurisdictional appointments from the states and District of Columbia, as well as appointees from the federal agencies that are part of the CBP. The other half of STAC are experts in needed subject areas who are nominated for four-year terms. The CBP has two scientific bodies, the STAC is independent and advises the upper management of the CBP including the state Governors and agency heads; and the Scientific, Technical Assessment and Reporting (STAR), which works at a much more granular level. The STAC divides its time between proactive projects, such as the CESR report, and reactive issues, such as serving as a review board for many program activities. For example, the STAC reviewed parts of the TMDL which helped in addressing the court challenges to it.

Kurt Stephenson mentioned his past involvement with the Connecticut nitrogen trading program in the 1990s, the common discussions that both the LISS and CBP are currently undergoing, and then described the bottom-up origins of the STAC CESR report, which summarized many different issues already under discussion. It was a full year effort and involved the entire STAC. A major impetus was the degree of attainment of water quality standards. Though the slope of the graph from 1985 to 2020 is upward, which would not be the case without the CBP, the improvement is slower than desired. With a 2010 TMDL and a target date of 2025 that was unlikely to be met, the need for a new strategy was apparent.

Of the ten restoration goals in the Chesapeak Bay Agreement, meeting the water quality criteria dominates and includes Federal permitting, nonpoint source funding, and TMDL accountability. It consumes the greatest resources and has legally binding obligations. The water quality standards breakdown the Bay into five different habitats for the designated uses of living resources. These include deep channels, deep water, open water, shallow water, and migratory fish habitat. These habitats are spread across 92 water segments in the Chesapeake Bay. Some of the segments have all five habitats and some have fewer. Each of the habitats in each segment are assessed for numerous water quality criteria including dissolved oxygen (DO, instantaneous minimum, 7-day mean, and 30-day mean), chlorophyll a (chl *a,* chl *a* narrative criteria), and water clarity (SAV or water clarity acres).

When you combine all the habitats in all the segments with the water quality criteria, that yields 1,052 assessment points to meet full compliance with water quality standards. The Chesapeake Bay TMDL includes nitrogen, phosphorus, and sediment. The sediment goal has been met, the phosphorus goal is close, and the nitrogen trend is downward but still above the goal. Like LIS, there have been great reductions from wastewater treatment plants. Given all the improvements, why is the Bay still stuck at 30% attainment of water quality standards? Unlike the LIS, however, nonpoint sources are very important and currently make up the predominant sources of nitrogen loading and much of the phosphorus loading.

Kurt then reviewed three response curves central to the CESR report. First, the N, P, and sediment response to management actions, second, the water quality criteria (such as DO) response to the N, P, and sediment reductions, and third, the living resource response to the achievement of water quality criteria. Both the achievement of TMDL goals for nutrient and sediment reductions in response to management actions and the achievement of water quality criteria in response to nutrient and sediment reductions appear to be far below the expected responses from model predictions. Furthermore, the living resource abundance response, which is ultimately the most important in terms of designated uses to the public, is unclear, is it a high-level or low-level response? The expected response is unknown because all the focus has been on chemical water quality criteria. Therefore, the CESR report took a comprehensive approach to evaluating the system response, going from implementation policies and their impacts on nutrient loading to the assessment water quality resulting from these policies, and finally to the impacts of this water quality on habitats and living resources. This is already a long causal sequence but must also consider external factors like climate, the economy, population, and technology.

The main conclusions of the report are: 1. Gaps and uncertainties present major challenges to achieving the water quality goals of the TMDL and improving the living resource response, 2. There are opportunities to improve program effectiveness, but they will require a change in thinking and approach. Seventy-four percent of the controllable nitrogen load to the Chesapeake Bay is from nonpoint sources (NPS), but since the start of the TMDL in 2009, almost 15 years ago, there has been very little reduction in NPS nitrogen loading. In addition, NPS programs have a response gap and are not as effective as expected. This is particularly true for phosphorus loads, where CAST model predictions from the Choptank River show a decline, but USGS flow normalized measured loads show an increase. This is not just true for the Choptank but also other parts of the Chesapeake Bay according to USGS monitoring.

These “response gaps” are a result of several problems including nutrient mass imbalances and the limits of the NPS BMP control programs, which are primarily voluntary cost-share programs. Areas of excess phosphorus and phosphorus loading are found on the Eastern Shore of the Delmarva Peninsula and the lower Susquehanna River valley in Pennsylvania, which are areas with significant animal agriculture, primarily poultry and dairy. The urban areas of Baltimore and Washington, DC, are also significant sources of phosphorus loading. Overall, the NPS efforts may not be producing the expected response because of 1. Lag times/legacy sources, 2. Poor BMP effectiveness, 3. BMP behavior and implementation, and 4. Nutrient data limitations. Therefore, existing NPS water quality programs are insufficient to achieve the NPS reductions required by the TMDL. More money would help, but it will not be sufficient by itself. The implications of this are as follows: 1. Shift the emphasis to achieving outcomes, less on counting practices. 2. Increase the focus on addressing mass imbalances, 3. Focus on policy innovation, and 4. Explicitly acknowledge and evaluate uncertainty.

Denice then took over to discuss the impact on the Bay itself. Overall, on a Bay-wide scale, total N and P loads and concentrations are declining. For at least two-thirds of the 92 Bay segments mentioned earlier, both loading, and concentrations of total N and P are decreasing, though a significant number of segments do not follow that pattern. However, though most stations (~80%) show a decline in N and P, a similar percentage shows a decrease or no change in DO. The wide spatial variation in DO changes suggests that different habitat types might exhibit different trajectories. She showed plots of TN loads vs. DO criteria attainment for three different habitats, open water, deep water, and deep channel. All showed a response gap between the expected attainment from model data and the actual observed attainment. The gap was greatest at low loading values for all three environments and overall largest in the deep channel. This suggests that some environments will reach attainment before others and the deep channel will be among the last. This is important because many of the policy directives of the CBP are directed at achieving a DO response in the deep channel.

When nutrient loading is reduced in a system, the recovery or attainment of water quality standards is often not a linear process. Recovery trajectories vary, and nutrients may have to be reduced far below prior level to achieve the initial water quality, or perhaps never achieve it at all. Possible reasons for this response gap include climate change, tipping points, biotic communities, and land use/land cover. Published evidence suggests that the hypoxic area in the Bay would have been larger, extended further south, and lasted longer without the 35 years of nutrient reductions that have occurred. The estimated impacts of nutrient load reductions on water quality have been dampened from 6 to 34% by warming. Changes in biotic communities can lead to tipping points, such as changes in tidal marshes, oyster populations, and benthic communities which can have profound effects on nutrient sequestration and other beneficial biogeochemical processes. Positive effects of tipping points can also be seen locally such as increases in SAV near wastewater treatment plant upgrades.

The Bay of the future is clearly not the Bay of the past. The cost to meet water quality standards increases as you approach 100% attainment and due to these response gaps the curve has moved to the left (higher cost at lower attainment) and the program may never be able to achieve 100% attainment. Re-examination of the goals is clearly warranted. Load reductions have not produced the expected level of response and the deep channel may be the last habitat to reach attainment. This suggests that policy should be refocused on habitats most likely to recover, such as the shallow waters where the living resources and stakeholders are located (a tiered approach to attainment favoring habitats most likely to recover). Monitoring in the Chesapeake Bay has been for accountability and not understanding, but the program has not been able to delist any of the 92 Bay segments for lack of data, even with a robust monitoring program. A further assessment of costs and tradeoffs of attainment in specific areas is needed. Finally, the goals of the program need to be rethought because it is currently working with goals set in the 1980s.

Since the CBP is focused on the entire aquatic community and not a single key species as are some other programs, the program does not have a good handle on the living resource response curve and how it is impacted by water quality, though whether the curve has a high or low response is crucial to improving living resources. Gaps and uncertainties still present major challenges in achieving water quality goals and improving living resource responses. Many other factors (temperature, salinity, SAV, benthic condition, etc.) besides water quality help to determine whether living resources respond just a little or a lot in response to improvements in water quality. Combining consideration of the costs of achieving water quality criteria, specifically DO, with the possible living resource response curves, if the response curve is high, full attainment of DO is not needed and resources could be devoted to other things which benefit living resources.

To date, the adaptive management in the CBP has mostly been at lower levels of decision making. The CESR report makes clear that the transfer of learnings to relevant decision makers needs to be improved and the scope of adaptive management expanded and implemented at higher levels. The report says that achieving the program's goals has been more difficult than anticipated, but states that opportunities for improvement are available, but only if major changes are made and not just minor changes at the margins. Kurt added that the perfect does not have to be the enemy of the good and there are numerous potential investments that are not nutrient-centric which may have a higher rate of return in terms of living resources. These investments may also help to address some of the concerns raised by those frustrated with the program's relentless emphasis on water quality.

Discussion:

-Carmela Cuomo asked about the organic content of nearshore sediments as well as nutrient export from them. She noted that higher temperatures would drive the sediment more towards anoxia. Denice responded that the CBP has 10 goals and 31 outcomes, 17 of the 31 outcomes involve shallow waters, and yet they are not modeled in the Bay model, or sufficiently monitored, despite their extreme variability. The new Bay model, now underway, does a better job with the shallows, and monitoring of them is increasing. Nonetheless, they are still understudied compared to other Bay habitats, including the deep channel which has been a major focus in the past. Carmela commented that small temperature increases could have major impacts on the shallow-water sediments and should be better studied.

-Nancy Seligson asked about how this report has been received and whether there has there been a sea change in thinking. Kurt replied that overall, there was a sense of relief that this was finally being discussed in the open rather just in private. The Chesapeake Bay Foundation, the area's largest NGO, had a very positive response. The challenge will be in implementation, particularly up in the watershed where many things will have to change. The CBP is very hierarchical and has been dominated by a focus on water quality and not living resources. Accountability largely focuses on checking boxes for activities rather than achieving outcomes. Therefore, it will likely be difficult for many people in the program to change. Voluntary agricultural programs, particularly the large ones in Pennsylvania, will likely be highly resistant to change. Nancy mentioned that the LISS has many of the same issues and is trying to focus more on outcomes and impacts rather than activities. The nutrient-centric focus in LIS has also proved inadequate to what needs to be achieved. Denice added that the CESR Report is a consensus report of 50 people which carries weight, it is the first major STAC report in 20 years and has also received positive agency reviews from NOAA and USGS, whose agencies include STAC members.

-Paul Stacey complimented them for an excellent job and said that the LISS STAC should write a similar report. He also said that the Chesapeake had done a good job with nutrient control, as has LIS, but that it is not sufficient to restore living resources. Nutrient control has been divorced from ecosystem structure and function and is a treatment and not a cure. Healthy and functional watersheds require more than just nutrient control. Sound watersheds with natural cover provide nutrient control. Restoring buffers is critical.

Can Watershed Land Use Legacies inform Nitrogen Management? Ashley Helton, UConn

The nutrient imbalance or response gap discussed above for Chesapeake Bay has been one of the inspirations for the studies that Ashley is about to discuss, most of which have been supported by the LISS Research Program. Other parts of the work have been funded by NSF, USDA, and UConn. Her study has been highly collaborative including participants from UConn, CT DEEP, USGS, and others. An outline of the talk includes: 1. Some background on legacies, 2. Evidence for legacies in the LIS watershed, and 3. An overview of the LIS current watershed project. The talk will be short on definitive results, but they could be discussed in more detail a year from now.

Ashley started with a quote about the importance of environmental history to a study site. Using nitrogen as an example, though it could apply to many other contaminants, she defined signal legacies as nitrogen applied in the past that accumulates in soils and groundwater and is eventually transported to surface waters over months to decades. This is called legacy nitrogen and can be part of the nutrient imbalance referred to in the previous talk. It can cause a lot of uncertainty in the response gap because it is stored for unknown amounts of time in the soil and groundwater. A second category of legacies is structural legacies, alterations of watershed structures which disrupt functions that maintain nitrogen cycling and tend to be longer term than signal legacies, even decades or centuries. These include soil tilling, stream entrenchment, de-population, and re-population of beavers, these can change the relationship between land use and nitrogen loading to streams and rivers, which can have major impacts on management of these nitrogen loads.

Most of the nitrogen legacy research has been on signal legacies in agricultural regions. In the Mississippi River basin, 55% of the nitrogen loads are older than 10 years. In the Chesapeake Bay watershed, 20–40-year groundwater travel times result in long lag times for BMPs to attain management goals. Such studies inspired Ashley to examine the LIS watershed and how its land use legacies might be different than others. In the Mississippi example there has been and continues to be high land use for agriculture since the early 1900s, with a gradual increase in human population density. Therefore, important questions to address include: 1. How have rates of nitrogen application changed over time? and 2. How long will reductions in nitrogen applications or agricultural BMPs take to improve water quality?

The history of the LIS watershed in New England is quite different, with a large decrease in farmland and a large increase in population from the late 1800s to the present. The model for legacy nitrogen and land use in New England will be significantly different from areas which maintain intensive agriculture, like the Mississippi basin. Groundwater discharge chemistry in the LIS watershed is decoupled in space from its source land use and development plays a larger role in nitrogen application. Reforestation must also be considered, how long does a reforested farm field take to “recover” and does it ever provide the same water quality benefits as older forests.

Remote sensing is a great way to visualize these changes, there is full aerial coverage across the state of Connecticut. Part of the LISS-supported study is to geo-reference those aerial photos and delineate the farm fields, which is being done by UConn CLEAR. The question is how can we use the relationship of legacies to water quality to inform watershed management.

In Connecticut, as is often true elsewhere, the average groundwater nitrogen concentration is four times the surface water concentration. Parts of the LIS watershed have high rates of nitrogen loading from groundwater to streams. John Mullaney’s work has shown that this is particularly true in areas of intense agriculture or onsite wastewater treatment. Ashley’s own work has shown groundwater nitrogen concentrations greater than 10 mg/l discharging directly into the Farmington River. There is a large amount of heterogeneity in the groundwater nitrogen concentrations discharging into Connecticut rivers and assuming an average concentration can be problematic. Ashley’s lab uses a 95% confidence interval, but groundwater can account for just a tiny fraction of a river load or almost all of it. They are working to better understand the variability by examining watershed sources, rates of groundwater fluxes, and reactive aquifer and near stream processes.

To finish the talk, she reviewed the three objectives of her current LISS research project and their current degree of progress. They include: 1. Geospatial classification of legacy potential in the LIS watershed, 2. Relationships between land use legacies and water quality, and 3. Land use legacies as a guide for watershed management. Her classification scheme includes agricultural land that has continued in agriculture, or has been reforested, or has been developed. A fourth category is changes in sewage infrastructure on developed land, especially installation of onsite sewage systems or a change from onsite to integrated sewage systems. Using NOAA C-CAP along with census data they are characterizing the vulnerability of land cover to these different legacies at a 30 m resolution. Within the LIS watershed, there has been little afforestation of agricultural land since 1996. Connecticut data for afforestation and other changes is available back to the 1930s, but not for the rest of the watershed. Therefore, the dominant legacies since 1996 are agriculture and the transition of agriculture to development. Additionally, they have mapped the septic system density distribution related to land cover based on the last time it was reported in the census in 1990. The projected outcome for this part of the study is a GIS map of land use legacy potential which should be publicly available online within the next year.

The relationships between land use legacies and water quality have been examined by selecting small streams from land use change maps and making a suite of biological and chemical measurements focused on water quality and biointegrity. Their land use/land cover analyses are then paired with existing data on water quality and watershed characteristics, some of it going back to the 1950s. The goal is to compare base flow stream chemistry, including nitrogen, with watershed land use/land cover and changes in land use/land cover. In the next year, they will provide the following publicly available tools, a land use change and legacy potential interactive map mentioned previously, and a water quality and watershed characteristics dashboard. The final goal is understanding how land use legacies can inform watershed management decisions. The project will provide the tools mentioned and hold webinars to get feedback, with the hope of developing a roadmap for considering and measuring impacts of land use history in your local watershed. Finally, the “ghosts” of land uses past must be considered, time lags and structural legacies need to be incorporated into planning.

Discussion:

-Paul Stacey mentioned that “past is prolog” and development today is creating tomorrow’s legacies. He expressed concern that we are not misled by our BMPs that allow infiltration to groundwater which may cause future problems.

-Penny Vlahos asked Ashley if she had seen any correlation between groundwater residence times and nitrogen concentrations? Ashley replied that in the Farmington River system, you need information about the nitrogen source area, the groundwater residence time, and the reactivity, and then you can predict over 50% of the variability of nitrogen loading to steams and rivers. Groundwater residence times in Connecticut range from months to decades, though most of those near the coast are short.

-Mark Tedesco asked if there were any plans to update the 1990 septic distribution map. Ashley replied that 1990 was the last census with that data and that future maps would be developed state by state. Updated Connecticut data is currently available and will be mapped when additional support is available.

Quantifying the ability of seaweed aquaculture in Long Island Sound to remove nitrogen, combat ocean acidification, improve water quality, and benefit bivalves: Chris Gobler, Stony Brook

Chris introduced the nitrogen problem with LIS water quality and briefly showed the CT DEEP hypoxia map and his lab's Long Island harmful algal bloom map from the summer of 2022, which also included fish kills. There were notable fish kills in the New York embayments of the western Sound in the summer of 2022, consistent with low oxygen levels in many of them. Global atmospheric CO_2 concentrations also continues to increase, which can lead to ocean acidification and decreasing pH, which threatens bivalve shellfish.

The focus of this project and today's presentation is seaweeds, they take up nitrogen and phosphorus as well as CO_2, and generate oxygen and secondary metabolites. Thus, they help to address three major issues in LIS, nutrient loading, acidification, and oxygen depletion. *Saccharina latissima*, the sugar kelp, the most aquacultured seaweed in the US. Most kelp farms are in Alaska and the Northeast, particularly Connecticut, Rhode Island, Massachusetts, and Maine. In the last five years, Chris' lab has grown kelp in 17 locations around Long Island and off Connecticut. Kelp does not like warm water, and in LIS kelp is put out in the fall and harvested by June. Since the major water quality problems around Long Island are in summer, however, his lab had an interest in growing summer seaweeds, particularly *Gracilaria*, which is indigenous to LIS and grown throughout the world, and *Ulva*, which can be problematic if uncontrolled, but it can also be grown under controlled aquaculture conditions.

The objectives of the current study are: 1. Grow multiples species of warm and cold-water seaweeds (*Saccharina latissima, Gracilaria tikvahaie*, and *Ulva* spp.) at multiple locations and scales in NY and CT waters. Also, to quantify the net removal rates of carbon and nitrogen and to map changes in DO and acidification parameters and HAB concentrations. 2. Quantify the growth, survival, settlement, condition, and bioextraction of nitrogen by Eastern oysters and blue mussels grown with and without seaweeds in multiple locations. 3. Future--Write a Guidance Document and host a workshop sharing best practices for seaweed growth and bioextraction, as well as the performance of bivalves and improvements to water quality. This project has three major study sites, the GreenWave kelp farm in the Thimble Islands where they grew bivalves and measured water chemistry, Mount Sinai Harbor, with good water quality, and Northport Harbor, with poor water quality, including fish kills and prone to HABs and hypoxia.

Kelp is normally grown on long lines in deep water (20 ft), but they also developed a new "staked line" method for growing kelp in shallow water (<4 ft), which is common in NY aquaculture sites. Comparison of temperature and kelp growth in a shallow and deep-water site showed earlier temperature increases and higher temperatures in the shallow water and corresponding earlier and greater kelp growth until the temperature got too warm and growth leveled off in the shallow water. The yields, however, were similar. The summer seaweeds (*Gracilaria* and *Ulva*) were also grown in the two NY harbors (Mount Sinai and Northport) by two different methods, in bags and on lines. The also grew various sizes of oysters in bags, both with and without seaweeds in the bags. The kelp on a one-acre farm can remove 100-220 pounds of nitrogen per year, which is the equivalent of upgrading the septic systems on 8-18 homes to advanced nitrogen removing systems. *Gracilaria* and *Ulva* also remove significant nitrogen and carbon in the summer, at rates like kelp, but with no temporal trends.

The Thimble Island studies comparing inside and outside of the GreenWave kelp farm showed lower pCO_2 and chlorophyll *a*, and higher dissolved oxygen and pH, in the kelp farm as opposed to outside of it. There was also a more rapid growth of oysters within the kelp line than outside of them. In Northport Harbor, the pH was on average higher inside the kelp lines than outside, and blue mussels grew almost twice as fast inside the kelp lines. *Gracilaria* growth increased pH in both Mount Sinani and Northport Harbors, at least for part of the season, and oysters grown with or near *Gracilaria* in Mount Sinai Harbor grew faster than the control without them. The pH impacts were not large, but pH is a log scale and bivalves are highly sensitive to changes in carbonate chemistry. Both small and large oysters grew faster when co-cultured with *Gracilaria* in both Northport and Mount Sinia Harbors.

Studies with *Ulva* grown in bags showed similar increases in pH and DO compared to controls, though the latter was not dramatic. Oysters also grew faster when co-cultured with or near *Ulva*, though the *Ulva* can also overgrow the oysters and limit the increase, suggesting that there is an optimal ratio of *Ulva* to oysters. Finally in a very shallow-water (2 ft) oyster farm on the South Shore of Long Island, there were significant increases in pH and oyster growth on or near the kelp compared to the controls. Exposure to kelp also caused lysis of *Alexandrium*, the dinoflagellate response for paralytic shellfish poisoning, and inhibited its growth in mesocosms. *Gracilaria* also reduced the growth of the brown tide organism *Aureococcus*. To conclude, seaweeds can locally extract significant amounts of carbon and nitrogen, suppress HABs and reduce their toxicity—including to below regulatory limits in bivalves, increase seawater pH and calcium carbonate saturation levels, and protect bivalves from ocean acidification in lab experiments and on oyster farms.

Discussion:

-Penny Vlahos asked how far the beneficial seaweed effects extended and Chris said it depended on water volume and flushing time but certainly for a least a few meters. The benefits would be greatest on an aquaculture site where the bivalves are located amongst the seaweeds.

-Paul Stacey asked about the use of invasive species like *Gracilaria*, or what about an invasive like *Hydrilla*? Chris mentioned that wild harvest might be the next step, like the harvest of pond weed in Georgica Pond on the South Shore of Long Island. This is harvested repeatedly all summer and removes 20% of the nitrogen and phosphorus, improving the water quality. Paul followed up with further questions about other seaweeds as the kelp season shortens from climate change increases in temperature.

-Chris responded to a chat question from Peter Linderoth about whether you might see a diel cycle in DO from intensive aquaculture sites. Chris said that the pH effects were more obvious but certainly such a DO response might be expected.