Long Island Sound Study

A Partnership to Restore and Protect the Sound

LONG ISLAND SOUND STUDY

SCIENCE NEEDS DOCUMENT

March 24, 2020

The Long Island Sound Study
Science Needs Document

This science needs document is a comprehensive summary of the science support needed to meet the management goals of the Long Island Sound Study (LISS). It has been developed based on the input from a diverse array of LISS partners. It is structured around the Themes and Ecosystem Targets of the 2015 Comprehensive Conservation and Management Plan (CCMP). Since the Sound Science and Inclusive Management Theme does not have Ecosystem Targets, a series of important cross-cutting issues were used instead, ranging from climate change to ecosystem-based management. This document lists monitoring and research needs for each Ecosystem Target or cross-cutting issue in the first column. The second column lists current monitoring or research activities which address these needs. The third column lists targeted monitoring and research efforts which if undertaken would further address these needs. (Modeling needs, current activities, and targeted efforts are also listed where appropriate.) This is a broad reference document which is meant to highlight needs but not to specify the top priorities and is subject to continuous revision to incorporate new information.

Comments and questions should be sent to Jim Ammerman, LISS Science Coordinator, at james.ammerman@longislandsoundstudy.net.

March 24, 2020

CCMP WATER QUALITY THEME

Hypoxic Area-Monitoring/Modeling

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Measure hypoxic volume in addition to area and duration. Apply these measurements to attainment of water quality standards. Confirm this measure provides an improvement towards more accurate hypoxia estimates over time.	1. The Connecticut Department of Energy and Environmental Protection (CT DEEP) is developing hypoxic volume calculations of data collected since 1994. Additional monitoring or research needs for this project will be determined following conclusion of the project.	
2. Improve flow and flux measurements through the East River into Long Island Sound including Acoustic Doppler Current Profiler (ADCP) measurements. (Need to define objectives and provide more specifics on monitoring design and intensity and targets for data adequacy that meet objectives.)	1. As part of CTSG research project announced in 11/2019, an ADCP profiler will be added to the East River to support modeling tidal barrier effects.	1.East River flow and nutrient flux measurements. A single ADCP is part of the solution but measurements of the product of the velocity and concentration of N at three levels every hour is really what is needed. How long a deployment is needed? Include carbon analyses – poorly constrained in the model and not well linked to DO scenarios, especially in embayments
3. Link embayment models linked to offshore model.		1. Monitoring should be designed to accommodate embayment models that can connect and integrate offshore and upland (watershed) models. 2. Be sure monitoring intensity has adequate power to detect potential changes.

Hypoxic Area-Research

Research Needs:	Current Research to Address Needs:	Targeted Research Support Needed:
1. Increased and improved water column and benthic respiration measurements and modeling to provide better simulations.	1. Benthic respiration measurements have recently been made and new projects are beginning which will measure water column respiration rates.	1. Follow-up on project recommendations. Consider analysis for other critical rates, such as productivity, air-sea gas exchange, shellfish filtration, zooplankton grazing & burial, ammonification, etc. 2. Hypoxia is largely controlled by the rates of vertical mixing of O_2 and water column respiration near the bottom. These things are of similar magnitude and vary at short time scales. Recent measurements by Tobias support this. Measurements at buoys for several seasons is necessary to ensure models get these rates right.
2. Develop new systemwide and nested models to address this and other Ecosystem Targets. The understanding of the quantitative relationship between nitrogen sources and hypoxia in LIS remains an unsettled issue. The new modeling effort will hopefully integrate what we have learned and identify outstanding needs.	1. New York City's Department of Environmental Protection (NYC DEP) just released an RFP for systemwide modeling in collaboration with EPA. 2. Other potentially nesting models for groundwater, embayments and watersheds are under development by the United States Geological Survey (USGS), the Long Island Nitrogen Action Plan (LINAP), and CT DEEP.	1. Assure model design and supporting data will meet research and application objectives. 2. Ensure nested models are adequate to the task and consider carbonaceous oxygen demand as well as nutrients. . 3. Further data collection and analysis to improve the calibration and validation of the systemwide model. 4. Support outside peer review of systemwide EPA-NYC DEP modeling effort.
3. Evaluate the drivers of hypoxia in LIS.		1. Synthesize available information and conduct an evaluation of the drivers of hypoxia, potentially using the Driver-Pressure-State-Impact-Response (DPSIR) framework.

Nitrogen Loading-Monitoring/Modeling (Page 1)

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Evaluate monitoring and modeling needs relative to the 2015 Workshop.	1. LISS held a workshop in 2015 and the final summary has been circulated to partners.	1. Revisit the workshop proceedings to identify areas where additional effort in terms of monitoring and modeling is needed.
2. Increase embayment monitoring. (Set objectives and provide more specifics on monitoring design and intensity and targets for data adequacy that meet objectives.)	1. Save the Sound's (STS) Unified Water Study (UWS) is coordinating monitoring of numerous embayments. 2. Certain citizen groups are also monitoring for nitrogen in embayments. 3. Support provided for CT DEEP for embayment monitoring and modeling for a total of three years.	1. Expand UWS monitoring to include more embayments and evaluate the need/potential to expand temporal scale to further support modeling efforts. 2. Analysis and translation of the UWS data; also, linkages between embayment and watershed/upland data needed.
3. Improve tributary monitoring. (Set objectives and provide more specifics on monitoring design and intensity and targets for data adequacy that meet objectives.)	1. USGS FY2019 pilot project to collect additional samples at 4 sites for 3 major tributaries to develop plan. 2. MADEP added CT River station at northern state border. 3. Connecticut River Conservancy LISFF project to develop a CT River monitoring plan upstream of the CT border. 4. USGS gage on the CT River at Middle Haddam. Collects flow and nutrient data.	1. Develop scope based on objectives and targets that meet desired outcomes. 2. Install gages at the mouths of the Housatonic and Thames Rivers. Based on feasibility, the Housatonic River should be a priority. 3. Define future enhanced USGS monitoring plan for three major tributaries.
4. Increase and improve tributary and embayment modeling.	1. USGS FY2018 project to develop a groundwater flow model of the watersheds on the northern shore of Long Island Sound in Connecticut, and nearby areas of Rhode Island and New York. 2. CT DEEP is pursuing the development of embayment specific models as well as a plan to develop indices of biological integrity. 3. CT DEEP is updating watershed HSPF model of CT watersheds. 4. Incorporating MS4 data into assessment of tributary inputs.	1. Develop scope based on objectives and targets that meet desired outcomes. 2. Expand collection of embayment specific data focused on holistic assessments to support the development of biological indices and estuarine models. 3. Expand data collection across the state to improve calibration and accuracy of the HSPF model.

Nitrogen Loading-Monitoring/Modeling (Page 2)

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Develop and implement a non-point source (NPS) tracking tool. Tracking tool should provide improved estimates of tributary and embayment nitrogen loading.	1. NEIWPCC has just selected a contractor to develop the framework for a NPS Tracking Tool for LIS and pilot it in 3 -4 communities. 2. A work scope has been prepared by UConn CLEAR for the NPS tracking tool and funding is anticipated for October, 2019. The effort will take two years to complete.	1. Ensure that tracking tool applies to net changes in loading, not just predicted BMP reductions. 2. Pair loading estimates with monitoring and modeling analyses and land cover interpretation. 3. Establish watershed targets for nutrients consistent with biointegrity and ecosystem services/natural capital outcomes. 4. Address data gaps/needs identified in the preliminary phase of tracking tool development. 5. Expand the tracking tool to include the entire LIS watershed.
2. Develop and implement a watershed and nonpoint source decision support framework for the protection and restoration of natural land cover.		1. Ground truth the relationship between land cover and aquatic ecosystem health to local watersheds.
3. Compile and update indicators of LIS nutrient drivers and pressures (population, atmospheric deposition, agricultural activity, etc.).	1. Indicators of nutrient drivers and pressures have recently been updated. (See UConn CLEAR and other data.) 2. Atmospheric N deposition in urban areas may be underestimated by the national sampling networks and better local information is needed. Faculty at Hofstra are building a local monitoring network for the SSER which could be expanded if needed.	1. Clean up definitions of Driver, Pressure and State variables for consistency and clarity. 2. Focus on ecosystem indicator development and interpretation, supportive of ecosystem based-management and biointegrity and ecosystem services outcomes, not just nutrients. 3. Evaluate the USGS approaches and others to develop a feasible method to track nonpoint sources of nitrogen as an indicator.
4. Continue to closely monitor the Point Source (PS) nitrogen loading from wastewater treatment plants (WWTPs) to assure compliance with the TMDL and monitor annual fluctuations in nitrogen loading due to variability and changes (including weather, population growth, and plant improvements).	1. Monitoring and reporting requirements have been incorporated in CT and NY permits, and also some permits of upstream states.	1. Be realistic about monitoring needs and uses. There should always be a link to better management as well as better understanding. 2. Assess recovery potential/best attainable condition for NPS/SW and relationship to ecosystem health/biointegrity outcomes in the watershed, embayments and LIS. 3. Include monitoring and reporting requirements in all permits of upstream states.
5. Keep Land Cover Database updated and use to assess watershed condition and link to biocondition of tributaries and estuaries.	1. Land cover for CT being updated to 1-m resolution and analyzed for condition and buffer condition. 2. Pair with ambient biological network monitoring to improve Biocondition gradient relationships.	1. Primary production in streams and embayments and LIS. 2. Biological integrity indicators in streams, embayments and LIS.

Nitrogen Loading-Research (Page 1)

Research Needs:	Current Research to Address Needs:	Targeted Research Support Needed:
1. Estimate the nitrogen load from Onsite Wastewater Treatment Systems	1. CT DEEP project to gather data and conduct spatial analyses in order to estimate the nitrogen load from OWTS in coastal watersheds.	1. Ground truth the assumptions and methods used to estimate nitrogen loading in CT's coastal watersheds from OWTS.
2. Conduct periodic long-term trends analysis of the drivers of nitrogen loading.	1. USGS conducted nitrogen trends analysis every 10 years.	1. Conduct a nitrogen trends analysis for the next 10 years of data (2010-2020).
3. Determine a method to estimate and track nitrogen loads from NPS and stormwater on an annual basis	1. USGS nitrogen trends report includes approaches to account for NPS and stormwater versus PS, and to estimate loads from unmonitored areas.	1. Evaluate the USGS approaches and others and develop a feasible method to track NPS loads annually.
4. Develop new strategies for nitrogen removal from embayments with seaweed and shellfish bioextraction aquaculture and other methods.	1. The LIS Bioextraction Coordinator is developing strategies to increase seaweed and shellfish bioextraction aquaculture in NY and CT around LIS. 2. The states of CT and NY support increased shellfish cultivation in numerous embayments around LI. 3. Academic and other researchers in NY and CT are exploring methods to increase seaweed and shellfish cultivation in local estuaries. 4. CT Shellfish Initiative established goals to grow and protect shellfisheries, populations, and habitat; and increase public support. It includes short-term and long-term outcomes with measurable targets. 5. CT Sea Grant provides aquaculture support with documents and information for growers. 6. The Joint Agency Aquaculture permitting work group recently released a draft guide to Marine Aquaculture Permitting in CT, July 2019.	1. Quantify potential benefits and value of bioextraction to water quality outcomes and potential consequences to ecosystem balance and integrity relative to scale of operations. 2. Assess and encourage private sector investments to make aquaculture/bioextraction profitable and economically sustainable. 3. Support for monitoring of nitrogen and bacteria testing prior to, during, and post-installation of bioextraction project.
5. Evaluate the market demand and regulatory requirements for seaweed and shellfish bioextraction products and determine ways to overcome any impediments to bioextraction.	1. The LIS Bioextraction Coordinator is identifying challenges to seaweed and shellfish bioextraction aquaculture in NY and CT around LIS	
6. Evaluate current nutrient trading strategies for PS nitrogen loading and develop new trading strategies for both PS and NSP nitrogen loading.	1. NEIWPCC-led FY2019 project to evaluate current nutrient trading strategies and develop new ones.	1. Refine analysis to incorporate ecosystem benefit outcomes (i.e., ecosystem goods and services, natural capital) rather than mass balance exchanges for a single nutrient.

Nitrogen Loading-Research (Page 2)

Research Needs:	Current Research to Address Needs:	Targeted Research Support Needed:
1. Synthesize and characterize the nitrogen removal effectiveness from bioharvesting of shellfish and algae.	1. Nitrogen uptake data relative to specific locations in LIS.	1. Characterize the error and variability of nitrogen uptake estimates to improve the applicability of bioharvesting as a nitrogen uptake tool.

Water Clarity-Monitoring/Modeling

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Track water clarity in embayments where eelgrass grows or can potentially grow, particularly in the east end of LIS.	1. The Unified Water Study (UWS) and other programs measure water clarity in numerous embayments, though not all eastern LIS embayments are monitored. 2. CT DEEP is pursuing the development of embayment specific models.	1. Monitor water clarity in additional eastern LIS embayments through the UWS or other programs. 2. See Monitoring/Research Needs under Ecosystem Target: Nitrogen Loading (1).

Water Clarity-Research

Research Needs:	Current Research to Address Needs:	Targeted Research Support Needed:
1. Review historical Secchi and turbidity data and establish background levels of turbidity for LIS and embayments.		1. Put water clarity in context of EBM targets for watershed and estuarine health outcomes such as biointegrity. 2. Long term trends in properties that have high temporal variability are not detectable without resolving the high frequency variability. This is true of DO in estuaries, and probably to water clarity. Moored instruments that are frequently cleaned and calibrated are essential.
2. Determine available habitat versus occupied habitat for LIS for seagrass. Survey across all embayments and compare to literature values; conduct planting experiments. Study light-limiting factors and other stressors from W to E in LIS.	1. Current LIS eelgrass occupies ~1-2% of suitable area in Vaudrey model (Pickerell et al., 2013, below).	
3. Investigate options to improve water clarity and expand eelgrass habitat and eelgrass area	1. Vaudrey 2008 - Establishing Restoration Objectives for Eelgrass in LIS. 2. Pickerell, Brousseau, Eddings, Vaudrey, Yarish 2013 - Development and application of a GIS-based LIS Eelgrass Habitat Suitability Index Model.	1. Synthesize available information and literature to evaluate further research needs in order to develop an approach that would improve water clarity and foster expansion of eelgrass. 2. Revisit the HSI model to confirm methods and identify additional improvements (if needed) to make the tool useable.

Impervious Cover-Monitoring

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Continue to monitor impervious cover, but also at increased resolution as technology improves. Track pervious green infrastructure through CLEAR Low Impact Development Atlas, NPS and stormwater tracking tool or NPS decision support framework.	1. UCONN/CLEAR FY2019 project to apply one-meter resolution 2016 land cover data and one-foot resolution 2012 impervious cover data for CT. (The CLEAR LIS Changing Landscape website is virtually completed pending a final review). It has interactive maps and charts of land cover and land cover change, riparian cover change, and impervious cover (by watershed) 2. NOAA's Office of Coastal Management (OCM) is considering creating a 10m resolution land cover product for their entire (coastal) area, CLEAR will find out more but it could well be the best future monitoring solution for the LISS. 3. The 121 MS4 communities in Connecticut are now required to reduce 2% of their directly connected impervious area by the end of the permit cycle (2022) through the use of green infrastructure. These actions will be reported in their annual permit reports and provide a potential monitoring opportunity for the LISS. 4. NEIWPCC has selected a proposal prepared by UCONN CLEAR for a Decision Support Tool related to NPS load reductions. A scope of work has been developed and the project is underway. The effort will take two years to complete.	1. Support increased resolution of monitoring. 2. See Monitoring/Research Needs under Ecosystem Target: Nitrogen Loading (2).

Impervious Cover-Research

Research Needs:	Current Research to Address Needs:	Targeted Research Support Needed:
1. Research to evaluate impact of green infrastructure projects in the LIS watershed. (New Haven bioswales are an example.)		1. Ground truth the relationship between green infrastructure and actual nitrogen reductions at the local level.
2. Social science research indicates that more education is needed to change behavior related to impervious cover or related topics.		
3. Consider a new another “paired watershed” study like the Jordan Cove Project. This one would be in any urban area like New Haven and compare paired “drainage sheds.”		
4. Critical need to evaluate and track LOSSES of existing natural structural and functional features of watersheds to prevent the problem from occurring.	1. Comprehensive, integrated and ecosystem-based approaches are essential to put management in context of cause and effect relationships, both degradation losses and improvement potential.	1. Critical need to establish watershed condition targets and recovery potential to guide integrated management towards environmental health outcomes, not just nitrogen loading with uncertain biointegrity outcomes.
5. Track pervious green infrastructure through CLEAR Low Impact Development Atlas, NPS and stormwater tracking tool or NPS decision support framework.	1. See UCONN CLEAR Decision Support Tool on previous page.	

Riparian Buffer-Monitoring

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Continue to monitor riparian buffer extent (in parallel with impervious cover).	1. UCONN/CLEAR FY2019 project to apply one-meter resolution 2016 land cover data for CT. (CLEAR 1m resolution riparian data will be a very good basis for various follow-up studies on evaluating riparian projects.) 2.NOAA's OCM is considering creating a 10m resolution land cover product for their entire (coastal) area, CLEAR will find out more but it could well be the best future monitoring solution for the LISS. Repeated from prior slide.	1. Support increased resolution of monitoring.

Riparian Buffer-Research

Research Needs:	Current Research to Address Needs:	Targeted Research Support Needed:
1. Research to demonstrate and evaluate riparian buffer projects in the LIS watershed. This should include the value of different buffer widths for different water quality outcomes. Need: Add Before-After-Control-Impact (BACI)-style monitoring to all LISFF restoration projects to quantify outcomes of restoration and results.	1. UCONN/Clear project above may be the most important work in this area. The UCONN/CLEAR project will develop a decision support tool, already in beta format, to provide decision makers with quantitative targets.	1. Watershed and buffer condition need to be assessed collectively, and quantitative targets for watershed and buffer condition established.
2. Develop and implement a watershed and nonpoint source decision support framework for the protection and restoration of natural land cover	1. A work scope has been prepared by UCONN CLEAR and the project is underway. The effort will take two years to complete.	1. Ground truth the relationship between land cover and aquatic ecosystem health to local watersheds.

Approved Shellfish Areas-Monitoring

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Improve coverage of areas not currently assessed. 2. Embayment and tributary bacteria monitoring. 3. The key variables that correlate with shellfish health threats are temperature and salinity. High temperature seems to be associated with vibrio and low salinity anomalies indicate the presence of fresh water which often carries pathogens from land mammals. Low cost instruments are adequate to resolve these variables in critical areas and a network could be deployed inexpensively.	1. Already a state program under the Clean Water Act (CWA). 2. All CT waters are assessed or classified.	1. Additional monitoring and state/shellfish commission support would help. 2. No central repository for bacteria data, nor any collaborative framework to analyze data across institutions.

Approved Shellfish Areas-Research

Research Needs:	Current Research to Address Needs:	Targeted Research Support Needed:
1. Facilitate the application of more rapid bacteria, HAB, and toxin detection techniques in LIS to accelerate opening of shellfish areas.		

Sediment Quality Improvement-Monitoring

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Continue to monitor sediment quality through the EPA National Coastal Condition Assessment (NCCA) monitoring stations in LIS.	1. The next NCCA survey is in the summer of 2020 and 50 LIS embayment stations will added.	1. Surveys should be conducted in conjunction with hydrography, current and biological measurements to expand the values of the effort. The newly added stations will be monitored using current NCCA protocols.

Sediment Quality Improvement-Research

Research Needs:	Current Research to Address Needs:	Targeted Research Support Needed:
1. Locate and assess contaminated/toxic sediment regions in LIS and potential methods to remediate these problems. Need to develop a chart of contaminated areas.	1. State and federal prerogative and programs required under the CWA. 2. CT DEEP is pursuing the development of embayment specific models as well as a plan to develop indices of biological integrity.	1. Evaluate and develop monitoring protocols and criteria for managing toxic substances that are not currently addressed adequately, including endocrine disruptors. 2. Support and help coordinate state and federal programs under the CWA that set criteria, assess conditions and risk, and develop management plans to resolve impairments, such as TMDLs. 3. Identify sources of sediment data (Long Island Sound Resource Center [LISRC], CT Sediment Quality Information Database [SQUID], USGS, Universities), collate for data synthesis, identify data gaps, flag potential problematic areas, and recommend further monitoring/research needs. 4. See Monitoring/Research Needs under Ecosystem Target: Nitrogen loading (1).

CCMP HABITAT THEME

Coastal Habitat Extent-Monitoring

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. See monitoring needs for eelgrass and tidal wetlands in subsequent sections.		
2. Monitoring for coastal habitat types other than eelgrass or tidal wetlands, including coastal forests, etc.		
3. Consider monitoring habitats important to riparian buffers and habitat connectivity.		
4. Regularly monitor wildlife listed as state and or federally threatened and endangered, as well as species of special concern and SGCN species, within priority coastal habitat types. Specifically, monitor beach-nesting birds (including Piping Plover, American Oystercatcher, Least Tern, Common Tern, and Black Skimmer) as well as migratory shorebird species (including the Red Knot). Certain species are already being monitored (see current monitoring below), but this should be identified as a priority for LISS and funding sources should support monitoring threatened, endangered, and at-risk wildlife.	1. Most beach-nesting birds in NY and CT are monitored, but survey effort varies and productivity is not always tracked for each species (e.g. in NY, American Oystercatchers are counted every three years for the Long Island Colonial Waterbird Survey and many site managers don't monitor American Oystercatcher productivity). 2. Audubon conducts migrating shorebird surveys during spring and fall migration at select sites.	

Coastal Habitat Extent-Research

Research Needs:	Current Research to Address Needs:	Targeted Research Support Needed:
1. See research needs for eelgrass and tidal wetlands in subsequent sections.		1. Eelgrass and tidal wetlands are not the only coastal habitats of concern, and should be managed in the context of upland pressures for land change and climate drivers.
2. What is the carrying capacity of existing beach habitat for breeding Piping Plovers on Long Island Sound (under Beaches and Dunes habitat type)?		
3. Conduct a comprehensive study of prey base for the Piping Plover (under Beaches and Dunes and Intertidal Flats habitat types).		
4. Assess climate change and sea level rise impacts on Beaches and Dunes. Identify non-developed beach migration corridors.		

Eelgrass Extent-Monitoring

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Identify status and trends in eelgrass areal extent and condition.	1. Currently United States Fish and Wildlife (USFWS) aerial surveys every three to five years.	1. More frequent surveys are needed like the annual eelgrass surveys in the Chesapeake Bay, particularly since eelgrass acreage can be extremely variable over time.
2. New survey methods should be developed to enable cheaper, faster, and more frequent eelgrass surveys.	1. Several studies of New England eelgrass distributions using drones or satellites are currently underway and additional development efforts are needed to reliably apply these technologies (EPA RARE). 2. Also new U. Conn. imaging group using drones as mentioned in wetlands section.	1. Monitoring should support and be linked to specific management actions and targets, i.e., actionable rather than just informative. 2. Further testing and development of new techniques (aerial and drone) to improve efficiency of surveys.

Eelgrass Extent-Research/Modeling

Research Needs:	Current Research to Address Needs:	Targeted Research Support Needed:
1. Identify factors which may limit eelgrass in LIS, including water clarity, temperature, water quality, sulfide content of sediments, and others, and to develop management strategies for addressing these limitations. Evaluate past restoration efforts.	1. Limited academic research and modeling on eelgrass in LIS. 2. Eelgrass restoration efforts by Suffolk County Marine Program (Cornell Cooperative Extension).	1. Critical research on factors that limit eelgrass in LIS, including those which will change in the future with climate change. Evaluate past restoration efforts. These factors should be specified, and management harmonized with upland ecosystem needs and other estuarine targets.
2. Refine the Habitat Suitability Index Model for Eelgrass in Long Island Sound. The current model is based on a limited number of parameters.		1. Revisit the Habitat Suitability Index Model to evaluate the calibration/validation, and consider if expanding it to include more parameters would make it more useful for restoration efforts in LIS. Determine critical relationships for ease of applying the model and future data collection needs.
3. Determine available habitat versus occupied habitat for LIS for seagrass. Survey across all embayments and compare to literature values; conduct planting experiments. Study light-limiting factors and other stressors from W to E in LIS.		

Tidal Wetland Extent-Monitoring

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Survey and evaluate restored wetlands frequently to measure total acreage, marsh integrity and habitat quality (including high marsh), and also determine if previous restoration sites have been maintained. Determine needed frequency of surveys and criteria for restoration success.		1. Need map/database of all restored and natural sites; "Evaluation" should include vegetation community composition, elevation capital, creekbank loss, and other metrics. 2. Compare LIS marshes to other existing monitoring network databases (like NPS, NERRS); Assess available migratory space for upland migration. (USFWS proposal for marsh health assessment.)
2. All restored marshes should follow a standardized pre- and post- restoration monitoring framework.		
3. Evaluate new remote-sensing technologies (satellites, drones, and others) to assess wetland acreage and condition.	1. New aerial imaging group at U. Conn. using drones and imaging software could be useful for wetlands. It is collaboration between the Extension and Natural Resources (NR) departments. LIS Wetlands researchers Helton and Lawrence are in the NR Department.	1. Use new remote-sensing technologies for improved and more frequent assessment of tidal wetland extent and condition.
4. Regularly monitor salt marsh obligate bird species, including the Saltmarsh Sparrow, and their habitats to determine productivity, survivorship, habitat use, and threats.		
5. What is the extent of high marsh and low marsh habitat? Survey at regular intervals (every 3-5 years).		

Tidal Wetland Extent-Research/Modeling (Page 1)

Research Needs:	Current Research to Address Needs:	Targeted Research Support Needed:
1. Determine current limiting factors for tidal wetlands coverage in LIS and identify prime potential habitat regions for tidal wetlands restoration and the potential for success.		
2. Assess climate change and sea level rise impacts on marsh acreage and migration.	1. Recent (2016) report on “Sentinels of Change—Are Salt Marshes in LIS Keeping Pace with Sea Level Rise?” (NEIWPCC). 2. Recent (2017) LISS research project “How will sea level rise-driven shifts in wetland vegetation alter ecosystem services?”	1. In the context of management potential. Can wetlands keep pace with the sea level rise? 2. Research on plant-based factors impacting marsh elevation maintenance and inland migration with SLR to enable predictions not solely reliant on SLAMM. 3. Research is needed to determine how marsh-building plants will respond to multiple stressors, especially climate change factors within the LIS eutrophication gradient. 4. Research on growing season length and phenology in marsh plants.
3. Assess historic impacts of ditching on marsh stability and migration, and impacts of other historic alterations to elevation and hydrology.		1. Assess impacts of ditching on marsh stability and migration. 2. Quantification of ditching in LIS marshes, including extent and frequency of ditch maintenance. 3. Measure and model marsh levee growth and tidal response to ditch plugging.

Tidal Wetland Extent-Research/Modeling (Page 2)

Research Needs:	Current Research to Address Needs:	Targeted Research Support Needed:
1. Determine best methods for tidal marsh (especially high marsh) habitat restoration/enhancement and assess marsh integrity and habitat quality.	1. The Saltmarsh Habitat & Avian Research Program (SHARP) monitors and conducts research on tidal marsh nesting birds and their habitats across the east coast. But survey effort and frequency vary from place to place so not all sites are regularly monitored, and the future of that program is uncertain.	
2. Assess impact of nutrient loading and pesticide application (including Methoprene spraying) on marsh stability and migration.	1. Recent Ecosphere publication: Impact of salinity and nutrients on salt marsh stability (Alldred et al. 2017)	
3. Identify non-developed marsh migration corridors for priority saltmarshes.		
4. Improve SLAMM and other marsh migration modeling through: Objective 1. Understand the extent to which salt marsh migration into forests, including invisible migration (migration into forest not detectable using aerial photo interpretation) – is happening in Connecticut. Objective 2. Understand the sequence of steps involved in forest-to-marsh conversion. Objective 3. Understand the role of large storms in driving marsh migration into forests.		

Miles of Fish Passage-Monitoring/Research

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Track number of fish accessing river miles through restored passage points.	1.Some limited fish counters in place.	
Research Needs:	**Current Research to Address Needs:**	**Targeted Research Support Needed:**
1. Evaluate past efforts to restore fish passage for current effectiveness and explore improved methods.		

Shellfish Harvested-Monitoring/Research

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Better reporting of harvest data by industry is needed. Reporting needs to be more complete and using consistent units between CT and NY.	1. CT has new reporting regulations and shellfish management plan.	1. Would better reporting of shellfish harvesting improve management? 2. Incorporate seaweed harvest amounts into the tracking plan.
Research Needs:	**Current Research to Address Needs:**	**Targeted Research Support Needed:**
1. Identify habitat and policy limitations of increased shellfish harvest and explore solutions.	1. Bioextraction coordinator is working to facilitate increased shellfish and seaweed aquaculture by overcoming habitat and policy limitations. 2. Joint Agency Aquaculture Workgroup released a guide to Marine Aquaculture Permitting in CT for review and comment. 3. NOAA aquaculture research opportunities through Sea Grant.	1. Need to better quantify the benefits and potential of aquaculture and bioextraction and ascertain any trade offs for more natural ecosystem structure and function.

Habitat Connectivity-Monitoring/Research/Modeling

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Habitat connectivity is not currently measured because measurement methods are still under development.	1. The LISS Habitat Workgroup is currently evaluating existing tools used to measure habitat connectivity for potential use in the LIS watershed. 2. CLEAR previously developed a Forest Fragmentation model and recently ran it for the period from 1985 to 2015.	1. Consider using the Long Island Sound Blue Plan to assess habitat connectivity and identify areas that provide high priority habitat for the groups of species assessed.
Research Needs:	**Current Research to Address Needs:**	**Targeted Research Support Needed:**
1. Develop decision support tools to help guide land and watershed protection decisions focused on "ecological value".	1. UCONN/CLEAR decision support tool for watershed conservation is under development.	1. Magnitude and integrity of forested/wetland areas may be a good structural indicator of ecological value, and in concert with riparian buffers for aquatic ecosystem health relationships. Buffers could also be important corridors.

Protected Open Space-Monitoring/Research/Modeling

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. A systematic program to monitor the effectiveness of land acquisitions in reaching goals is necessary. The current metric is simply acres of land.		
2. CT needs a more complete GIS data layer of protected open space. The only partially completed data is available on the Advanced Viewer on CT ECO.	1. The CT DEEP Green Plan includes a goal of updating Protected Open Space GIS data for the state.	1. Add GIS mapping to the LISS “Habitat Restoration Database” for both CT and NY.
Research Needs:	**Current Research to Address Needs:**	**Targeted Research Support Needed:**
1. Develop criteria to help identify potential target areas for preservation.	1. Could make additional use of the Stewardship Initiative Site-Selection GIS Tool that was developed in 2011 to support land acquisition and conservation priorities.	
2. Develop innovative acquisition and financing strategies to increase open space preservation.		
3. Develop an acquisition process specifically for open space to which tidal marshes could migrate based on marsh migration models.		

CCMP SUSTAINABILITY THEME

Waterfront Community Resiliency-Monitoring/Research

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Additional tracking of both planning and implementation of resilient development by both Connecticut and New York coastal communities.		
Research Needs:	**Current Research to Address Needs:**	**Targeted Research Support Needed:**
1. Define resiliency metrics that can be assessed for each municipality. 2. Social science and economic research to identify why local adaptation actions have been slow.	1. The Connecticut Institute for Resilience and Climate Adaptation (CIRCA) is developing strategies for encouraging and enabling the development of municipal resiliency plans and resilient development.	

Harbor and Bay Navigability-Monitoring/Research

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Monitor projects for the effectiveness of dredged material reuse.		
Research Needs:	**Current Research to Address Needs:**	**Targeted Research Support Needed:**
1. Assess methods to increase beneficial uses of dredge material.		

Public Engagement-Monitoring/Research

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Update assessments of public engagement through surveys, workshops, etc.	1. Limited area public surveys are part of a new research project.	
Research Needs:	**Current Research to Address Needs:**	**Targeted Research Support Needed:**
1. Identify methods to increase effectiveness of public outreach efforts.		

Beach Closures-Monitoring/Research/Modeling

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Broader sampling for bacteria beyond beaches to compare with beach data; and frequent monitoring of beaches and other coastal recreation areas (i.e., harbor where rowing/boating take place).	1. Health department data and NGO data.	1. Need centralized database and public notification system.
2. Watershed monitoring for bacteria. Coordination of existing efforts.		
3. Salinity monitoring and circulation modeling will help to diagnose the causes of closures.		
Research Needs:	**Current Research to Address Needs:**	**Targeted Research Support Needed:**
1. Optimize and implement more rapid bacterial detection techniques to prevent unnecessary beach closures.		
2. Refine DNA/source tracking for bacteria.		
3. Assess human health impact from other than human sources of bacteria at beaches.		
4. Assess closure frequency versus expectations with increasing frequency/intensity of storms and climate change impacts.		

Marine Debris-Monitoring/Research

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Improve marine debris source and in-Sound assessments beyond current coastal cleanup.	1. New York City floatables monitoring program.	
2. Need to adopt standard protocols for any micro-plastic assessments in LIS.		
3. Baseline survey of type and distribution of marine debris should be made in the Sound.		
4. After adoption of standard protocols, debris should be integrated into regular CT DEEP surveys.		
Research Needs:	**Current Research to Address Needs:**	**Targeted Research Support Needed:**
1. Assess marine debris sources in LIS and methods of decreasing inputs.		1.Consider implementation of the NOAA marine debris monitoring protocol.
2. Include micro-plastics in marine debris source assessments.	1. Current Futures Fund project (U Conn.) on micro-plastics in CT waters of LIS. 2. CTSG-funded project to examine the degree to which LIS aquaculture practices contribute to the creation of microplastics and the extent to which they are ingested by cultured oysters	

Public Access-Monitoring/Research

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
Research Needs:	**Current Research to Address Needs:**	**Targeted Research Support Needed:**
1. Innovative approaches to increasing access should be developed.		

CCMP SOUND SCIENCE THEME

Climate Change-Monitoring/Modeling

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Climate change parameters—build on current monitoring as indicated by the current LIS climate vulnerability assessment and recent sentinel monitoring reports	1. New research projects are adding more monitoring of acidification parameters. Projects include - Shell Day 2019, LISICOS buoy with pCO2 sensor, RESPIRE project, Dominion Foundation funded project with Vlahos Lab. 2. Target data gathered by NWS, NRCC, USGS, CT DEEP marine trawl survey.	
2. The two things that need to be measured at higher resolution around the Sound to improve design and evaluation of SLR risk reduction are: (1) water levels in areas that are getting flooded now (the 4 NOAA tide gages are inadequate) and (2) wave statistics in areas where there is high erosion and overtopping. These, with models, will allow the design of cost effective, and environ-mentally sensitive, flood risk and erosion mitigation strategies.		

Climate Change-Research

Research Needs:	Current Research to Address Needs:	Targeted Research Support Needed:
1. Research on climate change vulnerability and impacts in the LIS region.	1. Three recent LISS Sentinel Monitoring Pilot Projects: a. 2016 report on “Sentinels of Change—Are Salt Marshes in LIS Keeping Pace with Sea Level Rise?” b. 2016 report on “Detecting Climate Change Impacts in Long Island Sound”. c. 2017 report on “How will sea level rise-driven shifts in wetland vegetation alter ecosystem services?” 2. Recently completed LIS Climate Change Vulnerability study by CT Sea Grant.	
2. How does climate change impact forage fish species abundance, age class, and range shifts in the Long Island Sound? This includes impacts on sand lance and others as prey for birds and other fish species.		
3. Does climate change and sea level rise affect marine invertebrate prey availability in the intertidal zone and on beaches?		

HABs/Invasive Species-Monitoring

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Monitor harmful Algal Blooms (HABs) in LIS.	1. Gobler Lab at Stony Brook does routine monitoring of HABS in embayments around Long Island. 2. NY Sea Grant developed plan for Suffolk County to address HABs. 3. CT Department of Agriculture/Bureau of Aquaculture (DA/BA) does routine HAB monitoring under the FDA's National Shellfish Sanitation Plan Model Ordinance (NSSP-MO) in select embayments. 4. NYSDEC has a tracking/mapping tool for HABs. 5. CUNY remote sensing research project includes HABs.	1. Add monitoring of HABS (cell counts/toxins) to routine offshore cruises.
2. Are there LIS invasive species which require monitoring?		

HABs/Invasive Species-Research

Research Needs:	Current Research to Address Needs:	Targeted Research Support Needed:
1. Do HABs significantly impact forage fish populations?		
2. Research on important invasive species in LIS watersheds and coastal regions.		
3. Identify tidal marsh areas that have been most impacted by *Phragmites australis*. At those sites, determine which removal technique(s) (e.g., herbicide application and/or restoring tidal flow) would be most effective.		
4. Identify/develop/support biological control for Mugwort *(Artemisia vulgaris),* Common Reed *(Phragmites australis)*, and other invasive plant species.		

Ecosystem-Based Management-Monitoring

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Consider additional parameters or synthesis which addresses ecosystem health/integrity.	1.Do any current surveys or other measures yield information about ecosystem health/integrity in LIS?	
2. Track menhaden, sand lance, and other forage fish species numbers in the Long Island Sound, including in restored areas, to determine if populations are stable.		
3. Track changes in availability of preferred versus less nutrient dense forage fish prey species for seabirds.		

Ecosystem-Based Management-Research

Research Needs:	Current Research to Address Needs:	Targeted Research Support Needed:
1. Assess and evaluate overall ecosystem health.		
2. Develop an EBM schematic that addresses overarching questions and is linked to ecosystem indicators.	1. An abundance of data and information exists. 2. EBM schematics and approach have been applied elsewhere.	1. Adapt an Ecosystem Based Management approach for LIS using an established framework. 2. Enter data and information into the conceptual model.
3. What factors contribute to the decline of forage fish populations? Currently there is a lot of speculation but lack of data.		
4. How do forage fish population declines and changes in species composition affect seabird populations and productivity?		

Sound Science-Monitoring

Monitoring Needs:	Current Monitoring to Address Needs:	Targeted Monitoring Support Needed:
1. Identify and communicate high-priority monitoring needs.	1. This effort.	
2. Develop an integrated monitoring plan incorporating new technologies and citizen science.		1. Prepare a comprehensive monitoring plan for LIS with targets to modify based on monitoring needs and technology efficiencies. 2. Need additional efforts to capture other parameters/study areas, like bacteria.
3. Expand professional monitoring as well as by citizen groups.	1. Increased citizen science embayment monitoring by the Unified Water Study; expanded monitoring by citizen groups. 2. Audubon's community scientists help monitor breeding shorebirds and seabirds as well as migrating shorebirds. Audubon Connecticut has its own database for community science data on shorebird populations in CT. This volunteer program and database could be a "case study" for other organizations trying to develop a citizen science monitoring program.	
4. Improve database functionality for monitoring information.	1. New citizen science database projects funded by LIS Funders Collaborative 2. NYSDEC and USGS are developing a new database—LIQWDS—targeting nitrogen data and LINAP.	
5. Develop a modern data system for LIS.		1. Move towards consistent data storage/management using WQX and EPA's WQ Portal. 2. Support needed for implementation of database/visualizations based on these projects.
6. Investigate monitoring applications of remote sensing for chlorophyll *a* and other parameters.	1. Tzortziou and Goes labs at CUNY and Columbia, also Greenfield lab at CUNY, and Dierssen at UCONN.	

Sound Science-Research/Modeling

Research Needs:	Current Research to Address Needs:	Targeted Research Support Needed:
1.Identify and communicate high-priority research needs	1.This effort.	
2. Investigate research applications of remote sensing for chlorophyll *a* and other parameters	1. Recent and current remote sensing projects for phytoplankton and other parameters (see monitoring).	
3. Develop new systemwide and nested models (see hypoxia ET)	1. LISS partners are developing in integrated set of technical tools to understand and manage the sources and impacts of nutrients on Long Island Sound. These include 1) watershed and groundwater models to understand the generation and delivery of nutrients to Long Island, 2) a series of nested circulation and water quality models to understand the impact of delivered nutrients at local (embayment), regional, and systemwide (including the New York/New Jersey Harbor) scales. Additional monitoring is being conducted to provide the data necessary to calibrate and validate these models and test their ability to represent real-world conditions.	
4. Improve database functionality for research.		