SNEP Watershed Grants

Final Grant Report

Enhancing Rhode Island's estuaries through oyster habitat conservation and restoration planning

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Title Photo Credit. High densities of oysters on a small boulder (30 X 20 X 15 cm) located in Fresh Pond, 2023, on mixed silt, sand, gravel, and cobble substrates. This small boulder held 141 individual oysters and is typical of the high density of recruitment in this system. (Photo credit: Jim Turenne, NRCS)

Grant Partners and Contributions: This SNEP funded grant was a partnership of Rhode Island (RI) Department of Environmental Management (DEM), Division of Marine Fisheries (DMF), Northeastern University (NU), and The Nature Conservancy (TNC), with unfunded assistance from the RI Natural Resources Conservation Service (NRCS). Significant contributions were made by RIDEM DMF Principal Marine Biologists J.A. Macfarlan, PhD, and Eric Schneider, NU Professors Jonathon Grabowski, PhD, and Randall Hughes, PhD, Heather Kinney (TNC), Jim Turenne (NRCS), and Blake Busch (University of Tampa/RI DMF).

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Acronyms:

DEM	Department of Environmental Management
DMF	Division of Marine Fisheries
HSI	Habitat Suitability Index
NRCS	Natural Resources Conservation Service
NU	Northeastern University
QAPP	Quality Assurance Project Plan
RI	Rhode Island
SNEP	Southern New England Program
SREP	Shellfish Restoration and Enhancement Plan
TNC	The Nature Conservancy

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1. Executive Summary

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2.A Project Report Narrative

I. Problems the Project Addressed

Despite the depleted population status of the Eastern oyster (*Crassostrea virginica*) and decades of restoration attempts in Rhode Island (RI), there was a lack of baseline data on the location, size structure, and abundance of oysters. This project focused on addressing the information gap for both natural and restored oyster beds to inform a more wholistic approach to future restoration endeavors. Building upon existing partnerships among the RI Department of Environmental Management (DEM) Division of Marine Fisheries (DMF), The Nature Conservancy (TNC), and Northeastern University (NU), this project aimed to enhance the viability of future oyster reef habitat restoration efforts in coastal RI to enhance ecosystem service delivery. To achieve this goal, we collected critical baseline data on the environmental and habitat characteristics of restored and natural oyster reefs that will be directly incorporated into the RI Shellfish Restoration and Enhancement Plan (SREP) and used to develop a habitat suitability index (HSI) model to help guide future restoration efforts in RI. We achieved this goal by addressing the following objectives:

> Objective 1: Evaluate existing oyster reef restoration sites in the South Shore Coastal Ponds and Western Narragansett Bay.
>
> Objective 2: Assess wild oyster populations and potential restoration sites in the South Shore Coastal Ponds and Narragansett Bay.

II. Short and Long-term Objectives

In addition, results from this work (e.g., status of former restoration and wild populations) will be used as part of the SREP process to help set restoration goals and provide a baseline that can be used to evaluate the success of future restoration work. For example, information on the spatial distribution of oysters in concert with environmental attributes and reef characteristics (oyster density, abundance, and size distribution) may be used to assess the amount of ecosystem services being provided by existing oyster resources (restored and wild), and thus, assist with the formation of spatially explicit restoration goals and targets. As noted above, results will also provide recent baseline for assessing the success of future work.

III. Relevance of Project to Restoration and Protection of Coastal Ecosystems

The overarching motivation of the proposed study was to “restore water quality and physical processes that support ecosystem function and watershed resilience” (SNEP Goal 1) by the collection of key data that will be used in the development of an oyster restoration suitability model that would facilitate the implementation of the RI SREP and guide future oyster habitat restoration efforts in RI. In addition to being directly used by RI DMF, the datasets produced by this work will be made available to potential partners and end-users (e.g., Narragansett Bay Estuary Program) and will provide a baseline of restored and wild oysters to “assess, track, and communicate change in condition and the effectiveness of actions” (SNEP Goal 3) in RI state waters. We also expect that including attributes of restoration sites and wild populations in the HSI modeling process will illuminate habitat and design elements that may “enable[s] innovative solutions [to] facilitate new technologies and approaches to improve habitat, aquatic life, and water quality” (SNEP Goal 4). Because oyster reefs provide nursery habitat for economically valuable fish (Brumbaugh and Toropova 2008, Grabowski et al. 2012) and remove excess nitrogen from estuaries (Piehler and Smyth 2011, Wall et al. 2011), our project would also “bolster sustainable communities by protecting and enhancing ecosystem services that support local economies in the SNEP region” (SNEP Goal 2).

IV. Geographic Area of the Project

The original geographic area of this project included five regions within the South Coast Salt Ponds, Narragansett Bay, and the Providence River. Utilizing unfunded support from other projects and additional personnel (e.g., NRCS, YEFP, research assistants) we expanded into two additional regions, eastern Narragansett Bay and Block Island(see Section 4, Part IV Photographs, Images 12 and 14. This increased geographic area spans a gradient of salinities, urbanization, tidal influence, and a host of other abiotic and biotic factors that are relevant to meeting the needs of project Objectives 1 and 2 (see Supporting Materials Section 4 Part II, Project Maps and results, Figures 1-8.)

V. Activities to Execute the Project: Techniques, Materials Used

Executing the breadth of tasks to support the completion of Objectives 1 and 2 required a complex sequence of activities that included:

i. QAPP-Quality Assurance Plan Protocol Development

Full scale sampling could not be accomplished until the Quality Assurance Plan Protocol was written, vetted, and signed by all partner organizations. Please see the QAPP development narrative in the; Section 2.C Compliance.

The QAPP includes detailed instructions on field sampling protocols that we have included excerpts of here. After drafting the QAPP and reviewing relevant literature we tested various methods for surveying natural oyster populations. We then consulted with partners about the results of the methodology testing, further refined those in the field to suit the idiosyncratic conditions in RI.

These finalized field methods involved a tiered approach to sampling that begins with identifying a site during a brief visit, then returning for more detailed sampling depending on the density and extent of natural oyster populations found.

The distribution of oysters in RI is unique in that across many locations oysters can be found however they occur in discontinuous patches rather than extensive beds or reefs (i.e. more typical of the mid-Atlantic). Additionally, beds and reefs of oysters are frequently of low density and limited vertical relief. These factors influenced how we arrived at the sampling scheme and were further detailed in the QAPP. Please see Supporting Materials, Section 4, IV Technical Memoranda, Data Analysis and Modeling Reports, QAPP, and the final report package including a digital copy of the latest version of the QAPP.

ii. Historical Data Gathering

In support of both Goals 1 and 2 to assess previous restoration efforts and historical presence of Eastern oysters within the state we gathered and digitized historical reference materials found in DEM archives. This resulted in 45 documents containing information relevant to our search for oyster populations and restoration activities within the state. The onboarding of several interns and the addition of research fellows during the spring of 2021 and 2022 (all of which were supported on non-SNEP funds) allowed us the personnel capacity to systematically search by hand thousands of pages of archived digital and hard-copy reports (see Supporting Materials Part 4, IV. Files g).

The majority of these documents were summary reports on shellfish surveys, landings, locations, out plantings for restoration purposes, and aquaculture records spanning the last approximately 130 years. Included in the supporting materials are scans of one particular report with pertinent oyster data and maps that were printed about fifty years ago (See Section 4 Supporting Materials, V Photographs, Image 19). These historical records although less pertinent to contemporary observations of water conditions and oyster presence are nonetheless valuable evidence of the history of oysters in RI and provided a basis for conducting reconnaissance at several locations.

iii. Site Selection

Prior to the commencement of field work, specific areas within each of the regions (see Section 4, II, Figure 1) were selected for reconnaissance based on a variety of factors. Initially locales were picked based on available historical records (see ii above), input from partners with local expertise, and at times using knowledge from local community members via in situ, unscheduled public outreach opportunities. An example of a historical document found within the DMF archives shows a detailed hand-drawn map of oysters from surveys conducted 40 years ago (See Section 4 Supporting Materials, Part V, Project Photographs, Image 19).

As field reconnaissance continued, we expanded our sites by identifying landscape level features that contained factors known to influence oyster recruitment and survival. For instance, contemporary maps of subaqueous soils (e.g. showing cobble/sand/boulder habitat types), areas with variable salinities created by fresh water sources, small impoundments with bathymetric choke points (e.g., Fosters Cove, Greenhill Pond, Wickford Harbor, Nannaquacket) were chosen to be visited. Typically, those areas were first briefly surveyed to establish presence or absence of oysters, and then further investigated if sufficiently high densities and/or multiple size classes of oysters were found (see parts i and iv in this section for further details on the tiered sampling approach).

For systems such as Ninigret or Nannaquacket(see Section 4 Supporting Materials, Part II, Figures 1,2,5) where populations of oysters are more plentiful and where their distribution is highly patchy, a finer-scaled approach to sampling those was utilized. Here walking, wading, and snorkeling the shorelines of much of the system was accomplished to establish bed sizes, densities, and size structure of the populations present. Important to note is that although we did not survey 100% of the shoreline in all regions and systems, the spatial coverage of this survey is the finest scaled attempt to gather landscape level data on oysters in the state.

iv. Field technique development, implementation, materials

The following two protocols were developed for sampling fundamentally different oyster populations: reefs and beds created by restoration and enhancement activities versus naturally occurring populations. Protocol A for restoration sampling (see part A below) has been in used in the state, is consistent with best practices, DMF survey methodologies (Baggett et al 2014), and directly supports Objective 1. Protocol B (see below) was developed specifically for RI waters and to support Objective 2. This methodology was tested and refined following extensive fieldwork, and consultation with partners during the spring and summer of 2021 (see Supporting Materials, Section 4, Part V Photographs, Images 1-3). The narratives below are an abridged excerpt of pertinent field methods from the QAPP, see Section 4, IV, Technical Memoranda for files included in this report package.

A. Protocol for Restored Reef Sampling

1. A 0.25 m2 quadrat will be placed haphazardly on the reef to collect a representative sample. “Haphazardness” is achieved by the in-water sampler positioning themselves within the reef area and gently tossing the quadrat over their shoulder in the opposite direction to which they are facing.
2. The position of the quadrat will be marked with a small weight and floating buoy.

3. Using a 25-point grid, the percent cover of macroalgae within the quadrat will be quantified.

4. All algae will be brushed away and the percent cover of benthic substrate will be quantified at each grid point.

5. The reef’s vertical relief will be measured by quantifying the difference between the water depth adjacent to the reef edge and the water depth at the center of the quadrat.

6. All oysters and dead shell material within the quadrat will be excavated to a depth of 10 cm and placed in mesh polypropylene bags.

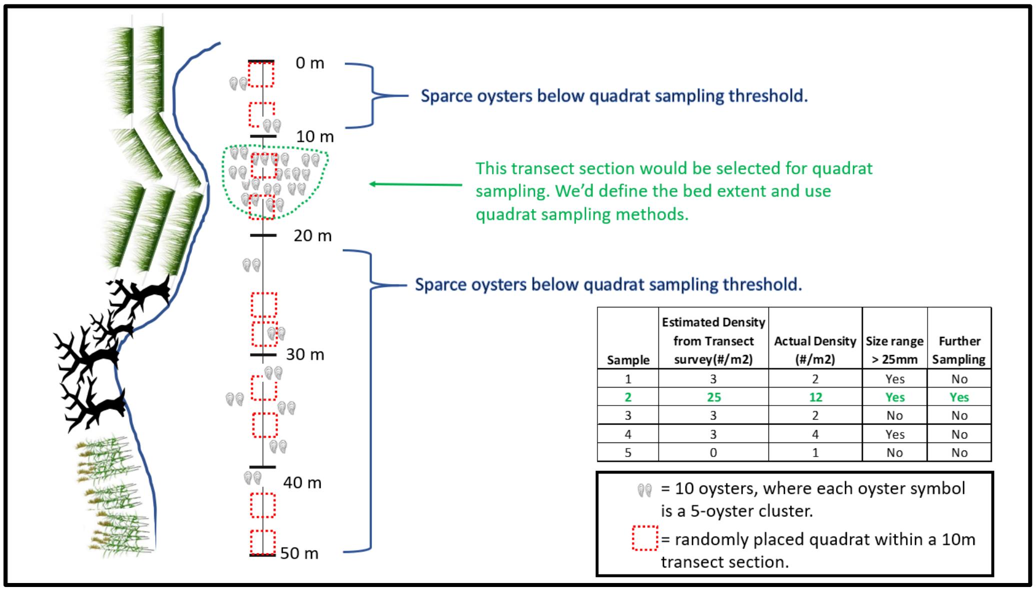
I. The contents are then sieved to remove excess sediments and transported to the boat. The sample bags are brought onto the deck, tagged with a unique sequence of letters and numbers that are linked to the specific reef and quadrat.
II. Samplers will then empty those bags onto the sorting area to be sampled.
III. To assess the size-frequency distribution of oysters on reefs a subset (up to 20 per reef sample) of randomly selected live and dead “box” (hinges still attached) oysters will be measured (see Section 5, Supporting Materials, V Photographs Image 5).
IV. Oyster shell “heights” are measured from umbo to lip.
V. All material will be re-bagged and returned to the sampling location to minimize the disturbance to the bed/reef.

B. Protocol for Natural Bed/Reef Sampling

To document the presence and community characteristics of natural oyster populations and associated habitat, we will conduct targeted surveys across the geographic regions. Initial rapid reconnaissance trips will be conducted to determine the presence and extent of natural oysters. At locations with oysters, we will determine the level of sampling required using a random stratified approach along a transect running through the middle of the bed on the longest axis (Figure 4).

1. Census: If an area with wild oysters is relatively constrained in space and not densely populated (>10/per m2) then all oysters will be measured and counted, the area delineated, characterized (see #6 below), and no further sampling will be necessary.
2. Each transect will be stratified into 10m sections, with two 0.25m quadrats being placed at random per 10m section.
3. No less than 3 quadrats will be sampled per transect.
4. At each quadrat, the number of living oysters, the height of the two smallest and largest oysters will be measured with a caliper (United Scientific, 150mm, plastic, readability 1mm).
5. Within each quadrat we will characterize the sediment type, subaqueous soils, percent cover and species of algae will be recorded.
6. The overall area that the transect is placed will also be characterized by recording qualitative features such as adjacent marshes, upland vegetation, overhanging trees, presence of fresh water sources, cooccurring invertebrates, man-made structures (see Section 4 Supporting Materials, V Photographs, Image 6), and oyster scarring amongst other site level details.
7. Sampling Thresholds:
    a. Transect sections with (i) an average initial density estimates greater than 10 oysters per m^2 and (ii) a range in oyster height greater than 25mm (representing two age classes) will be considered self-sustaining oyster beds (Powers et al. 2009, Theuerkauf et al. 2017) and further sampled using the standard quadrat sampling approaches conducted at restored reefs (See Section B2, Task 3, #2, Part A).

b. Transect sections that do not meet that minimum threshold will not be sampled further and results from transect sampling will be used to characterize the site.



Sample	Estimated Density from Transect survey(#/m2)	Actual Density (#/m2)	Size range > 25mm	Further Sampling
1	3	2	Yes	No
2	**25**	**12**	**Yes**	**Yes**
3	3	2	No	No
4	3	4	Yes	No
5	0	1	No	No

Figure 4*. Schematic for transect sampling approach used in areas with natural oysters to determine the level of sampling required. Transect sections with (i) an average initial density estimates greater than 10 oysters per m2 and (ii) a range in oyster height greater than 25mm (representing two age classes) will be further sampled using the standard quadrat sampling conducted at restored reefs.

*Figure numbers referenced reflect the order and labels found in the QAPP, not this reporting document.

v. Creation of a RI-DMF Geodatabase in Support of Habitat Suitability Index Modeling and the SREP

Foundational to supporting Objective 2 was the collaboration of DEM with outside partners to collect, organize, and archive spatially explicit data on the locations of both water condition testing stations, habitat features, and natural/restored oyster populations, amongst other landscape scale features into one accessible geodatabase. Using both SNEP and non-SNEP funds we gathered relevant historical and contemporary habitat and water conditions data across a fragmented landscape of coastal salt ponds, harbors, and islands within the larger Narragansett Bay estuary. These individual data sets were then housed on DEM servers, QA/QC'd and then used to build an ARCMap based geodatabase. The various datasets existed in a variety of formats and were collected from non-profit, NGO, state, and federal agencies. While building this geodatabase we were simultaneously surveying much of the state of RI for the presence of oysters during the 2021-22-23 field seasons and placing temperature and salinity loggers at sites with large natural populations of oysters. The current geodatabase is comprised of individual feature layers for each type of data collected, all of which are housed in ARCGIS Pro (2023) and archived on DEM servers (See Section 4 Supporting Materials, Part IV, Technical Memoranda and Data Analysis, II Geodatabase Feature Layers Table).

This multidimensional geodatabase provides managers and restoration practitioners a means to gain a greater understanding of oyster habitat and water conditions. It includes historical data spanning decades, limited time series data on water conditions such as dissolved oxygen, salinity, and temperature, as well as aqueous soils, and submerged aquatic vegetation. The necessity of aggregating these data in one place and the utility of this archive are critical components to improving stewardship of oysters and other resources within the coastal zone of RI. The results of these efforts have already aided in the identification of restoration priorities and strategies in the state to manage oysters.

Important to the DEM and partners is that the geodatabase houses spatially relevant coastal data in a single place making future mathematical modeling or analyses requiring large data pulls straightforward and accessible (e.g. generalized additive models, habitat suitability indices). While oysters serve as the primary focal species for this work, the geodatabase has great utility to benefit other species of concern within Rhode Island such as soft-shell clams *(Mya arenaria)* or Bay Scallops *(Argopectin irradians).* Through the systematic analysis of these geospatial data we will make better informed decisions to address the interlinked challenges facing Rhode Island's coastal ecosystems and the efforts described here will aid in future effective restoration initiatives. The Division of Marine Fisheries will accept requests for access to these data from partners and collaborators on a case-by-case basis, and due to the sensitive nature of much of the feature layers it will not be an “open access” online database.

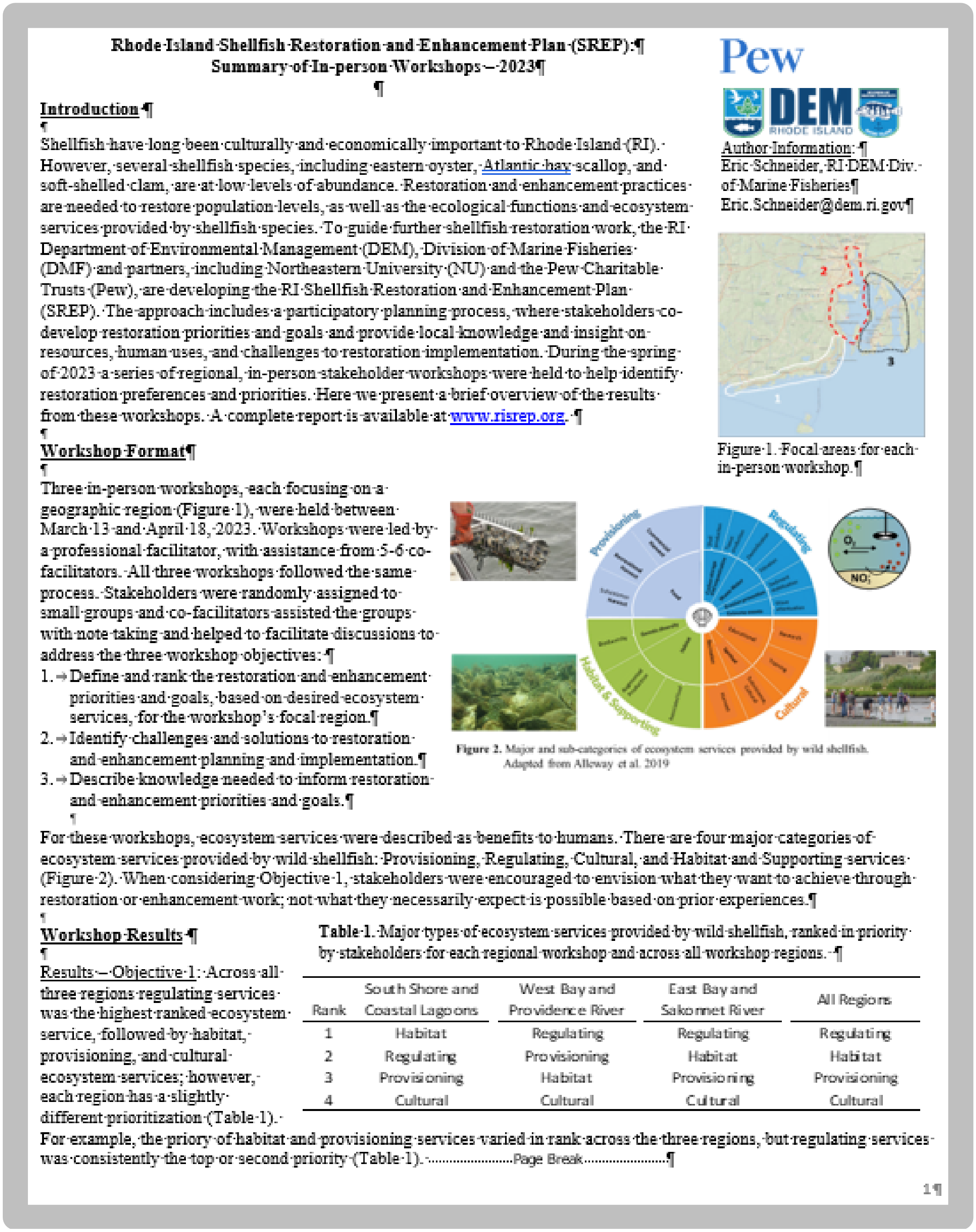
vi. Workshops: Statewide Shellfish Restoration and Enhancement Plan (SREP)

In recognition that shellfish restoration in RI is currently conducted without a unified plan or quantitative goals, the Rhode Island Department of Environmental Management (DEM), Division of Marine Fisheries (DMF), RI Shellfish Initiative, and RI Shellfish Restoration Working Group have all identified the need for a cohesive, overarching plan for shellfish restoration and enhancement activities that reflects the needs of both coastal stakeholders and managers. In response, RI DMF in partnership with NU, RI Sea Grant, URI Coastal Resource Center, NRCS, Narragansett Bay Estuarine Research Reserve, Narraganset Bay Estuary Program, and TNC, is leading the development of a statewide Shellfish Restoration and Enhancement Plan (SREP).

Key tasks during plan development include: collating past restoration and environmental data (SNEP Objective 1), collecting new information on natural eastern oyster *(C. virginica)* populations ((SNEP Objective 1,2), engaging the public and underrepresented stakeholder groups in the planning process, conducting outreach/workshop events, compiling and summarizing information and data from workshops, and forging partnerships between state agencies, NGOs, and RI communities. Ultimately these efforts will result in the compilation of socio-ecological data that will be used to guide the development of the SREP and inform a habitat suitability index (HSI) model for oyster restoration in RI that is at the same time equitable, inclusive, and ecologically restorative.

An early aspect of the SREP participatory planning process was a series of group meetings to capture stakeholder values, knowledge, and to identify priority ecosystem services to inform restoration goals for locations within RI. The remainder of this Section contains a two-page summary of these public workshops (See Inset 1). A full summary is available as part of the final report package and is included as a PDF (see Supporting Materials, Section 4, Part IV, Technical Memoranda, Files, Progress Reports)

Inset 1



Rhode Island Shellfish Restoration and Enhancement Plan (SREP):
Summary of In-person Workshops – 2023

Pew

DEM RHODE ISLAND

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Introduction

Shellfish have long been culturally and economically important to Rhode Island (RI). However, several shellfish species, including eastern oyster, Atlantic bay scallop, and soft-shelled clam, are at low levels of abundance. Restoration and enhancement practices are needed to restore population levels, as well as the ecological functions and ecosystem services provided by shellfish species. To guide further shellfish restoration work, the RI Department of Environmental Management (DEM), Division of Marine Fisheries (DMF) and partners, including Northeastern University (NU) and the Pew Charitable Trusts (Pew), are developing the RI Shellfish Restoration and Enhancement Plan (SREP). The approach includes a participatory planning process, where stakeholders co-develop restoration priorities and goals and provide local knowledge and insight on resources, human uses, and challenges to restoration implementation. During the spring of 2023 a series of regional, in-person stakeholder workshops were held to help identify restoration preferences and priorities. Here we present a brief overview of the results from these workshops. A complete report is available at www.risrep.org.

Figure 1. Focal areas for each in-person workshop.

Workshop Format

Three in-person workshops, each focusing on a geographic region (Figure 1), were held between March 13 and April 18, 2023. Workshops were led by a professional facilitator, with assistance from 5-6 co-facilitators. All three workshops followed the same process. Stakeholders were randomly assigned to small groups and co-facilitators assisted the groups with note taking and helped to facilitate discussions to address the three workshop objectives:

1. Define and rank the restoration and enhancement priorities and goals, based on desired ecosystem services, for the workshop's focal region.
2. Identify challenges and solutions to restoration and enhancement planning and implementation.
3. Describe knowledge needed to inform restoration and enhancement priorities and goals.

Figure 2. Major and sub-categories of ecosystem services provided by wild shellfish. Adapted from Alleway et al. 2019

For these workshops, ecosystem services were described as benefits to humans. There are four major categories of ecosystem services provided by wild shellfish: Provisioning, Regulating, Cultural, and Habitat and Supporting services (Figure 2). When considering Objective 1, stakeholders were encouraged to envision what they want to achieve through restoration or enhancement work; not what they necessarily expect is possible based on prior experiences.

Workshop Results

Results – Objective 1: Across all three regions regulating services was the highest ranked ecosystem service, followed by habitat, provisioning, and cultural ecosystem services; however, each region has a slightly different prioritization (Table 1).

Table 1. Major types of ecosystem services provided by wild shellfish, ranked in priority by stakeholders for each regional workshop and across all workshop regions.

Rank	South Shore and Coastal Lagoons	West Bay and Providence River	East Bay and Sakonnet River	All Regions
1	Habitat	Regulating	Regulating	Regulating
2	Regulating	Provisioning	Habitat	Habitat
3	Provisioning	Habitat	Provisioning	Provisioning
4	Cultural	Cultural	Cultural	Cultural

For example, the priory of habitat and provisioning services varied in rank across the three regions, but regulating services was consistently the top or second priority (Table 1). ....Page Break......................

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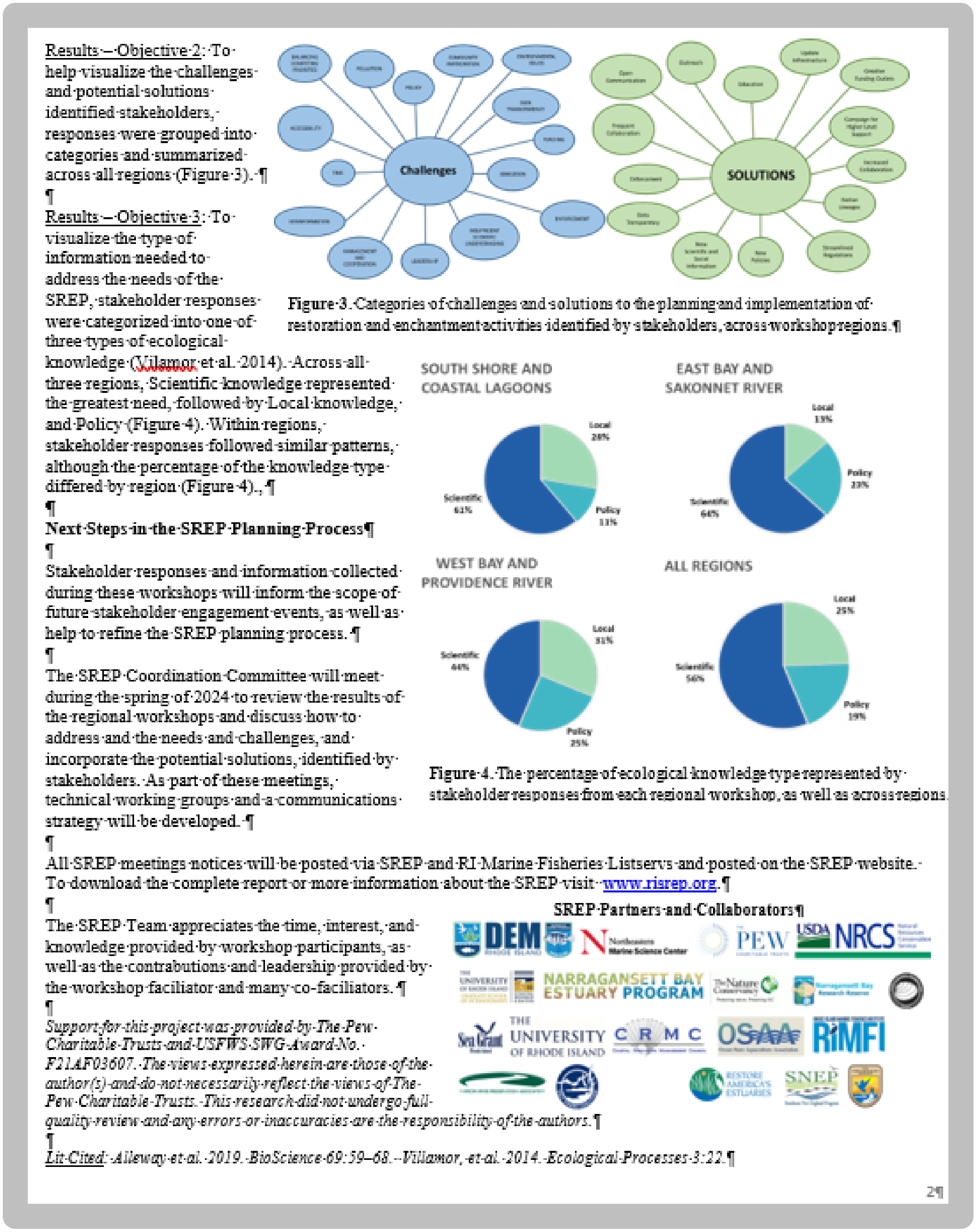
Inset 1 continued…



<u>Results – Objective 2</u>: To help visualize the challenges and potential solutions identified stakeholders, responses were grouped into categories and summarized across all regions (Figure 3).

<u>Results – Objective 3</u>: To visualize the type of information needed to address the needs of the SREP, stakeholder responses were categorized into one of three types of ecological knowledge (Vilamor et al. 2014). Across all three regions, Scientific knowledge represented the greatest need, followed by Local knowledge, and Policy (Figure 4). Within regions, stakeholder responses followed similar patterns, although the percentage of the knowledge type differed by region (Figure 4).,

Figure 3. Categories of challenges and solutions to the planning and implementation of restoration and enchantment activities identified by stakeholders, across workshop regions.

Figure 4. The percentage of ecological knowledge type represented by stakeholder responses from each regional workshop, as well as across regions.

Next Steps in the SREP Planning Process

Stakeholder responses and information collected during these workshops will inform the scope of future stakeholder engagement events, as well as help to refine the SREP planning process.

The SREP Coordination Committee will meet during the spring of 2024 to review the results of the regional workshops and discuss how to address and the needs and challenges, and incorporate the potential solutions, identified by stakeholders. As part of these meetings, technical working groups and a communications strategy will be developed.

All SREP meetings notices will be posted via SREP and RI Marine Fisheries Listservs and posted on the SREP website. To download the complete report or more information about the SREP visit www.risrep.org.

SREP Partners and Collaborators

The SREP Team appreciates the time, interest, and knowledge provided by workshop participants, as well as the contributions and leadership provided by the workshop faciliator and many co-faciliators.

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<u>*Lit Cited*</u>*: Alleway et al. 2019. BioScience 69:59–68. Villamor, et al. 2014. Ecological Processes 3:22.*

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VI. Deliverables and Milestones

Quality Assurance Project Plan Development

Building the QAPP required a thorough review of field methods, supporting literature, protocols, and procedures as referenced in the SNEP proposal. To facilitate the process of preparing the QAPP we held meetings with DMF personnel, EPA consultants and reviewers, partners NU and TNC. Of particular importance was a discussion of the scope and goals of the QAPP and how the two main objectives (see section 2.I) were integrated. Following those meetings, we prepared a series of drafts which we distributed to project partners for comment. We also conducted field reconnaissance and practiced various methodologies in support of the QAPP at sites in the southern RI salt ponds and western Narragansett Bay (see Supporting Materials, Section 4, Part V, Photographs, Images 1-3). Findings and lessoned learned that emerged from developing the QAPP have included detailed decision trees for sampling sites that may be difficult to access, formalizing the chain of custody for data, and review curation/acceptance and rejection of outside data. Additionally, we established field sampling priorities, and further developed the theoretical framework for the creation of the Habitat Suitability Index (see next section). The QAPP was signed and accepted by project officers and quality assurance experts at the EPA on August of 2021.

HSI-Framework.

Data needed to inform the Ecological Node of the SREP includes determining the status of restoration and wild populations and (2) developing an oyster habitat suitability index (HSI) model for oyster restoration (See Section 4 Supporting Materials, Part I-A and B). The data and results of the proposed work will inform the Ecological Node and be used within the SREP process by DMF and NU to develop an oyster reef HSI) to guide future restoration decision-making in RI. The following narrative contains a draft framework for the formulation of oyster habitat suitability index (HSI) models that was included in the draft QAPP document (See Section 4 Supporting Materials, Part I-B) . HSI models provide spatially explicit information on the capacity of a given habitat to support a species of interest. Using data collected from field and secondary sources, a series of spatially explicit GIS layers consisting of oyster conditions and environmental characteristics will be created for the study region. Variables used in the HSI model may include both physical and biological factors measured by field surveys or informed by secondary data (e.g., physical attributes, water condition monitoring).

At the time of this report, we have progressed through the first phase of the development stage (see Section IV, Supporting Materials, Part I.B) and are proceeding into the modeling stage in 2024, with HSI outputs and maps to be ready by 2025. Following the completion of the HSI work the model outputs will be include in the RI Statewide Shellfish Restoration and Enhancement Plan (SREP).

VII. Lessons Learned and Findings

Lessons Learned

During the grant period from October of 2020 to December of 2023 we overcame challenges and completed the tasks in support of Objectives 1 and 2 (See Section 2.I). In particular, the challenge of harmonizing field data collection, recording, and entry techniques consumed significant funded and unfunded project time. Although straightforward in theory, the acts of arriving to a site, assessing oyster size and density accurately, and then repeating those methods with different partners, and under various conditions was non-trivial.

Calibration of Data Collection and Techniques:
The refinement of field methods was ongoing in the first season May-September of 2021. During this time areas of varying oyster density and extant were found and the first collaborative field meetings were held with partners (TNC/NU). We spent several days in the field (see Section 4, Supporting Materials, Photographs, Images 1-3, 24-25, 40, 48) purposefully calibrating our techniques, modifying field data sheets, and the roles of personnel.

We encountered challenges based on the manner in which sampling can occur in shallow subtidal areas which is dependent upon the water conditions/turbidity at the time of the survey. The ability of a snorkeler to remain submerged, or a diver to maintain neutral buoyancy is paramount to obtaining accurate data (see Section 4, Supporting Materials, Photographs, Images 28, 35-37).

Training partners, interns, fellows, and research assistants how to properly take notes, the basic sampling schema, and in-field time management was central to collecting consistent data. Several sites were carefully surveyed only after we had 2 seasons of experience with other areas due to their high density and unique distributions of Oysters (see Section 4, Supporting Materials, Photographs, Images 40, 45, 46, 52-54, 55). Following on-the-water exercises we would conduct post-operation discussions, ask for guidance from partners, and evolve our techniques to be more efficient and pragmatic, which ultimately allowed us to collect better data, with higher confidence, across a larger geographic area.

Data Sheets:
Despite having existing data sheets to use from similar surveys of oyster projects conducted by DMF we found it necessary to develop a standardized sheet. This sheet took into account the several modes of sampling we employed and allowed us to more easily harmonize data across sampling strategies (reconnaissance, census, transect/quadrat). This “one-size-fits-all” type of sheet was quickly deemed too cumbersome and we settled on two main in field data collection sheets (see Section 4 Supporting Materials, Part IV, III, i-ii). Importantly following the collection of data in the field it was necessary to apportion at least 2 hrs per day of field work to clean, edit, and keypunch those field notes.

GPS and Digital Georeferenced Pictures

Throughout the course of our field work (see Section 2, Project Maps and Results, Part II, Field Work Table 2021-2023) for a complete list of sites/dates/activities) we relied upon handheld GPS units to collect point and polygon tracks, as well as smartphone handsets to collect thousands of images with imbedded temporal and georeferenced metadata (e.g. latitude/longitude/direction/time). The use of a digital camera coupled with global positioning was one of the most powerful tools for field work. Although digital image resolution and positional accuracy can vary based on satellite or cell signals much data is recorded in pictures of the work, and datasheets were quickly backed up in the field to ensure proper data chain of custody.

Data Entry QA/QC

At any stage of a project the time that should be apportioned to migrating data from analog to digital formats should not be underestimated. Taking data from handwritten hard-copy notes or digital images, then key punching them into a database, and finally checking those notes for errors was a time-consuming part of this project. Most of this work outside the QA/QC exercises was handled by interns/fellows/research assistants supported on non-SNEP funds.

Beginning in the late summer of 2021 and ending in December of 2023 Macfarlan began entering and training partners how to enter the large and multi-dimensional entries from fieldnotes into the linear confines of excel tables. As described above the development of a reliable and easy to follow datasheet aided in making data entry straightforward, however there invariably were details and notes collected within those sheets that needed special attention. The initial datasheets and field notes were relatively simple, overtime they became more complex, collecting data on a range of site level factors suspected of influencing oyster size and density. That complexity and the evolution of the field datasheets proved to be challenging for partners and resulted in significant time being spent in the QA/QC by the data manager to rectify errors and inconsistencies (see Section 4 Supporting Materials, Technical Memoranda, Part IV, i and ii).

Data Collection Application Development

Following the cessation of field activities for this grant, sites with high densities of naturally occurring oysters will continue to be monitored by DMF staff and occasionally by unfunded partners. These are considered “sentinel” sites and will be monitored for water condition parameters such at temperature and salinity.

To carefully and methodically collect data on these sites and new areas that may be found with healthy oyster populations a streamlined and electronic version of our paper data sheets is under-development. Based on the three seasons of field data collection and methodology refinement from keypunching to QA/QC we will be moving to a mostly electronic format for in situ observations in the future. At this time with unfunded partner NRCS and outside the scope of this grant we have developed several applications specifically for use while surveying oysters. As the constellation of free and modifiable platforms increases, we hope to reduce the large amount of time it took to enter and QA/QC data, while increasing accuracy, accountability, and ease of sharing those data with partners. This type of development could not have been possible without SNEP and the time afforded to field-test several iterations of physical data-sheets in the field and working through various sampling protocols and QA/QC exercises following field activities.

Findings

This project has captured a contemporary snapshot of the current extent of natural and restored Eastern Oyster populations within Rhode Island state waters. We canvassed biologically relevant shorelines from the Connecticut to Massachusetts borders, from the rivers that feed the upper Narragansett Bay to the coastal lagoons along the south shore and salt marshes in between. We found that although there are far fewer oysters now compared to historical accounts, these resilient bivalves are able to maintain persistent populations in some areas. Several factors appear to be working in combination to allow the recruitment, survival and growth of oysters including but not limited to freshwater inputs, bathymetric and landscape choke points that form larvae sinks, sheltered shores, overhanging trees, the presence of some types of green and brown algae.

We found the distribution of oysters in the state to be patchy and those patches were small (>10m2) compared to the potentially large size of the Narragansett Bay estuary and the south coast salt ponds. Although a total population abundance survey within the state was not a goal of this project it appears that abundance is much lower than historical highs and consistent with reports from other Atlantic states that have noted significant declines. At most sites visited where oysters were found their population density was less than 5 oysters/m2, there was single size class present, and oysters on average were less than 3 years old based on shell heights. The opposite was true of a small number of sites (3) that had large amounts of oysters where densities exceeded 100s per square meter, there were multiple size classes, however oysters were relatively small. Counterintuitively many sites that were chosen for field surveys, having a combination of characteristics known to support oyster populations, were found to have very low densities or none. Additionally, we found that most restoration sites for Eastern Oysters were in slow decline with regards to density of individuals and exhibited signals of a lack of recruitment further supporting the need for comprehensive HSI modeling efforts (see Section 4, Part IV Photographs, Image 49). For a detailed overview of the results please see Section 2.X.ii below.

VIII. Obstacles and Setbacks

We experienced delays related to several interrelated factors, including: an extended period needed for grant award finalization and acceptance, additional time needed for completion and execution of cooperative agreements (CAs) with partners (i.e., NU and TNC), and delays in hiring staff, supported by non-SNEP funds. The progression of the global pandemic affected personnel availability and travel. These delays affected the timing of QAPP development and the initiation and duration of field survey activities. It necessitated the request for and approval of a no-cost extension in November of 2022, that prolonged the timeline of the project through December of 2023.

IX. Processes and Project Outcomes

In support of project Objectives (1 and 2, see Section 2.I above) we developed standardized workflows, tiered sampling techniques, and methodologies that were communicated to partners. These included: field and desktop processes, conducting extensive field work, and gathering data on local oyster populations. We aggregated both published and unpublished data from partners, colleagues, collaborators, and outside organizations. Here we present an overview of the outcomes of those efforts and links to other sections within this document that provide better resolution.

In support of Objective 1 we evaluated existing oyster reef restoration sites in the South Shore Coastal Ponds, Block Island, the upper Providence River, eastern and western Narragansett Bay, and the Sakonnet River. We worked closely with partners to determine the locations and status of existing restoration reefs. We then sampled those reefs using the standardized techniques outlined in the QAPP that were consistent with ongoing surveys and the body of literature on restoration sampling (see Sections 4, Supporting Materials, V Photographs, Image 4, 23-26). We also gathered as much historical data as possible on those restoration reefs (e.g., area of restoration, oyster size at out planting, when out planting occurred).

In support of Objective 2 we assessed wild oyster populations and potential restoration sites in the South Shore Coastal Ponds, Block Island, the upper Providence River, eastern and western Narragansett Bay, and the Sakonnet River. After developing the QAPP and field data collection approaches we arrived at a methodology by which we can rapidly survey, evaluate, habitat and oyster characteristics in a given area based on an initial reconnaissance visit. By efficiently evaluating large swaths of the state for wild oyster populations and mapping historical oyster locatons we were able to gather the necessary data that will feed into habitat suitability index (HSI) modeling exercises. This fulfills the goals of the Ecological Node of SREP and the collection of “New and Existing data”. Those models are currently in progress and will allow the DEM and stakeholders to more appropriately pick where, when, and how shellfish restoration should be targeted (see above Section VI. Deliverables and Milestones, HSI Framework).

X. Changes to the Project, Summary of research results

<u>Changes to the Project:</u>
No significant changes were made to the project during funding period, with exception to acquiring a “no cost extension” from SNEP to complete work that was delayed. Minor clarifications to procedures described in the QAPP were vetted by all partners and communicated to all collaborators (see above Section V i and iv, for QAPP narratives and technical descriptions).

Summary of Research Results

We performed oyster reconnaissance sampling at a total of 350 unique locations throughout the seven regions in RI (See Section II, Project Maps and Results, Figures 1 and 2). Using the tiered approach, the density of oysters found in the initial site visits yielded a subset of 10% of sites receiving additional sampling to collect data on oyster shell heights, density, water conditions, and habitat types (See Section 4, Part IV, a. QAPP). Eighteen of those 30 locations have the potential to be “sentinel sites” for long term monitoring of populations and local water conditions (See Section II, Project Maps and Drawings, Figure 1, red dots indicating logger locations).

In the following narrative we distill in general terms where we found oysters, what their density and patch sizes were, what substrates oysters were growing on, and include some broad observations about site conditions. We are not including detailed maps, or size/density figures in this report to protect the location information of sites that could be easily overharvested. However, per the conditions of the proposal and scope of work those data will be made available to partner organizations in the future and will be used in the development of the SREP and HSI models.

i. Spatial Coverage of Oysters Samples

Most of the sampling efforts were in areas that were historically known to have oyster populations, were part of restoration efforts in the past, and/or were likely to hold populations of oysters due to local environmental conditions such as estuarine features, hard substrates, and restrictive water flow regimes. See Section 4 Supporting Materials, II. Project Maps and Results, Figure 1.

ii. Oysters Patch Size

Most oysters found and measured in the field surveys were located in just a few locations where densities were high and where there were several year classes present (see Section 4, V, Photographs, Image 9). Most regions across the study area had few oysters scattered over a large area (i.e., very low densities). Oysters in these areas often consisted of single-set oysters or several individuals clustered together. Typical low density patch sizes of oysters throughout the region were approximately 10 – 100 m^2 in size, while there were areas of much larger contiguous beds that were 100 - 1000 m^2 in total surface area coverage.

iii. Oyster Density-Overall

As previously stated, we identified many locations where oysters can be found although in low densities of less than 5 oysters m^2 (See Section 4 Supporting Materials, II. Project Maps and Results, Figure 9). With few exceptions, the majority of historical/contemporary oyster restoration sites appear to suffer from a lack of recruitment. Over time most restoration beds slowly decline in oyster density likely due to natural mortality being greater than the addition of new individuals. Exceptions to that rule are in a very small subset of sites located in the south coast salt ponds that receive episodic recruitment pulses. The areas with the greatest densities typically were along the south coast and Narrow River, while some small pockets of higher densities were found in other parts of the bay (see Section 4, Part IV Photographs, Image 54).

iv. Overall Size Frequency

In general, we found a high degree of variability in the shell shape and size in the course of our field work (see Section 4, V, Photographs, Image 10, 22). Based on our preliminary findings across the state there is a distinct pattern in the size and age of natural and restoration oysters. The majority of oysters range from approximately 40 - 80mm in shell height (See Section 4 Supporting Materials, III. Project Results Maps and Results, Figure 10). We observed small recruits(>13mm) in only a few areas of existing high population densities, and a very few large oysters throughout the regions. When viewed through the lens of shell height as a proxy for oyster age: we can see that most of the observed oysters are in their second year of growth. As they transition into year two there is a steep decline in overall number, with a long right-tail revealing a small number of individuals surviving beyond 4-5 years of growth.

v. Site Conditions

We found that most of the natural oysters surveyed had recruited to hard substrates (See Section 4 Supporting Materials, III. Project Results Maps and Results, Figure 11.). Restoration oysters tended to be growing on shell cultch and other oyster shells while natural oyster populations were typified by their attachment to pebbles, rocks, and cobble (see Section 4, V, Photographs, Image 2, 3, 4(restoration sampling), 5, 10, 13-18, 24, 30, 50, 51, 53). In the absence of those common hard substrates and in areas with generally softer subaqueous soils (e.g., Fort Neck or Pishagqua) we found oysters recruiting to living clusters of ribbed mussels (*G. demissa*) at the edges of *Spartina* spp. beds (see Section 4, V, IV Photographs, Image 32). Those ribbed mussels could be an overlooked refugia for oysters in areas where reefs or beds may not survive due to the subsidence of the relatively heavy shells into soft subaqueous soils.

Given the glaciated past of Narragansett Bay and the salt ponds the presence of gravel/rock and cobble in shallow subtidal and intertidal areas is common, thus settling substrate appears widely available. Most salt ponds such as Ninigret, and bay systems such as Wickford Harbor, Nannaquacket, Greenhill Pond, or the Narrow River have similar landscape level mosaics of marsh interspersed with cobble and boulder outcrops (see Section 4, V, Photographs, Image 7). However, despite the relatively common occurrence of these suitable substrate types those areas were mostly found to have patchy areas of low oyster density (see Section 4, V, Photographs, Image 20, 21, 27).

Throughout our surveys we recorded algae cover, and in many cases the genus and species found. In areas rich in rockweeds (e.g.-*Fucus* spp. and *Ascophyllum* spp.) and sea lettuce (*Ulva* spp.) species also co-occurred with natural oyster populations. Within the salt ponds and in parts of Narragansett Bay we also found that the presence of overhanging deciduous trees was associated with small relatively dense populations of oysters compared to surrounding suitable environments, and occasionally encountered venomous jellies in those same areas (see Section 4, V, Photographs, Images 38, 47).

Water temperature, dissolved oxygen, and salinity measurements were collected using handheld YSI Pro-Solo multiparameter tools for snap-shot measurements and longer-term autonomous loggers to collect long-term data. HOBO U20 loggers continue to collect temperature and salinity data at a subset of “sentinel” sites throughout the state (see Section 4, V, Photographs, Images 28, 29, 52). Those data collected since 2022 will be integrated into the HSI modeling framework and made available to partners on request. See Section 4, III, Figure 12 for an example plot of temperature and salinity over time at Fosters Cove in Charlestown RI.

vi. Historical Records, and Institutional Data Research Results

Thousands of pages of physical and scanned electronic historical documents in RIDEM DMF archives were examined. Thirty-five records were found that showed spatially specific notes on the location of living oyster beds at the time of their writing. All those areas were checked during the course of this project (see Section 2, V, Part ii for more information on how we gathered historical records).

vii. DEM, TNC Internal Survey Data, and Outside Sources: Water Conditions

In addition to gathering in situ measurements of temperature and salinity at sites that we directly surveyed, we also mined decades of survey and monitoring reports from projects conducted by the DMF or TNC (e.g.-coastal pond survey (finfish), bay seine survey (finfish), and annual eelgrass fish habitat productivity surveys. All those surveys use a similar means of taking snapshots of water conditions with hand-held multiparameter tools, refractometers, and thermometers, and some included longer term logger-based datasets. These data were evaluated and may be able to fill in spatial and temporal gaps for water conditions throughout the bay and salt ponds. In addition to those data, we also have incorporated the Watershed Watch and Salt Ponds Coalition water quality data which represent one of the longest citizen science datasets in the US.

XI. Project Impacts

The impacts of this project will be manifold. To date, the results of a subset of our work have already been used to inform localized shellfish management, including oyster harvest regulations, in a south coast salt pond. Moving forward the results will continue to advance SNEP goals throughout the region. The overarching goal of the proposed study was to encourage resilience (SNEP Goal 1) by the collection of key data that will be used in the development of an oyster restoration suitability model that will facilitate the implementation of the RI SREP and guide future oyster habitat restoration efforts in RI. In addition, our results will be directly used by RI DMF to inform management options and future monitoring and assessment survey work. The datasets produced by this work will be made available to potential partners and end-users (e.g., Narragansett Bay Estuary Program) and will provide a baseline of restored and wild oysters state waters. The tiered, rapid site assessments survey design developed and employed in this project presents an approach that should be considered for surveys of oysters and other shellfish species in RI and the New England region.

We also expect that the site-level attributes for wild oyster populations collected during this project will further illuminate habitat and design elements that may help us find solutions to facilitate new technologies and approaches to improve habitat, aquatic life, and water quality.

Given that oyster reefs provide nursery habitat for economically valuable fish and remove excess nitrogen from estuaries, our project also will have impacts on protecting and enhancing ecosystem services that support local economies in the SNEP region (SNEP Goal 2).

XII. Description of information created or acquired

Over the course of this project we have methodically gathered quantitative and qualitative information on oysters and their habitat characteristics throughout the state. We have also assembled a range of data types from a variety of sources. These data have been integrated into a larger geodatabase that is archived on DEM servers and is the database from which the forthcoming HSI model will be drawing from. Please see the following sections within this narrative for better resolution and descriptions of the information gathered for this project:

i. Historical Data/Surveys: Section V
Primarily from DEM archives, shellfish reports, hand drawn maps, and diagrams.
Data Type: Acquired

ii. Non-Oyster Focused Surveys(TNC/DMF): Section V
Survey work that operates throughout the state and collects data relevant to oyster habitat/water conditions
Data Type: Acquired

iii. SNEP Oyster Field Surveys: Section V
The bulk of the work funded by this SNEP grant, field and desktop
Data Type: Created

iv. Outside Sources Data: Section XI
Provided online by citizen science groups such as the “Salt Ponds Coalition.”
Data Type: Acquired

v. HOBO Loggers: Section XI
Placed throughout the state following the first year of reconnaissance in areas of high oyster density.
Data Type: Created

vi. Geodatabase: Section IV
An ArcGIS based collection of feature layers, spatial and temporal data from a variety of sources, and includes all data described above.
See Busch Poster, Supporting Materials, Section 5, Part IV, e.
Data Type: Created

2.B. Next Steps & Recommendations

During 2024 and 2025, the results of Objectives 1 and 2 will be used to inform a HSI model for oysters, aid in the development of the RI SREP, and inform future management and shellfish survey work. Please see Section VI, Deliverables and Milestones for a description of the HSI model development that will be occurring later this year. Recommended next steps, include:

- Maintain and expand the geodatabase of oyster and habitat variables as new data and information become available.

- Use the geodatabase of oyster and habitat variables to inform a HSI model for oyster restoration and explore the potential to inform other HSI modeling activities (e.g., seagrass).

- Evaluate the potential of including brood stock from natural oyster populations, identified during this project, in oyster restoration and enhancement practices to increase the resiliency of restored oyster beds. Evaluations should include genomic assessment to assess genetic diversity and potential advantageous traits, combined with hatchery and out planting approaches that allow for the evaluation of individual source populations, as well as multiple sources (combined).

- Design and implement a long-term monitoring plan to assess the condition of important estuarine habitats, including oyster and shellfish habitats, and their response to environmental stressors, including anthropogenic impacts and climate change.

- Update the SREP Coordination Committee and seek assistance from partners with analyses and writing of the SREP. Information from this work and subsequent HSI model development will inform social-ecoclinal system analyses to help determine the most appropriate locations for future oyster restoration.

2.C. Compliance

QAPP- Quality Assurance Project Plan Development. The QAPP was finalized and signed by all parties as of August 12th, 2021. Following collaborative and independent fieldwork conducted by TNC and DMF to test out field protocols we will amend the final version of the methods within the QAPP. In brief the edits will allow field samplers to better account for the patchy nature and variation in depths where populations of oysters occur across sites. In particular, clarifying changes were made in “Section B-2 Sampling Methods, Task 3: Assess natural and restored oyster populations and potential restoration sites in the South Shore Coastal Ponds and Narragansett Bay”. Changes will be made specifically to subsections 1 & 2 that deal with surveying the spatial extent and properties of oyster populations. Please see “Findings to Date, Field Methods and Techniques” in this document. Updates to the QAPP will be submitted to the partner organizations by late March of 2022 for review.

2.D. Project Partners

The RIDEM-DMF was the lead organization on this grant, with collaborators from Northeastern University (NU), and the Nature Conservancy (TNC), RI Chapter. In addition to those partners, we received the support from a dedicated group of seasonal interns, research assistants, and Yale Environmental Fellows Program participants. These individuals over the course of the grant cycle were instrumental in completing a variety of tasks in the lab and field to keep our project on track. They also allowed us to exceed the limited geographic footprint of the project to the east bay sites and Block Island (see Section 4, Supporting Materials, Part III. A and B).

Rhode Island Department of Environmental Management, Division of Marine Fisheries

RI DEM-DMF coordinated and executed the majority of the operations to meet the goals and deliverables of the grant. Those tasks included ensuring field protocols were promulgated to staff within DMF, TNC, and NU. In the spring of 2021 preparing the QAPP for dissemination dominated much of the desktop work accomplished and was refined thereafter when necessary.

Importantly the DMF also led field exercises to calibrate techniques and communicate expectations for the various evolutions of field work amongst partners including but not limited to: field reconnaissance, transect and quadrat sampling (see Section 4, Supporting Materials, Part V, Image 29), water condition measures, the tiered sampling approach (see Section 4, Supporting Materials, Part IV, a). The DMF also had the largest areas of the state to cover with regards to geographic distribution of sites, and the most sites with the highest densities of oysters (see Section 5 Supporting Materials, Part II, Figure 1 and). The DMF also increased the geographic area of the original grant to encompass the eastern part of the Narragansett Bay estuary, specifically the Sakonnet River, Mount Hope Bay, and the Kickemuit River, as well as the salt ponds on Block Island. Although that work was unfunded by this grant it was critical in developing a more thorough understanding of the current state of natural oyster populations within RI waters.

The Nature Conservancy (TNC), Rhode Island:

The Nature Conservancy was responsible for reviewing the field techniques, in particular the early development of the QAPP. TNC also was aided by DMF staff at several sites to help finish sampling in particularly dense areas and to provide logistical support. Please see Section 4, Part IV Photographs, Images 31, 33, 34, 44, 48, of TNC staff and interns in the field conducting survey work.

Northeastern University (NU)

NU professors Jonathan Grabowski, PhD, and A. Randall Hughes, PhD, provided valuable expertise and guidance with project scope and design, grant proposal development, QAPP development and survey methodologies, and data QA/QC, and reporting. For example, meetings were held with Drs. Grabowski and Hughes frequently in 2021 to streamline the sampling protocols and ensure a focus on the primary factors to be analyzed and included in post-collection modeling efforts. In addition, Drs. Grabowski and Hughes provided valuable insight about how to build-in efficiencies regarding subsampling areas of RI that had relatively high densities of oysters, as well as purchasing field survey supplies (e.g., data loggers). For instance, it was determined quite early in the project that due to the nature of man-made materials such as docks and seawalls we would exclude those features from sampling (see Section 4, Part IV Photographs, Image 39, 41). This saved time and allowed us to look only at natural areas-which are far more abundant than built structures. Drs. Grabowski and Hughes were in frequent contact with RI DMF (PI, Schneider) to discuss the evolution of sampling and experimental design, to ensure the highest degree of accuracy across a patchwork of habitats and the currently fragmented natural oyster landscape. NU graduate students (see Section 4, Part IV Photographs, Image 11) and lab technician also assisted with field surveys, data collection and interpretation. NU partners were instrumental in shaping the sampling design and with particular emphasis on how and where to sample for natural oyster populations. During the spring of 2021 John Grabowski came down to RI and was able to accompany DMF staff in the field for a day on the water to practice and discuss methods (see Section 4, Part IV Photographs, Image 1).

2.E. Volunteer and Community Involvement

Many people that were not supported by this grant made the work possible and allowed us to cover more of the state than what was geographically scoped for the initial proposal. Three distinct groups of collaborators are highlighted below, however due to the wide-ranging nature of our data gathering this list could be even more detailed.

Community Involvement:
There was not an organized volunteer or community group involved in this project, however coastal residents, fishers, and various other users of the shore were willing to share their local knowledge (see Section V, Photographs, Image 8). Typically, conversations while out in the field with the public prompted us to investigate further, or collect historically relevant anecdotal accounts of oyster presence and absence within their local area of familiarity. These field-based outreach opportunities although spontaneous allowed us to amplify what we were doing with SNEP funding and without exception those interactions were 100% positive in nature.

Fellows, Research Assistants, and Interns:
Another category of personnel although not specifically volunteers were employed through the DMF on non-SNEP funds.

Yale Environmental Fellows Program:

Significant contributions were made by a group of highly motivated interns, fellows, and research assistants over the course of the grant cycle. Of particular note, are two Yale Environmental Program Fellows Natalia Jaworski and Madeline Armstrong who spent the summers of 2022 and 2023 working on this project.

Research Assistants

Consequential efforts mapping, organizing, and working on the QA/QC of spatial data in support of the geodatabase as well as field work was accomplished by research assistant Blake Busch. Following a successful summer season as a DMF intern in 2022, Mr. Busch returned in 2023 as a research assistant and developed his own independent funding to continue working solely on this project.

RI DEM-DMF-Seasonal Interns

Ove the course of grant a group of seasonal interns worked on various aspects of this project. Field activities included wading, snorkeling, walking a large portion of the RI shoreline in search of natural oysters. In lab work included data entry and checking, gear preparation and maintenance, and planning.

Unfunded/Unnamed Partners: Natural Resources Conservation Service

Natural Resources Conservation Service (NRCS) has been a strong partner with oyster restoration, conservation, and research for more than a decade in RI. Via help from the Assistant State Soil Scientist, Jim Turenne, we gained invaluable knowledge of coastal geomorphology, and subaqueous soils. His help in the field whether sampling, measuring, or traveling by NRCS vessel to sites throughout the bay and salt ponds was crucial to expanding our surveys beyond the original regions. His mentorship of staff, interns, fellows, and others involved on the project combined with his technical expertise made it possible to conduct impactful surveys efficiently and accurately (see Section 4. Supporting Materials, Part III).

2.F. Outreach & Communications

Please section 2.E above for explanations of impromptu public outreach in the field, and the list below for structured outreach, scientific talks, posters, and other media germane to this SNEP grant, but not necessarily supported by SNEP funds.

2022

0. Macfarlan and Schneider mentored Blake Busch on an independent GIS project during the fall of 2022 which was voluntary and required no funding while providing valuable maps and insights. Blake is a former DEM seasonal intern who has contributed heavily to field reconnaissance, expanded sampling, and historical data compilation for this project.

   Blake used a subset of the data that we collected to create a series of maps that explored the spatial relationships between natural oyster populations, sources of fresh water, and the presence of phragmites. The completion of that mapping work marks the beginning of formally organizing and using those data described in grant Objectives #1 and #2 into a single repository of related files. Blake presented a poster of this work at the University of Tampa, a picture of which is included in the supporting materials within this document (see Section 4, Figure 2).

2023

I. The Nature Conservancy/ Department of Marine Fisheries Collaborative Summit
    i. Date: March 2, 2023
    ii. Format: In person, 15-minute scientific talks
    iii. Macfarlan presented: “Oyster Habitat Evaluation”
    iv. Schneider presented: “Shellfish Restoration and Enhancement Plan”

II. Annual EQIP Growers Meeting
    i. Date: March 6, 2023
    ii. Format: In Person, Coastal Institute, URI Graduate School of Oceanography Campus, RI
    iii. Macfarlan: Oyster Lifecycles and Restoration Practices

III. Block Island Shellfish Commission Meeting.
    i. Date: May 9th, 2023
    ii. Format: remote, video conference to discuss restoration opportunities, current status of oyster survey work with the Block Island Shellfish Commission
    iii. Presenters: Schneider/Macfarlan
    iv. In attendance: Block Island Shellfish Commission (5 members), public attendees, Block Island Harbor Master, NRCS, DEM, CRMC staff

IV. SREP Workshops:

Please see Supporting Materials Section 4.I for the Draft Framework, see an abbreviated version of the Workshop Results above in Section V, and for additional details and the full text of the workshop report see Section 4. Supporting Materials. V Technical Memoranda, Files, Progress Reports.

a. Workshop No. 1: South Shore and the Coastal Lagoons
    i. March 13, 2023, from 6:00 – 8:00PM, at the Hazard Conference Room, at the URI Coastal Institute on the URI Narragansett Bay Campus: 210 S Ferry Rd, Narragansett, RI 02882

b. Workshop No. 2: West Passage of Narragansett Bay and the Providence River
    i. April 18, 2023, from 6:00 – 8:00PM, at the Hazard Conference Room, at the URI Coastal Institute on the URI Narragansett Bay Campus: 210 S Ferry Rd, Narragansett, RI 02882

c. Workshop No. 3: East Passage of Narragansett Bay and the Sakonnet River
    i. March 15, 2023, from 5:30 – 7:30 PM, at the Common Fence Point Arts, Wellness, and Community Center, in Portsmouth, 933 Anthony Rd, Portsmouth, RI 02871

V. RI Oyster Restoration Training Session-Hosted by RI NRCS in Partnership with RI DEM

  i. September 19-20, 2023
  ii. Schneider and Macfarlan attended both days, were involved in field outings and classroom discussions. They both worked with NRCS personnel to present on several topics: Life Cycle of Oysters, Soils and Site Selection, Permitting Challenges and RI's SREP

VI. RI State Technical Team Meeting-NRCS and Partners

  i. November 8th, 2023
  ii. Format: Remote
  iii. Schneider and Macfarlan attended, Schneider provided updates on oyster restoration work in the state for the past year and provided background and context for those efforts, SREP, and SNEP.

VII. WBLQ Westerly, RI, Gray Sails Studio: Resiliency Radio Hour

  i. October 12, 2023
  ii. Eric Schneider and Gina Fuller District Manager, Southern District
  iii. RI Restoration and Enhancement Plan, in particular oyster restoration, coastal pond ecology.

3. Project Budget Report

Summary Budget Table 1: Grant funds and match expended and processed by RI DEM Management Services through December 31, 2023. An updated budget table, reflecting total costs and invoices through June 30, 2024, will be submitted immediately after DEM and RAE have accepted the final invoices and closed the grant accounting.

Budget Category	Total Budgeted Funds	Total Budgeted Match	Grant Funds Expended Cumulative	Match Funds Expended Cumulative	Match Source (note cash or in-kind)
Personnel	$21,191.81	$4,443.00	$15,525.38	$0.00	**Cash**
Fringe	$11,730.45	$3,206.00	$8,944.36	$0.00	**Cash**
Travel	$0.00	$0.00	$0.00	$0.00	
Equipment	$0.00	$0.00	$0.00	$0.00	
Supplies	$1,666.00	$0.00	$1,628.24	$0.00	
Contractual	$0.00	$0.00	$0.00	$0.00	
Other	$98,937.85	$53,030.00	$87,834.12	$0.00	**In-Kind**
Total Direct	$133,526.11	$60,679.00	$113,932.10	$0.00	
Indirect	$16,473.89	$1,472.00	$10,091.34	$0.00	**Cash**
Total	$150,000.00	$62,151.00	$124,023.44	$60,160.50	

Summary Budget Table 2: Expenditures by project task (Grant Funds Only).

Budget Category	Budgeted Grant Funds	Estimated Expended Progress Period 4	Estimated Expended to Date
Task 1- Grant Implementation and QAPP Approval	Not defined by task	0	0
Task 2- Objectives 1, 2	Not defined by task	In Process	$124,023.44
Task 3 - Outreach and Reporting	Not defined by task	0	0
Total	150,000	In Process	$124,023.44

3.B. Budget Narrative

DEM - Budget Narrative

Grant funds expended by RI DEM through December 31, 2023 were comprised of personnel ($ 15,525), fringe ($ 8,944), indirect ($10,091), and DEM Audit Fee ($750.00), as shown in Summary Budget Table 1. These costs were for participation in oyster survey activities to support of Task 2 (see Table 3 and report narrative for details). The remainder of time committed by DMF staff, including interns, contract employees, and full-time staff utilized non-match, non-SNEP project funded time used to plan and implement reconnaissance and preliminary site assessments, and for the collection of historic and background information.

TNC - Budget Narrative

Grant costs for totaled $28,884, including $15,694 and $6,466 for personnel and fringe, respectively, as well as $5,273 for indirect costs. Additional costs included materials and supplies, including data loggers and field and survey supplies, totaling $26 and costs for travel for field surveys was $1,424. Total match provided by TNC was $10,078.

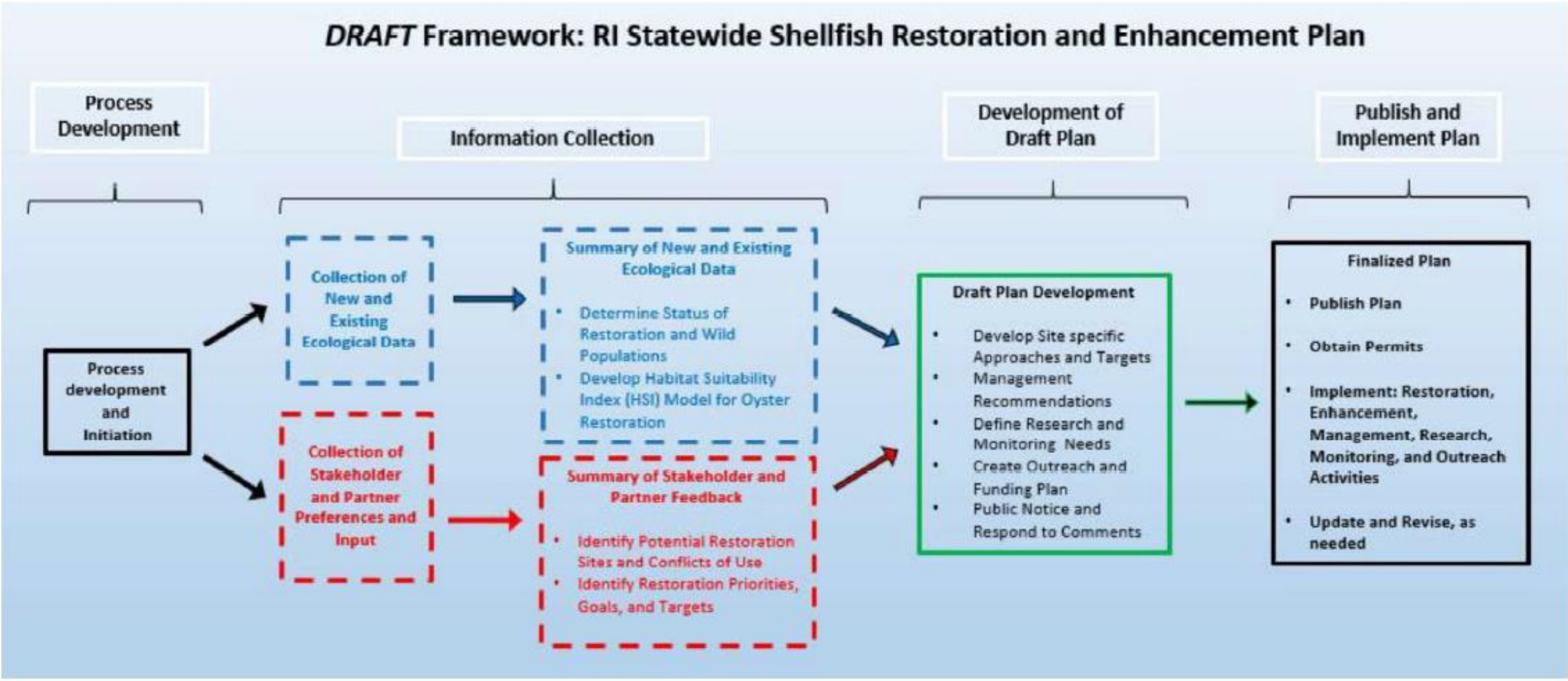
NU - Budget Narrative

Grant costs for totaled $72,676, including $45,375 and $ 4,773 for graduate student personnel and fringe, respectively, as well as $14,567 for indirect costs. Additional costs included materials and supplies, including data loggers and field and survey supplies, totaled $7,221 and costs for travel for field surveys was $740. Total match provided by NU was $39,414.

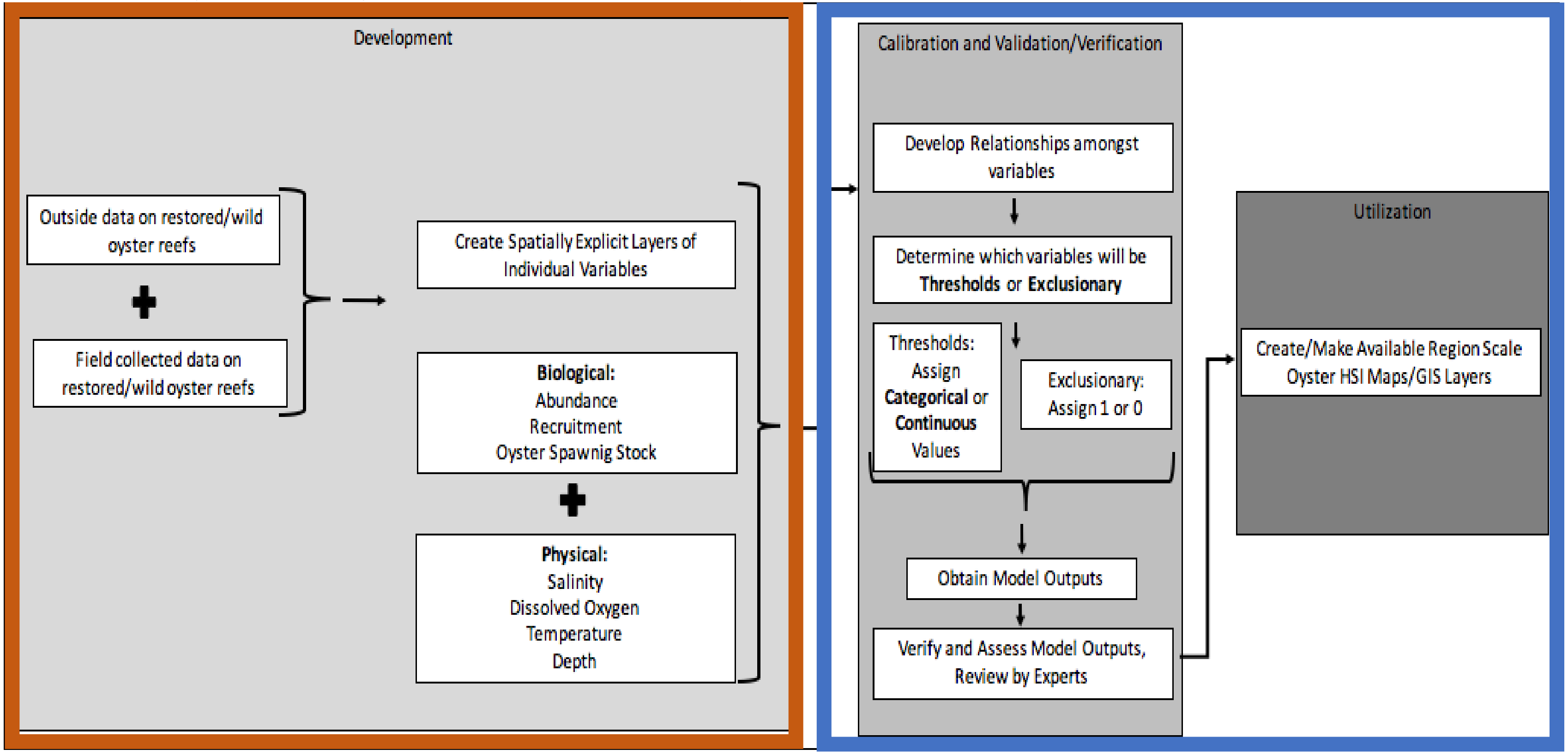
4. Supporting Materials

I. SREP Outline and Oyster HSI Framework

A. **Draft Framework for the RI Shellfish Restoration and Enhancement Plan (SREP).** Work related to this SNEP Grant Proposal directly focuses on, and is restricted to, the Collection and Summary of Ecological Data (blue boxes below).



B. **Oyster Habitat Suitability Framework**. Oyster HSI Framework. The above diagram outlines the process by which the data from Objectives 1 and 2 will be used to develop an oyster Habitat Suitability Index (HSI), a critical component of the SREP. The orange box indicates the information collected under the SNEP funding agreement for this project (i.e., Outside data and field collection of data on restored and wild reefs) and the initial phases of HSI model development (post-SNEP grant award). The blue box encompasses the steps which are scheduled for completion in 20



II. Project Maps and Results

Figure 1. Map showing spatial extent of proposed work reproduced here from the QAPP. Regions 1-5 were originally proposed and funded, while regions 6-7 were unfunded additions. Former restoration areas are excluded from these projections, but have been mapped and are included in the geodatabase.

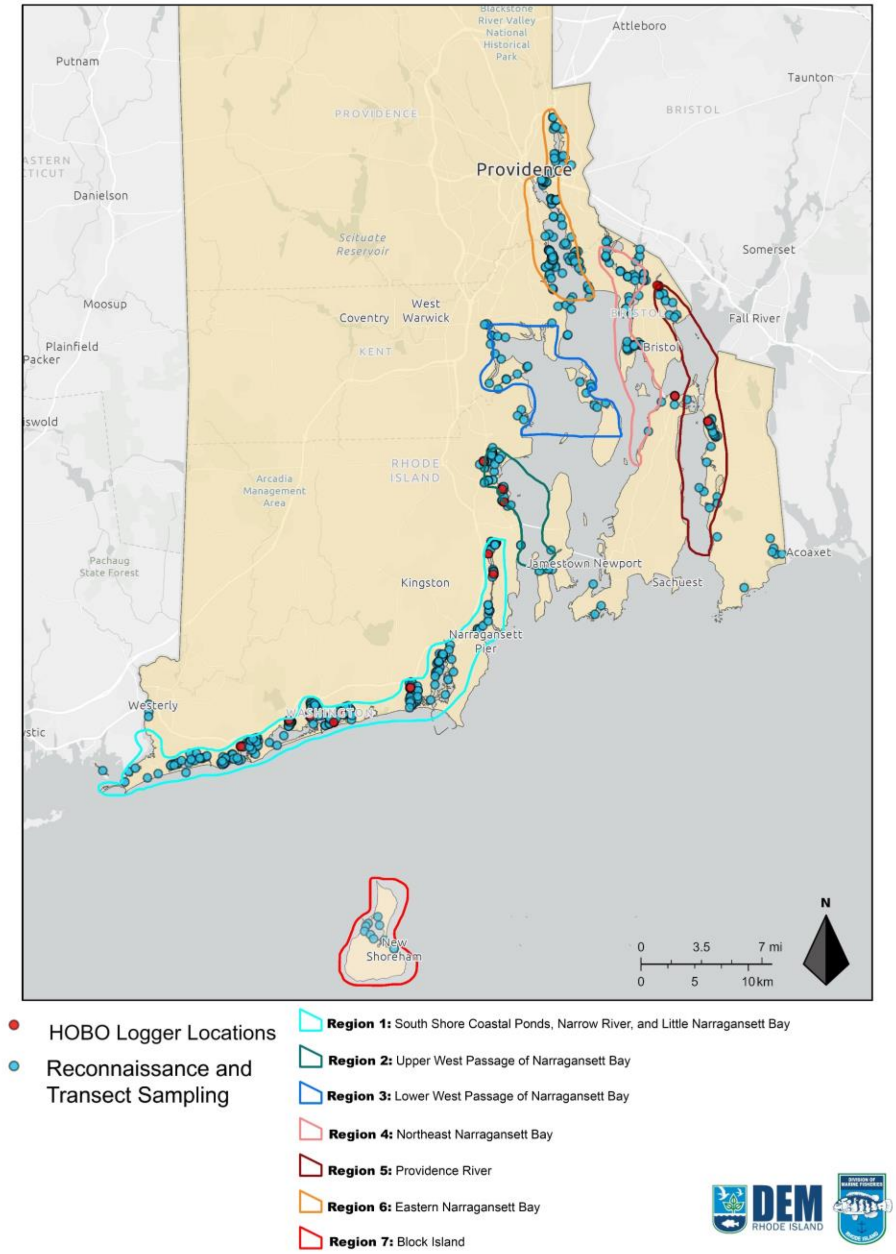


Figure 2. Map of south shore coastal ponds and the Narrow River, Region 2.

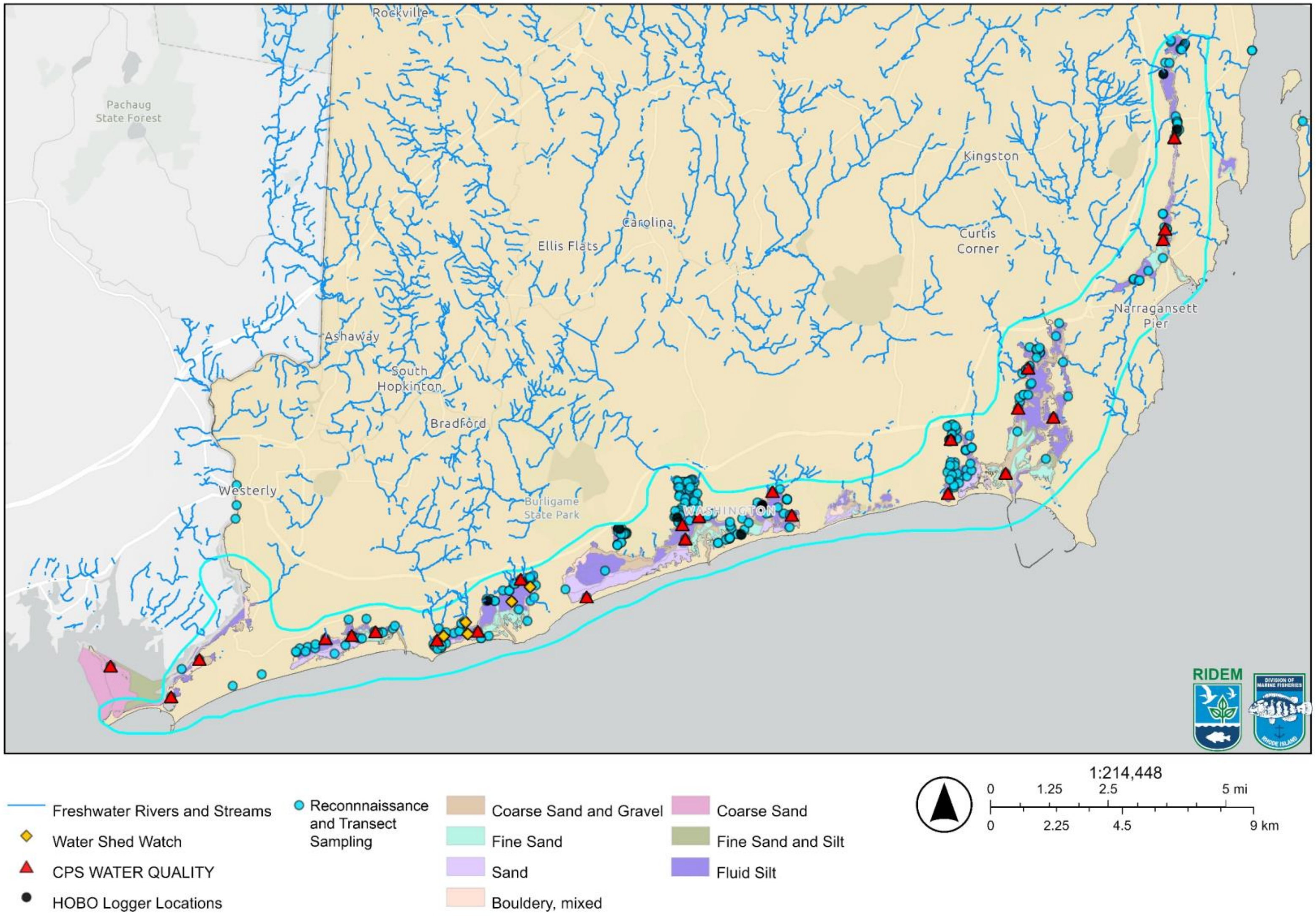


Figure 3. Map Of Region 3, lower west passage including Wickford Harbor and Jamestown.

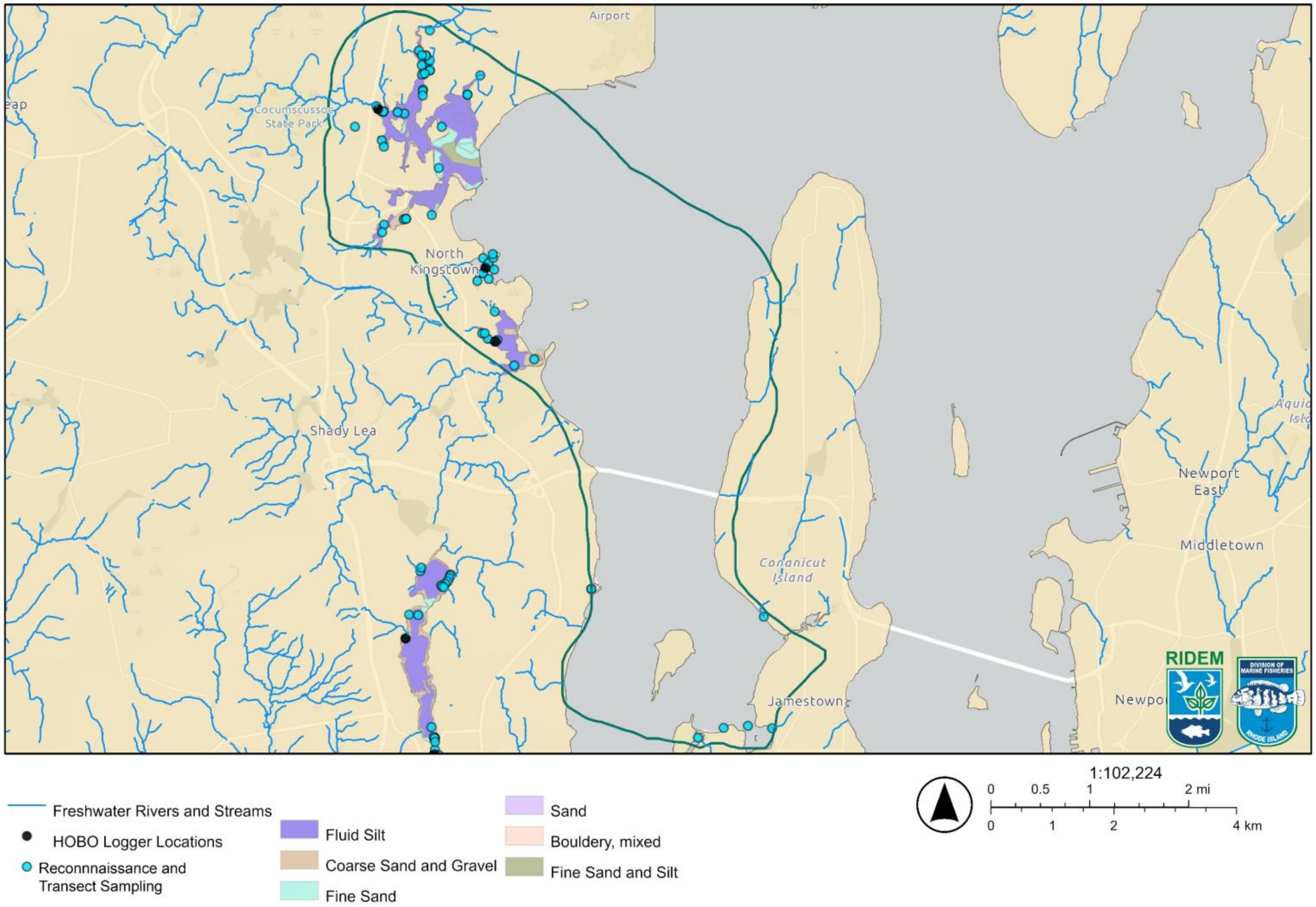


Figure 4. Map of region 4, Northern Prudence Island, Quonset, East Greenwich and Warwick.

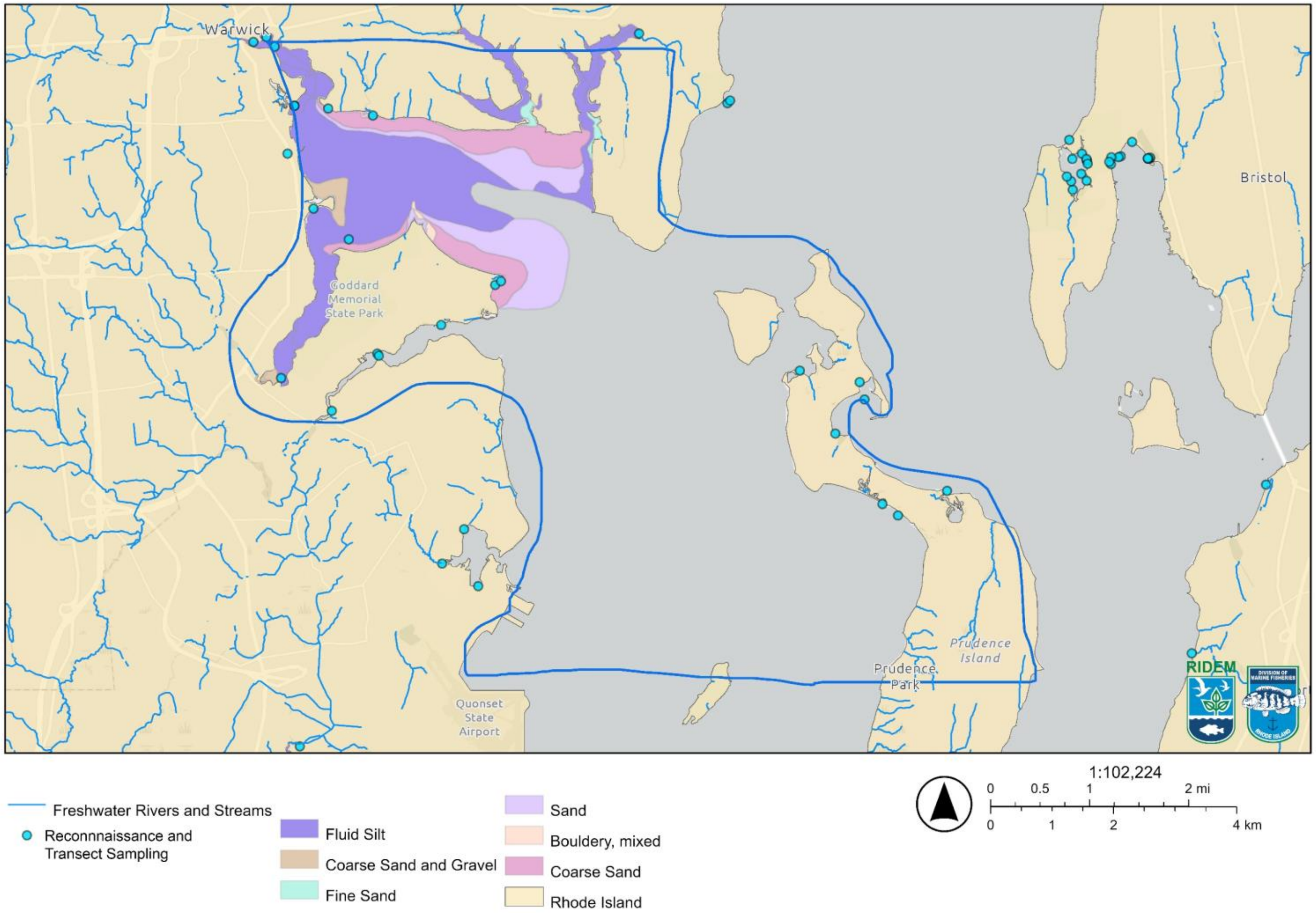


Figure 5. Map of Region 4 Barrington, Warren and Palmer Rivers, Bristol Harbor and northern Aquidneck Island.

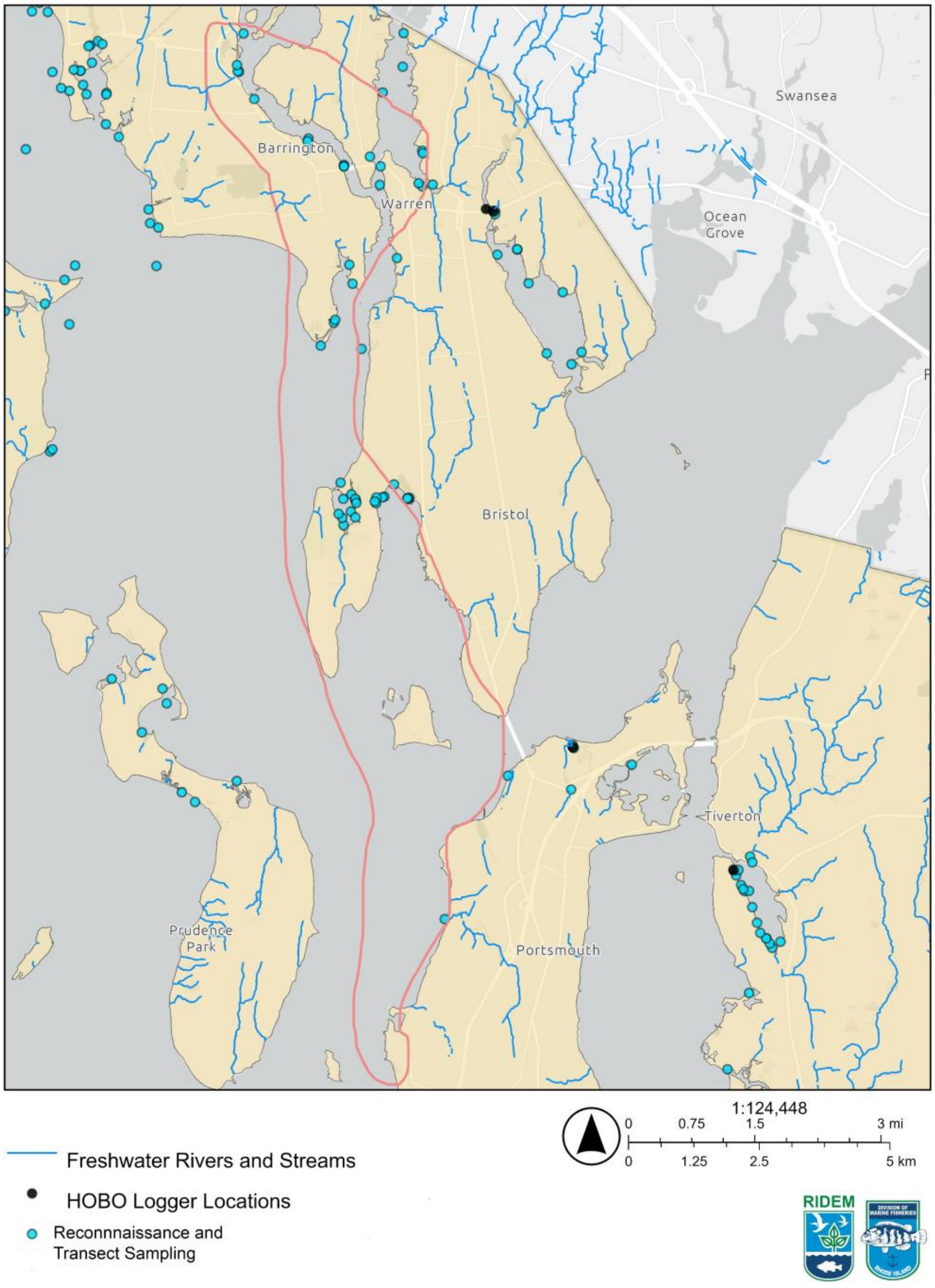


Figure 6. Map of Region 5 lower Providence River.

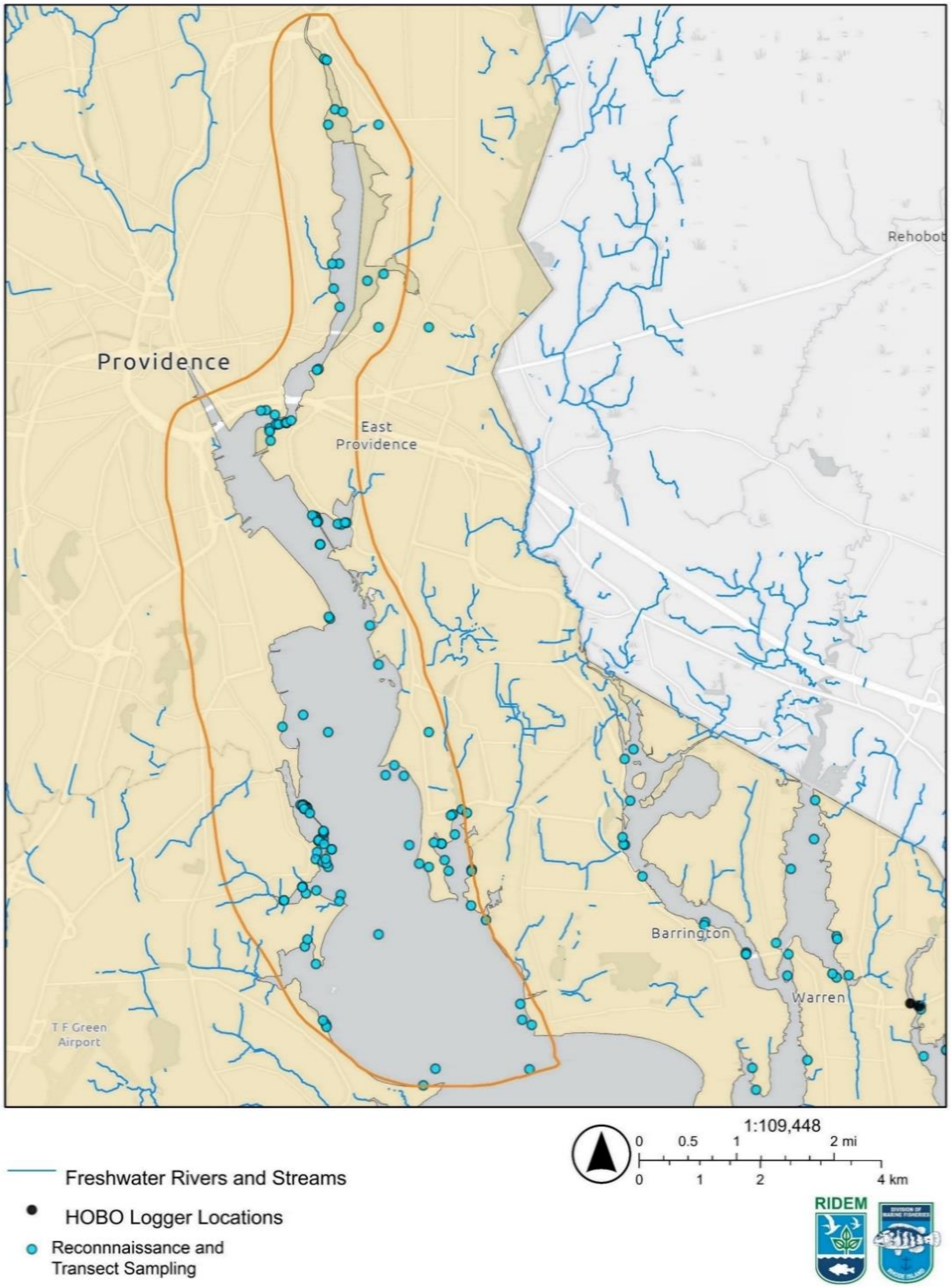


Figure 7. Map of region 6 the Sakonnet and Kickemuit Rivers, Nannaquaket and Little Compton.

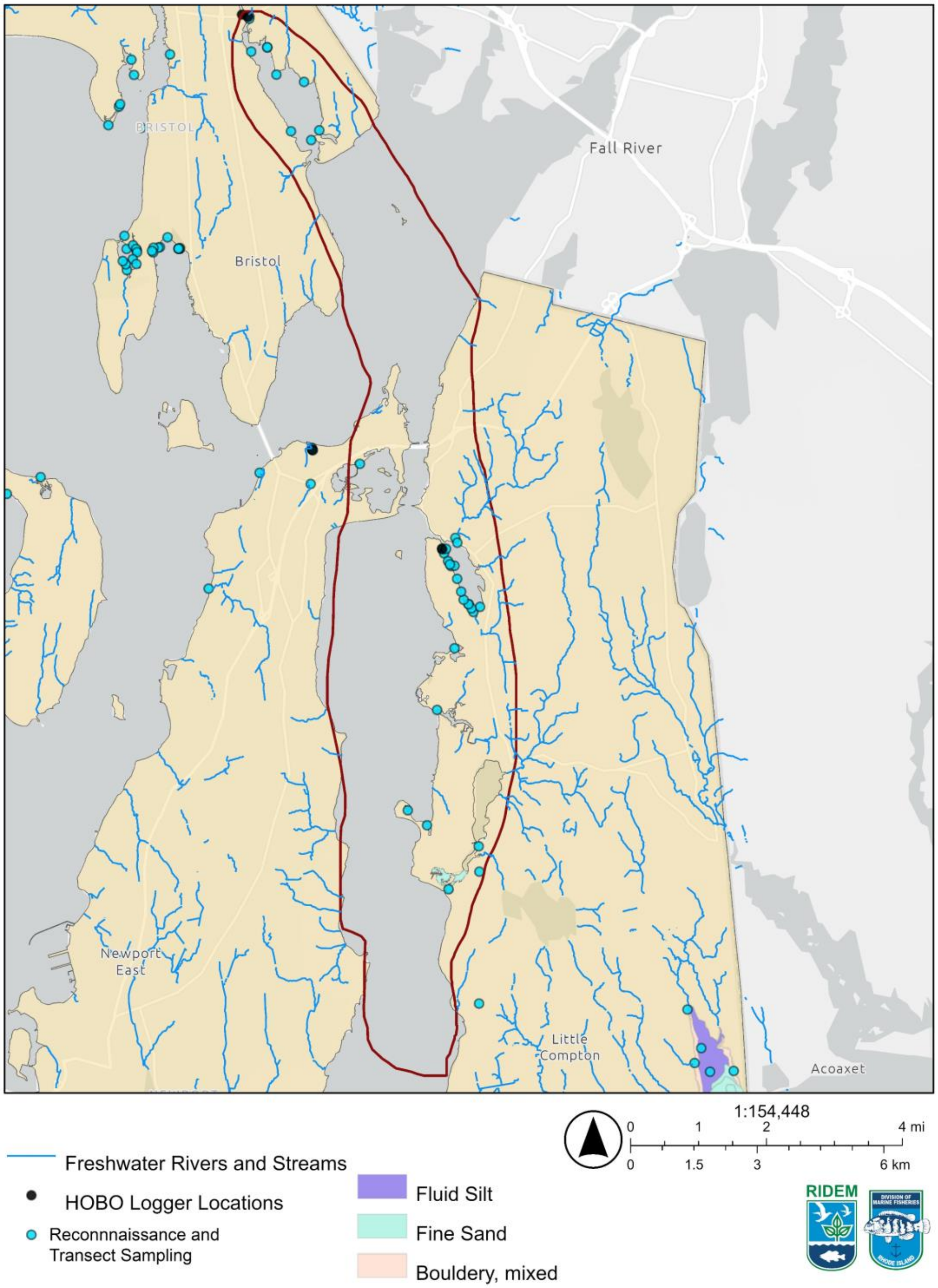


Figure 8. Map of Region 7 Block Island, and the Great Salt Pond.

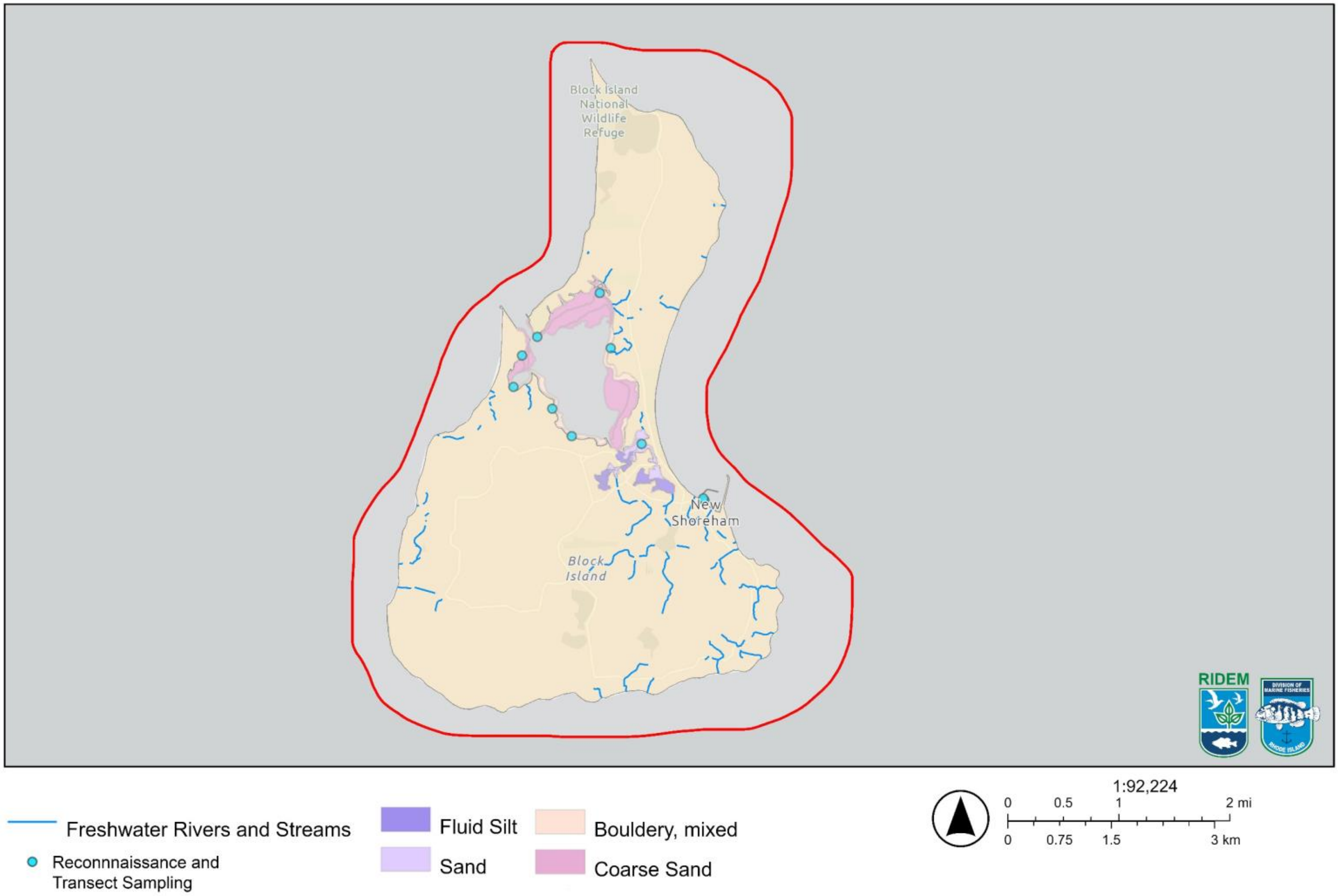


Figure 9. Oyster density per square meter across regions.

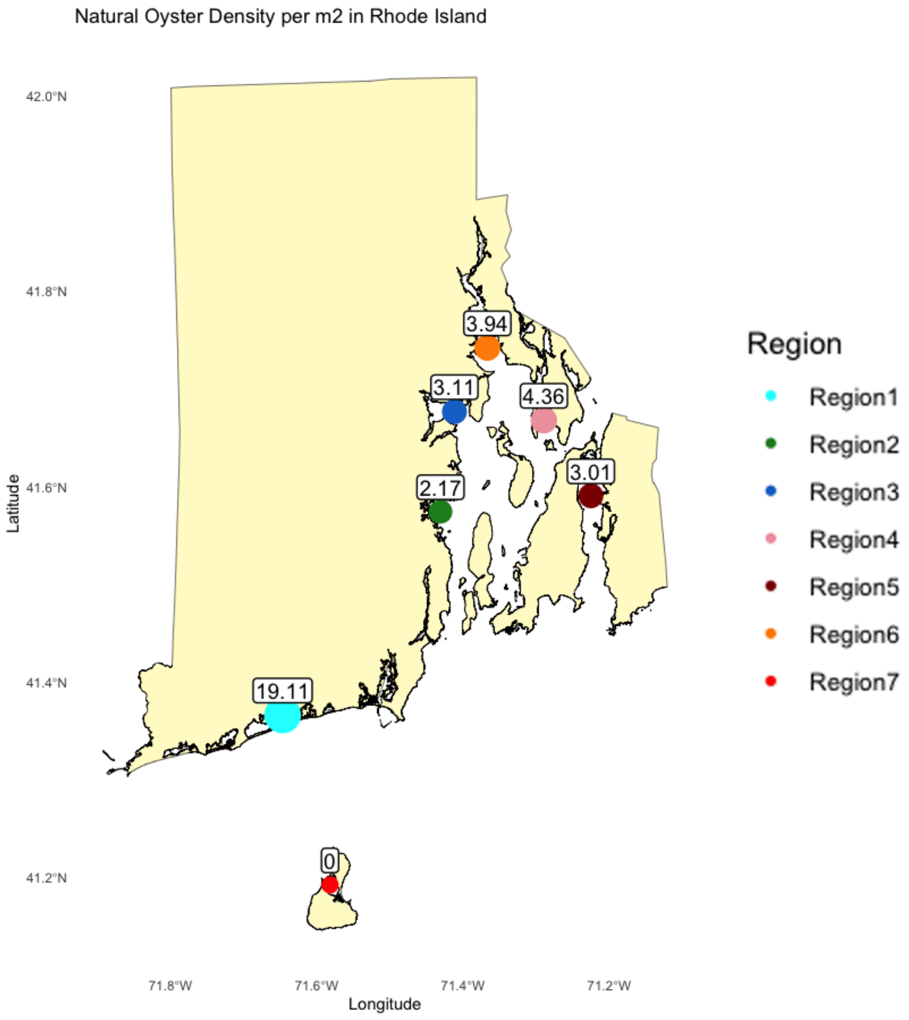


Figure 10. Size frequency of oysters across all regions, both restored and natural oyster beds

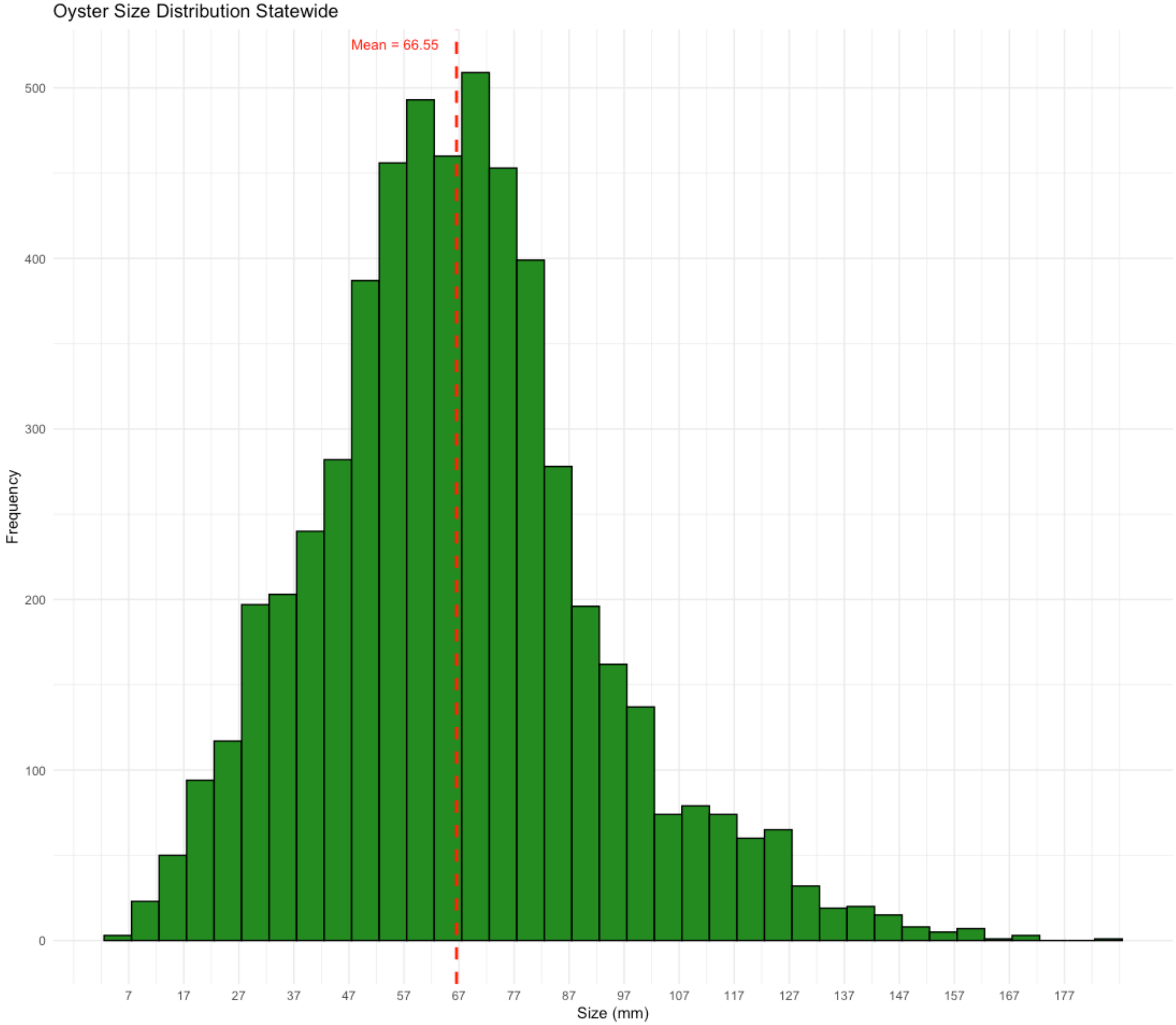


Figure 11. Substrate Types. The top 5 most common substrate types where live natural oysters were found.

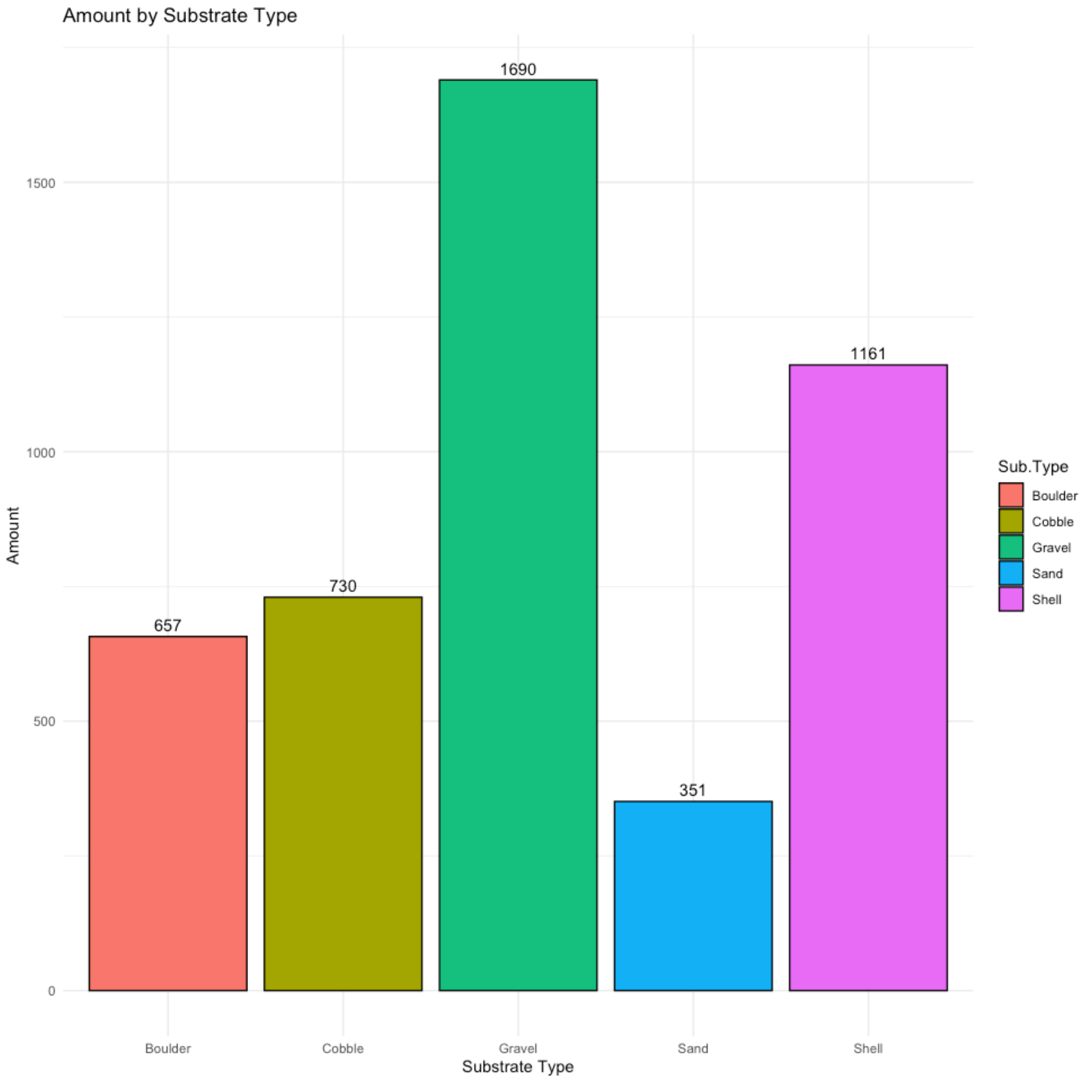
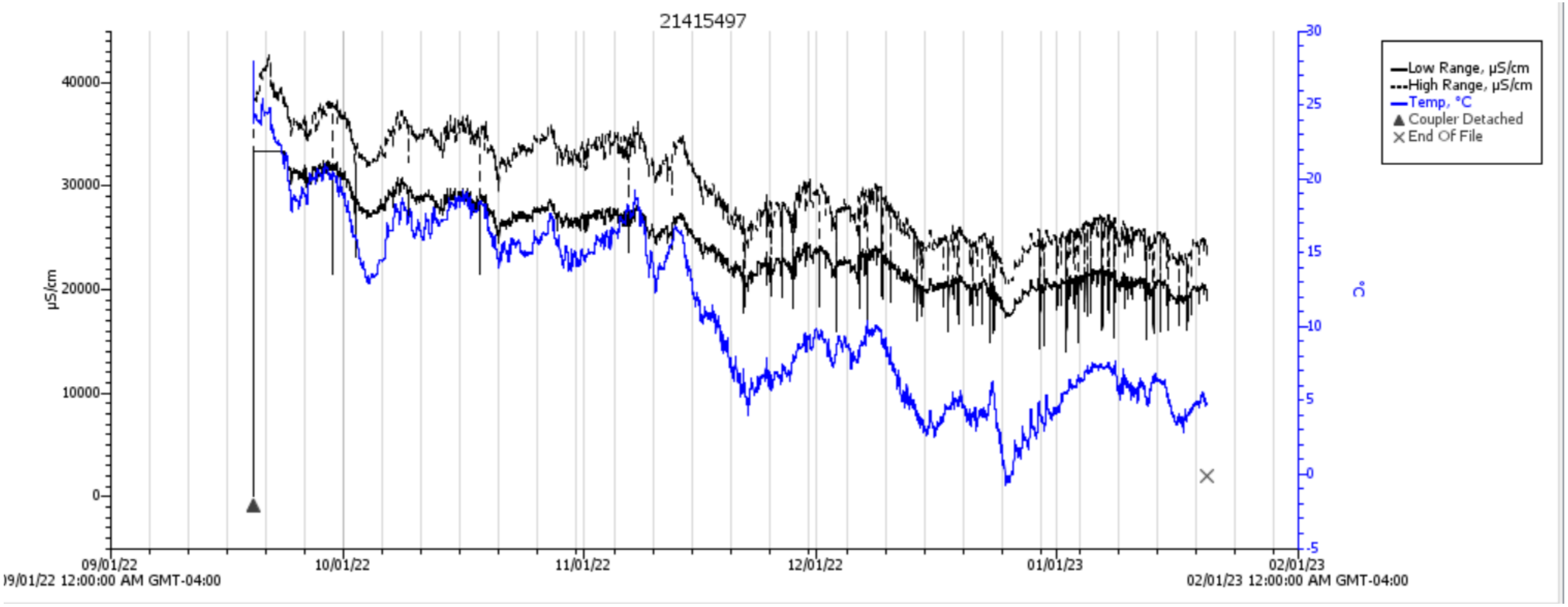


Figure 12. HOBO logger data from Fosters Cove, showing temperature and salinity from September of 2022 to February of 2023. Temperature and salinity measurements are recorded every 15 mins and then downloaded every three months.



II. Field Work Table 2021-2023

Date	Site Name	Regions: 1-7	Partners Involved	Personnel Involved:	Proj. Obj's/ Tasks	Survey Techniques	Expanded Sampling	Field Notes	Land or Vessel
8/6/2021	Town Pond, Portsmouth	4	DMF/NU	1 Staff/1 Grad student	2-E	Recon, Hand Collection, Genetic Sampling	No	Collected samples for NU/Population Genetics Sampling, and searched for wild oysters, found several on a shell bank near the entrance of the pond.	Land
8/16/2021	Potter and Point Judith Ponds	1	DMF	1 Staff/2 interns	2-A	Recon, Natural Oysters	Yes	Surveys conducted of upper Potter and Lower Pt Judith Ponds, higher densities found in Potter Pond. Upper and Western Potter Ponds have densities that meet expanded sampling threshold.	Skiff
8/30/2021	Ninigret Pond	1	DMF	1 Staff	2-A	Recon, Natural Oysters	Yes	Concentrated on central and eastern Ninigret Pond. Mid-pond area has densities that meet expanded sampling threshold.	Skiff
9/1/2021	Narrow River	1	TNC/ DMF	3 Staff/1 intern	2-A	Recon of Natural Oysters, Transect	Yes	This was a multi-stop field visit conducted along the Narrow River to test out field methods	Skiff

								across a range of densities and substrate types, these areas will require expanded sampling.	
9/14/2021	Quonochontaug Pond	1	DMF	1 Staff/2 interns	2-A	Recon, Natural Oysters	Yes	Focused on the west end of the pond, investigated areas adjacent to existing oyster restoration areas, found densities that meet expanded sampling threshold.	Skiff
9/15/2021	Quonochontaug Pond	1	DMF	2 Staff/2 interns	2-A	Recon Natural Oysters and Survey of Restored Bed	No	Worked in the western end of the pond, sand flats, and eel grass areas, found some dead half shells but no live oysters.	Skiff
9/16/2021	Quonochontaug Pond	1	DMF	1 Staff/2 interns	2-A	Recon, Natural Oysters	No	Worked in the western end of the pond, adjacent to restoration reefs, subtidal gravel and shell bars, emergent boulders, and freshwater inputs, found no live oysters.	Skiff

9/17/2021	Quonochontaug Pond	1	DMF	1 Staff/2 interns	2-A	Recon, Natural Oysters	Yes	Survey work concentrated on the central pond, found oysters associated with overhanging Rhododendrons, large boulders, and freshwater inputs along several small coves. Mostly single oysters were found however there were some small clumps. Some of these areas have densities that meet expanded sampling threshold.	Skiff
9/20/2021	Quonochontaug Pond	1	DMF	1 Staff/1 interns	2-A	Recon, Natural Oysters	No	Worked in the eastern end of the pond, along shore and small islands and creeks where freshwater enters the system, found very few live oysters.	Skiff
9/21/2021	Quonochontaug Pond	1	DMF	1 Staff/1 interns	2-A	Recon, Natural Oysters	No	Finished Quonochontaug Pond in the middle Section along the southern shore, found limited evidence of oysters, dead half shells, however no live oysters.	Skiff

9/30/2021	Ninigret Pond	1	DMF	1 Staff/2 interns	2-A	Recon, Natural Oysters	Yes	Finished up the Fort Neck area. Wild oysters found along shores and in shallow rocky areas, overhanging trees and fresh water seeps seem to hold high density areas appropriate for further expanded sampling.	Skiff
10/4/21	Eastern Ninigret	1	DMF/NU	2 Staff/1 Grad Student	2-A	Recon, Natural Oysters	Yes	Remnant natural population sampled for population genetic work.	Skiff
10/4/21	Green Hill	1	DMF/NU	2 Staff/1 Grad Student	2-A	Recon, Natural Oysters	Yes	Remnant natural population sampled for population genetic work, low-density beds also investigated which will require additional sampling.	Skiff
10/18/2021	Bold Point	5	TNC	3 staff	2-D	Recon of Natural Oysters, Transect	Yes	Surveyed and conducted 3 transects. Found sparse oysters around West and North sides of the point along the intertidal and shallow subtidal. These areas have densities that meet expanded sampling threshold.	Land

10/20/21	Nannaquacket System	4	DMF	1 Staff	2-E	Recon, Natural Oysters	Yes	Investigated fresh water/saltwater input areas, found significant densities and multiple size classes of oysters in the system which will require additional sampling.	Land
10/21/21	Potter Pond	1	DMF		2-A	Recon, Natural Oysters	Yes	Returned to historically known natural oyster recruitment locations and found new areas of high density oysters previously undocumented.	Skiff
10/22/2021	Occupessatuxet Cove	5	TNC	3 staff	2-D	Recon, Natural Oysters	No	Surveyed. Oyster shell found but no live oysters.	Skiff
10/22/2021	Passeonkquis Cove	5	TNC	3 staff	2-D	Recon of Natural Oysters, Transect	Yes	Surveyed and conducted 1 transect. Found small area with some oysters in shallow subtidal at the transect site. These areas have densities that meet expanded sampling threshold.	Skiff
11/1/21	Potter Pond	1	DMF/NU		2-A	Recon, Natural Oysters	Yes	Remnant Wild population sampled for population genetic work.	Skiff

11/1/2021	Watchemoket Cove	5	TNC	2 staff	2-D	Recon, Natural Oysters	No	Surveyed. Some oyster scars found along North side of bridge.	Land
11/1/2021	Pawtuxet Cove	5	TNC	2 staff	2-D	Recon of Natural Oysters, Transect	Yes	Surveyed and conducted 2 transects. There are oysters present along the rock jetty that bounds Pawtuxet Cove. Quadrat sampling will be performed in the Spring.	Land
11/3/2021	Winnapaug Pond	1	DMF	1 Staff	2-A	Recon, Natural Oysters	No	Checked sites in the eastern and middle pond for wild oysters, found very few, overall low density.	Skiff
11/9/2021	Rock Island	5	TNC	2 staff	2-D	Recon, Natural Oysters	No	Surveyed. Some sparse oysters present on boulders.	Kayak
11/9/2021	Pawtuxet Cove	5	TNC	2 staff	2-D	Recon, Natural Oysters	No	Surveyed. Some oyster scars found.	Kayak
11/15/2021	Wickford	2	DMF	2 Staff/1 Intern	2-B	Recon and PopGen Collection	Yes	Began systematic recon of Wickford system, populations of oysters found on rocky substrate and also on muddy areas will require additional expanded sampling.	Skiff

11/15/2021	Palmer River	4	TNC	2 staff	2-E	Recon, Natural Oysters	No	Surveyed. Some oysters found in Belcher Cove. Some oysters also present at the island located at the exit of the Palmer River, however densities too low to meet threshold for additional sampling.	Skiff
11/16/21	Narrow River	1	DMF/NU	1 Staff/1 Grad Student	2-A	Recon, Natural Oysters	Yes	Conducted pop-gen sampling in Narrow River upper and middle sections in three sites.	Skiff
11/16/21	Nannaquacket Pond	4	DMF/NU	1 Staff/1 Grad Student	2-E	Recon, Natural Oysters	Yes	Found significantly more oysters at the southern end of system in a newly investigated area.	Land
11/17/21	Kickemuit River	4	DMF/NU	1 Staff/1 Intern/1 Grad Student	2-D/2-E	Recon and PopGen Collection	Yes	Remnant Wild population sampled for populations genetics work, will need to return to survey more of the Kickemuet due to land based constraints and fading light.	Land
11/17/2021	Warren River, Barrington River	4	DMF/NU	1 Staff/1 Intern/1 Grad Student	2D/2E	Recon and PopGen Collection	Yes	Surveyed for oysters, high density areas were found and population genetics samples were collected at several	Land

								sites. Large enough densities in the lower end of this system meet the threshold for expanded sampling.	
11/18/2021	Wickford	2	DMF	1 Staff/1 Intern/1 Grad Student	2-B	Recon, Natural Oysters	Yes	Wild oyster recon, found several areas of high density oysters, surprising density of natural oysters on boulders and amongst rockweeds.	Land
11/18/2021	Hundred Acre Cove	4	TNC	2 staff	2-E	Recon, Natural Oysters	No	Limited numbers of oysters found along the rip rap shoreline densities do not meet threshold.	Skiff
11/19/2021	Rumstick Point	4	TNC	2 staff	2-E	Recon, Natural Oysters	No	Some oysters found on a man-made rocky outcropping in the marsh within Rumstick Point, densities do not meet threshold.	Boat
12/1/2021	Wickford and Allen Harbor	2	DMF	1 Staff	2-B	Recon, Natural Oysters	Yes	Wild oyster recon, significant findings in dense concentration of wild oysters in shallow tidal areas, these sites will require expanded sampling.	Land

11-Apr-22	Potowomut River	3	RIDEM	1	2-C	Recon	No	Hiked in from the fish ladder at low tide Potowomut river sampled for about 2 hrs, found very few live oysters, some dead.	Land
14-Apr-22	Potowomut River	3	RIDEM	1	2-C	Recon	No	Potowomut River, picked up where I left off on 4/11/22, hiked further down the river at low tide, crisscrossing and checking submerged logs, rocks and gravel beds. Very few found until the rocky choke point in the system which had densities of less than 10 per m2.	Land
5/18/2022	India Point, Providence	5	TNC	2 Staff	2-D	Recon of Natural oysters, survey of previous artificial reef project	No	Surveyed from land along the shore. Few oysters were found along the rip-rap shoreline. The previous artificial reef installation by URI and RISD was investigated but no oysters were found in direct proximity though a small patch was found just west of the area.	Land

5/18/2022	Mill Pond, Bristol	4	TNC	2 Staff	2-E	Recon, Natural Oysters	No	Surveys conducted along the southern shoreline; no oysters found.	Land
5/24/2022	Mill Gut, Bristol	4	TNC	2 Staff	2-E	Recon, Natural Oysters	Yes	The entire area was surveyed by kayak. Some of the areas along the eastern side have densities that meet the expanded sampling threshold.	Kayak
24-May-22	Lower Kickemuit	4	RIDEM	6	2-E	Recon/Census	No	Lower Kickemuit downstream from the dam was fully censused, higher than expected density found at low tide, in very warm(20+C) water and low salinities.	Land
24-May-22	Pond Bridge Rd	4	RIDEM	2	2-E	Recon	No	Found live oysters beneath the culvert, measured all, lower system could be a better place to check for further oyster populations.	Land
25-May-22	Prudence Island, North	3	RIDEM	3	2-E	Recon	No	Prudence Island, checked several estuary sites on the northern end, and middle western facing shore, few live oysters found.	Vessel

26-May-22	Dutch Harbor	2	RIDEM	4	2-B	Recon	No	Recon within Dutch Harbor found some boulders with limited density associated with marsh habitat and fresh water inputs.	Vessel
26-May-22	Greene Point	2	RIDEM	4	2-B	Recon	No	Small tidal lagoon with daily tidal flows located, no live oysters found	Vessel
26-May-22	Casey Point	2	RIDEM	4	2-B	Recon	No	Similar to Greene Point, however Casey Point is a larger lagoon that does have a very small(>10) oysters.	Vessel
14-Jun-22	Prudence Island	3	RIDEM	5	2-E	Recon	No	Finished up Prudence Island, small coastal estuary systems on east and west sides, Potter Cove. Found limited populations of oysters, nothing over 5 oysters per m2.	Vessel
14-Jun-22	Aquidneck Island	4	RIDEM	5	2-E	Recon	No	Checked coastal lagoon on the Northwestern shore, west of the Mt. Hope bridge, no oysters found, shallow lagoon.	Vessel
15-Jun-22	Wickford Harbor	2	RIDEM	3	2-B	Recon/Transect Quadrat	Yes	NW corner and Rock Island transect and quadrat surveys.	Vessel

15-Jun-22	Bissell Cove	2	RIDEM	3	2-B	Recon	No	Few live oysters found on rock outcrop identified in Fall 2021 by local commercial quahaug fisherman.	Vessel
16-Jun-22	Potowomut	3	RIDEM	3	2-C	Recon/Transect Quadrat	No	Potowomut 2 locations were sampled by quadrat and then snorkeling recon.	Vessel
16-Jun-22	Warwick Cove	3	RIDEM	3	2-C	Recon	No	No live oysters found, perused cove from mouth to head of the cove.	Vessel
16-Jun-22	Brushneck Cove	3	RIDEM	3	2-C	Recon	No	No live oysters found, perused cove from mouth to head of the cove.	Vessel
16-Jun-22	Buttonwoods Cove	3	RIDEM	3	2-C	Recon	No	No live oysters found, some half shells and scars on the eastern shore by the entrance to the cove.	Vessel
22-Jun-22	Pawcatuck	1	RIDEM	5	2-A	Recon	No	Checked from the dam in town to the mouth of the River, and part of Little Narragansett Bay.	Vessel
24-Jun-22	Green Hill Pond	1	RIDEM/TNC	7	2-A	Transect/Quadrat	Yes	Training with partners and sampling down in the mouth of Greenhill Pond, large mass of live wild oysters was sampled, we	Vessel

								worked out logistics of sampling several hundred oysters per m2.	
28-Jun-22	Ninigret	1	RIDEM	4	2-A	Transect/Quadrat	Yes	Ft Neck area transects, then the channel in Ninigret, and also the Hummocks.	Vessel
6/28/2022	Green Hill Pond	1	TNC/ DMF	3 Staff/3 interns	2-A	Unify transect and survey methods Natural Oyster, transect, reef survey	Yes	This was a single field visit conducted at a specific site at Green Hill to test out field methods in dense reef locations. Focused on the upper pond, closely investigated areas with higher gravel/cobble substrate, found densities that meet expanded sampling threshold and surveyed one reef along the northeastern shore.	Land
6/29/2022	Narrow River - Upper Pond	1	TNC	2 Staff/2 interns	2-A		Yes		Kayak
29-Jun-22	Wickford Harbor	2	RIDEM	6	2-B	Transect/Quadrat	Yes	Finished upper Northwest coves and then started to transect sample Duck Cove.	Vessel

29-Jun-22	Duck Cove	2	RIDEM	6	2-B	Transect/Quadrat	Yes	Within Duck cove we transect sampled areas that I identified in 2021 as potential high density areas and conducted recon the northern shore.	Vessel
30-Jun-22	Duck Cove	2	RIDEM	5	2-B	Transect/Quadrat	Yes	Finished up Duck cove transect/quadrat sampling.	Vessel
6-Jul-22	Nannaquacket	4	DEM	6 Interns, 3 staff	2-E	Transect/Quadrat	Yes	Combination of boat and land based sampling to canvas multiple areas within the Nannaquacket system.	Land/Vessel
8-Jul-22	Winnapaug Pond	1	DEM	4 interns, 2 staff	2-A	Reconnaissance	No	Reconnaissance work to finish off this system, very few oysters found.	Vessel
20-Jul-22	Greenwich Bay	3	DEM	4 staff, 1 intern	2-C	Reconnaissance/Quadrat transect	Yes	Extensive reconnaissance of low density areas, and expanded sampling inner Greenwich Cove.	Vessel
28-Jul-22	Wickford	2	DEM	2 interns	2-B	Recon	No	Finished the reconnaissance of the Wickford harbor system by parking and hiking into several sites, low densities of oysters.	Land

1-Aug-22	Greenhill Pond	1	DEM	1 staff 2 interns	2-A	Transect/Quadrat	Yes	Expanded quadrat sampling in areas previous areas identified by reconnaissance.	Vessel
16-Aug-22	Nannaquacket	4	DEM	2 interns	2-E	Transect/Quadrat	Yes	Finished off the expanded sampling within the Nannaquacket system.	Vessel
24-Aug-22	Greenhill Pond	1	DEM	2 staff, 2 interns	2-A	Transect/Quadrat	Yes	Expanded quadrat sampling in areas previous areas identified by reconnaissance.	Vessel
26-Aug-22	Greenhill Pond	1	DEM	1 staff, 3 interns	2-A	Transect/Quadrat	Yes	Expanded quadrat sampling in areas previous areas identified by reconnaissance.	Vessel
29-Aug-22	Nannaquacket, Town Pond, Wickford, Duck Cove	4	DEM	1 staff	2-A, 2-E, 2-B	Logger Deployment	No	Logger deployments across multiple sites.	Land
31-Aug-22	Quonochontaug Pond	1	DEM	1 staff, 2 interns	2-A	Logger Deployment	No	Single Logger deployment in Quonochontaug Pond.	Vessel
12-Sep-22	Narrow River-La Forge Park and Bridgetown Rd.	1	DEM	1 Staff	2-A	Logger Deployment	No	Deployed two loggers within the Narrow River system in areas with high density in a channel and lower diffuse density along a wooded shoreline.	Land

14-Sep-22	Fresh Pond	1	DEM	2 staff	2-A	Logger Deployment	No	Logger deployment.	Vessel
19-Sep-22	Fosters Cove	1	DEM	1 Staff	2-A	Logger Deployment	No	Logger deployment.	Vessel
26-Sep-22	Kickemuit River	4	DEM	1 Staff	2-E	Logger Deployment	No	Logger deployment.	Land
7/5/2022	Narrow River -Upper and Lower	1	TNC	2 Staff/ 2 interns	2-A	Recon, Natural oysters, transect surveys	Yes	Returned to areas identified in June that met the expanded sampling threshold	Boat
7/20/2022	Pawtuxet, Warwick	5	TNC	1 Staff/ 3 interns	2-D	Recon, Natural Oysters	Yes	Field staff returned and conducted transects at specified sites from previous recon conducted in November 2021. Staff did not complete all transects due to rising tide and needed to return again to conduct a reef survey.	Land
7/26/2022	Mill Gut, Bristol	4	TNC	2 interns	2-E	Natural Oysters, transect surveys	Yes	Field staff returned to Mill Gut based on first recon visit back in May to conduct transects in areas that displayed densities that met the expanded sampling threshold	Kayak

7/27/2022	Mussachuck Creek, Barrington	5	TNC	2 interns	2-D	Recon, Natural Oysters	No	Surveyed from land along the shore, no oysters were found. Shoreline was cobble and shell, mostly *Crepidula* and transitioned to sand moving northward	Land
7/27/2022	Latham Park, Barrington	5	TNC	2 interns	2-D	, Natural Oyster	No	Surveyed from land along the shore, no oysters were found. Walked along the riprap and rocky shoreline on the outer edge of the park	Land
8/12/2022	Seekonk Waterfront, East Providence	5	TNC	1 Staff/2 interns	2-D	Recon, Natural Oyster, transect	Yes	Surveyed area north of the bridge along Waterfront Drive. Oysters were found in densities that met expanded sampling threshold and surveyed one? Reef. Areas of higher oyster densities were small and scattered	Boat/ Land
8/26/2022	Pawtuxet, Warwick	5	TNC	1 Staff/1 intern	2-D	Natural Oysters, Transect, Reef survey	Yes	Field staff returned to complete a reef survey from a previous transect survey in July	Kayak

9/9/2022	Bold Point, East Providence	5	TNC	1 Staff/1 intern	2-D	Natural Oysters, Reef survey	Yes	Field staff returned and conducted transects at specified sites from previous recon conducted in October 2021. Reef surveys were completed.	Land
9/15/2022	Narrow River-Narrows and Upper	1	TNC	2 Staff/ 1 intern	2-A	Recon	No	Further recon of new areas. Final areas in Upper Pond and along the shore of the narrows	Boat
20-Jan-23	Kickemuit River	4	DMF	1, Staff	2-E	Logger swapping and some assessment of habitat in the Kickemuit	No	Routine maintenance of loggers, swapping out/downloading data and cleaning biofouling.	Land
23-Jan-23	Wickford	2	DMF	1, Staff	2-B	Logger swapping.	No	Routine maintenance of loggers, swapping out/downloading data and cleaning biofouling.	Land
24-Jan-23	Green Hill Pond	1	DMF	1, Staff	2-A	Logger swapping.	No	Routine maintenance of loggers, swapping out/downloading data and cleaning biofouling.	DMF Vessel
2-Feb-23	Ninigret, Fresh Pond	1	DMF	1, Staff	2-A	Logger swapping.	No	Routine maintenance of loggers, swapping out/downloading	DMF Vessel

								data and cleaning biofouling.	
8-Feb-23	Green Hill Pond	1	DMF	2, Staff	2-A	Logger swapping.	No	Routine maintenance of loggers, swapping out/downloading data and cleaning biofouling.	Land
3-May-23	Fosters Cove	1	DMF/TNC	3 Staff, 2 Interns	2-A	Recon	No	Recon and methods calibration amongst TNC/DMF	DMF Vessel
18-May-23	Fosters Cove	1	DMF/TNC	3 Staff, 2 Interns	2-A	Recon and transect surveys	No	Identification of large beds and shorelines with high concentrations of oysters for future sampling, mapping.	DMF Vessel
22-May-23	Narrow River	1	DMF/TNC	4 Staff, 3 Interns	2-A	Logger swapping and recon surveys.	Yes	DMF with TNC help worked through the quadrat and transect sampling of a large bed just north of the Bridgetown Rd culvert, high densities of relatively small oysters	DMF Vessel
30-May-23	Town Pond	4	DMF	2	2-E	Recon and transect surveys	Yes	Surveyed previously delineated bed of historic oyster restoration zone at the mouth of Town Pond.	Land

1-Jun-23	Fosters Cove	1	DMF	3 Staff, 2 Interns	2-A	Recon and transect surveys	Yes	Continuation of survey work within Fosters Cove, Inner closed area.	DMF Vessel
6-Jun-23	Ninigret	1	DMF	1 Staff, 1 Intern, I graduate student	2-A	Logger swapping.	No	Routine maintenance of loggers, swapping out/downloading data and cleaning biofouling.	DMF Vessel
7-Jun-23	Quonochontaug Pond	1	DMF	1 Staff, 1 Intern, I graduate student	2-A	Logger swapping.	No	Routine maintenance of loggers, swapping out/downloading data and cleaning biofouling.	DMF Vessel
8-Jun-23	Fosters Cove	1	DMF	2 Staff, 3 Intern, I graduate student	2-A	Recon and transect surveys	Yes	Finished transect/quadrat and recon surveys for this cove, overall large amounts of small oysters found and sampled throughout the cove.	Partner vessel
14-Jun-23	Green Hill Pond	1	DMF	2 Staff, 2 Intern, I graduate student	2-A	Recon and transect surveys	Yes	Finished surveys of Greenhill Pond, large oyster beds found deeper into the pond to the west of historically surveyed areas.	Partner vessel
22-Jun-23	Fresh Pond	1	DMF	2 Staff, 2 Intern, I graduate student	2-A	Logger Swapping and recon and transect surveys	Yes	Initial recon efforts in the eastern end of Fresh Pond during 2022 located dense beds of oysters, those were	Partner vessel

								surveyed and further recon was conducted along the banks of the pond where additional oysters were found	
28-Jun-23	Aquidneck Island, Conanicut Island	4	DMF	3 Intern, I graduate student	2-E	Recon site visits.	No	Recon work was performed in several areas on mid-bay islands, no oysters were found.	Land
29-Jun-23	Narrow River	1	TNC	1 Staff, 2 Interns	2-A	Recon site visits.	Yes	Completion of Bridgetown Rd area transect and quadrat surveys	Vessel
30-Jun-23	Bullocks Cove	5	TNC	1 Staff, 2 Interns	2D	Recon site visits.	No	Recon of inner Bullocks Cove area.	Vessel

III. Project Partners, Organizations, and Individuals

A. Interns and fellows that contributed to this project on non-SNEP funds. The table below includes several major contributors to this project that were not included in the original project team but were brought aboard during the grant period. These undergraduates, recent graduates, and graduate students were instrumental in accomplishing the project Objectives 1&2, especially regarding field work and initial data entry tasks. They all shared a common interest in restoration ecology and worked tirelessly.

Individuals	Institution	Program/Funding	Contributions	Year
Natalia Jaworski, (Masters Candidate)	Florida Atlantic University	Yale Environmental Fellows Program	Fieldwork, data entry and QA/QC, historical data.	2022
Madeline Armstrong, (PhD candidate)	Central Michigan University, Nowheresville	Yale Environmental Fellows Program	Field work, data entry, loggers.	2023
Blake Busch, (Undergraduate, BS)	University of Tampa, DMF Seasonal Intern	RIDEM(2022), Experiment.com-Ocean Solutions Challenge Grant (2023)	Fieldwork, mapping, data entry, outreach materials.	2022-23
Olivia Chatowsky, Postbaccalaureate	DMF-Seasonal	RIDEM	Fieldwork	2021
Erin Drumm	DMF-Seasonal	RIDEM	Fieldwork	2021
Jess Rugeri, Postbaccalaureate	DMF Seasonal	RIDEM	Fieldwork, data entry	2023
Courtney Caccomo, Postbaccalaureate	DMF-Seasonal	RIDEM	Fieldwork, data entry	2023

B. Table of Work Elements, tasks, status, schedule, and contributions for the grant from 2020 to 2024. Asterisks (*) indicate non-SNEP support.

Project Elements	Major Tasks and Project Deliverables	Schedule	Staff and Contributors	Current Status
Grant Implementation, QAPP Approval	Develop QAPP, Establish Cooperative Agreements.	Signed August 12, 2022	DMF* (E. Schneider/JA Macfarlan), NU* (J. Grabowski, R. Hughes), TNC	Completed
Objective 1: Evaluate existing oyster reef restoration sites in Regions 1 and 3.	(1-A) Review and assemble pertinent data collected during past and current restoration projects and obtain field supplies	Feb 3, 2021-July 31, 2023	DMF (E. Schneider/JA Macfarlan*), and NU coop student, with assistance from other DMF staff*	Completed
	(1-B) Sample restored oyster reefs that have not recently been sampled by collaborative DMF work in RI's South Shore Coastal Ponds, and Western Narragansett Bay	Aug 15, 2021 – July 31, 2023	DMF (E. Schneider/JA Macfarlan*) and NU coop and graduate students using a DMF vessel, with assistance from other DMF staff*	Completed
Objective 2: Assess natural oyster populations and potential restoration sites in Regions 1, 2, 3, 4, 5.	(2-A) Little Narragansett Bay, South Shore Coastal Ponds, and Narrow River	Oct 1, 2021 – Aug 31, 2023	DMF (E. Schneider/JA Macfarlan), NU graduate student, and TNC using DMF and TNC vessels	Completed
	(2-B) Lower West Passage of Narragansett Bay	Oct 1, 2021 – Aug 31, 2022	DMF (E. Schneider/JA Macfarlan), NU graduate student using DMF vessel, with assistance from other DMF staff*	Completed
	(2-C) Upper West Passage of Narragansett Bay	April 15 – Aug 31, 2022	TNC using TNC vessels, with assistance from other DMF staff*	Completed
	(2-D) Providence and Seekonk Rivers	June 1 - Aug 31, 2023	TNC using TNC vessel	Completed
	(2-E) Northeast Narragansett Bay	Sept 1 – Aug 31, 2023	TNC using TNC vessel	Completed
Outreach and Reporting	(3-A) Present results at Restore America's Estuaries 2022 Conference, and SSREP, RIMFC, and other public meetings	Winter 2022 Summer 2024	DMF (E. Schneider) DMF Macfarlan-presented at the SNEP Symposium in June 2024	Completed
	(3-B) Assemble and analyze information, produce Report and Maps of findings that will be directly incorporated into the RI Statewide Shellfish Restoration and Enhancement Plan	August, 31st, 2024.	DMF (E. Schneider) and NU graduate student, with guidance from NU (J. Grabowski, R. Hughes) and assistance from other DMF staff*	Completed

IV. Technical Memoranda, Files, Progress Reports

I. Files included within the Final Report Package

Portions of the following are included in the report narrative in this document. However more detail and the entirety of the text, and slides can be found in the following files:

a. QAPP
    i. File: a-QAPP-RIDEM-SNEP_ 20210812

b. SREP Workshops Full Report
    i. File: b-RIDMF -RISREP-Workshop Summary _09032024

c. Annual SNEP Conference Slides
    i. File: c-Macfarlan-SNEP-Symposium_06052024

d. Macfarlan TNC-DEM Summit Slides
    i. File: d-Macfarlan-TNCSummit-Talk_03012023

e. Busch Posters
    i. University of Tampa, undergraduate research:
        1. File: e1-Busch-UT-OysterPoster_2022
    ii. Benthic Ecology Meeting:
        1. File: e2-Busch-BEM-OysterPoster_GEO_04102024

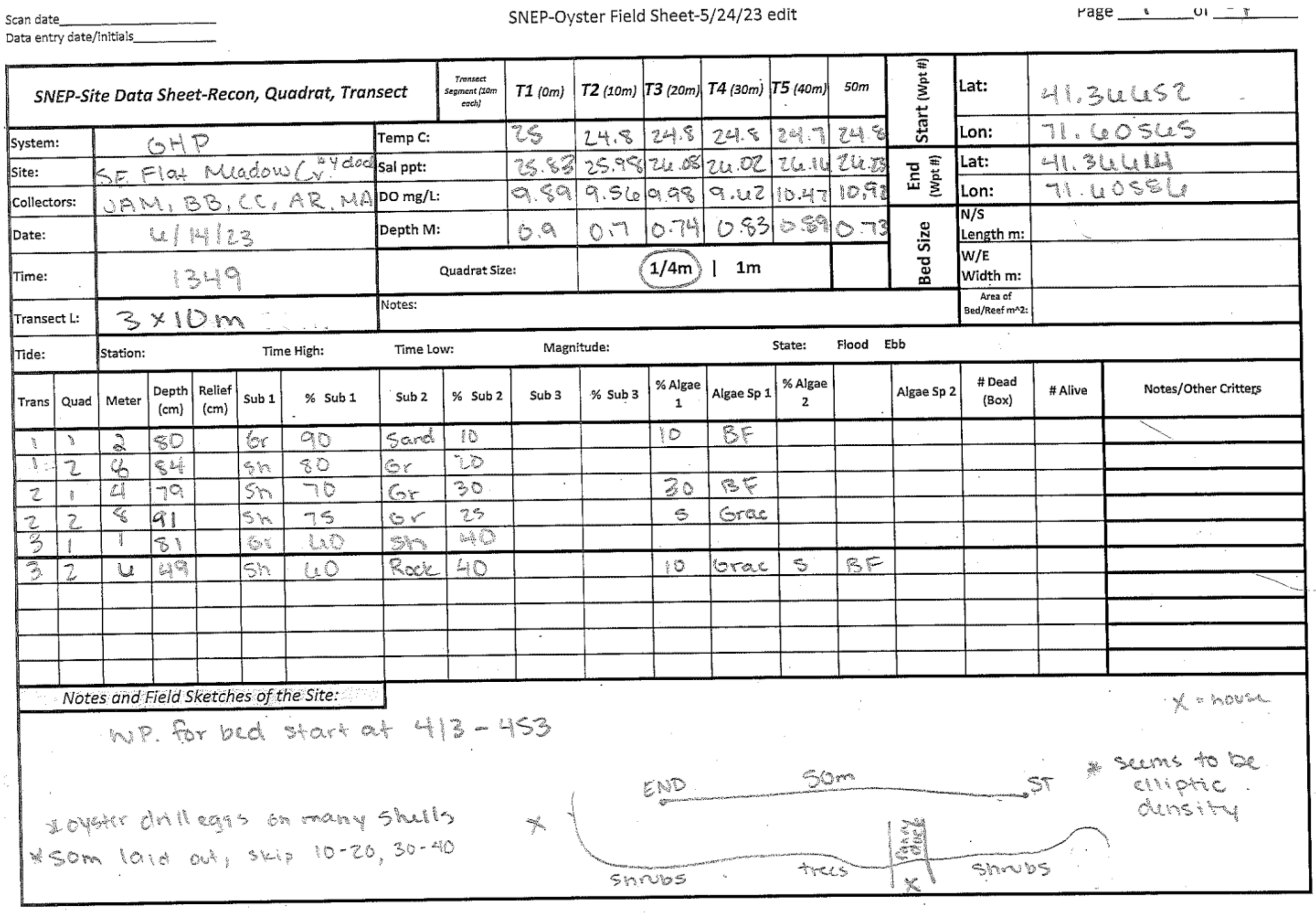
f. Progress Reports 1-6.
    i. File: f-SNEPWG20-RIDEMDMF-Prog_Report_1
    ii. File: f-SNEPWG20-RIDEMDMF-Prog_Report_2
    iii. File: f-SNEPWG20-RIDEMDMF-Prog_Report_3
    iv. File: f-SNEPWG20-RIDEMDMF-Prog_Report_4
    v. File: f-SNEPWG20-RIDEMDMF-Prog_Report_5
    vi. File: f-SNEPWG20-RIDEMDMF-Prog_Report_6
g. Archived Records Research
    i. File: g-SNEP-RIDEM-FileCabinetMining-Protocol2022

II. **Geodatabase Feature Layer Table.** At this time the geodatabase contains the following 10 distinct layers, but will grow in complexity in the future as other studies become available and additional spatial data on other species is added. The geodatabase is being constructed as a living repository that will be maintained and updated. In brief this Geodatabase

	Data Name	Type	Source	Regions	Temporal Coverage	Georeferenced Details
1	Watershed Watch	Water Quality	URI	1	1988-2022	Latitude/Longitude Points, periodic sample collection
2	Coastal Pond Survey	Water Quality	DMF	1,2	1994-2023	Latitude/Longitude Points, Temp, Sal, DO for coastal pond sites
3	Subaqueous Soils	Bottom Type	NRCS	1,2,3,5,7	Updated: 5/28/2021	Polygons of subaqueous soil data for coastal ponds
4	SNEP Points	Location, Oyster Size, Density	DMF	1,2,3,4,5,6,7	2021-2023	Latitude/Longitude of recon and transect sampling sites, abundance data.
5	TNC Points	Location, Oyster Size, Density	TNC	1,4,6	2021-2023	Latitude/Longitude of recon and transect sampling sites, abundance data.
6	HOBO Loggers	Water Quality	DMF	1,2,5	2022-2023	Latitude/Longitude Points, periodic sample collection
7	Restoration Reefs	Oyster Size, Density	DMF	1	No Date Data	Polygons of Quonochontaug Restoration sites
8	Salt Marsh	Saltmarsh plant delineations	NRCS	1	2012	Ecosystem attribute delineations
9	Freshwater Rivers and Streams	Map	RIGIS	1,2,3,4,5,6,7	Updated: 12/15/2006	Mapped statewide streams and rivers
10	Historical Shellfish Surveys	Hand Drawn Maps	DMF	1,2,3,4,5,6,7	Various years	Statewide shellfish surveys conducted by DEM staff

III. **Data Sheet Example:** The data sheet below is representative of the final version used to collect site level data, the companion sheet for oyster measurements is also included which is used to collect data on oyster heights, presence of macroparasites and other notes.

i) Example of a typical cover sheet for a site visit with multiple transects, including water conditions, a small site map, and other metadata



Scan date____________

Data entry date/initials__________

SNEP-Oyster Field Sheet-5/24/23 edit

Page ____ of ____

SNEP-Site Data Sheet-Recon, Quadrat, Transect

System: GHP

Site: SE Flat Meadow Cv. *4 dock

Collectors: JAM, BB, CC, AR, MA

Date: 6/14/23

Time: 1349

Transect L: 3 x 10m

Transect Segment (10m each)	*T1 (0m)*	*T2 (10m)*	*T3 (20m)*	*T4 (30m)*	*T5 (40m)*	*50m*
Temp C:	25	24.8	24.8	24.8	24.7	24.8
Sal ppt:	25.83	25.98	26.08	26.02	26.14	26.23
DO mg/L:	9.89	9.56	9.98	9.42	10.47	10.9
Depth M:	0.9	0.7	0.74	0.83	0.89	0.73

Quadrat Size: [✓ 1/4m] \| 1m

Notes:

Start (Wpt #)	Lat:	41.36452
	Lon:	71.60545
End (Wpt #)	Lat:	41.36444
	Lon:	71.60556
Bed Size	N/S Length m:	
	W/E Width m:	
	Area of Bed/Reef m^2:	

Tide: Station: Time High: Time Low: Magnitude: State: Flood Ebb

Trans	Quad	Meter	Depth (cm)	Relief (cm)	Sub 1	% Sub 1	Sub 2	% Sub 2	Sub 3	% Sub 3	% Algae 1	Algae Sp 1	% Algae 2		Algae Sp 2	# Dead (Box)	# Alive	Notes/Other Critters
1	1	2	80		Gr	90	Sand	10			10	BF						
1	2	6	84		Sh	80	Gr	20										
2	1	4	79		Sh	70	Gr	30			30	BF						
2	2	8	91		Sh	75	Gr	25			5	Grac						
3	1	1	81		Gr	60	Sh	40										
3	2	6	49		Sh	60	Rock	40			10	Grac	5	BF				

Notes and Field Sketches of the Site:

W.P. for bed start at 413 - 453

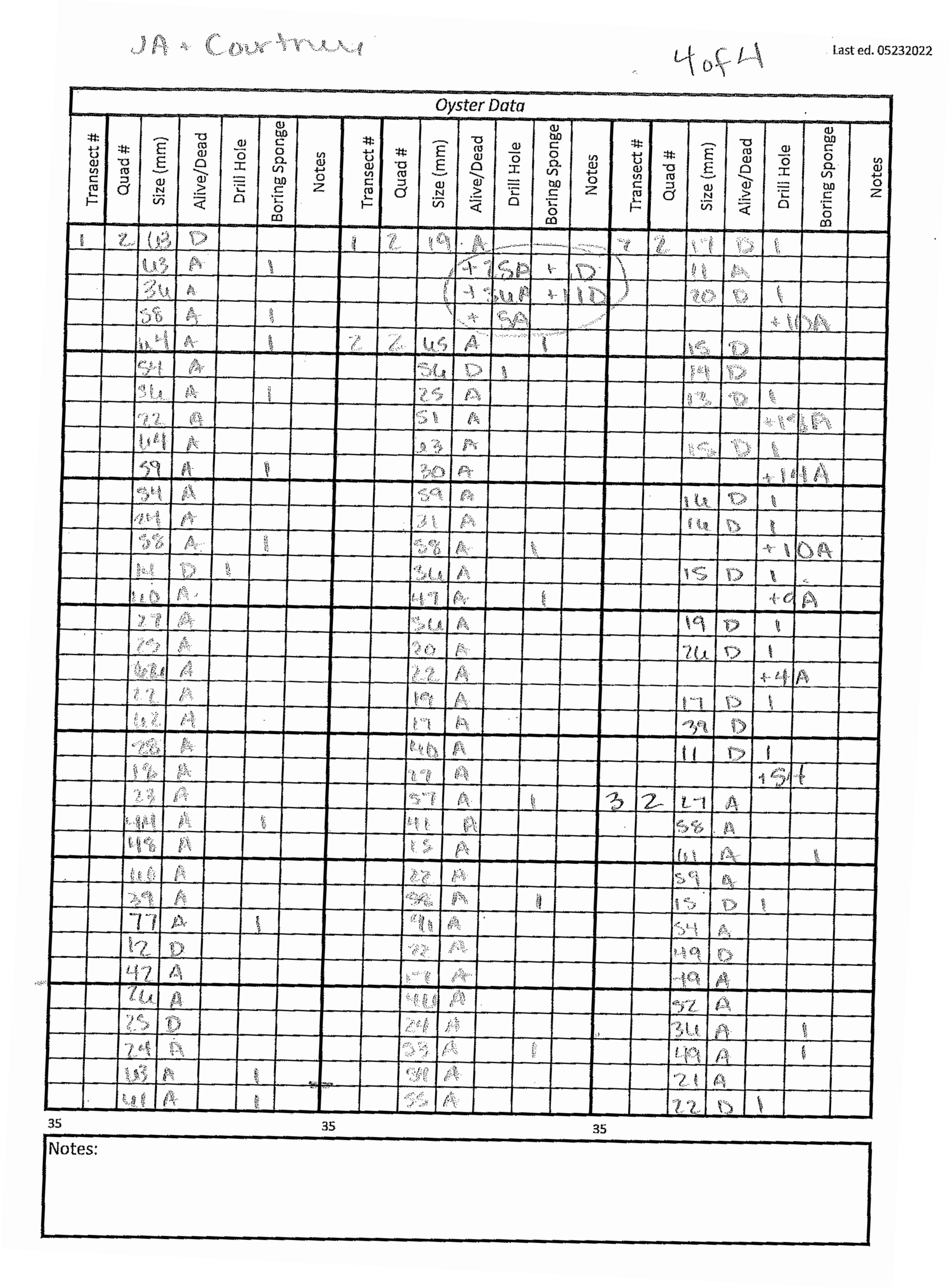
X = house

*oyster drill eggs on many shells

*50m laid out, skip 10-20, 30-40

* seems to be elliptic density

III.ii) Example of length frequency and individual oyster level data.



JA + Courtney

4 of 4

Last ed. 05232022

Oyster Data

Transect #	Quad #	Size (mm)	Alive/Dead	Drill Hole	Boring Sponge	Notes	Transect #	Quad #	Size (mm)	Alive/Dead	Drill Hole	Boring Sponge	Notes	Transect #	Quad #	Size (mm)	Alive/Dead	Drill Hole	Boring Sponge	Notes
1	2	63	D				1	2	19	A				2	2	17	D	1		
		63	A		1					+7SP		+	D			11	A			
		34	A							+3UA		+	1D			20	D	1		
		58	A		1					+SA								+10A		
		64	A		1		2	2	45	A		1				15	D			
		54	A						36	D	1					14	D			
		36	A		1				25	A						13	D	1		
		22	A						51	A								+19A		
		64	A						23	A						15	D	1		
		59	A		1				30	A								+14A		
		54	A						59	A						16	D	1		
		24	A						31	A						16	D	1		
		58	A		1				58	A		1						+10A		
		14	D	1					36	A						15	D	1		
		60	A						47	A		1						+9A		
		27	A						56	A						19	D	1		
		25	A						20	A						26	D	1		
		66	A						22	A								+4A		
		22	A						19	A						17	D	1		
		62	A						17	A						39	D			
		28	A						40	A						11	D	1		
		16	A						29	A								+5A		
		23	A						57	A		1		3	2	27	A			
		44	A		1				41	A						58	A			
		48	A						15	A						61	A		1	
		60	A						22	A						59	A			
		29	A						46	A		1				15	D	1		
		77	A		1				41	A						54	A			
		12	D						22	A						49	D			
		42	A						17	A						19	A			
		26	A						46	A						52	A			
		25	D						24	A						34	A		1	
		24	A						23	A		1				49	A		1	
		63	A		1				31	A						21	A			
		61	A		1				35	A						22	D	1		
35							35							35						

Notes:

V. Photographs

Image 1. Green Hill Pond, Southern Coast. Prof Jonathan Grabowski (NU), Project Lead Eric Schneider(RI DMF) and NU technician Jonathan August, discussing field sampling techniques while examining a shallow subtidal oyster bed, June 29th, 2021.

Image 2. Green Hill Pond, Southern Coast. Oysters recruiting on naturally occurring gravel substrate with a complex community of algae, tube worms, barnacles and other fouling organisms found in shallow subtidal beds, June 29th, 2021.

Image 3. Green Hill Pond, Southern Coast. Maturing oyster that had recruited to a pebble within a shallow subtidal bed in Green Hill Pond, June 29th, 2021.

Image 4. Quonochontaug Pond, Southern Coast. DMF biologist Patrick Barret examining an oyster restoration reef. The area of restoration reefs in the Northern part of the pond is characterized by a complex boulder field with a sand and cultch bottom, May 19th, 2021.

I

Image 5. Casey Point, Western Narragansett Bay. Wild live(left) and dead "box" (right) oysters found during a field reconnaissance site visit, July 3rd 2021.

Image 6. Green Hill Pond, Southern Coast. An oyster community on vertical man-made substrate at the entrance to Green Hill Pond, June 29th, 2021.

Image 7. Green Hill Pond, Southern Coast. This picture is typical of the complex mix of substrates in RI salt ponds. In the foreground is a mix of low relief sand, mud and shell oyster bed, and middle/background a grouping of boulders with high vertical relief and oyster aggregations, June 29th, 2021.

Image 8. Commercial quahaug fisherman who offered local knowledge on the presence of natural oysters in Region 2 (September 2021)

Image 9. Two live oysters showing found only meters apart in a location with low density natural oyster recruitment. This size difference is indicative of multiple year classes occurring in a single location, and potentially evidence of self-sustaining populations and spawning success across years (September 2021).

Image 10. An example of the distinctive rounded cup-shaped shell morphometry versus the elongated shell shapes observed at various sites, we found a large variation in shell shape during the course of the project (from left Images from September and October 2021).

Image 11. JA Macfarlan in foreground with Serit Truskey, PhD Candidate at Northeastern University collecting genetic samples from the Kickemuit River in Warren RI, November 2021.

Image 12. Natural oysters found in the upper Kickemuit River, Warren RI, November 2021

Image 13. In situ measuring of live oysters attached to rocks or boulders can be challenging with rigid calipers, December 2021.

Image 14. Rising Environmental Leader High School Intern, conducting reconnaissance for natural oysters in Trims Pond Block Island, July 2023.

Image 15. A large natural oyster attached to cobble on a shoal in Winnapaug Pond, July 2022.

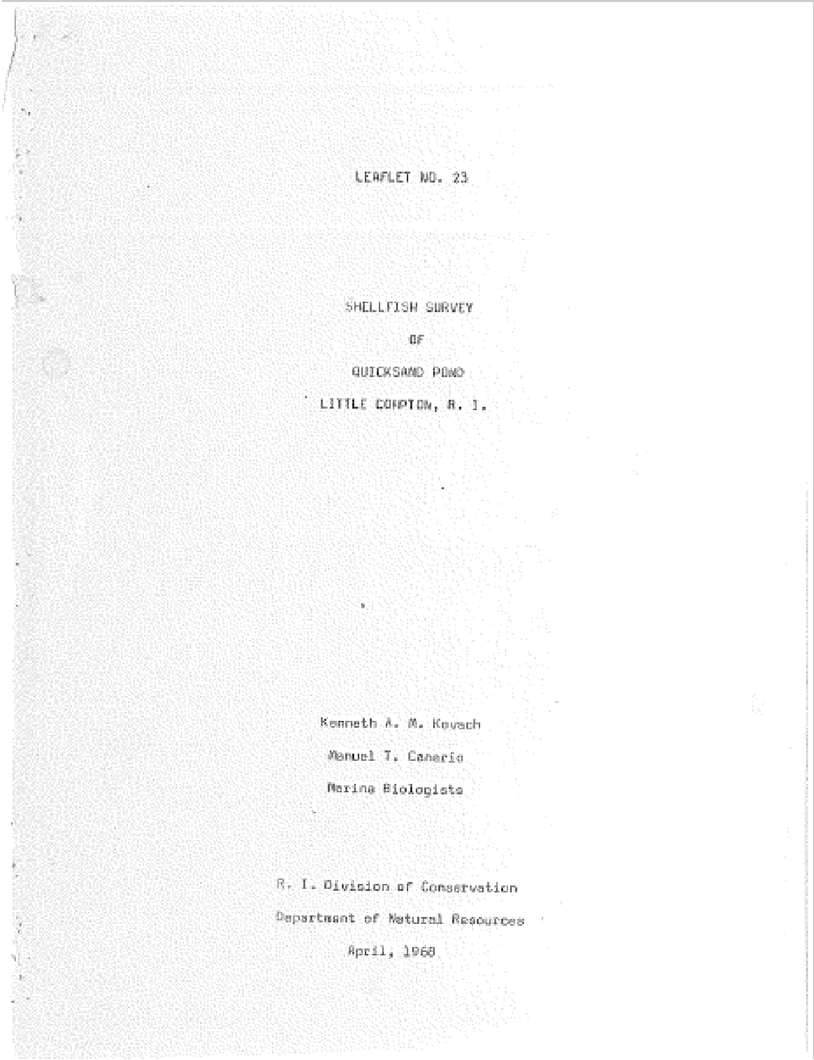
Imaged 16. A cryptic oyster camouflaged in barnacles and Ulva spp, Jamestown RI, May 2022.

Image 17. This was one of the only oysters found in the reconnaissance of the Pawcatuck River, June, 2022.

Image 18. RI DMF Intern Erin Drumm holds two large oysters in Potter Pond, South Kingston, October 2021.

Image 19. Historical Shellfish Survey document from ~54 years ago showing locations of wild and transplanted oysters in a salt pond

ca. 1965.

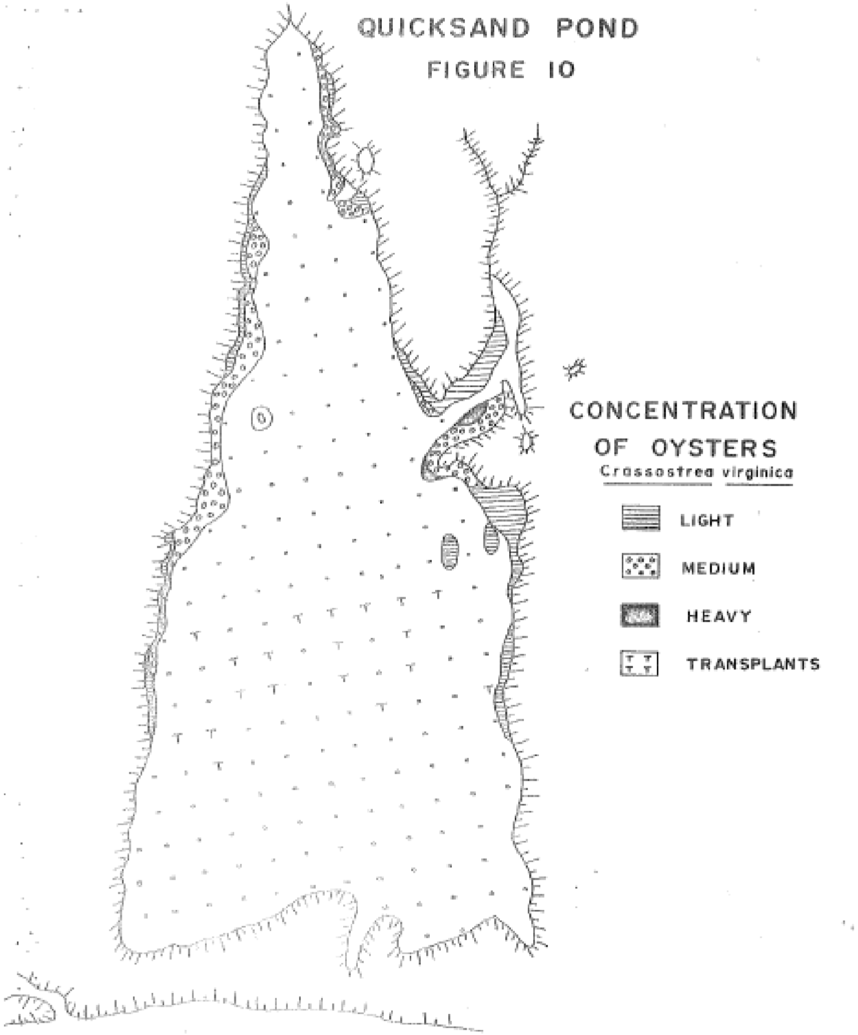


LEAFLET NO. 23

SHELLFISH SURVEY
OF
QUICKSAND POND
LITTLE COMPTON, R. I.

Kenneth A. M. Kovach
Manuel T. Canario
Marine Biologists

R. I. Division of Conservation
Department of Natural Resources
April, 1968



QUICKSAND POND
FIGURE 10

Image 20. The southern end of Greenwich cove contains freshwater inputs from a small stream, groundwater seeps, and plentiful substrate. Oyster density although low and patchy are fairly common within this system which is permanently closed to shell fishing. (April 2022).

Image 21. A higher density area within the Potowomut system typified by exposed granite, overhanging deciduous trees, and a complex of encrusting barnacles, ribbed mussels and eastern oysters. (March/April 2022).

Image 22. Large oysters are found in RI, and this 140mm+ example was found associated with a small creek, overhanging trees and freshwater inputs within the Wickford Harbor system (June 2022).

Image 23. DMF interns working along a transect within Duck Cove, this picture includes most habitat types encountered in our fieldwork state-wide: intertidal mud flats, cobble fringe, interspersed boulders, naturally deposited shells/cultch, and a gradient of algae and deciduous trees from subtidal to upland habitat zones(June 2022).

Image 24. DMF interns working on a typical low tide quadrat in Wickford Harbor, this system is dominated by "fort Neck" type soils that are relatively soft(June 2022).

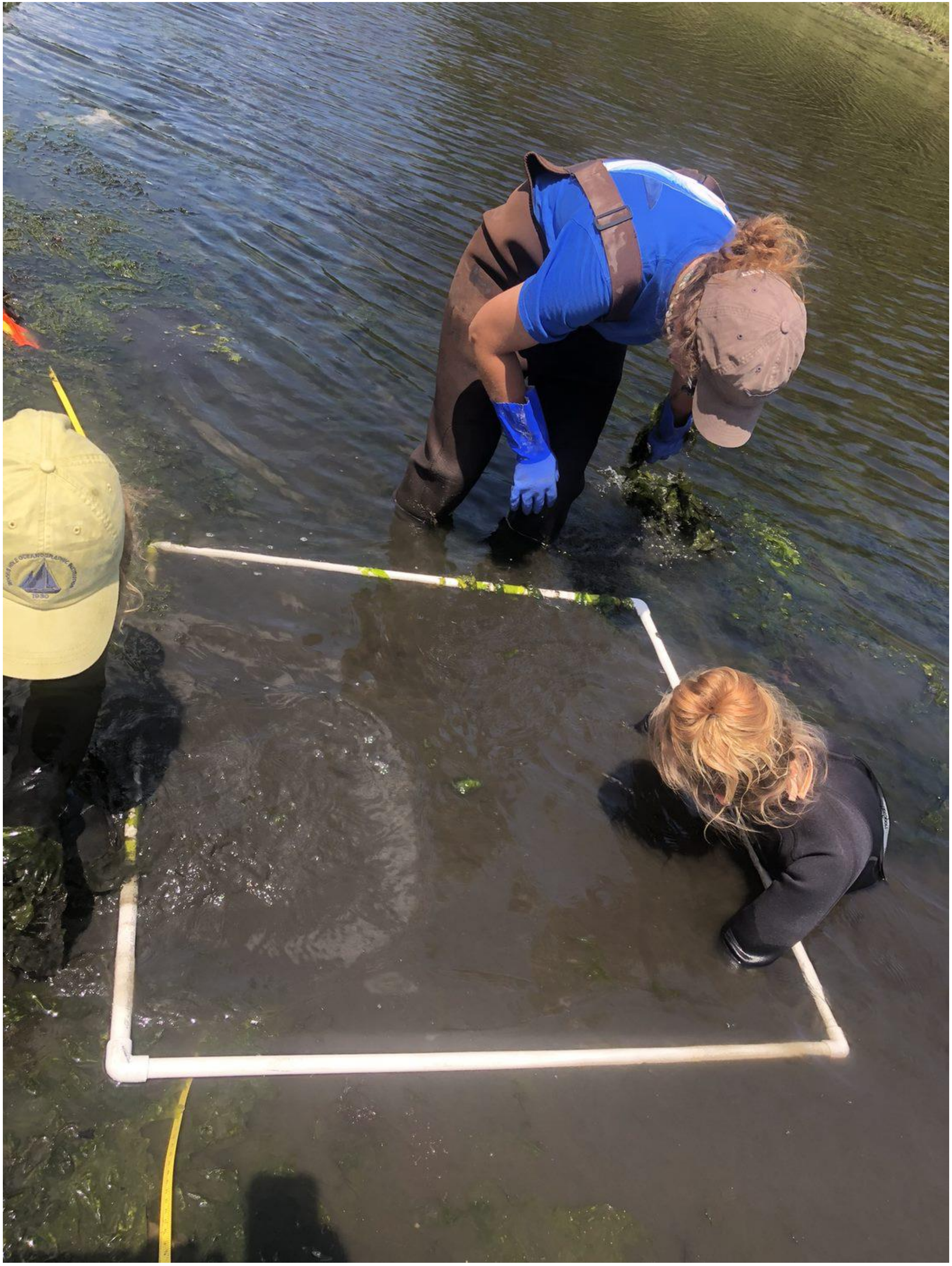


Image 25. From left Heather Kinney (TNC), intern Blake Busch (RIDEM), and Principle Marine Scientist Eric Schneider (RIDEM) discussing algae species while transect and quadrat sampling in Greenhill Pond (June 2022).

Image 26. Epiphytic loading in some ponds is greater than others, here tube worms (*Hydroides dianthus*) are the dominant fouling organisms on this otherwise healthy clump of eastern oysters.

Image 27. DEM Interns Blake Busch and Alejandro Rojas prepare a transect for quadrat surveying in the "Hummocks" area of Ninigret Pond, this the second of two transects conducted to specifically account for the large density of oysters found beneath the branches of overhanging vegetation(June 2022).

Image 28. Sampling in the coastal salt ponds as the waters warm in the summer can be complicated with various blooms of stinging Cnidarians such as this Clinging Jelly (*Gonionemus vertens).* This individual was netted on algae adjacent to study areas in Ninigret Pond, a large group of them required a change in sampling plan due to their potentially painful stings (July 2022).

Image 29. (Eastern oysters found in the course of a reconnaissance visit to Dutch Harbor, these oysters were particularly cryptic and mostly hidden by rockweed *(Fucus spp.)* and sea lettuce *(Ulva lactuca*) (May 2022).

Image 30. A narrow berm of cobble and shell deposits separate a small marshy estuary from the rest of Narragansett Bay on Prudence Island, in the right hand background of the image is a former oyster restoration site where we found no live oysters (May 2022).

Image 31. TNC field staff (Will Helt) measuring an oyster on some rip-rap covered in rock weed at India Point on 5/18/22. Many of the oysters found in this area were attached to man-made structures like cement blocks from hardened shorelines.

Image 32. On left, Shoreline sampled in the Mill Gut on 5/25/22. On right, single oyster set on ribbed mussel. The majority of oysters in this area were singles and had signs of setting on ribbed mussels as juveniles then breaking off the mussel shell over time.

Image 33. On left, TNC field staff (Heather Kinney) holding two oysters attached to a small stick in the Upper Pond of the Narrow River on 6/28/22. On right, a larger excavated oyster is held by TNC staff. The majority of oysters found in the upper pond were buried deep in the mud with only a small bit of the oyster peeking above the surface. Note the thick black layer along both oysters.

Image 34. DMF Fellow Natalia Jaworski and NRCS staff conduct expanded transect and quadrat surveys in Greenwich Cove, July 2022.

Image 35. DMF interns set a HOBO logger in a Wickford tidal creek and take calibration measurements with a YSI multiparameter tool, August 2022.

Image 36. Blake Busch holds a large cobble stone with naturally recruited oysters that he is measuring in Nannaquacket, July 2022.

Image 37. DMF interns sampling a subtidal natural oyster bed amongst boulders in Greenhill Pond, August 2022.

Image 38. From foreground to background, a HOBO U-24-002C logger, the PVC housing, and the "oyster castle" ready to be deployed in Greenhill Pond, August 2022.

Image 39. Oysters on an inflow pipe along the Narrow River narrows, September 2022.

Image 40. From left: Emma Venarde, William Helt and Vanessa Sedore conducting a reef survey in Narrow River, July 2022.

Image 41. Thomas Ardito (SNEP Grants Director) aboard the DMF skiff holding a native oyster in Fishing Cove, Wickford, November 2022.

Image 42. View of the oysters recruiting on man-made structures at Pawtuxet Cove, July 2022.

Image 43. One of many large oysters found during transect sampling along the Seekonk River, August 2022.

Image 44. Vanessa Sedore (intern) conducting a transect survey and measuring oysters along the Seekonk River, August, 2022.

Image 45. 2023. Collaborative TNC and DMF sampling of the Narrow River May 22, 2023..

Image 46. Blake Busch(DMF) and Sarah Paulson(TNC) working up a bag of oysters collected from a quadrat on the Narrow River, May 2023.

Image 47. Examples of biofouling of “oyster castles” by various organisms from around the state, on the left *Ulva spp.* dominates the sunlit surfaces of the castle while diatoms and encrusting invertebrates such as bryozoans and tube worms coat the sides. On the above right image ascidians(sea squirts) can be seen on the inner corners of this oyster castle. These castles serve two purposes at present (1)to anchor HOBO loggers to the substrate at sentinel sites and (2) allow for the detection of oyster spat recruitment in these areas on a surface that is specifically formulated to attract mobile larvae to settle out of the plankton.

Image 48. Collaborative DMF/TNC transect sampling on a typically chilly early May field excursion (2023) in the northern portion of Foster's Cove, south coast salt ponds.

Image 49. Sampling 15 year old oysters at a historical restoration site DMF interns Jessica Rugeri and Courtney Caccomo measure and record data in Quonochontaug Pond (June 2023).

Image 50. 2023. Eric Schneider (PI-RI DMF) displays a cluster of oysters that have recruited to a small piece of cobble in May 2023.

Image 51. Pat Barret (RIDMF) holds a dense cluster of oysters found while surveying Fosters Cove May 3rd 2023.

Image 52. DMF Yale Environmental Fellow Madeline Armstrong and research assistant Blake Busch sample "Fresh Pond" ", this site is characteristic of oyster populations occurring with site conditions such as cobble and boulder substrates in conjunction with overhanging trees June 22, 2023.

Image 53. Transect and quadrat sampling within Fresh Cove, May 2023.

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Image 54. Transect running along the shore and showing a high density intertidal bed in Fosters Cove June 1, 2023.

Image 55. Courtney Caccomo and Blake (DMF) Fresh Pond, 2023.June 22 2023

5. Certification:

The undersigned verifies that the descriptions of activities and expenditures in this progress report are accurate to the best of my knowledge; and that the activities were conducted in agreement with the grant contract. I also understand that matching fund levels established in the grant contract must be met.

Eric Schneider, Principal Marine Fisheries Biologist

9/15/2024, Rhode Island Department of Environmental Management, Division of Marine Fisheries

6. References

Baggett, L.P., S.P. Powers, R. Brumbaugh, L.D. Coen, B. DeAngelis, J. Green, B. Hancock, and S. Morlock (2014). Oyster habitat restoration monitoring and assessment handbook. The Nature Conservancy, Arlington, VA, USA, 96.

Brumbaugh, R.D., and Caitlyn Toropova. 2008. Economic valuation of ecosystem services: A new impetus for shellfish restoration? Basins and Coasts News 2 (2):8-15.

Hancock B, DeAngelis B, Turek J, Lazar N (2007) North Cape Shellfish Restoration Program. Annu Rep, 66.

Environmental Protection Agency. (2001). EPA Requirements for Quality Assurance Project Plans. EPA QA/R-5.

Environmental Protection Agency. EPA R-5 Checklist for Review of Quality Assurance Project Plans.

Environmental Protection Agency. (2010). New England Quality Assurance Project Plan Program Guidance. EQAQAPP2005PG2

Griffin M, DeAngelis BM, Chintala M, Hancock B, Leavitt D, Scott T, Brown DS, Hudson R (2012) Rhode Island Oyster Restoration Minimum Monitoring Metrics and Assessment Protocols.

Grabowski, J.H., Brumbaugh R.D., Conrad R.F., Keeler A.G., Opaluch J.J., and C. H. Peterson. 2012. Economic valuation of ecosystem services provided by oyster reefs. Bioscience 62:900-909.

Griffin M (2016) Fifteen Years of Rhode Island Oyster Restoration: A Performance Evaluation and Cost-Benefit Analysis. Open Access Masters Theses. doi: 10.23860/thesis-griffin-matthew-2016

Helt W, Schneider E (2016) Assessment and Monitoring for the Oyster Reef Restoration Initiative.

Piehler, M. F., and A. R. Smyth. 2011. Impacts of ecosystem engineers on estuarine nitrogen cycling. Ecosphere 2:art12
Powers, S. P., C. H. Peterson, J. H. Grabowski, and H. S. Lenihan. 2009. Success of constructed oyster reefs in no-harvest sanctuaries: implications for restoration. Marine Ecology Progress Series 389:159–170.

Puckett BJ, Theuerkauf SJ, Eggleston DB, Guajardo R, Hardy C, Gao J, Luettich RA (2018) Integrating Larval Dispersal, Permitting, and Logistical Factors Within a Validated Habitat

Suitability Index for Oyster Restoration. Front Mar Sci 5:76. doi: 10.3389/fmars.2018.00076

RI Shellfish Management Plan (2014). In: Shellfish RI. https://www.shellfishri.com/the-plan/. Accessed 26 Jul 2021

Theuerkauf, S. J., D. B. Eggleston, B. J. Puckett, and K. W. Theuerkauf. 2017. Wave Exposure Structures Oyster Distribution on Natural Intertidal Reefs, But Not on Hardened Shorelines. Estuaries and Coasts 40:376–386.

Wall, C. C., Peterson, B. J., and Gobler, C. J. 2011. The Growth of Estuarine Resources (Zostera marina, Mercenaria mercenaria, Crassostrea virginica, Argopecten irradians, Cyprinodon variegatus) in Response to Nutrient Loading and Enhanced Suspension Feeding by Adult Shellfish. Estuaries and Coasts 34: 1262-1277.