CONNECTICUT SEA GRANT PROJECT REPORT FOR LIS PARTNERSHIP PROJECTS

Please complete this progress or final report form and return by the date indicated in the emailed progress report request from the Connecticut Sea Grant College Program. Fill in the requested information using your word processor (i.e., Microsoft Word), and e-mail the completed form to Syma Ebbin syma.ebbin@uconn.edu, Research Coordinator, Connecticut Sea Grant College Program. Do NOT mail or fax hard copies. Please try to address the specific sections below. If applicable, you can attach files of electronic publications when you return the form. If you have questions, please call Syma Ebbin at (860) 405-9278.

Please fill out all of the following that apply to your specific research or development project. Pay particular attention to goals, accomplishments, benefits, impacts and publications, where applicable.

Name of Submitter: Dr. Sarah Crosby

Date of Report submission: 03/31/2026

Project #: R/CMB-50-CTNY Check one: [ ] Progress Report [X] Final report

Duration (dates) of entire project, including extensions: From [03/01/2023] to [02/28/2026].
//
Project Title or Topic: *Assessing the impacts of warming and planting strategy on the resilience of restored salt marshes to improve restoration efficacy*

Principal Investigator(s) and Affiliation(s):

1. Sarah Crosby, The Maritime Aquarium at Norwalk

2. Nicole Spiller, Harbor Watch at Earthplace

3. LaTina Steele, Sacred Heart University

4. Randall Hughes Northeastern University

A. COLLABORATORS AND PARTNERS: *(LIST ANY ADDITIONAL ORGANIZATIONS OR PARTNERS INVOLVED IN the project.)*

Restoration practitioners are key end users of the data and findings of this research. The practitioners engaged have included (and will include): Dr. LaTina Steele (Sacred Heart University; also a project PI), Christopher Samorajczyk (CT DOT), colleagues at CT DEEP (E.g.

Roger Wolfe and Harry Yamalis), NY DEC and other groups around LIS engaged in restoration, such as Save the Sound, NOAA, Connecticut Audubon, The National Audubon Society, Connecticut Chapter, and Connecticut College. The findings will also be shared with the LIS Coastal Restoration Coalition (8 member organizations).

We wish to also formally acknowledge the contributions of the late Dr. Jennifer Mattei, who was a PI on this project during its development and the original grant application submission. Dr. Mattei was instrumental in providing access to the salt marsh restoration site at Stratford Point and provided valuable feedback during project conception.

B. PROJECT GOALS AND OBJECTIVES:

Objective 1. *In situ warming to assess restored and natural marsh response to climate change*

- Artificial in situ warming experiment to assess restored and natural marsh responses to climate change. Field warming treatments tested effects on *S. alterniflora* growth responses, phenology, genetic diversity, and belowground decomposition rate in the low marsh in natural and restored salt marshes.
- Research question: How will natural and restored salt marsh structure and function change with increasing air temperatures due to climate change, and will these changes impact their resilience with sea-level rise?

Objective 2. *Field planting experiment at a current Long Island Sound salt marsh restoration site to assess if salt marshes can be made more resilient by including southern-source plants in restoration plantings*

- Experimental planting of local-source and southern-source *S. alterniflora* (plant source x warming). Local and southern-source plants, both separately and mixed (3 source treatments), planted at an existing restoration site at Stratford Point in the low marsh. ½ of the plantings maintained at ambient temperature and ½ experimentally warmed in situ. Measure *S. alterniflora* growth responses, phenology, genetic diversity and belowground decomposition.
- Research questions: Can restored salt marshes be made more resilient by including southern source plants in restoration plantings? Do these benefits only manifest under future temperature conditions?

Objective 3. *Greenhouse study on the potential for genetic mixing among salt marsh plants sourced from different regions that could enhance adaptive potential.*

- Greenhouse study on the hybridization potential of local-source and southern-source *S. alterniflora* (source x warming). Local and southern-source plants will be grown in a common

garden under 2 temperature treatments (½ ambient temperature, ½ warming).
● Research questions: Will differences in phenology across local and southern sources limit hybridization in restoration plantings? Will warming decrease phenological differences?

C. LIS PARTNERSHIP CCMP ACTIONS: *List the top primary CCMP Action(s) (up to 3) that this project addresses. Please refer to the 2025 LIS Partnership CCMP Actions which can be found at https://lispartnership.org/wp-content/uploads/2025/06/CCMP_Final_Accessible_10-07-2025.pdf)*

1. THAW 1-3: "Survey, research, and monitor changes and associated causes in extent and abundance of coastal habitat types and their associated wildlife with focus on tidal wetlands and seagrass."
2. THAW 1-1: "Restore coastal habitat by supporting projects that implement established restoration techniques or help validate innovative techniques and include broad collaboration and communication."
3. *N/A*

D. LIS PARTNERSHIP CCMP PERFORMANCE METRICS: Please select one Performance Metric for each Action identified in section C (above); use the table of metrics attached at the end of this form as Appendix I to identify; use NA if there is no match)

1. THAW 1-3: NA
2. THAW 1-1: NA
3. *N/A*

E. Quantity Of LIS Partnership CCMP Metrics: For each Performance Metric selected, Please enumerate the quantitative number associated with the metric(s) identified in section D (above). For second year progress and completion reports, this number should be cumulative, tracking total progress across all reporting periods.

1. THAW 1-3: NA. Other relevant metrics:
    i. 3 research objectives completed
    ii. 8 salt marshes studied to assess changes with warming
    iii. 4 salt marsh restoration sites studied
2. THAW 1-1: NA. Other relevant metrics:
    i. 1 salt marsh received experimental restoration plantings
    ii. 1 greenhouse study conducted on restoration plantings
    iii. 8 salt marsh site managers engaged
    iv. 4 institutions collaborated

F. <u>PROGRESS</u>: (*Summarize progress relative to project goals and objectives. Highlight outstanding accomplishments, outreach and education efforts; describe problems encountered and explain any delays.)*

Objective 1. *In situ warming to assess restored and natural marsh response to climate change*

- Warming structures were deployed at all marsh sites in 2023 and 2024, and plant growth and flowering were measured throughout the growing season of both years.

Field data collection was completed in October 2024, and all structures were removed from the field sites. The field work went according to plan, including the efficacy of the warming structures in achieving desired warming treatments.

- Above and below ground biomass samples, litter bags, seed heads, and plant tissue samples were collected from the experimental plots. All samples were transported to a laboratory space and have been processed.
- A data analysis plan was developed to analyze the effects of warming on plant growth, flowering phenology, and decomposition rate.
- Data analysis is almost complete, and a manuscript draft is currently being reviewed within the project team.
- Results from this objective have been presented at multiple scientific conferences (see below).

Objective 2. *Field planting experiment at a current Long Island Sound salt marsh restoration site to*
assess if salt marshes can be made more resilient by including southern-source plants in restoration plantings

- *Spartina alterniflora* plugs sourced from Southern and Northern populations were planted at Stratford Point at the beginning of the growing season in 2023 and 2024. Warming structures were deployed on all sampling plots. Field data collection was completed in October 2024, and all structures were removed from the field sites.
- Plants were monitored for growth and flowering throughout the field season of 2023 and 2024.
- Above and belowground biomass samples and plant tissue samples were collected from the experimental plots. All samples were transported to a laboratory space and have been processed.
- Data analysis is currently in progress.

Objective 3. *Greenhouse study on the potential for genetic mixing among salt marsh plants sourced from different regions that could enhance adaptive potential.*

- *Spartina alterniflora* plugs sourced from Southern and Northern populations were planted in a greenhouse and exposed to soil warming conditions in 2023 and 2024. Data collection was completed at the end of the growing season in 2024.
- Plant tissue samples were collected from experimental plots and have been processed for genetic analysis.
- Data analysis is currently in progress.

G. <u>PROJECT PUBLICATIONS, PRODUCTS, PRESENTATIONS AND PATENTS</u>: *(Include published materials with complete references, as well as those which have been submitted but not yet published and those in press. Please attach electronic versions of any journal articles, reports, and abstracts not previously provided.)*

Journal Articles (List URLs):

Conference Papers:

Proceedings or book chapters:

Web sites, Software, etc.:

Technical Reports/Other Publications:

Other Products (including popular articles):

Publications planned / in progress:

Patents: *(List those awarded or pending as a result of this project.)*

Presentations and Posters: *(Include name and date of the conference or meeting, whether it was a talk or poster, if it was invited, and who the presenter was.*)

Ocean Sciences Meeting 2024: Poster was presented by Marisa Fajardo (Conservation Project Manager, The Maritime Aquarium at Norwalk) on 2/21/2024 at the Ocean Sciences Meeting in New Orleans, Louisiana. Approximately 6000 attendees were present at the conference and approximately 50 attendees interacted with the presenter during the poster presentation.

Eastern Colleges Science Conference 2024: Poster was presented by undergraduate student Kaitlyn DeJordy (LaTina Steele's laboratory, Sacred Heart University) in April 2024 at the Eastern College Science Conference in Niagra Falls, New York. Approximately 150 attendees were present for this poster presentation.

Benthic Ecology Meeting 2024: Poster was presented by LaTina Steele (Sacred Heart University) in April 2024 at the Benthic Ecology Meeting in Charleston, South Carolina. Approximately 300 attendees were present for this poster presentation.

Long Island Sound Research Conference 2024: Talk was presented by Sarah Crosby (Director of Conservation and Policy, The Maritime Aquarium at Norwalk) on May 15 at the Long Island Sound Research Conference in Port Jefferson, NY. Approximately 150 attendees were present at the conference and approximately 50 attendees watched the presentation.

RAE 2024 Coastal and Estuarine Summit: Poster was presented by Sarah Crosby (Director of Conservation and Policy, The Maritime Aquarium at Norwalk) and Mary Donato (Research and Education Coordinator, Harbor Watch and Earthplace) on October 7 at the RAE 2024 Summit in Washington D.C. Approximately 1400 attendees were present at the conference and approximately 50 attendees interacted with the presenter during the poster presentation.

Long Island Sound Study: Science and Technical Advisory Committee Meeting: Data was presented by Sarah Crosby (Director of Conservation and Policy, The Maritime Aquarium at Norwalk) and Marisa Fajardo (Conservation Project Manager, The Maritime Aquarium at Norwalk) on November 22, 2024 at the LISS STAC virtual meeting. Approximately 50 attendees were present at this meeting.

Coastal and Estuarine Research Federation Biennial Conference 2025: Poster was presented by Marisa Fajardo (Senior Project Manager, The Maritime Aquarium at Norwalk) on 11/10/2025 at the Coastal and Estuarine Research Federation Conference in Richmond, Virginia. Approximately 1,500 attendees were present at the conference and approximately 50 attendees interacted with the presenter during the poster presentation.

Submitted abstract: RAE 2026 Coastal and Estuarine Summit: A proposal for a talk titled *Improving the Resilience of Salt Marshes in a Warming* World was submitted by Marisa Fajardo (Senior Project Manager, The Maritime Aquarium at Norwalk) on 03/20/2026.

H. FUNDS LEVERAGED: *(If this Sea Grant funding facilitated the leveraging of additional funding for this or a related project, note the amount and source below.)*

As of the end of the grant period, a total of $233,873.70 in additional funds were leveraged towards this project. The Maritime Aquarium leveraged $129,020.93 through personnel salary/fringe, supplies, travel, and indirect funding. Harbor Watch at Earthplace Inc. contributed $22,612.11 in funds. $51,262.99 was contributed by Northeastern University, and Sacred Heart University contributed $30,977.67 in additional funds.

I. STUDENTS: ***(****Document the number and type of students supported by this project.)*
*Note: **"Supported"** means supported by Sea Grant through financial or other means, such as Sea Grant federal, match, state and other leveraged funds. "**New"** students are those who **have not** worked on this project previously. "**Continuing"** students are those who **have** worked on this project previously. If a student volunteered time on this project, please use section G, below.*

Total number of **new*** K-12 students who worked with you:
Total number of **new** undergraduates who worked with you:
Total number of **new** Masters degree candidates who worked with you:
Total number of **new** Ph.D. candidates who worked with you:

Total number of **continuing**** K-12 students who worked with you:
Total number of **continuing** undergraduates who worked with you: 1 (Northeastern University)
Total number of **continuing** Masters degree candidates who worked with you:
Total number of **continuing** Ph.D. candidates who worked with you:

Total number of volunteer hours:

*(Note: ***New** students are those who have not worked on this project previously.*
*****Continuing** students are those who have worked on this project previously.)*

In the case of graduate students, please list student names, degree pursued, and thesis or dissertation titles related to this project.

Student Name:
Degree Sought:
Thesis or Dissertation Title:
Date of thesis completion:
Expected date of graduation:

No new students during this project period; prior reports include all students who were engaged in the project.

J. VOLUNTEER HOURS:

(List the number of hours provided to the project by volunteers, i.e., individuals who were not compensated in any way or for whom involvement is not part of their paid occupation. This could be students or citizens. What was their contribution?)

50 volunteer hours from Jan-March 2026 provided by undergraduate student Emma Heimgartner, who was previously supported by this project and currently has a research award from Northeastern to continue her analysis and interpretation of the genetic data from the Stratford Point warming experiment.

K. PICTORIAL: Please provide high resolution images/photos of personnel at work, in the field or laboratory, equipment being used, field sites, organism(s) of study. Attach images as separate files (do not embed). Include links to websites associated with the research project. Please include proper photo credits and a caption with date, location, names of people, and activity. These images are useful to document your project in future CTSG publications, websites and presentations.

Image 1: Rebha Raviraj installing warming plots at our Oyster River marsh site in Milford, Connecticut. May, 2023. Photo taken by Justin Susarchick, The Maritime Aquarium at Norwalk

Image 2: Marisa Fajardo and Torrance Hanley measuring the height of flowering *Spartina alterniflora* stems at Stratford Point in Stratford, Connecticut. 9/26/2023. Photo taken by Bill Jenak, The Maritime Aquarium at Norwalk.

Image 3: *Spartina alterniflora* flowering stem in front of experimental warming cubes at our Gulf Pond marsh site in Milford, Connecticut. September 6, 2023. Photo taken by Emily Lavin, The Maritime Aquarium at Norwalk

L. HONORS AND AWARDS: *(List any honors or awards received during the reporting period, for anyone working on the project. This can be for best paper or poster, university awards, etc.*) Specify: N/A

a) Name of person or group receiving recognition:
b) Name of award or honor:
c) Group or individual bestowing the award or honor:
d) What it was for:
e) Date:

M. DATA MANAGEMENT PLANS: Proposals funded in 2014-2016 and later cycles are required to have a data management plan in place. All environmental data and information collected and/or created must be made visible, accessible, and independently understandable to general users, free of charge or at minimal cost, in a timely manner (typically no later than two years after the data are collected or created). This is a reminder that your CTSG funded research data needs to be archived and accessible as outlined in the data management plan you submitted with your proposal. If there have been any modifications, adjustments or new information available regarding the location, timing, type, formatting and metadata standards, content, sharing, stewardship, archiving, accessibility, publication or security of the data produced please elaborate here.

No modifications.

FOR FINAL DEVELOPMENT AND RESEARCH GRANT REPORTS, PLEASE COMPLETE THIS SECTION:

N. PROJECT OUTCOMES AND IMPACTS

Results from this project will be published through several manuscripts in scientific journals to communicate findings to a broad audience. Our findings suggest that heat stress may negatively impact salt marsh plants as temperatures increase due to climate change. Additionally, restoration status of salt marshes may affect resilience to climate change.

Our results on flowering phenology, genetics, and planting of nursery grown *S. alterniflora* in the field and in a greenhouse are currently in development. These results will provide greater context on the impacts of warming on salt marsh function and can evaluate the efficacy of assisted migration of *S. alterniflora* with southern genotypes. Genetics results will evaluate potential short term genetic effects of experimental warming and can evaluate the genetic composition of plants in different marshes and planted plugs, and how this may affect their response to warming conditions. These results will be valuable to restoration practitioners and land managers working in Long Island Sound and will aid in projections of warming impacts on salt marsh function. Although this research is most applicable to coastal habitats in Long Island Sound, these results can be applied on a larger scale, as heat stress impacts on *S. alterniflora* are applicable to all *S. alterniflora* dominated salt marsh systems. This research will also provide context on the feasibility of planting southern sourced plants in Northern salt marshes, which can further develop restoration strategies in the future. Through developing a better

understanding of how different marsh systems will respond to climate change, management strategies can be tailored to the needs of specific marshes. These results will be particularly valuable to site managers at our research sites, due to the site-specific data predicting the effects of warming on *S. alterniflora* growth at each site.

RELEVANCE OF PROJECT: *(Describe briefly the issue/problem / identified need(s) that led to this work.)*
Salt marshes are at risk of drowning due to sea level rise and must gain elevation or migrate landward to survive. In highly urbanized areas, such as the Connecticut coastline, landward migration is often not feasible due to presence of man-made structures, and the ability of salt marshes to gain elevation at the rate necessary to survive is unclear. Additionally, effects of warming temperatures on salt marsh plants are not fully understood and likely differ based on regional marsh conditions and community genetics. Many salt marshes along the Connecticut coastline have been restored after degradation or destruction due to human impacts. Recent research from The Maritime Aquarium found that re-planted restored salt marshes in Connecticut differ both structurally and functionally from natural salt marshes, with differences in plant morphology and genetics based on restoration status. These results created further uncertainty on if restored and natural marshes will be able to keep pace with sea level rise to the same degree. It is unclear if assisted migration of southern sourced plants could improve salt marsh resilience due to the greater heat tolerance of southern genotype *S. alterniflora*, and if this is a feasible option to contribute to conservation in New England salt marsh systems. This research aims to address these knowledge gaps to improve marsh restoration strategies and management and better understand how our marshes may change over time and how to improve survival.

RESPONSE: *(Describe briefly what key elements were undertaken to address the issue, problem or need, and who is/are the target audience(s) for the work.)*
To better understand projected responses of natural and restored marshes to climate change, we studied key plant growth metrics important to elevation gain, while exposing plants to experimental warming in natural and restored marshes. Warming was achieved using 1 m x 1 m open top greenhouse cubes, constructed from PVC and greenhouse sheeting, and followed designs used in similar studies. At 3 points during the field season, we measured *S. alterniflora* stem height and diameter at a subset of 10 stems per plot, and stem density in each experimental plot. Data were collected on timing of flowering and flowering stem density throughout the field season. We also collected data on above and belowground biomass, decomposition rate, plant genetics, soil temperature, air temperature, and submergence percentage at each plot.

To determine the feasibility of using planting Southern genotype *S. alterniflora* in northern environments to improve heat tolerance, we planted Northern and Southern sourced *S. alterniflora* plugs at a restoration site and in a greenhouse and exposed these plants to experimental warming. Growth of these plugs was monitored throughout the growing season as described above by measuring stem growth metrics, flowering phenology, and genetics.

Effects of warming on the Southern and Northern sourced plugs will indicate if Southern sourced plugs are truly more heat tolerant when placed in a Northern environment.

Our data analysis focused on warming effects on plant growth and comparisons of warming effects between natural and restored marshes. Further analysis will explore the effects of experimental warming on flowering phenology in *S. alterniflora*, to determine potential reproductive effects of warming temperatures on plants in natural and restored marshes. Analysis of *S. alterniflora* genetic composition for each of our research objectives is currently underway to further understand genetic responses of *S. alterniflora* to experimental warming. Data analysis is currently underway to evaluate the effects of warming on growth of planted *S. alterniflora* from Northern and Southern sourced plugs to determine success of different restoration planting strategies. This research is intended to be used by restoration practitioners and land managers working in coastal salt marshes in Connecticut and the greater Northeastern region to improve management and restoration strategies.

RESULTS: *(Summarize findings and significant achievements in terms of the research and any related education or outreach component; cite benefits, applications, and uses stemming from this project, including those expected in the future. Include qualitative and quantitative results.)* We found that warming conditions associated with the greenhouse cubes most often had negative effects on *S. alterniflora* growth. Warming conditions had more frequent negative effects on plant growth in natural marshes compared to restored marshes. Results from this study indicate that salt marsh plant growth may be adversely impacted by warming temperatures in the future. Furthermore, restored marsh plants may be more heat tolerant to warming conditions, likely due to more southern source genetics of planted populations within the studied restored marshes. Preliminary data analysis on flowering phenology also indicates that warming temperatures may delay flowering. Timing of flowering was notably different between natural and restored marshes, and warming may further offset the differences in flowering phenology across marsh types. Our results also reflect highly variable plant growth conditions across sites, highlighting the need for management strategies tailored to the needs of specific marshes. These findings provide a greater knowledge base for site managers and restoration practitioners, so informed decisions can be made when restoring and managing marshland with resilience in mind. This addition of knowledge to the field of study broadens our understanding of how marshes will change in the future, allowing us to better prepare for climate-induced stressors.

Our findings have been communicated at multiple scientific conferences, ensuring that our results reach a wide audience. Preliminary results have been shared with site managers and stakeholders, and the completed manuscript will be shared with all site managers and will be published with open access to make our findings available to all audiences. Our study is highlighted in The Maritime Aquarium's Just Add Water exhibit, with information for aquarium guests on research processes for this project. We work with the Education Department within The Maritime Aquarium to provide information to guests and answer questions from guests about this research project.

Results are currently in development to evaluate flowering phenology, genetics and effects of warming on Northern and Southern sourced planted plugs.

Consider the following as they apply to your research and any related outreach/education.

- What new tools, technologies, methods or information services were developed from this work? Have any been adopted / implemented for use and by whom?

  For this project, we designed a new temperature logging system to get an accurate representation of temperature within our experimental plots. While collecting temperature data, we noticed a temperature gradient within our plots, with lower temperatures close to the ground, and higher temperatures at higher elevation points in our plot. To create an accurate temperature estimate throughout the entirety of the cube, we used an array of 3 loggers, placed at .2 m, .5 m, and .8 m heights. The average temperature of the logger array was calculated and used for data analysis. This is a novel approach to collecting temperature data in the field. This method has not been adopted by other organizations, but is currently being used for another one of our current research projects.

- What are the environmental benefits of this work? Have policies been changed? How has conservation (of ecosystems, habitats or species) been improved?

  This work is expected to create long term conservation benefits by providing predictive information that can be used to promote marsh resilience and providing guidance on planting strategy for salt marsh restoration. Understanding ecosystem change under climatic pressures is an important first step towards implementing efficient restoration and management strategies. These results provide valuable information that can help bolster the framework for decision-making in salt marsh management. Furthermore, understanding climate change impacts on important ecosystems provides a greater foundation for environmental advocacy. This work has not directly affected policy, but future publications can be utilized to promote greater conservation of salt marshes and mitigation strategies for climate change.

- What are the social payoffs of this work? Who has benefited from this work? Have attitudes / behaviors of target audience changed? Elaborate. Have policies been changed?

  We have engaged with various audiences about the results of this study, including stakeholders, land managers, local communities, and attendees at scientific conferences. These findings are expected to improve conservation techniques for Long Island Sound salt marshes, which will benefit local populations; however, these results can be applied to *S. alterniflora* in other regions and can contribute to large scale conservation benefits. This work is not directly focused on policy change, but provides

important context for decision-making in the field of salt marsh conservation. All residents of Connecticut and New York who live and work in Long Island Sound's coastal communities benefit from increasing the positive impacts of salt marsh conservation and restoration. We anticipate additional change will result from this work, but the translation of our work into those policy and practice changes is still in its early stages.

- What are the economic implications / impacts of this work? (Where possible, please quantify.) Have new businesses been created /or existing businesses retained as a result of this research? Have new jobs been created or retained? Are new businesses or jobs anticipated?

  This work does not aim to stimulate economic benefits through the creation or promotion of businesses or jobs.

J. Stakeholder Summary (This is an abstract of your research and findings written for a lay audience)

Salt marshes protect coastlines, filter water, provide wildlife habitat, and mitigate against climate change impacts. Yet, these ecosystems are highly threatened by sea level rise and warming. It is natural for marshes to flood at high tide and drain at low tide, but too much flooding can drown marsh plants, leading to the death of important species. As sea level rises, salt marshes are vulnerable to drowning and must gain elevation or migrate landward to survive. Whether salt marshes can gain elevation fast enough is unclear, and climate change may affect plant growth in ways that affect elevation gain. Furthermore, restored salt marshes may respond differently to warming than natural marshes, leading to greater uncertainty on impacts of warming on salt marsh survival. To evaluate effects of warming on salt marshes, we monitored the growth of an important salt marsh plant in the region, while exposing plants to experimental warming using greenhouse cubes in natural and restored marshes along the Connecticut coastline. Results from our study showed that warming typically stunted the growth of plants, likely due to stress caused by warming conditions. Warming negatively impacted the growth of plants in natural marshes more frequently than in restored marshes. These results suggest that rising temperatures due to climate change may negatively affect plant growth along the Connecticut coastline. Differing responses of natural and restored marshes to warming suggest that not all marshes will respond the same to climate change. This highlights the need for different management strategies to fit the needs of specific salt marshes. These results provide valuable insight into the resilience of salt marshes and can assist land managers in their goal of preserving salt marsh habitat.

Appendix 1: CCMP Performance Metrics

Action	Performance metric
CWHW 1-1	BMPs delivered
CWHW 1-1	Pounds of nitrogen prevented
CWHW 1-1	Pounds of nitrogen removed
CWHW 1-1	Systems installed (nitrogen-reducing)
CWHW 1-1	N/A
CWHW 1-2	Monitoring events
CWHW 1-2	Monitoring groups
CWHW 1-2	Sets of data collected
CWHW 1-2	Monitoring devices deployed
CWHW 1-2	Number of research projects
CWHW 1-2	N/A
CWHW 1-3	Number of policies, strategies, and programs
CWHW 1-3	Number of TMDLs, mitigation plans, and protection plans
CWHW 1-3	Number of watershed-based plans
CWHW 1-3	Number of estuarine models
CWHW 1-3	Number of watershed models
CWHW 1-3	Number of groundwater models
CWHW 1-3	N/A
CWHW 2-1	Number of acres conserved and restored
CWHW 2-1	Number of acres riparian buffer
CWHW 2-1	Number of acres of tree and urban canopy conserved and restored
CWHW 2-1	N/A
CWHW 2-2	Number of acres riparian buffer
CWHW 2-2	Number of acres urban canopy
CWHW 2-2	Number of BMPs installed
CWHW 2-2	Number of land use reports
CWHW 2-2	N/A
CWHW 3-1	Number of onsite wastewater treatment systems upgraded
CWHW 3-1	Number of onsite wastewater treatment systems removed
CWHW 3-1	Systems installed (nitrogen-reducing)
CWHW 3-1	Miles of piping repaired
CWHW 3-1	N/A
CWHW 3-2	Number of new waterbodies sampled
CWHW 3-2	Number of new sampling sites
CWHW 3-2	Number of samples collected
CWHW 3-2	Number of new pathogen detection methodologies developed
CWHW 3-2	Number of pathogen sources identified
CWHW 3-2	N/A
CWHW 4-1	Synthesis report
CWHW 4-1	Action plan

CWHW 4-1	Number of mitigation plans
CWHW 4-1	N/A
CWHW 4-2	Sets of data collected
CWHW 4-2	Sets of data evaluated
CWHW 4-2	Number of assessment tools
CWHW 4-2	N/A
CWHW 4-3	Sets of data collected
CWHW 4-3	Sets of data evaluated
CWHW 4-3	N/A
CWHW 5-1	Number of research projects
CWHW 5-1	Monitoring groups
CWHW 5-1	Monitoring events
CWHW 5-1	Monitoring devices deployed
CWHW 5-1	Sets of data collected
CWHW 5-1	Monitoring framework report
CWHW 5-1	Marine debris hot spot report
CWHW 5-1	N/A
CWHW 5-2	Pounds of marine debris prevented from entering the Sound
CWHW 5-2	N/A
CWHW 5-3	Pounds of marine debris removed
CWHW 5-3	Miles of clean-ups
CWHW 5-3	N/A
CWHW 5-4	Pounds of debris collected by category
CWHW 5-4	N/A
THAW 1-1	Number of coastal habitat restoration projects completed
THAW 1-1	Coastal habitat acres restored
THAW 1-1	Tidal wetland acres restored
THAW 1-1	Seagrass acres restored
THAW 1-1	Shellfish reefs restored
THAW 1-1	N/A
THAW 1-2	Number of completed living shoreline projects
THAW 1-2	Linear feet of living shoreline constructed
THAW 1-2	Linear feet of hardened shoreline converted to living shoreline
THAW 1-2	Linear feet of shoreline protected by a living shoreline project
THAW 1-2	Acres of coastal habitat protected by a living shoreline project
THAW 1-2	N/A
THAW 1-3	Annual seagrass extent mapped on an annual basis
THAW 1-3	Number of monitoring sites
THAW 1-3	N/A
THAW 2-1	Number of offshore fisheries and seafloor habitat studies supported and completed and applied to regulatory decision-making
THAW 2-1	Number of management plans or programs implemented

THAW 2-1	Number of management plans or programs updated
THAW 2-1	N/A
THAW 2-2	Acres of seafloor habitat areas fully characterized
THAW 2-2	Number of sites monitored
THAW 2-2	N/A
THAW 2-3	Number of action plans or programs developed
THAW 2-3	N/A
THAW 3-1	Number of projects focused on data collection and analysis
THAW 3-1	Number of road stream crossings assessed
THAW 3-1	N/A
THAW 3-2	Stream miles reconnected
THAW 3-2	Number of dams removed
THAW 3-2	Number of culverts modified
THAW 3-2	Number of fish ladders and fish lifts installed
THAW 3-2	Number of eel passes installed
THAW 3-2	Number of projects designed and planned
THAW 3-2	N/A
THAW 3-3	Number of projects permitted
THAW 3-3	Number of permits issued under one year
THAW 3-3	N/A
THAW 4-1	Number of parcels and acres acquired
THAW 4-1	N/A
THAW 4-2	Number of public access sites added
THAW 4-2	Number of sites maintained
THAW 4-2	Number of Stewardship Sites added
THAW 4-2	N/A
SRC 1-1	Number of unique trainings and events developed
SRC 1-1	Number of decision-makers that receive training
SRC 1-1	New decision-makers engaged
SRC 1-1	N/A
SRC 1-2	Resources developed and modified/improved
SRC 1-2	N/A
SRC 2-1	Number of new or updated plans
SRC 2-1	N/A
SRC 2-2	Number of established/active regional partnerships/collaborations
SRC 2-3	Number of new partners/community groups engaged in resilience planning/decision-making
SRC 2-3	Number of new communities engaged in resilience planning/decision-making
SRC 2-3	N/A
SRC 3-1	Number of capacity support programs established
SRC 3-1	Number of capacity support programs maintained

SRC 3-1	N/A
SRC 3-2	N/A
SRC 3-3	Number of nature-based initiatives implemented
SRC 3-3	Number of nature-based initiatives in progress
SRC 3-3	N/A
SRC 3-4	Number of infrastructure initiatives implemented
SRC 3-4	Number of infrastructure initiatives in progress
SRC 3-4	N/A
SRC 3-5	Number of adaptive management strategies developed
SRC 3-5	N/A
IEP 1-1	Number of collaborations, inspiring new projects for public access
IEP 1-1	Number of plans and designs supported
IEP 1-1	N/A
IEP 1-2	Number of community stakeholders applying for Partnership grants
IEP 1-2	Number of grants awarded for increasing public access and a sense of belonging at public access sites
IEP 1-2	Number of new public access sites created in Long Island Sound coastal study area
IEP 1-2	Number of existing sites in Long Island Sound watershed with physical or long-term programmatic improvements
IEP 1-2	Number of sites improved for accessibility
IEP 1-2	Number of sites improved for resiliency
IEP 1-2	Number of new physical and programmatic improvements for public access at Stewardship Sites
IEP 1-2	N/A
IEP 1-3	Number of collaborations and stakeholders reached
IEP 1-3	Number of signs promoting public access, including at Long Island Sound Stewardship Sites
IEP 1-3	Number of new interpretive signs, including signage in multiple languages
IEP 1-3	Number of articles and social media posts by Partnership communications staff promoting public access
IEP 1-3	Number of web visitors to the Long Island Sound Stewardship Atlas and the Connecticut Coastal Access Guide
IEP 1-3	Number of youths reached with public access and recreational programming
IEP 1-3	Number of festivals and events scheduled at coastal access sites
IEP 1-3	N/A
IEP 2-1	Number of new environmental education initiatives supported by the Partnership
IEP 2-1	Number of partners engaged in Partnership-supported environmental education networking and resource sharing opportunities
IEP 2-1	N/A

IEP 2-2	Number of Partnership-hosted or supported educational programs for students Long Island Sound Comprehensive Conservation and Management Plan
IEP 2-2	Number of Partnership-hosted or supported educational events and programs
IEP 2-2	Number of formal and informal educators engaged through Partnership-supported professional development programs
IEP 2-2	Number of students and youth involved in Partnership-supported educational programs and events
IEP 2-2	Number of adults engaged in Partnership-supported educational programs and events
IEP 2-2	Number of promotional materials shared, Number of schools involved in Long Island Sound Schools Network
IEP 2-2	N/A
IEP 2-3	Number of clicks or site-visits to Partnership educational and communications resources
IEP 2-3	Number of digital and print materials distributed, Number of educational materials, tools, and activities developed
IEP 2-3	Number of users of educational tools and/or resources when applicable
IEP 2-3	N/A
IEP 2-4	Number of research projects exploring environmental education best practices
IEP 2-4	Number of social media subscribers
IEP 2-4	N/A
IEP 3-1	Number of Partnership communications products promoting or celebrating volunteer and participatory science opportunities
IEP 3-1	Number of volunteers engaged in Partnership-supported volunteer, participatory science, or community-led action opportunities
IEP 3-1	Number of groups participating in Partnership-supported volunteering or participatory science programs
IEP 3-1	Number of groups participating in Partnership-supported community-led projects or programs
IEP 3-1	Number of new sign-ups through Partnership volunteer channels
IEP 3-1	Visits to the Partnership volunteer opportunities webpage
IEP 3-1	N/A
IEP 3-2	Number of Partnership-supported social science research projects
IEP 3-2	N/A
IEP 3-3	Number of visits or clicks on Partnership digital media channels for Partnership-produced informational tools and resources
IEP 3-3	Number of participants at Partnership-supported events and webinars aimed at promoting sustainable behaviors in the Partnership watershed

IEP 3-3	Number of people who have demonstrated or committed to a change in behavior through pledges, by making use of incentive or reimbursement programs
IEP 3-3	N/A
IEP 3-4	Number of campaigns, programs, or materials developed to encourage behavior change for user groups of the Sound
IEP 3-4	Number of visits or clicks in online webpages for Partnership-produced informational tools and resources
IEP 3-4	Number of participants at events and webinars hosted or supported by the Partnership that focus on sustainable behaviors at the Sound, its coast, and its tributaries
IEP 3-4	Number of people who have demonstrated or committed to a change in behavior through pledges, by making use of incentive or reimbursement programs, etc.
IEP 3-4	N/A
IEP 3-5	Number of Partnership-supported events that educate stakeholder groups on information and tools they can use to promote sustainable behaviors locally
IEP 3-5	Number of individuals engaged at Partnership-supported events that educate stakeholders on information and tools they can use to promote sustainable behaviors locally
IEP 3-5	Number of community-based campaigns supported by the Partnership or Partnership resources
IEP 3-5	Number of visits to the behavior change dashboard
IEP 3-5	Number of materials and tools developed to support communities in promoting sustainable practices locally
IEP 3-5	N/A