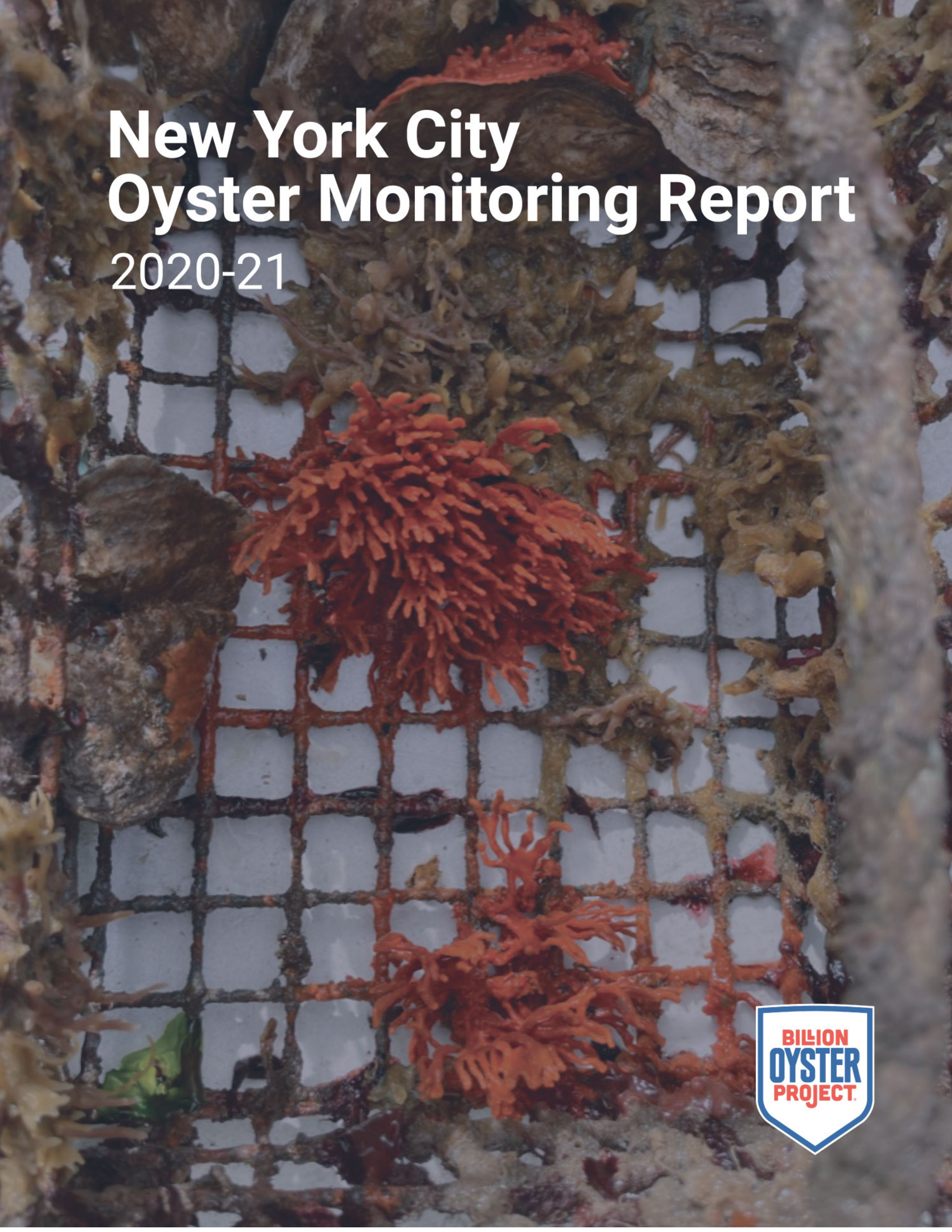
New York City Oyster Monitoring Report

2020-21



BILLION OYSTER PROJECT

ABOUT BILLION OYSTER PROJECT

The mission of Billion Oyster Project is to restore oyster reefs in New York Harbor through public education initiatives. Oyster reefs contribute to several ecosystem services, including providing habitat complexity that enhances species biodiversity and abundance, improving water quality through filtration and sediment stabilization, and enhancing shoreline resilience and adaptation.

We envision a future in which New York Harbor is the center of a rich, diverse, and abundant estuary. The communities surrounding this complex ecosystem have contributed to its construction and, in return, benefit from it with endless opportunities for work, education, and recreation. The Harbor is a world-class public space, well-used and well-cared for—our Commons.

By 2035, Billion Oyster Project aims to create self-sustaining oyster populations by deploying 1 billion oysters, creating 100 acres of oyster reef habitat, and engaging 1 million people in their work.

To date, Billion Oyster Project has collected 2 million pounds of shells from restaurants. These shells provide habitat for oysters in the waters of New York City. Over 100 million live oysters have been reintroduced by Billion Oyster Project in the waters of New York City, and over 11,000 NYC students have been engaged in the process.

RECOMMENDED CITATION

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ACKNOWLEDGEMENTS

Restoring New York Harbor takes a city! We are grateful to the thousands of students, educators, volunteers, partners, funders, and supporters who are making oyster restoration a reality. We thank all who contributed to a successful season of monitoring, maintenance, and data collection in 2020-2021. We'd also like to specifically acknowledge the property managers for working with us to install these oyster reefs, and the many ambassadors and volunteers for their support and efforts - thank you!

ORGANIZATIONS

New York City Department of Parks and Recreation
One°15 Brooklyn Marina
Brooklyn Bridge Park Conservancy
Brooklyn Bridge Park Corporation
Brooklyn Navy Yard
The Trust for Governors Island
Hudson River Park Trust
Princess Bay Boatmen's Association
Richmond County Yacht Club
Sebago Canoe Club
SUNY Maritime College

SUPPORTERS

11th Hour Racing
Barclays Capital
Bloomberg Philanthropies
CIT
Con Edison
Dalio Philanthropies
Daniel and Mitra O'Neill
DeLaCour Family
Familia Torres Foundation
Doris Duke Charitable Foundation
George Loening
Hudson River Foundation
Jamestown Charitable Foundation
Jeanne Donovan Fisher
John Needham
Joseph and Katherine Macari Foundation
Kamco
Lily Auchincloss Foundation
Mellam Family Foundation
Moët Hennessy
Monarch Impact Fund
National Science Foundation
New York City Council
Noah Clothing
NYC Department of Environmental Protection
NYC Ferry Operated by Hornblower
NYS Department of Environmental Conservation
NYS Governor's Office of Storm Recovery
Pincus Family Foundation
Sandy Hook Pilots Association
Scintilla Foundation
Simeon and Jean H. Locke Foundation
Simons Foundation
Statue Cruises
Talisker Single Malt Scotch Whisky
The Harrison Foundation
The Henry L. and Grace Doherty Charitable Foundation
The Marine Society of the City of New York
The McCance Foundation
The Monarch Foundation
The Nature Conservancy
The Overbrook Foundation
The Pew Charitable Trusts
The Rudolph J. and Daphne A. Munzer Foundation
Tito's Handmade Vodka
TK Foundation
Two Trees
William and Mary Greve Foundation

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Introduction

This is the fourth edition of the New York City Oyster Monitoring Report. The report was produced by Billion Oyster Project staff and research partners and summarizes the 2020-2021 monitoring results of 12 oyster study sites in New York Harbor (**Table 1**, **Figure 1**). These reports were delayed due to COVID-19 restrictions. Data were collected by academic partners, community scientists, students, teachers, etc., using protocols developed by Dr. Michael McCann from The Nature Conservancy. For more information about past oyster restoration projects, please refer to our annual reports, which are available on our website.

Figure 1. 2020-2021 oyster restoration sites in New York Harbor described in this report. Refer to Table 1 for acronym definitions.

Billion Oyster Project deploys oysters in various restoration structures; refer to **Overview of Oyster Structures and Sources** (p. 6) for more information. For a quick overview of findings from 2020-2021, refer to the **Main Findings** (p. 12) and **Site-Specific Findings** (p. 13). The remainder of the document summarizes the results of scientific monitoring in greater detail for each site and is intended for a technical audience. It is organized around specific topics, including **Performance Metrics** (p. 16), **Oyster Growth** (p. 18), **Oyster Survival** (p. 25), **Disease** (p. 30), **Reproductive Status** (p. 33), **Recruitment** (p. 36), **Water Quality** (p. 39), and **Biodiversity** (p. 48).

While this report focuses on active restoration sites maintained and monitored by Billion Oyster Project, Billion Oyster Project is also involved in other activities throughout the city. For example:

- Since 2015, school groups, various community groups, and individuals have been participating in Billion Oyster Project's Oyster Research Station program. Data and results from this program are not included in this report. With the expansion and standardization of this program along with the launching of the BOP digital platform, we plan to incorporate the data from this program in our upcoming report.
- As part of the Supporting Oyster Aquaculture and Restoration (SOAR) effort led by The Nature Conservancy and The Pew Charitable Trusts, Billion Oyster Project and the Urban Assembly New York Harbor School introduced 5,000 donated adult oysters to the Governors Island reef site in the Buttermilk Channel between Brooklyn and Manhattan in May 2021.

Large-scale oyster restoration projects at Hudson River Park in Tribeca (north of Pier 26) and Gansevoort (south of Pier 54) sites are not discussed in this report. Results from previous years can be found on the Hudson River Foundation's website[1]. Billion Oyster Project anticipates that restoration will occur at other sites, including the Living Breakwaters, and Soundview Oyster Habitat Restoration Project. To learn more about the Living Breakwaters project, please visit the project website[2] for the most current update. Ongoing oyster research and restoration at Soundview started back in 2006 and has expanded since; please look forward to our final report of the project in 2023. Billion Oyster Project is planning with other organizations to conduct post-construction monitoring for previous installations at the Governor Mario M. Cuomo/New NY Bridge Project at Tappan Zee and the Head of Bay Oyster Bed Enhancement Project.

[1] https://www.hudsonriver.org/article/hudson-river-foundation-publications
[2] https://stormrecovery.ny.gov/living-breakwaters-project-background-and-design

Overview of Oyster Structures and Sources

Oyster Structures

Depending on site conditions, project objectives, and our evolving understanding of best practices for oyster restoration in a heavily urbanized city, Billion Oyster Project use various approaches and structures:

- **Bagged shells** (**Figure 2A**) are individual plastic mesh fishing bags that hold approximately 600 spat-on-shell and 1.4 cubic yards of material. Individual bags are placed within a 10' x 6.6' plot and secured with strategically placed PVC pipes that are inserted on the outer edge of the plot.
- **Gabions** (**Figure 2B**) are metal framed, vinyl-coated steel mesh formed into rectangular or cube (also known as mini gabions) shapes. Each block is filled with oyster shells that have been cured following NYSDEC recommended guidelines.
- **OysterGros®** (**Figure 2C**) is an aquaculture farming system developed in New Jersey to handle high-volume oyster rearing. OysterGro® trays consist of 12-Gauge, vinyl-coated, wire mesh cages supported by high-density, polyethylene, air-filled floats. The floats that suspend the units are constructed of rigid, UV-resistant marine plastic. Each cage has six separate compartments for storing oysters. Soft, plastic mesh ADPI bags hold the oysters within each compartment. Each OysterGro® unit measures 41" x 31" x 9".
- **Community Cabinet Reefs** (**Figure 2D**) is a 10' x 2' x 2' welded rebar frame cabinet that holds 28 mesh files, each file containing approximately 7,500 2 mm spat-on-shell at the time of installation. These sleeves are locked in place with a section of rebar that Billion Oyster Project staff can remove during monitoring events.
- **ECOncrete® discs** (**Figure 2E**) have enough surface area for approximately 1,000 oyster spat and weigh approximately 10-12 pounds per disc. These discs are made of eco-friendly materials that create an ideal substrate for oysters to settle on.
- **SuperTrays** (**Figure 2F**) are rigid, UV-resistant marine plastic trays measuring 51 centimeters square by 20 centimeters tall. Super Trays stack and are held together with a bridle made of ⅜ inch polypropylene line. When suspended from floating docks or buoys they are fully subtidal; when suspended from fixed piers they can be configured to be intertidal.
- **SEAPA Cages** (**Figure 3**) filled with spat-on-shell were installed in 2020 to form a suspended nursery reef at One°15 Brooklyn Marina in Brooklyn Bridge Park. These SEAPA cages were designed to facilitate the rotation of the structure for oysters to form a well-cupped shape (as opposed to long and thin) with a high meat content. The SEAPA Cages at One15 Marina were hung off a cleat in stacks of 2-3 cages.

Figure 2 A-F. Examples of structures employed to install oysters: (A) bags, (B) mini-gabions, (C) OysterGros®, (D) community reef files, (E) ECOncrete® discs, and (F) Super Trays. (Photos courtesy of Finola Fung-Khee, Dr. Elizabeth Burmester, Robina Taliaferrow, and Dr. Michael McCann)

Figure 3. SEAPA cages filled with spat-on-shell (left) in stacks of 3 to be hung off the dock (right) at One°15 Brooklyn Marina in Brooklyn Bridge Park. (Photos courtesy of Steven DeWitt)

Oyster Sources

Oysters found in restoration structures at a given site come from one of three sources. Most oysters have been intentionally added to these sites by Billion Oyster Project. These oysters come from either our Remote Setting Facility (located in Red Hook Terminals) and/or the MAST Center Hatchery in the Harbor School on Governors Island (New York, USA). At each of these locations, larval oysters (which are planktonic) spawned from adult oysters (wild, farmed, and/or restored) by Billion Oyster Project staff or purchased from Muscongus Bay Aquaculture (Maine, USA) are set onto shells (recycled from partner restaurants, **Figure 4**) or other structures. Additionally, wild larvae that came from adult oysters, either naturally found in New York Harbor or installed by Billion Oyster Project, may also settle on these restoration structures and be included in the monitoring. For more information on the oyster life cycle and our shell collection process, please check out Billion Oyster Project's website.

Figure 4. This spat-on-shell was set at the hatchery on Governors Island. (Photo courtesy of Rebecca Resner)

Overview of Activities in 2020-2021

All sites were permitted and installed by Billion Oyster Project. The number of oysters deployed to each site are summarized in **Table 1**. Two sites were added and one site was removed from this report since the 2019 New York City Oyster Monitoring Report:

1. In 2020, Billion Oyster Project installed a bagged shell reef at Bayswater Point State Park.
2. In 2020 and 2021, Billion Oyster Project deployed three installations at One°15 Brooklyn Marina in Brooklyn Bridge Park: (1) a SEAPA nursery, (2) community cabinets, and (3) gabions.
3. In 2021, Billion Oyster Project removed Lemon Creek Nursery from our portfolio due to heavy sedimentation rates.

Table 1. Restoration structures and installation details.

Site	Structure	Install date	Larvae source *	**Size at install** (shell height, mm)	Number of oysters installed
Brooklyn Navy Yard (**BNY**)	Super Tray Nursery	4/10/2017	Muscongus Bay, ME	34.9	2,750
Paerdegat Basin (**PB**)	Cabinet Reef	7/27/2018	Muscongus Bay, ME	~5	480,000
Great Kills Harbor (**GKH**)	Super Tray Nursery	8/23/2016	Muscongus Bay, ME	27.7	15,836
		6/12/2017	Oysters reared in Great Kills Harbor oyster cages	4.1	141,327
		7/10/2019	Muscongus Bay, ME	2-5	200,000
Lemon Creek Nursery (**LCN**)	OysterGro® Nursery	6/12/2017	Oysters reared in Great Kills Harbor oyster cages	4.1	228,780
Lemon Creek Lagoon (**LCL**)	ECOncrete® Discs	8/15/2018	Governors Island nursery broodstock	~5	242,000
	Gabions	8/15/2018	Muscongus Bay, ME	~5	
	Bagged Shell Reef	8/15/2018	Muscongus Bay, ME; Governors Island nursery broodstock	~5	
Bush Terminal Park (**BTP**)	Cabinet Reef	6/28/2016	Muscongus Bay, ME	~2	969,452
	Cabinet Reef	8/22/2018	Muscongus Bay, ME; Governors Island nursery broodstock	~5	180,000
	Bagged Shell Reef	8/23/2018	Muscongus Bay, ME; Governors Island nursery broodstock	~5	135,000
SUNY Maritime (**SM**)	Super Tray Nursery	8/28/2019	Muscongus Bay, ME	<10	1,739,714
	Super Tray Nursery	8/10/2021	Muscongus Bay, ME	<10	2,570,689
Coney Island Creek (**CIC**)	Community Reef +	9/18/2019	Muscongus Bay, ME	~5	14,223
	Community Reef	6/24/2021	Muscongus Bay, ME	2-5	117,772
Governors Island EcoDock (**GI**)	Super Tray Nursery	6/15/2020	Muscongus Bay, ME	<10	439,108
		6/16/2021 8/11/2021	Muscongus Bay, ME	<10	3,623,473
Bayswater Point State Park (**BW**)	Bagged Shell Reef	7/20/2020	Muscongus Bay, ME	~5	30,514
	Bagged Shell Reef	9/14/2020	Muscongus Bay, ME	2-5	384,235
Brooklyn Bridge Park Nursery (**BBPN**)	SEAPA Cage Nursery	8/28/2020	Muscongus Bay, ME	2-5	215,280
Brooklyn Bridge Park - One°15 Marina	Cabinet Reef (**BBPC**)	9/8/2021	Muscongus Bay, ME	2-5	185,071
	Gabions	8/30/2021	Muscongus Bay, ME	2-5	588,861
Williamsburg Field Station (**WFS**)	Bagged Shell Reef	9/17/2021	Muscongus Bay, ME	2-5	270,000
	Cabinet Reef	9/15/2021	Muscongus Bay, ME	2-5	151,422

* See text for a complete explanation of oyster sources.
\+ Due to regulatory requirements, all oysters installed at this site were removed at the end of the season of the following year.

Main Findings

Oysters continue to grow and cement to one another to form reefs.

At the sites monitored biannually, oyster growth was observed during spring and fall in 2020 and 2021. Oysters at sites monitored annually in 2021 also showed growth. Consistent with our knowledge of oyster biology and building upon monitoring results from previous years, these findings suggest oysters grow rapidly in their first year, and older oysters grow at a slower rate.

Disease was not a major issue during this period.

None of the tested oysters had fatal infection of Dermo and MSX. Continued disease monitoring is necessary as disease prevalence and intensity are changing compared to previous years.

Reproduction is promising at select sites.

Oysters collected in July 2020 showed signs of developing gonads and sexual maturity. Considering Billion Oyster Project's goal to restore oyster reefs to New York Harbor, this is a great sign!

Hypoxia (i.e., low oxygen) is a problem for oysters at certain sites.

Oysters require oxygen to support their growth and maintain good health conditions. Presently, oysters at all of Billion Oyster Project's restoration sites have experienced periodic hypoxia.

Recruitment data is limited.

Continued and increased efforts to measure recruitment at Billion Oyster Project's restoration sites and other potential sites are necessary to understand oyster population dynamics across a broader geography.

A diversity of organisms live in and around oyster reefs.

A variety of organisms rely on restored oyster reefs as a habitat in which to feed, reproduce, and take shelter. Billion Oyster Project staff regularly identify 70+ marine species living on or around our oysters.

Adaptive management is key to successful oyster restoration.

Although oyster restoration and research activities have been underway in NY/NJ Harbor for nearly two decades, it's still a newly-developing restoration field. Therefore, an adaptive management approach is necessary as we learn and make data-informed decisions while refining our protocols.

New sites are new learning opportunities.

Each new site is an opportunity to learn and improve our practice. Each site has different needs and conditions, and new restoration techniques and structures should be developed and refined with adaptive management in mind.

Site Specific Findings

Oyster nurseries and on-bottom reef sites serve distinct purposes and are characterized by different deployment methods. Oyster nurseries generally involve suspended cages positioned in the upper water column. These nurseries serve two primary functions: they act as holding areas for broodstock, which are used for future spawning at the MAST Center hatchery, and they provide a space to house oysters before their eventual deployment to reef sites.

On the other hand, on-bottom reef sites serve as active restoration areas where oysters are strategically deployed to rebuild reefs. These reef sites are typically located on the bottom of the water body. The main goal of reef sites is to facilitate oyster growth, survival, and the establishment of healthy oyster populations within the ecosystem. By deploying oysters in reef sites, restoration efforts aim to enhance the three-dimensional complexity of the habitat, promote biodiversity, and improve overall ecosystem health.

Both oyster nurseries and reef sites play vital roles in oyster restoration and conservation efforts, each contributing to the successful revival of oyster populations in their respective ways.

Nurseries

Brooklyn Bridge Park
The nursery at Brooklyn Bridge Park, established in 2020, incorporates oysters housed in SEAPA cages (**Figure 3**), a novel structure utilized by Billion Oyster Project. Data from ongoing monitoring efforts demonstrate a consistent pattern of heightened growth and notable natural recruitment within the nursery environment.

Brooklyn Navy Yard
The nursery at the Brooklyn Navy Yard is designed to accommodate adult oysters, which are suspended in stacks of plastic Super Trays (**Figure 2F**) beneath buoys. However, due to regular site maintenance and the need to move the trays, monitoring activities were not conducted at this particular site in 2020 or 2021.

Lemon Creek
The oyster nursery located at the mouth of Lemon Creek is relatively small and consists of four OysterGro® structures (**Figure 2C**). Unfortunately, due to high sedimentation rates in the area, the nursery experienced total oyster mortality, rendering it unsuitable for supporting oyster growth and survival. As a result, monitoring activities at this site ceased after April 2021. In light of these unfavorable conditions and the lack of viability for oyster restoration, the decision was made to remove this site from Billion Oyster Project's nursery locations.

Great Kills Harbor
The nursery at Great Kills Harbor features adult oysters suspended in stacks of plastic Super Trays beneath floating docks (**Figure 2F**). While oysters are growing in this environment, the site has also experienced significant oyster mortality. Upon observation, it has been noted that oysters at this location are infected with boring sponges. Boring sponges are parasitic organisms that can negatively impact oysters, leading to increased mortality rates.

Governors Island EcoDock
The EcoDock serves as a temporary nursery for oysters reared in the MAST Hatchery. Oysters in this nursery grow out in stacks of Super Trays suspended from the dock until they are ready for deployment to other restoration sites. The frequent movement of oysters and their eventual transfer to other locations make it challenging to conduct regular monitoring activities at this site.

SUNY Maritime College
The nursery at SUNY Maritime College, established in 2021, consists of 60 Super Trays (**Figure 2F**) containing adult oysters suspended in stacks near Olivet Pier. Additionally, another 60 Super Trays filled with spat-on-shell were also newly installed at the site in 2021. Dense populations of oyster drills were observed at this location, which is not uncommon in newly established sites. Oyster drills are predatory snails that feed on oysters and can pose a threat to the oyster population, especially in recently established areas where the oyster density might still be developing.

On-Bottom Reef Projects

Bayswater Point State Park
In 2020, Billion Oyster Project installed a bagged shell reef, which consisted of 66 bags filled with spat-on-shell and 30 bags filled with blank shells. The live oysters were contained within plastic mesh (as depicted in **Figure 2A**) and coconut coir bags.

Brooklyn Bridge Park - One°15 Brooklyn Marina
In addition to the SEAPA cages installed at the nursery site, three community reef cabinets (**Figure 2D**) and five gabions were added as on-bottom reefs. Despite the slower growth rate of the nursery oysters since their installation (as specified in **Tables 3A** and **3B**), they displayed a higher survival rate than those in the community reef cabinets (**Table 5**).

Bush Terminal Park
Billion Oyster Project installed five community cabinets in 2016, five community cabinets in 2018, and one bagged shell reef comprising 96 bags (66 bags filled with spat-on-shell and 30 bags filled with blank shells) in 2018. Unfortunately, monitoring activities in 2020 had to be suspended due to COVID-19 restrictions. However, oysters were still collected during that time to test for disease and histopathology. Oysters were close to an even sex ratio, and 44% were

sexually mature and spawning. The condition index of oysters was highly variable between seasons (see p. 34).

Coney Island Creek

In 2019, Billion Oyster Project installed a community cabinet in Coney Island Creek, adjacent to Kaiser Park. In 2021, the original cabinet was replaced with two smaller cabinets, which together occupy a smaller footprint. Subsequently, a biodiversity assessment was conducted at the site, and it revealed the presence of 11 different taxa captured in both the minnow traps and the cabinet files.

Lemon Creek Lagoon

In 2018, Billion Oyster Project undertook several installations at the site, including the placement of 36 ECOncrete® disks (**Figure 2E**), 12 mini gabions **(Figure 2B**), and a bagged shell reef (**Figure 2A**) comprising 96 bags (66 filled with spat-on-shell and 30 filled with blank shells). Notably, oysters in the bagged shells demonstrated a positive trend in growth over three seasons, indicating successful development and maturation. During the 2020 sampling, the oysters at this site had reached an even sex ratio, with 50% of the sampled oysters being sexually mature and actively spawning.

Paerdegat Basin

In 2018, Billion Oyster Project installed five community cabinets filled with both spat-on-shell and blank shells. The oysters at this site exhibited a notable and positive trend of growth, leading to the substantial expansion of oysters protruding from the files. Disease analysis revealed no lethal infection or prevalence and the condition index of the oysters continues to increase between seasons.

Performance Metrics

To assess the performance of oyster restoration at each site, nine metrics were used to evaluate oyster survival, growth, disease, and reproduction. These metrics specify qualitative categories that essentially translate to “good,” “moderate,” and “poor” performance. These metrics do not directly indicate whether the restoration activities are providing ecosystem benefits (e.g., biodiversity enhancement, water quality improvements), although growth indicates oysters are feeding, and thus filtering the water, and oysters store some carbon in shells and tissues as they grow. Not all metrics can be applied to every site due to the type of site conditions, date of restoration installation activity, or age of restored oysters. Some metrics are not relevant in the first 1–2 years of restoration. For example, the presence of more than one oyster size class would not be expected immediately at a site where juvenile oysters were installed. The nine performance metrics are described in **Table 2**.

Table 2. Performance metrics for oysters at restoration sites. *See Reproductive Status (page 31) for more information about quantitative assessments.

Metric Category	Parameter and unit of measurement	Explanation	What indicates good oyster performance?
Growth	Shell height of oysters that are less than 6 months old (unit: mm/day)	Growth of spat is measured based on multiple spat shell height measurements during the first 6 months post settling. Growth during this time is most rapid.	Spat growth equal to or faster than 0.25 mm/day is classified as rapid.
	Continued shell height of oysters that are greater than 6 months old (unit: mm)	Growth of older oysters is assessed based on less frequent measurements, typically performed once in spring and once in fall.	Average shell height increases within the growing season and between years.
	Oyster "reefing" or cementation (unit: count of oysters per clump)	As oysters increase in size, they should "reef" or cement to each other or other hard structures.	Oysters attached to each other and to restoration structures. This outcome is desirable at reef sites but not within nursery gear.
Survival	Density of live oysters: a) Live oysters per clump OR b) Live oysters per unit area (e.g. m^2) OR c) Live oyster per unit structure	As spat, oysters naturally have a high mortality rate. After an initial period of high mortality, survival increases, and the density of oysters (i.e., number of oysters per clump or number of oysters per m^2) should stabilize.	Oyster density stabilizes after initial mortality.
Disease	Disease prevalence (unit: %) and intensity (unit for MSX is qualitative i.e. low, medium, high and for Dermo described by Mackin scale from 0 to 5)	Dermo and MSX are types of oyster diseases that can lead to lower fitness and mortality. Prevalence describes the proportion of individuals that are infected, while intensity describes the infection degree.	Older (>2-3 years old) oysters are susceptible to disease, and those are sampled at a subset of Billion Oyster Project sites. Oysters growing at sites with highest salinity are most vulnerable.
Reproduction	Stages of gonadal development (unit: % of individuals per stage)	Stages are determined based on expert assessment of gonad condition that describes the development of gonads and gametes within them and readiness to spawn.	Oysters mature following their 2nd year of life.* Therefore only these larger/older oysters are sampled. An equal ratio of males and females with developing or fully ripe gonads indicates a well-performing oyster population.
	Sex ratio	Oysters switch sexes during their adult life. They all begin as males. As oysters mature, their ratio in population approaches 50:50 (i.e., one female for one male).	
Recruitment	Multiple peaks on size distribution histograms	Size frequencies are calculated based on the total number of assessed oysters that are then classified into specific size groups.	On the histogram, more than one peak indicates the recruitment of new oysters. A much larger size of the smaller oysters' peak in comparison to the older oysters' can indicate the development of a sustainable reef.
	New spat = natural recruitment	Mature oysters produce larvae that are pelagic and swim in the water for 2-3 weeks. After, the larvae transition to the bottom, settling onto hard structures such as other oyster shells or rocks.	The presence of naturally recruited wild oyster spat.

* According to Dr. Bassem Allam, oysters can produce gametes as early as the age of one with a limited quantity and will increase in quantity in the following years. See *Reproductive Status* (page 33) for more information about quantitative assessments.

Assessing Performance At Each Site

The oyster performance metrics were applied to the 12 restoration sites. Of those sites, four (Governors Island EcoDock, Great Kills Harbor, Lemon Creek Lagoon, and Bush Terminal Park) had multiple cohorts or restoration approaches. In those cases, the performance metrics are reported for each cohort or restoration approach. **Tables 3A and 3B** summarize survival and mortality at Billion Oyster Project nursery and on-bottom reef sites, while **Table 4** summarizes the 2020 reproduction and disease data. No oysters were tested for disease and reproduction in 2021. Subsequent sections of this report describe in greater detail the oyster data used to complete this assessment and provide other environmental data that either describe oyster habitat suitability (e.g., water quality) or characterize other organisms at select sites.

Table 3A. Oyster growth and survival performance metrics at nursery sites. NA = not applicable

Nurseries	Growth			Survival
	Growth rate of oysters that are less than 6 months old	***Continued shell height of oysters that are greater than 6 months old***	***Oyster "reefing" or cementation***	***Density stabilizes after initial mortality***
Brooklyn Bridge Park - *SEAPA Cages* (2020)	**Slow** 8.2 mm (9/2020) 9.0 mm (10/2020) *0.03 mm/day*	**Yes** 19.2 mm (5/2021) 11.1 mm (6/2021) 27.1 mm (10/2021)	**Yes**	**Slight Decline** 50 oysters/clump (5/2021) 47 oysters/clump (10/2021)
Brooklyn Navy Yard - *Super Trays* (2017)	NA (installed at 1+ year)	NA (insufficient data)	NA (insufficient data)	NA (insufficient data)
Governors Island EcoDock - *Super Trays* (2020)	NA (insufficient data)	NA (oysters are <1 year old)	NA (insufficient data)	NA (oysters are <1 year old)
Governors Island EcoDock - *Super Trays* (2021)	**Slow** 10 mm (8/2021) 13.6 mm (10/2021) *0.05 mm/day*	NA (oysters are <1 year old)	NA (insufficient data)	NA (oysters are <1 year old)
Great Kills Harbor - *Super Trays* (2016)	NA (installed as 1+ yr)	**Yes** 84.1 mm (7/2019) 97.9 mm (11/2019) 101.6 mm (11/2021)	**Light** However, oysters were maintained to prevent them from cementing to gear	**Declining** 41.3 live/tray (7/2019) 21.7 live/tray (11/2019) 6.8 live/tray (11/2021)
Great Kills Harbor - *Super Trays* (2017)	**Rapid** 4.1 mm (6/2017) 33.5 mm (9/2017) *0.35 mm/day*	**Yes** 44.3 mm (6/2018) 78.0 mm (11/2018) 110.3 mm (11/2019) 110.2 mm (11/2021)		**Declining** 23.5 live/tray (7/2019) 19.0 live/tray (10/2019) 8.0 live/tray (11/2021)
Great Kills Harbor - *Super Trays* (2019)	NA (insufficient data)	**Yes** 110.7 mm (11/2021) 121.0 mm (10/2022)		NA (insufficient data)
Lemon Creek Nursery - *OysterGro* (2017)	**Rapid** 4.1 mm (6/2017) 36.6 mm (9/2017) *0.40 mm/day*	**Yes** 36.6 mm (9/2017) 74.8 mm (9/2018) 102.9 mm (12/2020) 104.9 mm (4/2021)	**Yes**	**Declining** 4.6 oysters/clump (12/2020) 1.9 oysters/clump (4/2021)
SUNY Maritime - *Super Trays* (2021)	NA (insufficient data)	NA (insufficient data)	NA (insufficient data)	NA (oysters are <1 year old)

Table 3B. Oyster growth and survival performance metrics at on-bottom reef sites. NA = not applicable

Reefs	Growth			Survival
	Growth rate of oysters that are less than 6 months old	***Continued shell height of oysters that are greater than 6 months old***	***Oyster "reefing" or cementation***	***Density stabilizes after initial mortality***
Bayswater Point State Park - *Bagged Shell Reef* (2020)	**Slow** 8.4 mm (9/2020) 14.1 mm (11/2020) *0.10 mm/day*	**Yes** 39.5 mm (5/2021) 52.2 mm (10/2021)	**Light**	NA (oysters are <1 year old)
Brooklyn Bridge Park - *Cabinet Reef* (2021)	**Rapid** 5 mm (9/2021) 16.3 mm (10/2021) *0.25 mm/day*	NA (oysters are <1 year old)	**Light**	NA (oysters are <1 year old)
Bush Terminal Park - *Bagged Shell Reef* (2018)	**Moderate** 5 mm (7/2018) 20 mm (11/2018) *0.20 mm/day*	**No** 50.2 mm (7/2019) 109.4 mm (5/2021) 92.6 mm (10/2021)	**Yes**	NA (insufficient data)
Bush Terminal Park - *Cabinet Reef* (2016)	**Rapid** 2 mm (6/2016) 8.34 mm (7/2016) *0.30 mm/day*	**No** 74.6 mm (7/2019) 107.6 mm (5/2021) 92.6 mm (10/2021)	**Yes**	**Slight decline** 0.6 oysters/clump (5/2021) 0.4 oysters/clump (10/2021)
Bush Terminal Park - *Cabinet Reef* (2018)	**Rapid** 5 mm (8/2018) 23.7 mm (10/2018) *0.30 mm/day*	**No** 40.6 mm (7/2019) 107.6 mm (5/2021) 92.6 mm (10/2021)	**Yes**	NA (oysters are <1 year old)
Coney Island Creek - *Cabinet Reef* (2018)	**Rapid** 5 mm (7/2018) 47.1 mm (11/2018) *0.36 mm/day*	**Yes** 27.5 mm (9/2020) 33.4 mm (10/2020)	**Light**	**Declining** 5.4 oysters/clump (9/2020) 4.8 oysters/clump (10/2020) 3.4 oysters/clump (4/2021)
Coney Island Creek - *Cabinet Reef* (2021)	**Rapid** 5 mm (6/2021) 41.9 mm (10/2021) *0.31 mm/day*	**Yes** 47.7 mm (10/2021)	**Yes**	NA (oysters are <1 year old)
Lemon Creek Lagoon - *ECOncrete®* (2018)	**Rapid** 5 mm (8/2018) 45.9 mm (11/2018) *0.47 mm/day*	**Yes** 101.5 mm (7/2020) 108.9 mm (10/2020) 106.7 mm (4/2021)	**Light**	**Declining** 7.3 live/disc (7/2020) 14.3 live/disc (10/2020) 10.5 live/disc (4/2021)
Lemon Creek Lagoon - *Gabions* (2018)	**Rapid** 5 mm (8/2018) 36.4 mm (11/2018) *0.34 mm/day*	**No** 101.4 mm (10/2019) 93.1 mm (7/2020)	**Yes**	NA (insufficient data)
Lemon Creek Lagoon - *Bagged Shell Reef* (2018)	**Moderate** 5 mm (8/2018) 22.8 mm (11/2018) *0.20 mm/day*	**Yes** 77.7 mm (7/2020) 94.0 mm (10/2020) 114.4 mm (4/2021)	**No**	NA (insufficient data)
Paerdegat Basin - *Cabinet Reef* (2018)	**Rapid** 5 mm (8/2018) 39.1 mm (12/2018) *0.25 mm/day*	**Yes** 57.4 mm (7/2020) 59.7 mm (10/2020) 67.4 mm (5/2021) 92.0 mm (10/2021)	**Yes**	**Slight Decline** 0.9 oysters/clump (5/2021) 0.8 oysters/clump (10/2021)
Williamsburg Field Station - *Cabinet Reef* (2020) *	**Slow** 4.4 mm (11/2020) 5.1 mm (12/2020) *0.034 mm/day*	NA (insufficient data)	NA	NA (insufficient data)
Williamsburg Field Station - *Bagged Shell Reef* (2021)	NA (insufficient data)	NA (insufficient data)	NA	NA (oysters are <1 year old)

* Billion Oyster Project no longer monitors the oysters in the cabinet reef at Williamsburg Field Station in 2021 due to restricted access to the site.

Table 4. Oyster disease and reproduction performance metrics at three restoration sites in 2020. NA = not applicable

Nursery	**Disease**	**Reproduction**		**Recruitment**	
	Disease prevalence and intensity **(October)**	***Gonad condition scores G1–S4**** **(June)**	***Even sex ratios*** **(June)**	***Multiple size classes***	***Spat on unseeded or off-reef structures***
Lemon Creek Nursery - *OysterGro* (2017)	**Low** MSX prevalence: 7%	**Yes** 93% spawning or developing	**~50:50** Male: 43% Female: 50% Undetermined: 7% (n = 30)	**No**	**No**
Bush Terminal Park - *Bagged Shell Reef* *Community Reef* (2016) *Community Reef* (2018)	**High** Dermo prevalence: 73% Dermo lethal intensity: 0% MSX prevalence: 4%	**Yes** 93% spawning or developing	**~50:50** Male: 48% Female: 44% Undetermined: 8% (n = 27)	NA (no monitoring in 2020)	NA
Paerdegat Basin - *Community Reef* (2018)	**Moderate** Dermo prevalence: 68% Dermo lethal intensity: 0% MSX prevalence: 0%	**Yes** 93% spawning or developing	**~50:50** Male: 57% Female: 43% Undetermined: 0% (n = 30)	**Yes**	NA

* See Table 9 for explanation of gonad condition scores.

Size Frequency Distribution

Oysters that are installed at a location are expected to survive and grow over time (**Figure 5**), although smaller oysters may experience higher mortality rates. As differences exist within a site (e.g., crowding, location on the reef) and among individual oysters (e.g., genetic variations), these differences are likely to become more noticeable as the oysters grow. To visually analyze these changes, smoothed density plots or histograms, which account for differences in sample sizes, are employed. These plots allow for easy assessment of oyster growth or the impacts of other factors by comparing graphs for different sampling periods, structures, or cohorts.

In the case of a single cohort of oysters of similar age, their shell heights are expected to follow a normal distribution, forming a bell-shaped curve with a single peak and two nearly symmetrical tails. However, if there are multiple cohorts (different age groups) of oysters present in a single sample, two peaks, not necessarily of equal size, may be visible. When comparing data from different sampling dates, it is not uncommon to observe smaller oysters in later samples than those noted in earlier samples. This could be due to slow growth during specific periods or because only a portion of the oyster population is sampled. Additionally, the appearance of smaller oysters in later samplings may also be a result of the emergence of a new cohort on an established reef due to natural settlement events.

To assess these patterns, size frequency distributions of five nursery sites and seven on-bottom reef sites are presented as smooth density plots in **Figures 6 - 10** and **Figures 11 - 17**, respectively. These plots allow for a visual understanding of the growth patterns and size distribution of oysters at the monitored locations, providing valuable insights into the dynamics of the oyster populations in different environments.

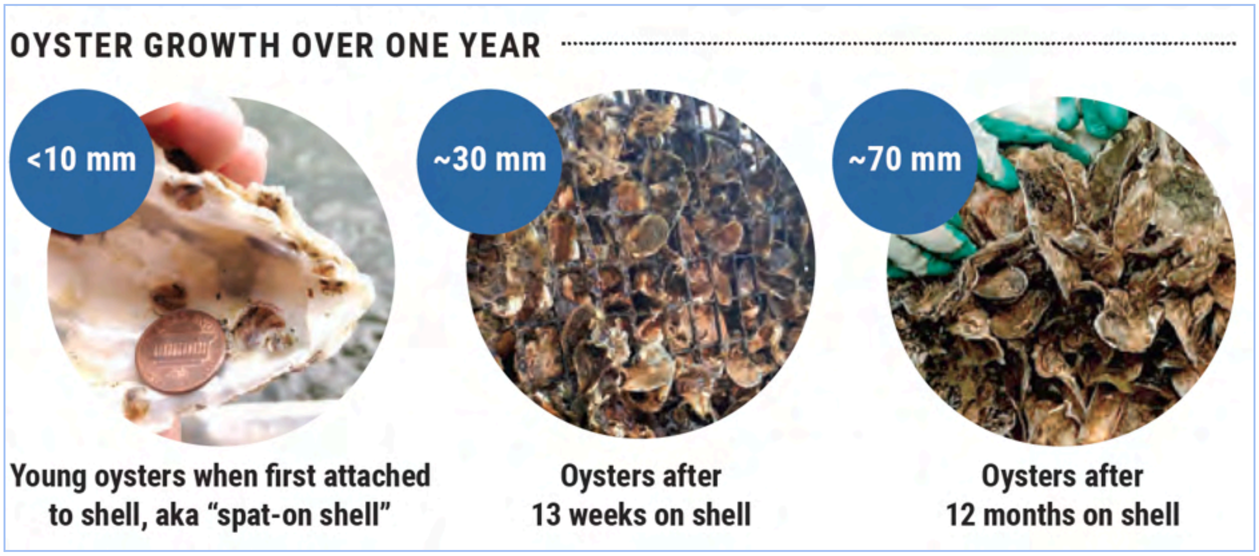

Figure 5. These photos show oyster growth in the first year of restoration at sites with fast growth. (Photos courtesy of Billion Oyster Project Staff)

Nurseries

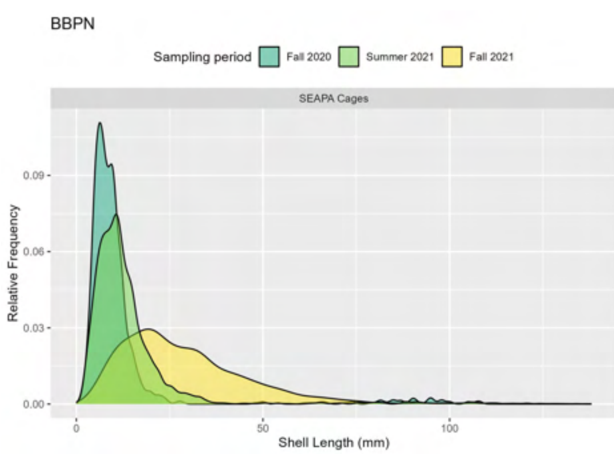

Figure 6. Size frequency distribution graph shows increasing shell length over three monitoring seasons for a single cohort at Brooklyn Bridge Park, One°15 Brooklyn Marina Nursery.

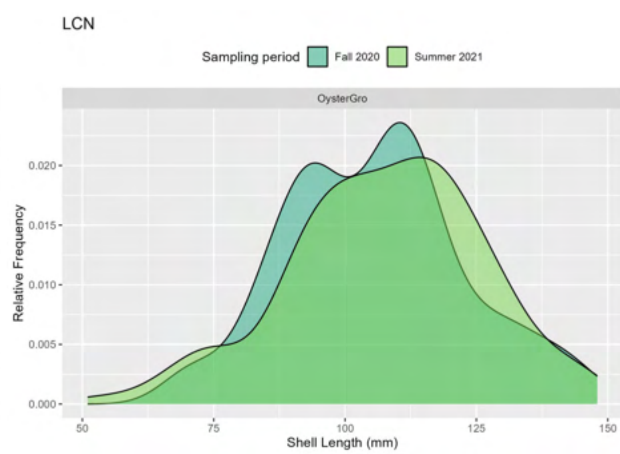

Figure 7. Size frequency distribution graph shows increasing shell length over two monitoring seasons for a single cohort at Lemon Creek Nursery.

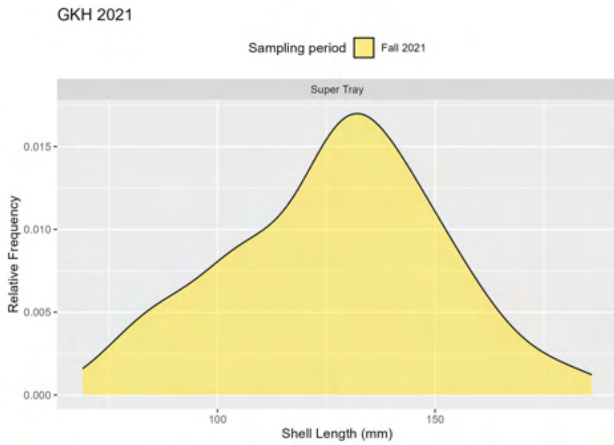

Figure 8. Size frequency distribution graph shows a normal distribution of shell length at Great Kills Harbor Nursery. No monitoring was conducted at this site in 2020.

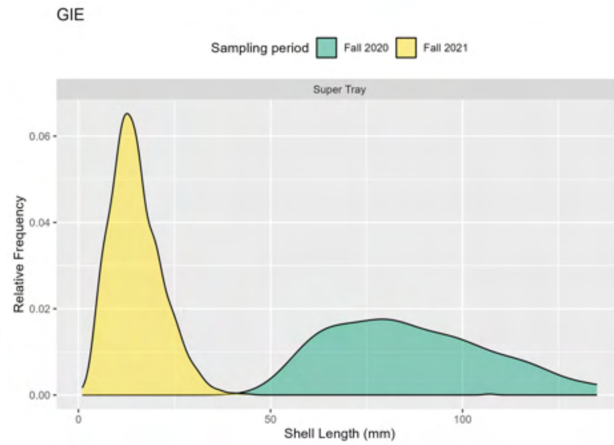

Figure 9. Size frequency distribution graphs of 2020 and 2021 oyster cohorts at Governors Island EcoDock Nursery. The two cohorts are independent of each other as oysters are only grown over the summer at the EcoDock before being deployed to other restoration sites.

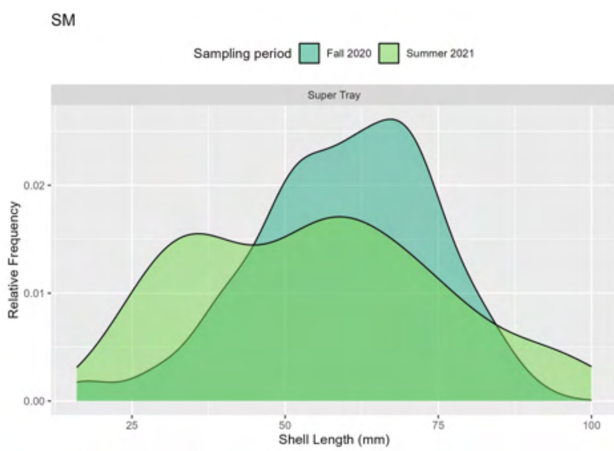

Figure 10. Size frequency distribution graph shows variability in shell length over two monitoring seasons at SUNY Maritime College Nursery.

On-Bottom Reef Projects

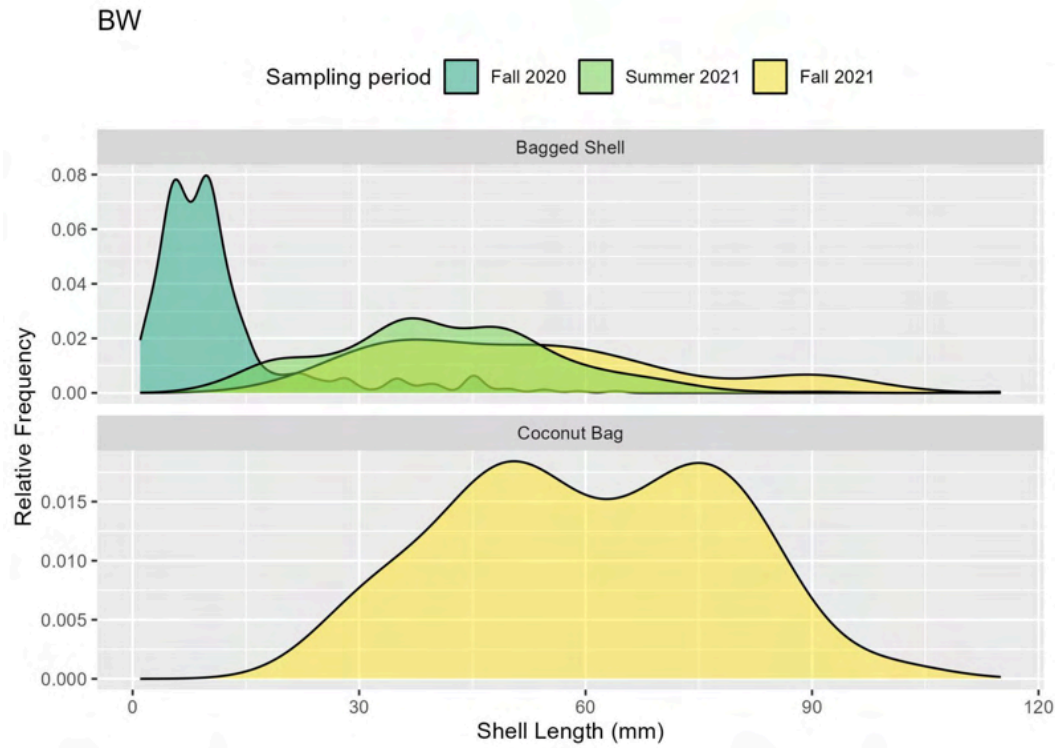

Figure 11. Single cohorts of oysters in plastic mesh bags (top) and coconut bags show increasing oyster shell length over three monitoring seasons at Bayswater Point State Park.

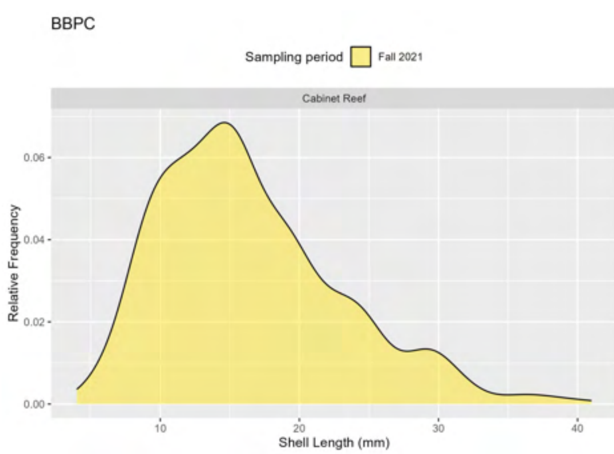

Figure 12. New installation of community cabinets at Brooklyn Bridge Park Pier 4 Beach shows a normal distribution of oyster shell length.

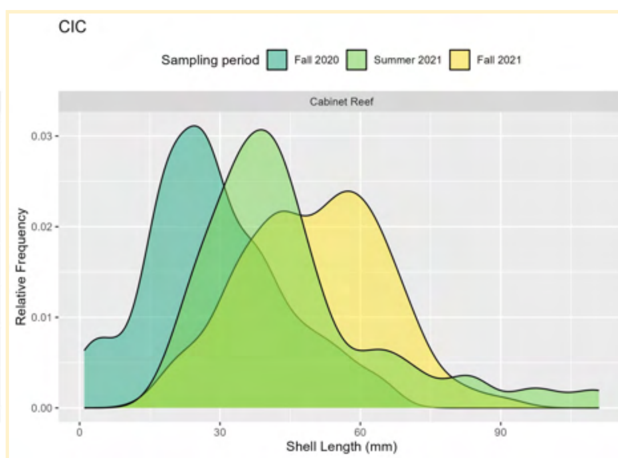

Figure 13. Community cabinets at Coney Island Creek show an increasing trend of growth over three monitoring seasons.

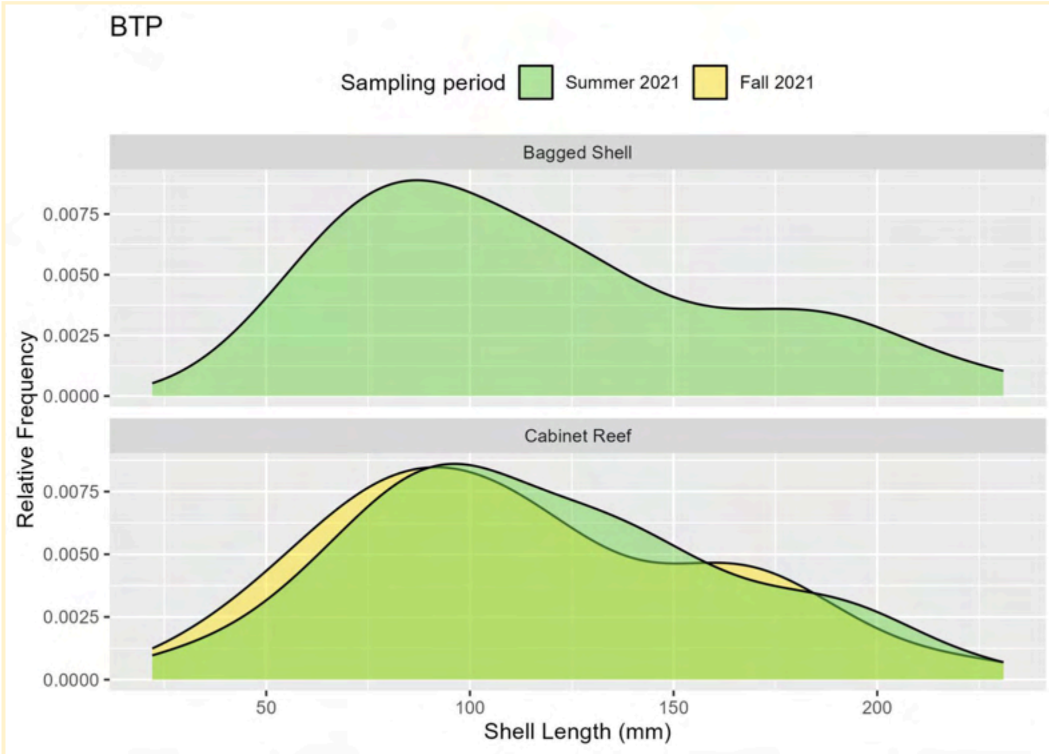

Figure 14. Size frequency distribution graph showing little to no difference in oyster shell length between monitoring seasons at Bush Terminal Park.

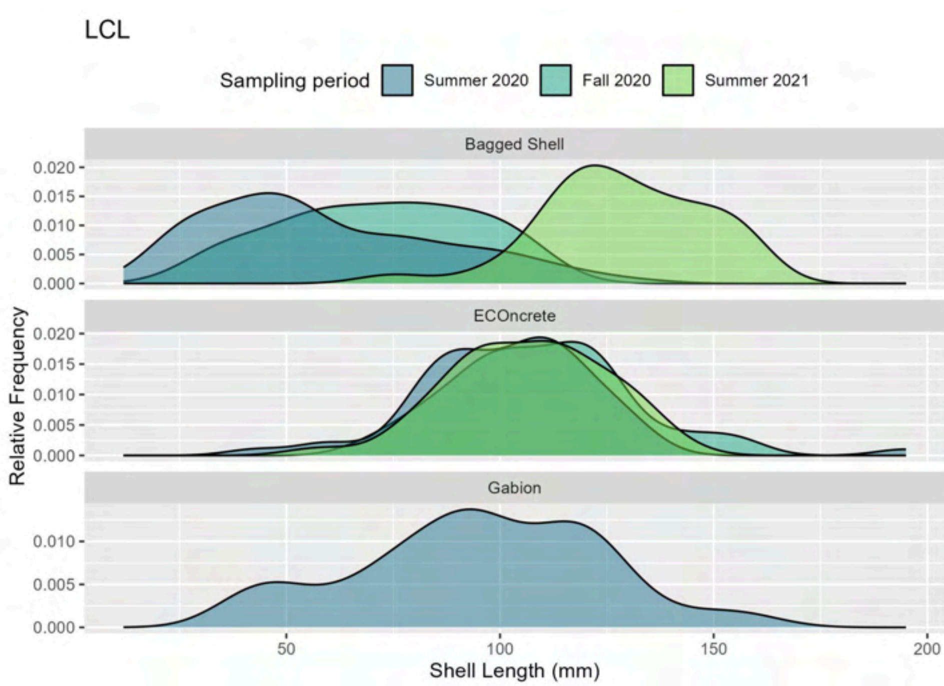

Figure 15. Bagged shell reef (top) shows increasing oyster shell length while ECOncrete disc (middle) shows a stable shell length over three monitoring seasons at Lemon Creek Lagoon. Gabions at this site were only monitored once in 2020.

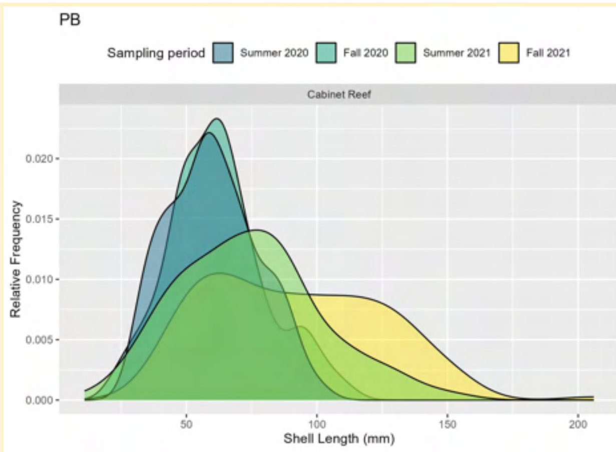

Figure 16. The oysters from a single cohort in the cabinet reef show an increasing shell length across four monitoring seasons at Paerdegat Basin.

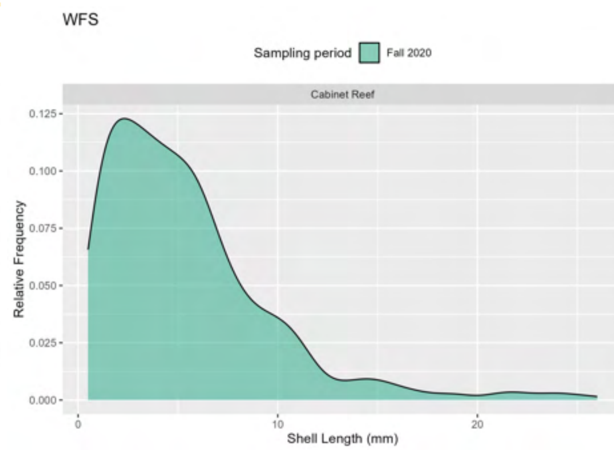

Figure 17. Size frequency distribution of oysters in cabinet reef installed at Williamsburg Field Station.

Oyster Survival

Like growth, oyster survival is an important metric in understanding the success of oyster restoration, but it can be difficult to track over time as oyster reefs become more spatially complex and as new recruits settle to the reef.

Small, juvenile oysters, called spat, attach to hard substrate in high densities. These spat grow quickly over the first 1–2 years of life, but as they grow they must also compete for space. As a result, only a few oysters are expected to survive. On an individual basis, mortality is thus expected to be greatest in the first several years after installation. As oysters grow, the mortality rate of mature individuals should decline and stabilize over time. Target density for oysters may vary depending on the type of reef structure and the structure's maintenance requirements. Mortality can be measured in several ways, depending on the reef structure, pace of oyster growth, and accretion:

(1) *Live oysters per "clump"*: this technique focuses on post-installation spat survival in the new environment. A clump is defined as a group of oysters growing on a single shell. It is typically used during spat counts before and shortly after installation and before oysters grow through mesh openings and attach to reef structures. Ideally, the density of live oysters per clump stabilizes over time. Billion Oyster Project utilized this technique at the following sites:
   - Brooklyn Bridge Park Nursery
   - Bush Terminal Park
   - Bayswater Point State Park
   - Governors Island EcoDock
   - Great Kills Harbor
   - Lemon Creek Lagoon (bagged shell reef)
   - Paerdegat Basin Community Reef
   - SUNY Maritime
   - Williamsburg Field Station

(2) *Live oysters per square meter*: this technique counts and measures all live oysters identified within a 0.1-m^2 quadrat. The expectation is the cementation of live oysters and ideally, the formation of an oyster reef, over time. Billion Oyster Project utilized this technique at the following sites:
   - Bayswater Point State Park
   - Lemon Creek Lagoon Bagged Shell Reef
   - Paerdegat Basin Community Reef

(3) *Live oysters per unit structure*: this technique determines the density of live oysters within a structure of known volume that is not suitable for overgrowth. Because neither live oysters per "clump" nor density (i.e., per square meter) is an accurate indicator, density is determined using a volumetric approach. Ideally, the density of live oysters per unit

structure stabilizes over time, with wild recruitment observed. Billion Oyster Project utilized this technique at the following sites:

- Lemon Creek Lagoon (ECOncrete® discs and mini gabions)
- Lemon Creek Nursery

Live Oyster Per "Clump"

At Brooklyn Bridge Park and Bayswater Point State Park, the oysters installed in 2020 showed a higher number of live oysters per clump, but the drop of live oysters per "clump" observed in subsequent monitoring seasons shows heightened mortality (**Table 5**). At Williamsburg Field Station, the oysters installed and monitored in 2020 also showed a high number of live oysters per "clump," but experienced increased mortality based on percent survival (**Table 5**). Higher mortality during the initial post-construction period is expected as spat transition from temperature-controlled, filtered hatcheries to the polluted urban waters of New York Harbor. The overwintering period also contributes to this higher mortality during Year 1. Billion Oyster Project could not monitor the oysters at Williamsburg Field Station during the 2021 monitoring season due to ongoing construction of the adjacent site and restricted access.

The Governors Island EcoDock showed a high survival rate of oysters per clump in 2021, as they were reared earlier that year in the hatchery (**Table 5**). Oysters held at the EcoDock are used for Oyster Research Stations, Oyster Research Tanks, and community engagement.

Previous reports indicate that oyster density usually stabilizes at approximately 1–2 oysters per clump. However, the oysters in Great Kills Harbor showed the lowest number of live oysters per clump, averaging less than one oyster per clump in all super trays (**Table 5**). Boring sponge infection observed at a higher frequency at Great Kills than at other sites could contribute to the site's low survival rate. Similarly, the oysters at SUNY Maritime showed one of the lowest percent survival rates across all of the sites, possibly due to predatory oyster drills present (**Table 5**).

Other sites similarly show this declining trend of live oysters per clump in subsequent monitoring seasons (**Table 5**). This is likely due to competition for space, predation, disease, and other environmental factors. An increase in live oysters per clump in the next fall monitoring season after the initial setting potentially indicates wild recruitment at the site.

Table 5. Oyster density (i.e., oyster per clump) post-installation at Brooklyn Bridge Park Nursery (BBPN), Brooklyn Bridge Park Cabinets (BBPC), Bush Terminal Park (BTP), Bayswater Point State Park (BW), Coney Island Creek (CIC), Great Kills Harbor (GKH), Lemon Creek Lagoon (LCL), Paerdegat Basin (PB), SUNY Maritime (SM), and Williamsburg Field Station (WFS). Cells with two values in the Live Oysters Per Clump and % Survival columns indicate the two seasonal monitoring events of that year. ND = no data and n = total sample size.

Site	Structure Type and Year of Installation	Oyster Cohort	Live Oysters Per Clump		% Survival	
			2020	2021	2020	2021
BBPN	*SEAPA Cages 2020*	Unknown from GIE	**1.0** (n = 52)	ND	**89.8%**	ND
	SEAPA Cages 2020	MBSOS073020 GIRemSet	**27.7** (n = 1700)	ND	**95.8%**	ND
	SEAPA Cages 2020	ND	ND	**36.9** (n = 3826) **47.2** (n = 1738)	ND	**91.3%** **89.6%**
BBPC	*Cabinet 2021*	ND	ND	**29.4** (n = 621)	ND	**80.5%**
BTP	*Bagged Shell 2018*	ND	ND	**1.3** (n = 54)	ND	**74.1%**
	Cabinet 2016/2018	ND	ND	**2.3** (n = 194) **1.6** (n = 185)	ND	**56.2%** **40.0%**
BW	*Bagged Shell 2020*	MBSOS073020 GIRemSet	**5.9** (n = 221)	ND	**80.0%**	ND
		ND	**5.9** (n = 283)	**7.4** (n = 320) **2.3** (n = 107)	**82.0%**	**71.6%** **61.7%**
	Coconut Bag 2020	ND	ND	**1.5** (n = 84)	ND	**53.6%**
CIC	*Cabinet 2019*	MBSOS07032020 RHTTank4	**2.6** (n = 416)	**1.6** (n = 452)	**68.1%**	**42.8%**
	Cabinet 2021	ND	ND	**8.8** (n = 434)	ND	**85.0%**
GI	*Super Trays 2021*	ND	ND	**50.0** (n = 1257)	ND	**95.4%**
GKH	*Super Trays 2016*	ND	ND	**0.34** (n = 205)	ND	**22.9%**
	Super Trays 2017	GKSOS03242017	ND	**0.26** (n = 194)	ND	**24.7%**
	Super Trays 2019	ND	ND	**0.69** (n = 188)	ND	**43.6%**
LCL	*Bagged Shell 2018*	MBSOS06262018 GISOS07252018	**19.0** (n = 27)	**1.6** (n = 45)	**70.4%**	**73.3%**
PB	*Steel Cabinet 2018*	MBSOS06262018	ND	**5.2** (n = 223) **4.6** (n = 189)	ND	**69.5%** **72.4%**
SM	*Super Trays 2019*	MBSOSxxxx19 GIRemSet	**3.3** (n = 285)	ND	**68.4%**	ND
	Super Trays 2021	ND	ND	**1.5** (n = 367)	ND	**26.2%**
WFS	*Cabinet 2020*	MBSOS070320 GIRemSet	**8.3** (n = 961)	ND	**51.6%**	ND
	Bagged Shell 2021	ND	ND	ND	ND	ND

Live Oysters Per Square Meter

At certain sites, oysters can grow through the wire mesh; because of this, it can be difficult to calculate the mortality rates of oysters within the bag. Percent survival is calculated by dividing the number of live oysters measurable on the outside of the restoration structure and by the total number of oysters measured (both live and dead) within a 0.1 m^2 quadrat (**Table 6**). Of the three sites, Paerdegat Basin showed the highest oyster density, while Bayswater Point State Park showed the highest survival rate (**Table 6**).

Table 6. Oyster density in Community Reefs: Bayswater State Point Park (BW), Lemon Creek Lagoon (LCL), and Paerdegat Basin (PB) in 2020. ND = no data and NA = not applicable.

Site	Structure Type and Year of Installation	Oyster Cohort	Live Oysters Per Square Meter		% Survival
			Spring/Summer	Fall/Winter	
BW	*Bagged Shell 2020*	MBSOS070320 RHTTank4	ND	**327.8** (n = 62)	**88.7%**
LCL	*Bagged Shell 2018*	ND	**1343.8** (n = 255)	ND	**84.3%**
PB	*Steel Cabinet 2018*	MBSOS06262018	**426.4** (n = 254)	**525.7** (n = 280)	**70.6%**

Live Oysters Per Unit Structure

To calculate live oysters per unit structure at the Lemon Creek Lagoon sites, Billion Oyster Project measured all oysters on each ECOncrete® disc, on the face of each mini gabion, and in each bag within the OysterGro at Lemon Creek Nursery. Although Lemon Creek Lagoon and Lemon Creek Nursery are in close proximity, the different structures showed variable results in oyster survival (**Table 7**).

Table 7. Oyster density at Lemon Creek Lagoon (LCL) and Lemon Creek Nursery (LCN), percent survival is calculated based on data gathered during one or two monitoring events of the year. ND = no data.

Site	Structure Type and Year of Installation	Oyster Cohort	Live Oysters Per Unit Structure		% Survival	
			2020	2021	2020	2021
LCL	*ECOconcrete 2018*	GISOS07252017 GISOS07252018	**9.7** (n = 122) **14.3** (n = 48)	**2.2** (n = 43)	**95.1%** **89.6%**	**97.7%**
	Mini-Gabion 2018	MBSOS06262018	**26.6** (n = 156)	ND	**91.0%**	ND
LCN	*OysterGro 2017*	GKSOS03242017	**2.3** (n = 181)	**1.89** (n = 228)	**76.8%**	**82.9%**

Disease

A small sample of the total restored oysters at certain sites was collected and sacrificed to complete diagnostics for disease, reproductive status, sex ratio, and condition index. Dermo (*Perkinsus marinus*) and MSX (*Haplosporidium nelsoni*) are two parasitic protozoan diseases that can infect oysters with detrimental effects (Mackenzie Jr. 2007). In July and October 2020, oysters (n = 30) were collected from Bush Terminal Park (BTP), Lemon Creek Nursery (LCN), and Paerdegat Basin (PB) and sent to Dr. Bassem Allam at the Stony Brook University Marine Animal Disease Laboratory (SBU MADL) for disease diagnostics. Dermo diagnosis was made using FTM (fluid thioglycollate medium) on mantle and rectal tissues. MSX diagnosis was made using histopathology on formalin-fixed sections. For these diseases, "prevalence" refers to the percentage of the population that tests positive for a given disease, and "intensity" refers to the degree to which an individual oyster is infected with a given disease.

SBU MADL also provided data on shell height (**Figure 18**), condition index, stage of gonad development, and sex ratio of each oyster (see below). Samples from July were assumed to best represent the reproductive status of oysters, and samples from October represented the maximum disease loads.

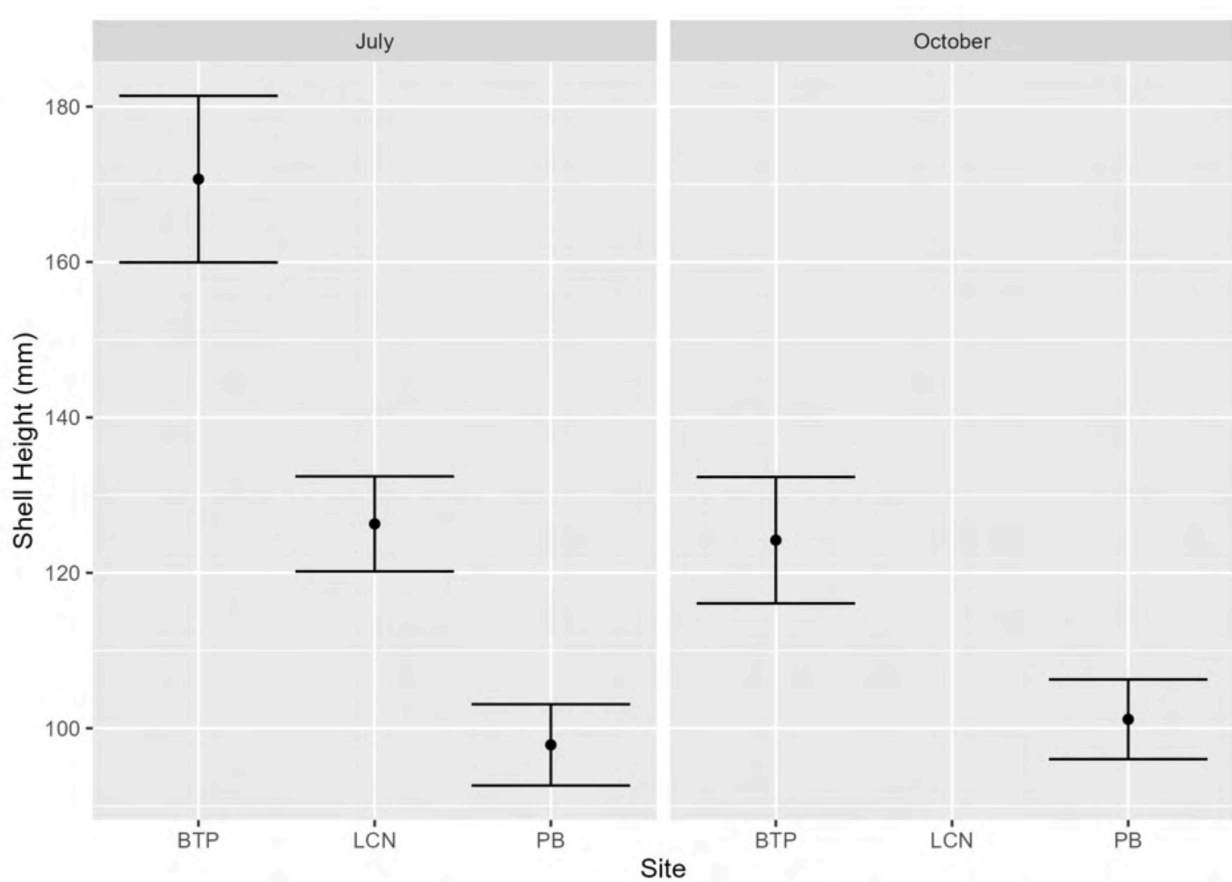

Figure 18. Shell heights of oysters sampled from Bush Terminal Park (BTP), Lemon Creek Nursery (LCN), and Paerdegat Basin (PB) in July and October (except LCN) (n = 30 oysters from each site, except n = 27 for BTP in July and n = 31 for PB in October. Points are mean, and whiskers are 95% confidence intervals.

Dermo (P. marinus)

Dermo intensity is reported on the Mackin scale from 0 to 5, with 5 being the highest intensity. Rankings of 3 or higher typically indicate lethal intensities that are presumed to cause mortality. Dermo prevalence and intensity were low in October in both Bush Terminal Park and Paerdegat Basin (**Figure 19**). Neither site had any oysters that showed lethal infection intensity.

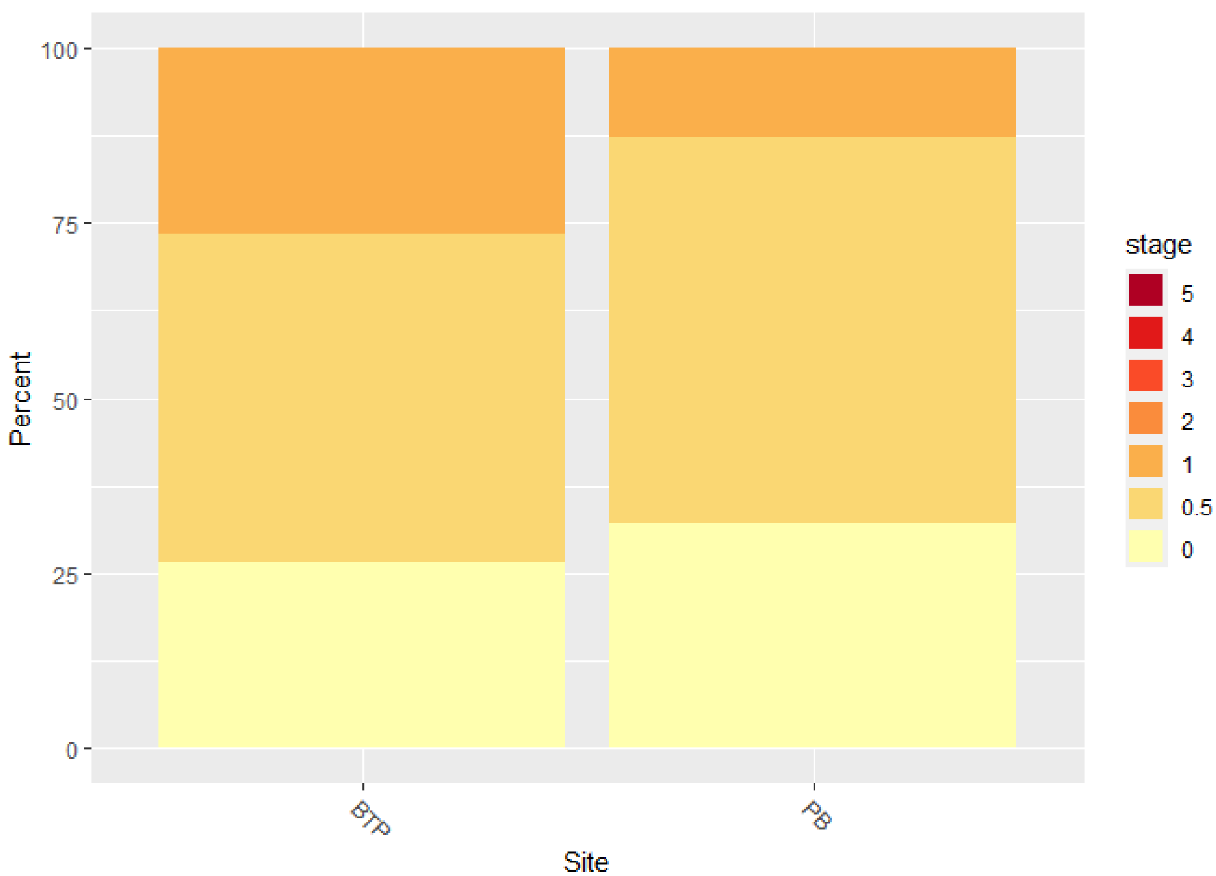

Figure 19. Dermo (*P. marinus*) prevalence and intensity in oysters sampled in October 2020 from Bush Terminal Park (n = 30 oysters) and Paerdegat Basin (n = 31 oysters). Oysters with intensities ranking 3 or higher are considered to be lethally infected.

MSX (H. nelsoni)

Overall, MSX prevalence was low at all sites. MSX was detected in one oyster from Bush Terminal Park (BTP) and two oysters from Lemon Creek Nursery (LCN), but it was not detected in any oyster samples from Paerdegat Basin (PB) in July (**Table 8**).

Table 8. MSX (*H. nelsoni*) prevalence and sample size of oysters sampled at Bush Terminal Park (BTP), Lemon Creek Lagoon (LCN), and Paerdegat Basin (PB) in July 2020.

Site	Sample Size	Prevalence (%)
BTP	27	3.7%
LCN	30	6.67%
PB	30	0%

Reproductive Status

The monitoring of reproduction in adult oysters provides insight into the reproductive timing and capability of a restored oyster population. Oysters have separate sexes and can switch sex (male to female) at the time of sexual maturity (typically ~2 years after settlement). In addition, oysters' gonads produce gametes (eggs and sperm) only during warmer seasons, when they are preparing to spawn. To determine the stage of reproductive development, both (1) sexual maturity and (2) readiness to spawn are assessed. (**Table 9**) To assess the populations' long-term growth potential, the sex ratio is determined.

Typically, oysters with gonads that are categorized as gametogenic (G1–G2) or developing (D1-D2) are preparing to spawn, while those that are ripe (R) or spawning (S1–S4) are actively reproducing (**Table 9**). Oysters in inactive (I) or undetermined (U) stages are either not ready to spawn or have recently spawned (**Figure 20**). Since oysters can change sex from male to female, equivalent (50:50) or female-skewed sex ratios indicate that a population has reached sexual maturity and conditions are optimal for successful fertilization (Powell et al. 2013, Harding et al. 2013).

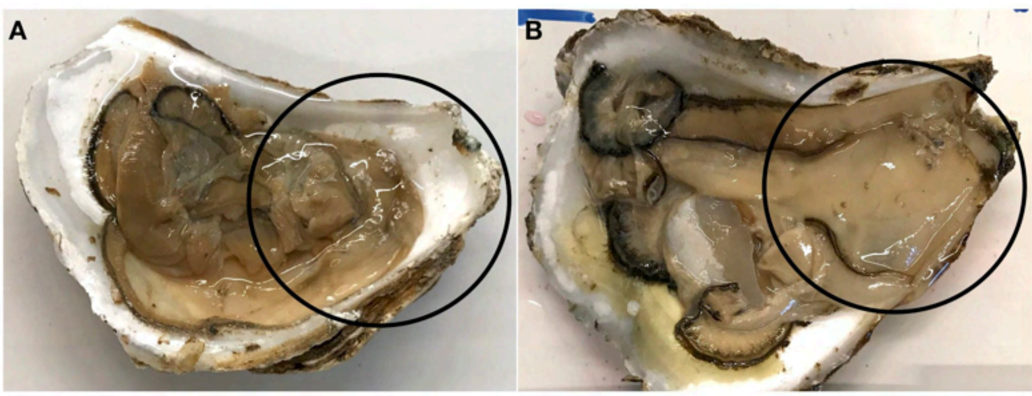

Figure 20. These pictures compare gonad development (circled) in (A) inactive or "unripe" and (B) "ripe" oyster tissue. (Photos Courtesy of Dr. Elizabeth Burmester and Dr. Michael McCann)

Table 9. Stages of reproductive development in oysters as assessed by the Stony Brook University Marine Animal Disease Lab.

	Stage	Description
I	Inactive	No gonadal activity, resting
G1	Gametogenic I	Gametogenesis has begun; no ripe gametes visible
G2	Gametogenic II	First ripe gametes appeared; gonad developed to about one-third of its final size
D1	Developing I	Gonad increased in mass to about half the fully ripe condition; each follicle contains about equal proportions of ripe and developing gametes

D2	Developing II	Gametogenesis still progressing; follicles mainly contain ripe gametes
R	Ripe	Gonad fully ripe, early stages of gametogenesis rare; follicles distended with ripe gametes; ova compacted into polygonal configurations; sperm with visible tails
S1	Spawning I	Active emission of gametes has begun; gamete density reduced
S2	Spawning II	Gonad about half empty
S3	Spawning III	Gonadal area reduced; follicles about one-third full of ripe gametes
S4	Spawning IV	Only residual gametes remain; some may be undergoing cytolysis
U	Undetermined	Gonad tissue rudimentary (completely undeveloped, as is the case in very young oysters) or absent

The reproductive status of oysters at three sites was assessed in 2020: Paerdegat Basin (PB), Bush Terminal Park (BTP), and Lemon Creek Nursery (LCN). Sexual differentiation and stages of gonad development among the tested individuals were performed by Dr. Bassem Allam. Samples collected in June were assumed to represent oysters' reproductive status because, after spawning, oysters resorb their gonads. While the oyster spawning season is not well understood in New York Harbor, it is assumed that oysters no longer reproduce in October.

A similar sex ratio of males to females was observed at all three sites, as were spawning oysters across all three sites (**Figure 21**). At least half of the sampled oysters at LCN (50%) and PB (80%) were sexually mature, but only 44% were sexually mature at BTP.

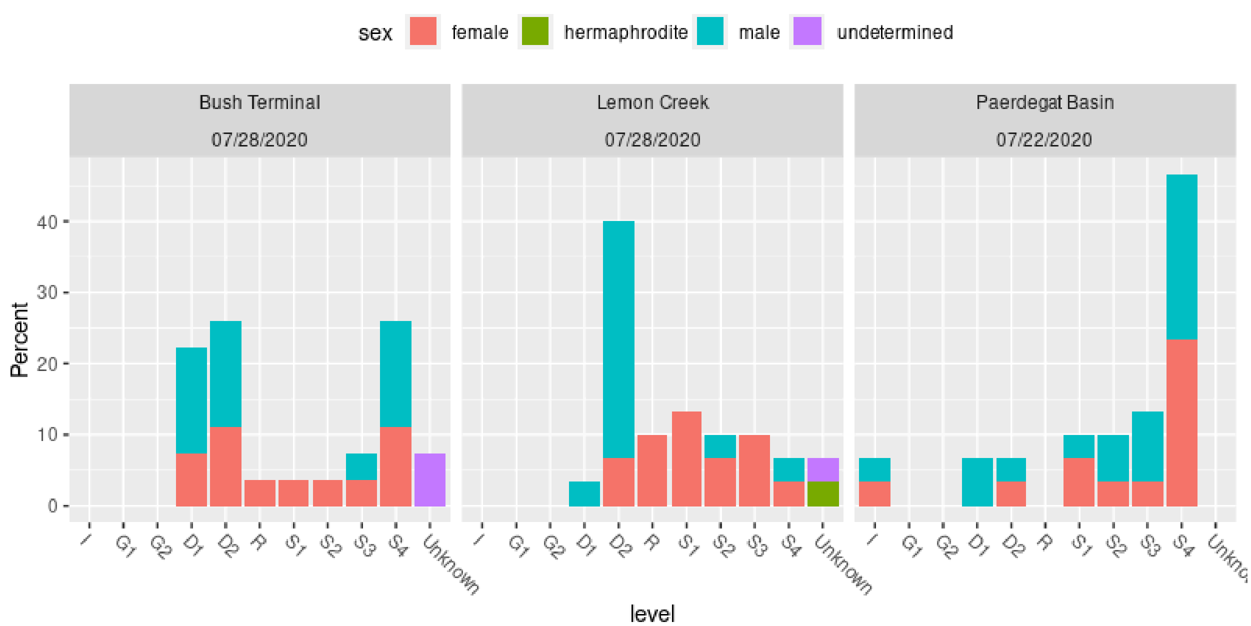

Figure 21. Percentage of oysters at different stages of reproductive development collected from Bush Terminal Park, Lemon Creek Lagoon, and Paerdegat Basin in July 2020.

Condition Index

Condition index (CI) is calculated as (dry mean weight / dry shell weight) x 100. Other condition indices for oysters are used in commercial production, with higher values indicating higher quality oysters (i.e., more internal body meat relative to shell). If the condition index of the same stock is measured repeatedly over the course of a season, a sudden drop in the condition index may indicate spawning or another event. However, because Billion Oyster Project sampled oysters only once during the reproductive season, it is not possible to link the CI data to the status of reproduction. These results thus provide a snapshot of condition index across sites.

In July of 2020, the average CIs of oysters from the three sites was similar, ranging from 2.76 at Bush Terminal Park to 5.05 at Paerdegat Basin (**Figure 22**). Compared to samples collected in October of 2020, the average CIs of oysters from Bush Terminal Park was 5.43, while the CI of oysters from Paerdegat Basin was 6.32. The level of variability was relatively high within the site and between seasons, especially for Bush Terminal Park; this may be due to differences in spawning status among individuals.

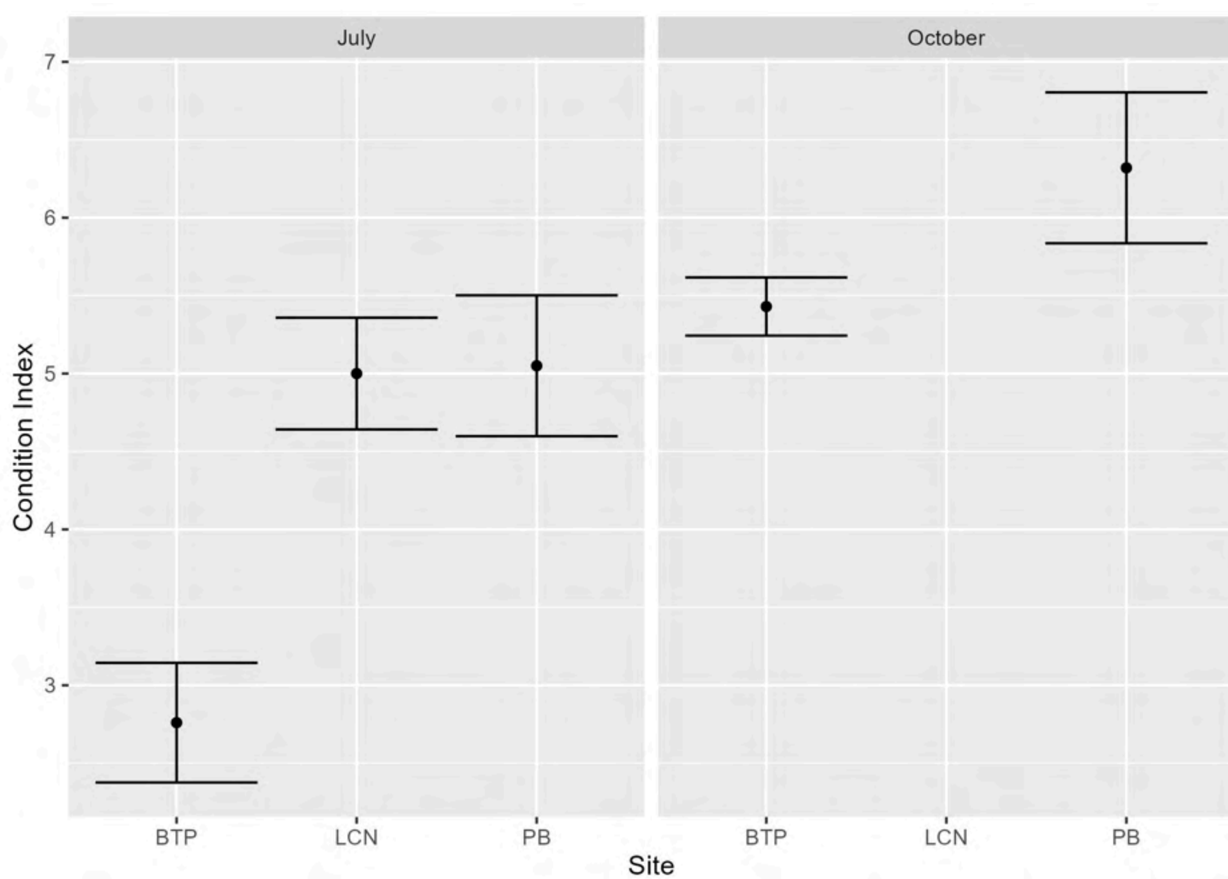

Figure 22. Mean condition index and standard error oysters from Bush Terminal Park (BTP), Lemon Creek Nursery (LCN), and Paerdegat Basin (PB) were collected in July and October 2020 (except LCN). The sample size was 30 oysters per site, except n = 27 oysters for BTP in July and n = 31 oysters for PB in October. Points are mean, and whiskers are 95% confidence intervals.

Wild Recruitment

The presence of juvenile oysters, or "recruits," is a positive indicator of a site (**Figure 29**). Recruits from wild populations indicate a naturally occurring source population is nearby and that site conditions are supportive of larval transport and survival. For example, the juvenile oysters observed on intertidal rocks at Coney Island Creek are not the offspring of the restored oyster population at that site, as they were less than one year old and therefore not yet reproductively mature. These factors suggest populations may become self-sustaining as restored oysters produce offspring.

Figures 30 and 31 show recruitment at selected sites around the Harbor in both 2020 and 2021, with some sites overlapping with Billion Oyster Project restoration sites. The sources of this data vary and include informal surveys of the substrate adjacent to the restored reef or nursery (e.g. intertidal rip-rap or bulkheads), "unseeded" restoration structures (e.g. ECOncrete® discs or bagged shell not set with larvae in the hatchery). Bags of blank shells were deployed as part of a larger, harbor-wide study by Dr. Matt Hare of Cornell University. These assessments complement the examination of size frequency distributions that looked for the presence of a second size class of oysters as an indication of recruitment.

Of the sites reported in **Figure 30**, no recruitment was observed at the Brooklyn (Coney Island Creek, Bush Terminal Park, and Paerdegat Basin) and Staten Island (Great Kills Harbor, Lemon Creek Lagoon, and Lemon Creek Nursery) sites. Billion Oyster Project reduced the number of sites monitored in 2020 due to the COVID-19 pandemic. Of the four sites reported in **Figure 31**, recruitment was observed at all sites except West Harlem.

Figure 29. (A) Wild oyster recruits circled in red, along with barnacles and anemones, on intertidal rocks adjacent to the Coney Island Community Reef in summer 2018 (Swiss Army multitool for size comparison), and (B) wild oyster recruits seen at West Harlem Piers Park at 125th Street in Manhattan.

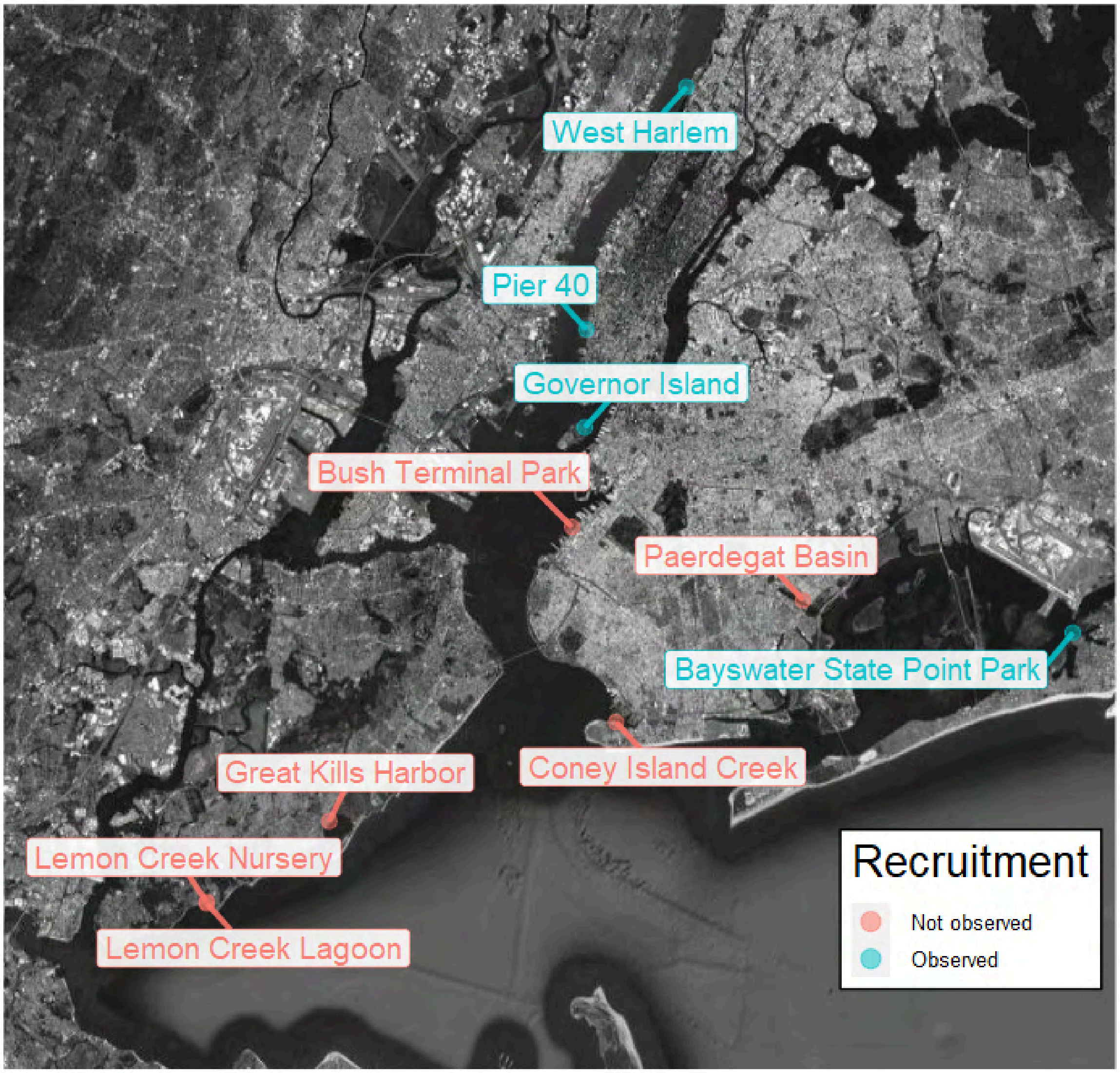

Figure 30. Map of 2020 restoration sites at which monitoring of wild recruitment, using mesh bags of blank shell, occurred. Sites in red did not show recruitment, while sites noted in blue observed wild oyster recruitment. This figure does not include other sites that were monitored for recruitment as part of a harbor-wide study with Dr. Matt Hare of Cornell University.

Figure 31. Map of 2021 restoration sites at which monitoring of wild recruitment, using mesh bags of blank shell, occurred. Sites in red did not show recruitment, while sites noted in blue observed wild oyster recruitment. This figure does not include other sites that were monitored for recruitment as part of a harbor-wide study with Dr. Matt Hare of Cornell University.

Water Quality

Oysters influence and are influenced by water quality, which makes monitoring water quality essential to identifying environmental conditions that favor oyster survival, growth, and reproduction.

Extreme events, such as hypoxia or low dissolved oxygen, can significantly impact the success of oyster restoration more than average water quality conditions. These extreme events are often challenging to detect using traditional monitoring methods, which rely on regular site visits and may miss critical events that occur at specific times, such as low oxygen levels at night or early in the morning. To overcome this limitation, Billion Oyster Project deploys Onset HOBO water quality loggers (models U-24 and U-26) that continuously record temperature, salinity, and dissolved oxygen data at 15-minute intervals at field sites.

In 2020, loggers deployed at eight sites collected continuous water quality measurements, including water temperature (**Figure 23**), dissolved oxygen (**Figure 24**), and salinity (**Figure 25**) values. Billion Oyster Project staff actively maintained the deployed loggers throughout the field season to prevent fouling and sediment build-up, retrieve data, and recalibrate the sensors using independent water quality measurements obtained with a Horiba U-52 multiparameter instrument. These independent measurements served as point water quality references for comparison.

It is important to note that due to differences in the deployment and maintenance schedule, adherence to quality assurance protocols, and exclusions of specific time periods, the data collected from the sites may not span the same time periods. The Onset HOBOware Pro software was used to compute salinity values from conductivity data, while the Horiba instrument collected water temperature values and field check values. The software also adjusted the dissolved oxygen values based on the salinity time series, considering adjustments for fouling.

By collecting continuous water quality data, Billion Oyster Project gains valuable insights into the dynamic changes in environmental conditions that may affect oyster populations and helps in making informed decisions regarding oyster restoration efforts.

Continuous Water Quality Measurements

Water temperature data presented in this report were collected using conductivity loggers, which were deployed for a longer period and at more sites compared to the dissolved oxygen loggers. The average water temperature values exhibited a steady decreasing trend for sites (BTP, BW, CIC, LCL, and PB) where loggers were deployed from summer through fall (**Figure 23**).

As for dissolved oxygen levels, the average values at most sites appear to be suitable for oysters, being greater than 5 mg/L. However, all sites experienced episodes of low dissolved oxygen levels (hypoxia), which can be harmful to oysters, with levels dropping below 3 mg/L (**Figure 24**).

Regarding salinity, Bush Terminal Park, Paerdegat Basin, and SUNY Maritime experienced relatively consistent levels, while Bayswater Point State Park, Coney Island Creek, and Lemon Creek Lagoon encountered greater variability in salinity. The salinity fluctuations in the latter three sites sometimes fell within the suitable range (approximately 20 – 25 ppt) for oysters (**Figure 25**). The changes in salinity from site to site were likely influenced by episodic decreases, which could be attributed to freshwater input from rain events.

Continuous monitoring of water temperature, dissolved oxygen, and salinity is crucial to understanding the environmental conditions that oysters face in their habitats. These data help in evaluating the suitability of restoration sites and provide insights into potential stressors that oyster populations may encounter, such as hypoxia events and fluctuations in salinity.

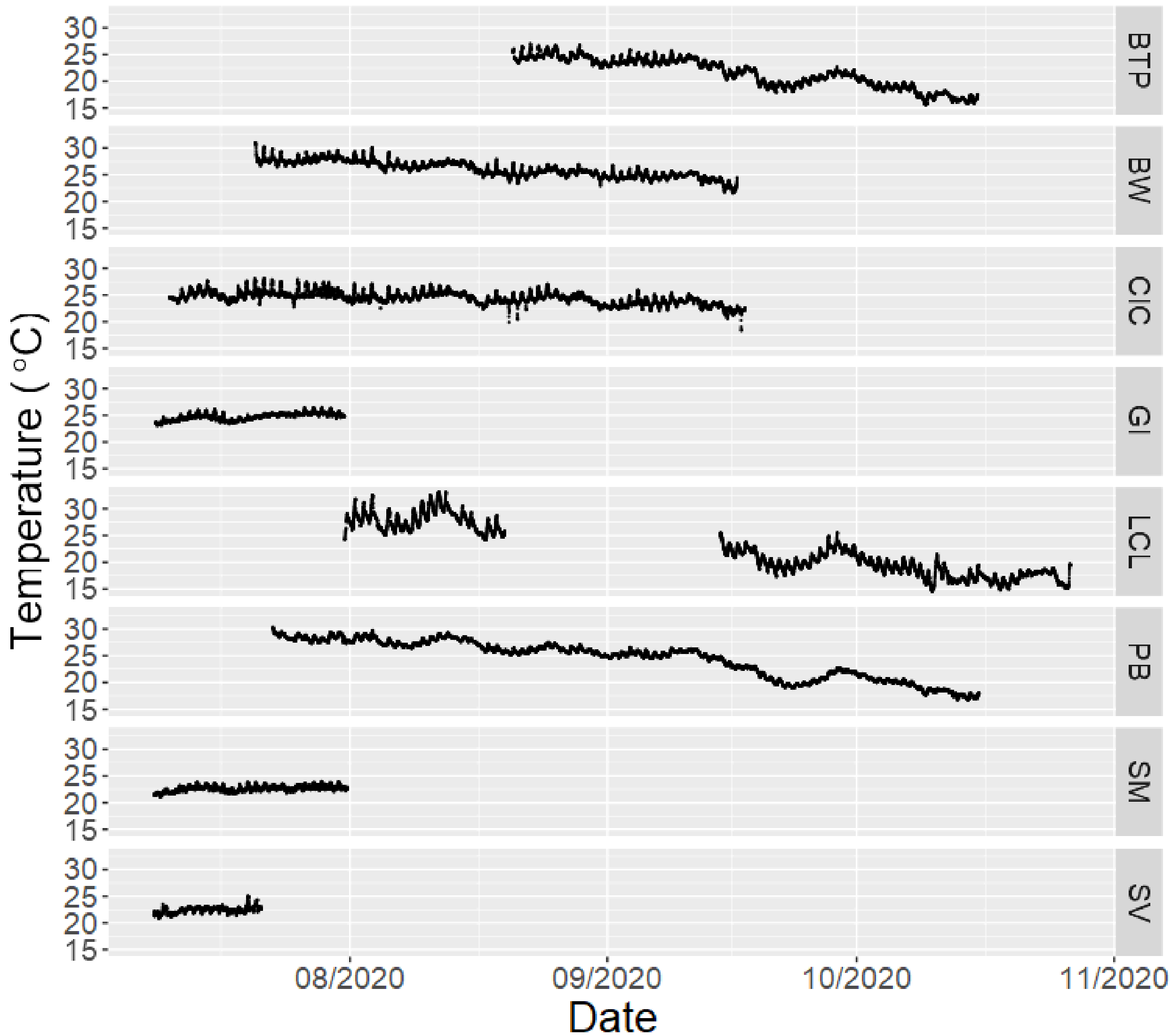

Figure 23. High-resolution (recorded every 15 minutes) water temperature data in 2020 for Bush Terminal Park (BTP), Bayswater Point State Park (BW), Coney Island Creek (CIC), Governors Island EcoDock (GI), Lemon Creek Lagoon (LCL), Paerdegat Basin (PB), SUNY Maritime (SM), and Soundview (SV).

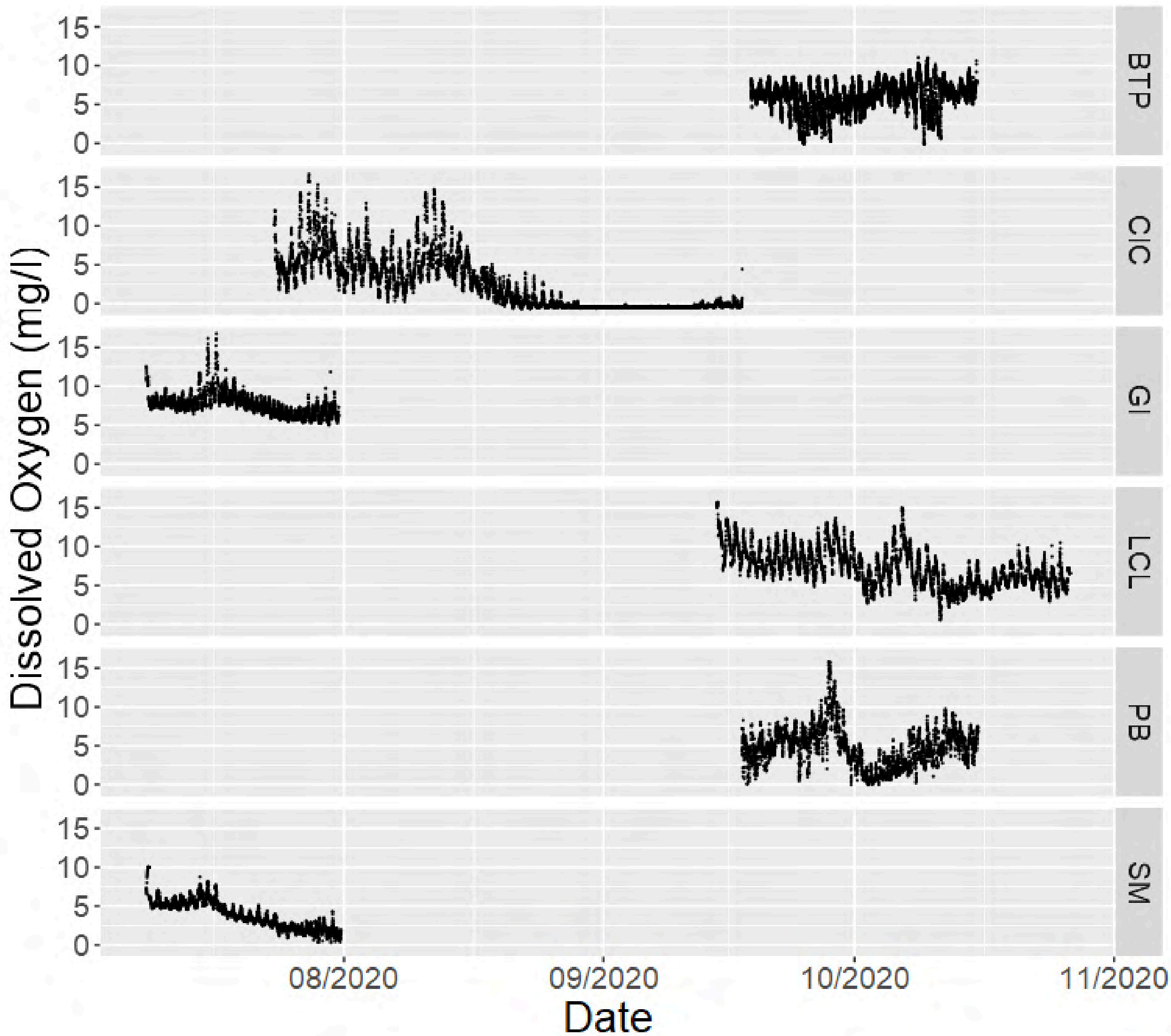

Figure 24. High-resolution (recorded every 15 minutes) dissolved oxygen and temperature data in 2020 for Brooklyn Bridge Park (BBP), Bush Terminal Park (BTP), Coney Island Community Reef (CIC), Governors Island EcoDock (GI), Lemon Creek Lagoon (LCL), Paerdegat Basin (PB), and SUNY Maritime (SM).

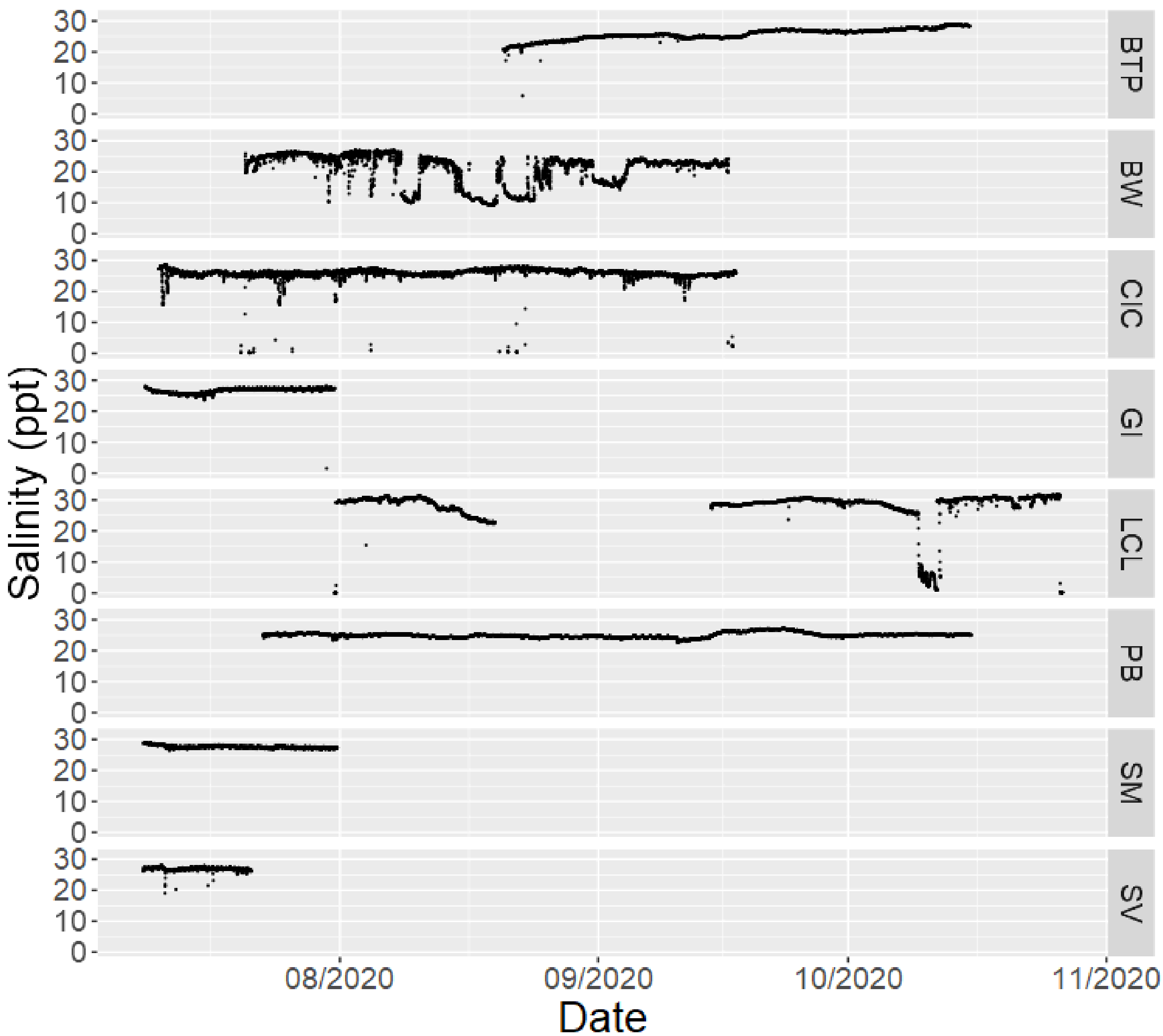

Figure 25. Salinity data in 2020 for Bush Terminal Park (BTP), Bayswater Point State Park (BW), Coney Island Creek (CIC), Governors Island EcoDock (GI), Lemon Creek Lagoon (LCL), Paerdegat Basin (PB), SUNY Maritime (SM), and Soundview (SV). Salinity data was calculated using high-resolution conductivity and water temperature data (recorded every 15 minutes) and default factory settings of Onset HOBOware Pro Software.

In 2021, time series data for temperature and salinity were collected at two sites, Brooklyn Bridge Park Nursery (BBPN) and Bayswater Point State Park (BW). The salinity values at BW exhibited greater fluctuations compared to BBPN, where the values remained consistently below 15 ppt (**Figure 27**). This indicates that the salinity at BW varied more over time, while BBPN had a more stable and consistently lower salinity level. Continuous monitoring of these parameters allows for a better understanding of the environmental conditions at the restoration sites and helps in assessing their suitability for oyster populations.

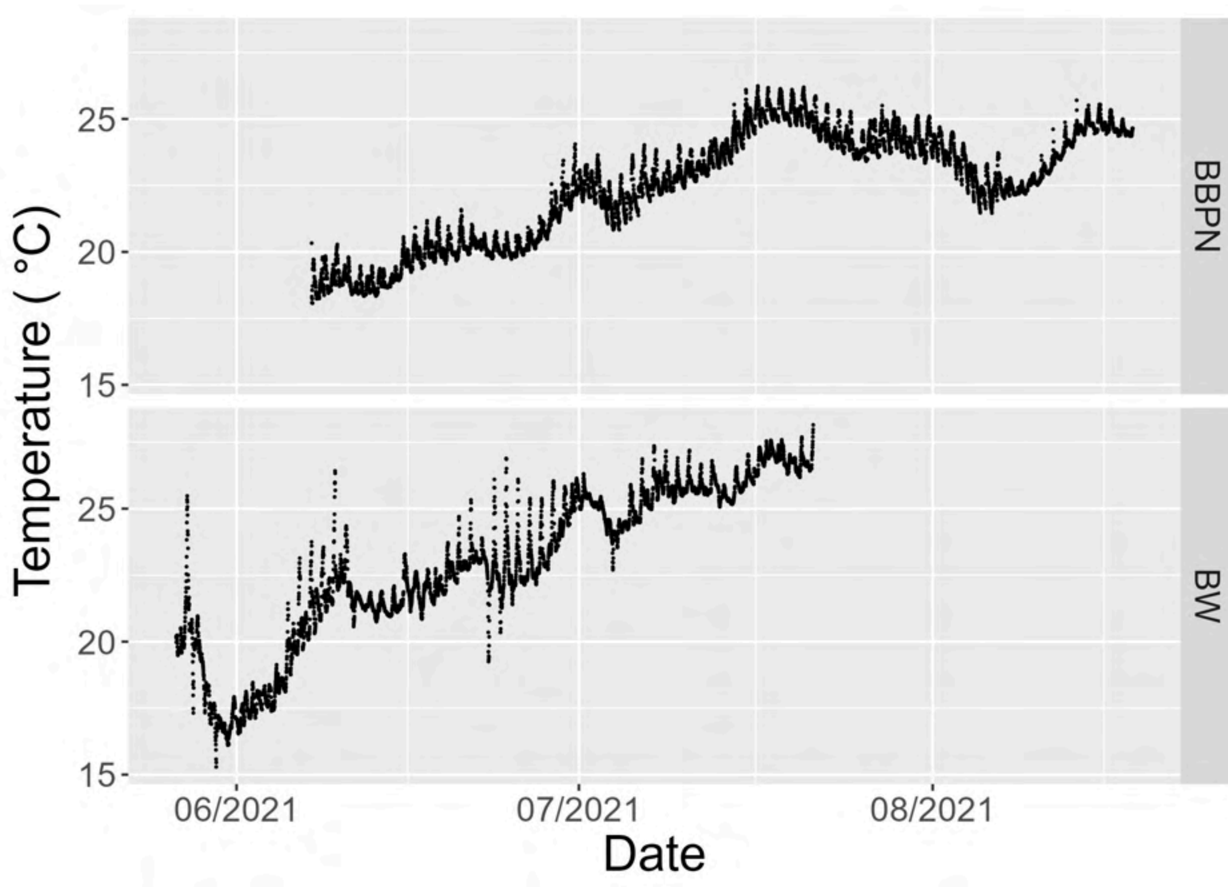

Figure 26. High-resolution (recorded every 15 minutes) water temperature data in 2021 for Brooklyn Bridge Park Nursery (BBPN), and Bayswater (BW).

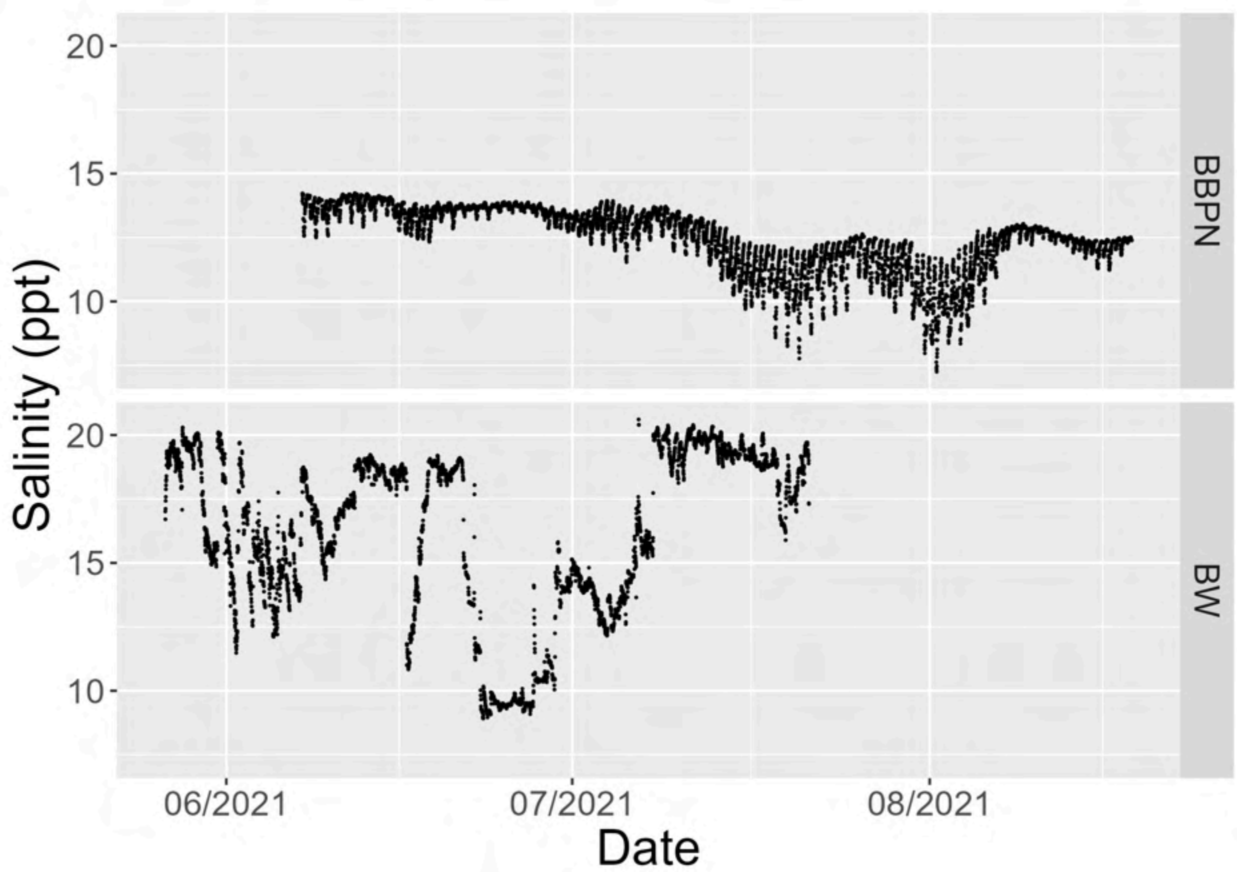

Figure 27. Salinity data in 2021 for Brooklyn Bridge Park Nursery (BBPN) and Bayswater Point State Park (BW). Salinity data was calculated using high-resolution conductivity and water temperature data (recorded every 15 minutes) and default factory settings of Onset HOBOware Pro Software.

Point Water Quality Measurements

Using a Horiba U-52 Multiparameter Meter (**Figure 28**), point water quality data was measured at several sites. Measurements by the handheld sonde are essential and are used to check the reliability of the loggers' data. The handheld sonde measures temperature, dissolved oxygen, salinity, pH, conductivity, turbidity, and total dissolved solids. All samples were collected just below the water surface, adjacent to the restored oysters. Typically, three replicate samples, taken at least two minutes apart, were recorded on each sampling date.

The point water quality samples provide a snapshot of the water quality conditions at a site, and are typically taken as complementary measurements to the regularly maintained water quality data loggers. It is important to note that such snapshot measurements cannot describe the suitability of conditions for oysters or other biota, because they do not accurately demonstrate the high variability in parameter values. Water quality within an estuarine site changes rapidly and is influenced by tidal stage, time of day, or season (Wallace et al. 2014, Baumann et al. 2015), which is why high-frequency measurements are required.

Table 10 presents the average values for temperature, pH, dissolved oxygen, and salinity for nine sites in 2020. Most sites had average pH values that were above or near the suitable pH of 7.5, with the exception of Bush Terminal Park in September, which had a pH of 5.29 (**Table 10**). Average dissolved oxygen values seemed to be suitable at most sites (> 5 mg/L), but Coney Island Creek had an average dissolved oxygen of 4.42 mg/L (**Table 10**), which is lower than optimal. However, all sites had average salinity values within suitable ranges for oysters, except for Brooklyn Bridge Park Nursery with 7.63 ppt in July (**Table 10**), which was near the optimal level of around 20 ppt. These water quality measurements are essential for understanding the environmental conditions that may influence oyster survival, growth, and reproduction at the restoration sites.

Figure 28. Billion Oyster Project summer intern deploying the Horiba probe at Brooklyn Bridge Park One°15 Brooklyn Marina (right) and recording point water quality measurements using the Horiba hand-held device (left). (Photos courtesy of Jennifer Zhu)

Table 10. Average point water quality measurements (water temperature, pH, dissolved oxygen, and salinity) taken by Horiba U-52 Multiparameter Meter at ten sites (BBP = Brooklyn Bridge Park Nursery, BNY = Brooklyn Navy Yard, BTP = Bush Terminal Park, BW = Bayswater Point State Park, CIC = Coney Island Creek, GI = Governors Island EcoDock, LCL = Lemon Creek Lagoon, PB = Paerdegat Basin, SM =

SUNY Maritime, SV = Soundview Park) in 2020. Values highlighted in red are outside the range of suitability for oysters and ND = no data.

Site	Date	Sample Size	Temperature (degC)	pH	DO (mg/L)	Salinity (ppt)
BBP	07/08/2020	5	24.61	7.63	8.64	7.63
BBP	09/15/2020	5	23.06	7.81	5.38	22.24
BBP	10/19/2020	5	26.06	10.19	6.18	23.75
BNY	08/20/2020	5	15.61	ND	ND	25.49
BTP	07/27/2020	5	19.66	7.88	7.98	26.12
BTP	08/18/2020	8	19.57	8.47	8.34	23.59
BTP	09/18/2020	6	26.41	5.29	8.92	23.71
BTP	10/15/2020	13	26.20	7.96	8.27	24.72
BW	07/20/2020	5	22.15	8.78	19.10	26.27
BW	08/21/2020	11	19.42	8.79	9.56	25.40
BW	09/16/2020	12	27.41	8.56	9.70	24.02
BW	11/12/2020	10	19.51	8.51	13.91	22.39
CIC	07/09/2020	5	22.54	8.30	8.38	26.63
CIC	07/21/2020	3	15.34	ND	ND	25.57
CIC	07/23/2020	5	16.01	ND	ND	25.27
CIC	09/17/2020	6	23.67	8.06	4.42	24.57
CIC	10/19/2020	7	26.19	8.82	5.80	25.23
GI	07/08/2020	5	23.64	7.65	8.62	26.44
LCL	07/13/2020	5	22.28	8.73	7.21	26.08
LCL	07/26/2020	5	15.46	ND	ND	26.91
LCL	08/19/2020	11	19.82	8.99	12.42	23.14
LCL	09/14/2020	5	16.69	ND	ND	26.65
LCL	10/25/2020	5	26.16	9.81	5.63	24.47
PB	07/22/2020	5	16.34	ND	ND	27.01
PB	08/18/2020	2	19.6	8.52	8.06	25.48
PB	09/17/2020	7	27.86	7.93	7.21	24.47
SM	07/08/2020	3	25.03	7.75	9.08	25.55
SV	07/08/2020	5	23.39	7.65	8.02	23.87
SV	07/20/2020	5	13.54	8.02	9.80	24.14

Biodiversity

Oyster beds and reefs play a crucial role in enhancing the three-dimensional complexity of the Harbor bottom environment, promoting greater biodiversity compared to adjacent non-structured habitats like muddy or sandy bottoms. Existing research on biodiversity enhancement by oyster beds primarily comes from other estuaries, including the Chesapeake Bay, bodies of water in the southeastern United States, and the Gulf of Mexico (Peterson et al. 2003, zu Ermgassen et al. 2016). The extent to which restored oysters enhance populations of fish, crabs, and shrimp depends on the specific biogeographic context, as different estuaries are home to different species. Therefore, in 2017, Billion Oyster Project initiated a study to understand the role of oyster restoration activities on species abundance and composition at several restoration sites. This study continued in 2020 with ongoing research and modifications to sampling methodologies.

In addition to using minnow traps, baited and unbaited fish trays were deployed for 48 hours at the restoration sites in 2020 (with traps filled with shell at roughly 50% capacity). The use of this methodology allows for the assessment of organisms residing in and around the community reefs, providing valuable insights into the impact of oyster restoration efforts on the surrounding ecosystem. It is important to note that the absence of specific fish species in the traps may be attributed to various factors, such as the location of traps, seasonal migration patterns, or avoidance of the traps by certain species. Therefore, the absence of certain species in the traps does not necessarily reflect their true absence at the site.

Meredith Comi and Dr. Allison Fitzgerald of NY/NJ Baykeeper also utilize a similar methodology at other reef locations, such as Naval Weapons Station Earle in New Jersey and Soundview in the Bronx. The consistent use of this approach allows for comparative analysis across different oyster restoration sites, providing a comprehensive understanding of the ecological impacts of these restoration efforts in different regions.

In July and October 2020, Billion Oyster Project conducted biodiversity assessments by deploying minnow traps to evaluate the presence of organisms residing in and around the community reef, which includes the files and cages of the oyster restoration site. To carry out the assessment, project staff swiftly removed the traps from the reef and transferred the trapped contents to plastic trays. This transfer included collecting all the organisms dislodged from the external surface of any files. By using this method, the project team aimed to comprehensively document the diverse organisms inhabiting the reef area, even those that might not have been captured by the minnow traps alone.

Once the contents were transferred to the plastic trays, each cage was rinsed with 25–30 gallons of seawater sourced directly from the site. This rinsing process allowed for the collection of any additional dislodged organisms that may have been present in the cages. This thorough approach ensured that the biodiversity assessment covered a wide range of species residing in the vicinity of the reef, providing a comprehensive understanding of the ecological interactions within the restoration site.

While biodiversity assessments were successfully conducted at Lemon Creek Lagoon in 2020, they were not possible at Bush Terminal Park and Coney Island Creek due to access restrictions to the respective restoration sites due to COVID. These limitations prevented the project team from conducting the necessary fieldwork and data collection at those locations during the specified period. As a result, biodiversity data for those sites during the mentioned time frame is unavailable in the report.

In **Table 11**, the recorded species encountered at both sites are listed. Specifically, 11 species were captured at Coney Island Creek, while five species were captured at Lemon Creek Lagoon. The report further summarizes the total abundance of all species in **Table 12** and presents the length of vertebrates in **Figure 32**.

Common species observed at both reef sites include mummichog, naked goby, and blue crab. The presence of these species in both locations is not surprising, as they are commercially valuable and frequently caught by recreational anglers. These findings indicate that oyster beds and reefs established by Billion Oyster Project are supporting a diverse range of marine life, contributing to the enhancement of biodiversity in the restoration areas.

Figure 33 provides visual examples of some of the animals that were found in association with Billion Oyster Project oyster reefs. These visual representations offer insights into the diverse ecosystem supported by the oyster restoration activities, highlighting the positive impact of the project on the surrounding marine environment.

Table 11. Species observed in minnow traps and restoration structures at Lemon Creek Lagoon and Coney Island Creek in July and October 2020.

Vertebrates			
Scientific Name	**Common Name**	**Coney Island Creek**	**Lemon Creek Lagoon**
Anguilla rostrata	American eel		X
Apeltes quadracus	Fourspine stickleback		
Cyprinodon variegatus variegatus	Sheepshead minnow		
Fundulus heteroclitus	Mummichog	X	X
Fundulus majalis	Striped killifish		
Gobiosoma bosc	Naked goby	X	X
Menidia menidia	Atlantic silverside		
Morone saxatilis	Striped bass		
Opsanus tau	Oyster toadfish		X
Paralichthys dentatus	Summer flounder	X	
Pseudopleuronectes americanus	Winter flounder		
Syngnathus fuscus	Northern pipefish		
Family *Belonidae*	Needlefish	X	
Tautoga onitis	Black fish	X	
Invertebrates			
Scientific Name	**Common Name**	**Coney Island Creek**	**Lemon Creek Lagoon**
Order Amphipoda	Amphipod		
Callinectes sapidus	Blue crab	X	X
Carcinus maenas	Green crab		
Crangon septemspinosa	Sand shrimp		
Geukensia demissa	Atlantic ribbed mussel		
Hemigrapsus sanguineus	Asian shore crab		
Mercenaria mercenaria	Hard clam (quahog)		
Mnemiopsis leidyi	Sea walnut	X	
Mytilus edulis	Blue mussel		
Nephtys sp.	Red-lined worm		
Nereis spp.	Clam worm		
Paguroidea	Hermit crab	X	
Palaemonetes spp.	Grass shrimp	X	
Panopeus spp.	Mud crab	X	
Class Polychaeta	Polychaete worm(s)		
Tritia obsoleta	Eastern mud snail	X	
Urosalpinx cinerea	Atlantic oyster drill	X	

Table 12. Total abundance of organisms collected in minnow traps (off reef deployment for 48 hours) and various restoration structures (on reef) at Coney Island Creek (CIC) and Lemon Creek Lagoon (LCL) in July and October 2020.

Month	Site	Trap or Structure	Vertebrate/ Invertebrate	Scientific Name	Common Name	Abundance
July	CIC	Minnow trap (shell absent)	Vertebrate	*Fundulus heteroclitus*	Mummichog	3
				Paralichthys dentatus	Summer flounder	1
			Invertebrate	*Callinectes sapidus*	Blue crab	1
				Mnemiopsis leidyi	Sea walnut	4
				Paguroidea	Hermit crab	6
				Palaemonetes spp.	Grass shrimp	7
				Tritia obsoleta	Eastern mud snail	4
	LCL	Minnow trap (shell absent)	Vertebrate	*Anguilla rostrata*	American eel	1
				Fundulus heteroclitus	Mummichog	4
			Invertebrate	*Callinectes sapidus*	Blue crab	1
		ECOncrete disc (shell present)	Vertebrate	*Gobiosoma bosc*	Naked goby	11
				Opsanus tau	Oyster toadfish	1
		Bagged Shell (shell present)	Vertebrate	*Anguilla rostrata*	American eel	1
				Gobiosoma bosc	Naked goby	13
				Opsanus tau	Oyster toadfish	5
			Invertebrate	*Callinectes sapidus*	Blue crab	1
October	CIC	Cabinet files (shell present)	Vertebrate	*Gobiosoma bosc*	Naked goby	2
				Strongylura marina	Atlantic needlefish	1
				Tautoga onitis	Black fish	2
			Invertebrate	*Palaemonetes* spp.	Grass shrimp	25
				Urosalpinx cinerea	Atlantic oyster drill	15

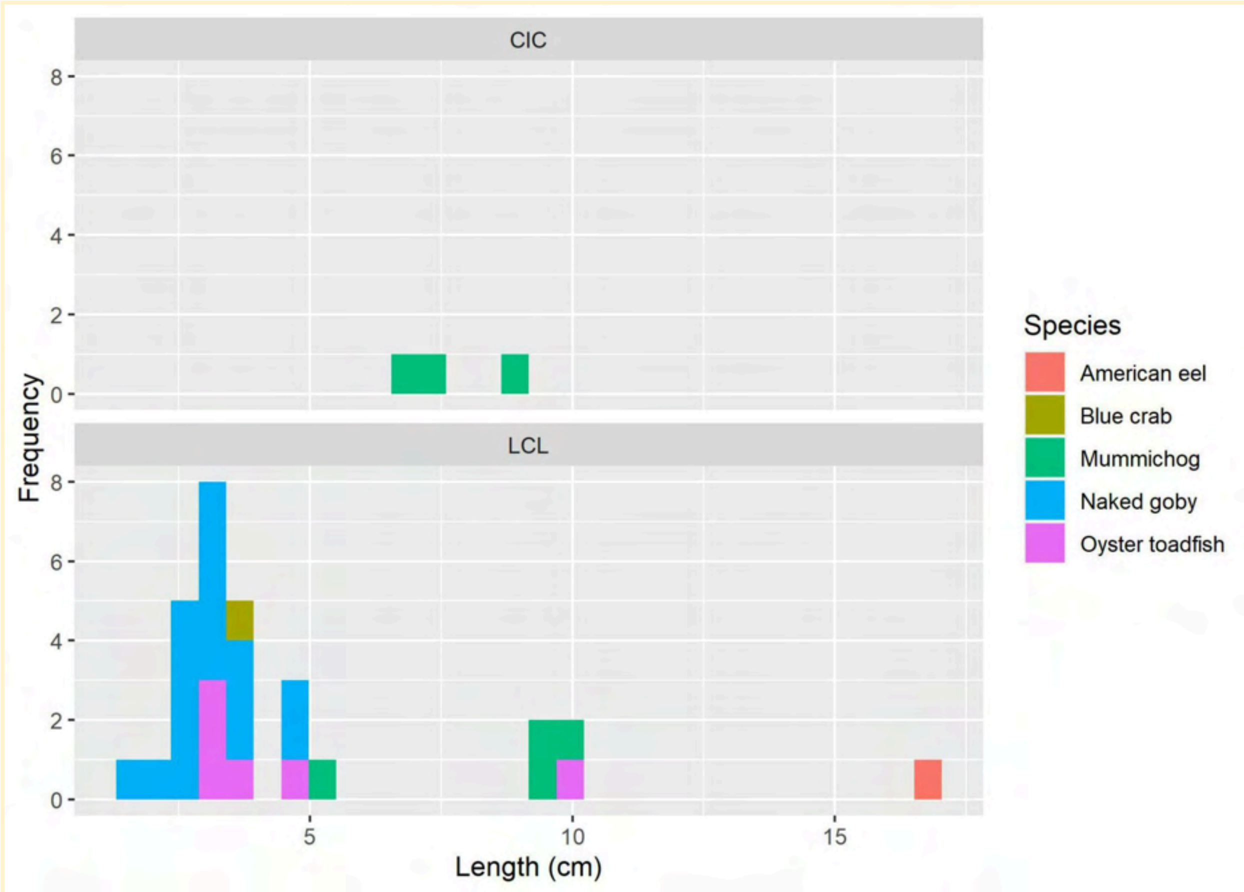

Figure 32. Histogram of fish length captured in minnow traps and various restoration structures at Coney Island Creek (top) and Lemon Creek Lagoon (bottom) in July.

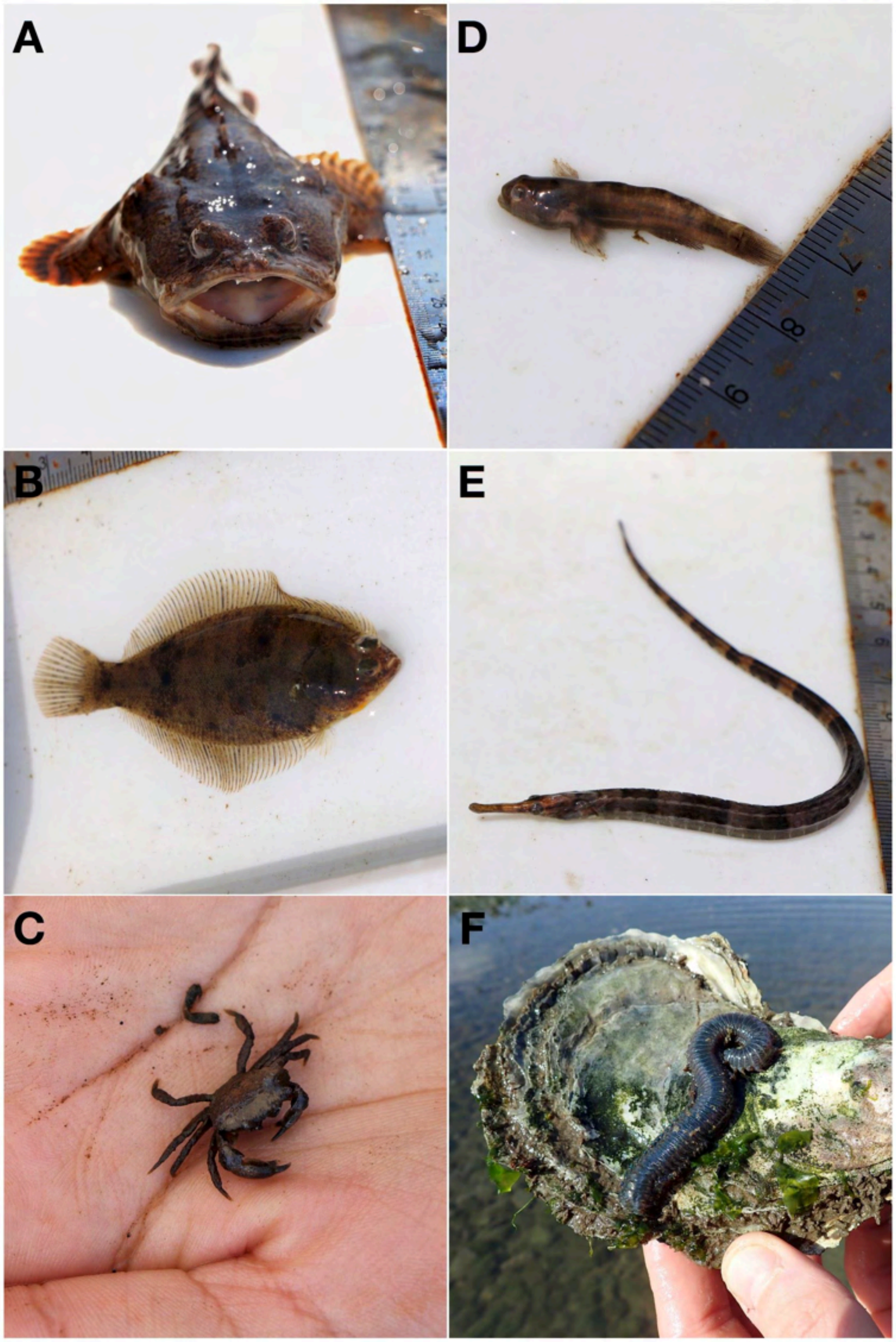

Figure 33. Examples of organisms inhabiting restored reefs: (A) Oyster toadfish (*Opsanus tau*), (B) Winter flounder (*Pseudopleuronectes americanus*), (C) Mud crab (*Panopeus sp.*), (D) Naked goby (*Gobiosoma bosc*), (E) Northern pipefish (*Syngnathus fuscus)*, and (F) Clam worm (*Nereis* sp.). (Photos courtesy of Elizabeth Burmester)

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