ANNUAL MONITORING REPORT 2025

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 provide several ecosystem services: they enhance habitat complexity, improve species biodiversity and abundance, improve water quality through filtration and sediment stabilization, and enhance shoreline resilience by dissipating wave energy.

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 2030, Billion Oyster Project aims to create self-sustaining oyster populations by introducing one billion oysters, and engaging one million students in our work.

By the end of 2025, Billion Oyster Project has collected 3.2 million pounds of shells from restaurants. These shells provide habitat for oysters in the waters of New York City. Over 180 million live oysters have been reintroduced by the Billion Oyster Project in the waters of New York Harbor, and over 40,000 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 2025. We'd also like to specifically acknowledge the property managers for working with us to install these oyster reefs, and the many Billion Oyster Project Interns, Ambassadors, and Volunteers for their support and efforts - thank you!

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Brooklyn Navy Yard
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Inwood Marina
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EXECUTIVE SUMMARY

This is the seventh edition of Billion Oyster Project's Annual Monitoring Report. The report summarizes the 2025 monitoring results from twelve oyster restoration sites in New York Harbor as well as pre-installation activities at several sites. Data were collected by staff, partners, community scientists, and students with standardized protocols that have been used by Billion Oyster Project and restoration practitioners for nearly a decade.

In 2025, our team counted and measured nearly 14,000 individual oysters. Rather than detailing every individual oyster, the key findings from 2025 monitoring are summarized below:

Multi-phase installation and reseeding sustain high oyster populations at long-running restoration sites.

Restoration approaches incorporating multiple cohorts and periodic reseeding have successfully maintained large oyster populations at long-term sites, including Brooklyn Bridge Park (~10.5 M oysters), Soundview Park (5.3–9.1M oysters), and Head of Bay (~13.8M oysters). These sites demonstrate that multi-phase restoration is an effective strategy for sustaining oyster populations despite expected mortality in recruitment-limited systems.

Oysters persist for multiple years and reach large sizes in New York Harbor.

Long-term monitoring confirms that oysters survive for several years and attain large shell sizes at multiple sites, including Bush Terminal Park (average shell height >160 mm), Paerdegat Basin (average shell height of nearly 100 mm), and Head of Bay (average shell height >147 mm), indicating the Harbor's capacity to support mature, reproductively viable oysters across multiple waterbodies.

Recruitment occurs at several sites but remains insufficient to offset mortality.

Recruitment of the next generation of oysters was observed at multiple restoration sites in 2025, including Soundview, Brooklyn Bridge Park, and the Living Breakwaters. However, recruitment remains low and highly variable and does not currently outweigh mortality. As a result, restored reefs have not yet achieved self-sustaining population dynamics.

Achieving self-sustaining reefs will require larger-scale restoration and improved larval connectivity.

Results suggest that overcoming low-density reproductive limitations will require larger, multi-acre restoration projects capable of supporting high adult densities, as well as a better understanding of larval dispersal and connectivity to facilitate the development of a metapopulation across a network of restoration sites in New York Harbor.

2025 established the first Harbor-wide quantitative baseline for mobile species use of oyster reefs.

In 2025, Billion Oyster Project and partners conducted over 580 minnow and sea bass trap deployments across eight sites, documenting more than 4,000 individual fish, crabs, shrimp, and other invertebrates representing 44 unique taxa. These data represent a significant advancement toward quantifying habitat use and ecological uplift associated with oyster restoration and provide a critical baseline for future assessment. Additional monitoring approaches such as eDNA and underwater video will enhance this effort.

Billion Oyster Project is transitioning from pilot-scale projects to landscape-scale restoration.

As Billion Oyster Project advances toward multi-acre restoration projects, several early pilot-scale reefs, while essential to building foundational knowledge of oyster performance in New York Harbor, have reached the end of their experimental value. Retiring these projects allows resources to be focused on larger, more durable reefs designed to achieve population-level sustainability and ecosystem-scale outcomes.

Collectively, these findings demonstrate that oyster restoration is biologically and technically feasible in New York Harbor, but requires sustained investment, adaptive management, and landscape-scale planning to achieve ecosystem-level outcomes.

The report that follows provides site-specific results. **Table 1** provides an assessment of three oyster performance metrics that were applied to the twelve sites around New York Harbor. **Table 2** provides a high-level overview of the recommended restoration actions for each site.

Table 1. Summary of oyster performance metrics at each restoration site. NA indicates data are not available. Grades are categorized as green, yellow, or red.

SITE	STRUCTURE	GROWTH	MORTALITY	RECRUITMENT
Brooklyn Bridge Park	SEAPA Nursery	Positive	Low	Low but consistent
	Cabinet Reef	Slow	High	Low but consistent
	Gabion Reef	Positive	Stabilizing	Low but consistent
	Bay Ball Reef	Positive	High	NA
Bush Terminal Park	Deepwater Cabinet	Positive	High	None
	Cabinet Reef	Positive	Stabilizing	Low but variable
Brooklyn Navy Yard	SuperTray Nursery	Stable	Low	Low but variable
Coney Island Creek	Cabinet Reef	Positive	Low	NA
Governors Island Ecodock	SuperTray Nursery	Positive	Low	NA
Great Kills Harbor	SuperTray Nursery	Stable	High	None
Living Breakwaters	Breakwater	Positive	NA	Low but consistent
Bayswater Point State Park	Bagged Shell Reef	Positive	Stabilizing	Low but consistent
Head of Bay	Shell Reef	Positive	Stabilizing	None
Paerdegat Basin	Cabinet Reef	Positive	Stabilizing	Low but variable
Soundview Park	Shell Reef	Positive	High	Low but variable
	Bay Ball Reef	Positive	Stabilizing	NA
SUNY Maritime	SuperTray Nursery	Positive	Stabilizing	NA

Table 2. Summary of recommended restoration action for each site.

WATERBODY	SITE	RECOMMENDED RESTORATION ACTION
Upper Harbor	Brooklyn Bridge Park	● Continue monitoring to inform the second phase of restoration.
	Bush Terminal Park	● Continue monitoring of structures inside the lagoon. ● Permit a two-phase, 1.3-acre subtidal reef with shell mounds and bay balls to introduce oysters in 2026 and 2029.
	Brooklyn Navy Yard	● Continue using the site as a nursery. ● Continue annual monitoring.
	Governors Island Ecodock	● Continue using the site as a nursery and temporary holding bay. ● Continue annual monitoring.
Lower Harbor & Raritan Bay	Coney Island Creek	● No plans to restock oysters to Coney Island Creek at this time.
	Great Kills Harbor	● Complete the removal of the nursery from the site in 2026. ● ORS will remain for local community stewardship.
	Living Breakwaters	● Conduct additional in situ trials to understand performance and scalability of this method. ● Continue annual monitoring.
Jamaica Bay	Bayswater Point State Park	● Conduct final monitoring and removal of reef materials in 2026.
	Head of Bay	● Continue annual monitoring. ● Reseed the shell reef to maintain multiple oyster cohorts.
	Paerdegat Basin	● Remove cabinets and potentially transfer adult oysters to existing off-bottom SEAPA cages. ● Permit Phase 1 (0.37 acres of seeded and unseeded substrate) of a multi-phase reef restoration project.
Western Long Island Sound	Soundview Park	● Continue annual monitoring of existing cohorts. ● Reseed shell reef and install more bay balls to protect the shell reef.
	SUNY Maritime	● Continue annual monitoring and using the site as a nursery.

Other Sites and Projects

While this report focuses on active restoration sites maintained and monitored, it's important to note that Billion Oyster Project is also involved in other oyster restoration projects throughout the estuary. These include the following.

- Since 2015, school groups, various community groups, and individuals have participated in Billion Oyster Project's Oyster Research Station program. Data from this program are not included in this report.

- In May 2021, Billion Oyster Project and New York Harbor School introduced 5,000 donated adult oysters to the Governors Island reef site in the Buttermilk Channel between Brooklyn and Manhattan as part of the Supporting Oyster Aquaculture and Restoration (SOAR) effort led by The Nature Conservancy and The Pew Charitable Trusts. Data from this site are not included in this report.

- In 2021 and 2022, Billion Oyster Project served as a sub-consultant to Hudson River Park Trust to set structures with juvenile oysters for their Tribeca (north of Pier 26) and Gansevoort (south of Pier 54) Habitat Enhancement projects. These sites are not discussed in this report. Reports may be found on the Hudson River Park Trust's website.

- Billion Oyster Project supports Hudson River Foundation in post-installation monitoring of the 2018 restored oyster reef at Governor Mario M. Cuomo/New NY Bridge Project at Tappan Zee. Data from this site are not included in this report.

Introduction

Restoration Objective

Billion Oyster Project (Billion Oyster Project) seeks to support the recovery of functional, self-sustaining oyster populations in New York Harbor through multi-acre restoration projects in five regional waterbodies: the Hudson River, Western Long Island Sound, Upper New York Harbor, Lower New York Harbor & Raritan Bay, and Jamaica Bay.

Functional oyster reefs provide ecosystem benefits by increasing habitat complexity and connectivity and supporting fish and invertebrate biodiversity, water filtration, and shoreline protection. A self-sustaining population persists over time without ongoing intervention and is characterized by reproductively active adult oysters, suitable reef substrate, consistent recruitment, and stable mortality. Unlike regions such as the Chesapeake Bay or Gulf Coast, New York Harbor is both larvae-limited and substrate-limited. While small wild oyster populations exist, their size, isolation, and lack of available reef substrate constrain their expansion and ecological function. This necessitates active restoration and adaptive management.

Restoration Strategy

As documented in previous monitoring reports, Billion Oyster Project employs two primary restoration strategies to address these constraints and advance its goal of restoring one billion oysters by 2030: (1) introducing multiple cohorts of oysters over multiple years and (2) adding hard substrate to support reef development.

1. **Introducing Multiple Cohorts of Oysters**

Long-term monitoring, recruitment studies, and pilot restoration projects indicate that isolated reproducing oyster populations are present in New York Harbor, but are insufficient to supply consistent recruitment across the estuary. To offset low or variable recruitment and high early mortality, restoration projects introduce multiple cohorts of oysters over successive years.

Billion Oyster Project monitoring data demonstrate substantial mortality following installation, particularly during the first three years. This pattern is consistent with oyster restoration efforts in other regions. As a result, high initial stocking densities and repeated seeding are necessary to achieve sufficient adult oyster densities and avoid population decline below viable thresholds. Because optimal stocking densities in New York Harbor remain uncertain and vary with environmental conditions, disease, and predation, higher initial seeding densities and continued intervention are an expected and necessary component of restoration.

2. **Adding Substrate**

Oysters require hard substrate for larval settlement and reef formation. Due to historic reef loss, shoreline modification, and dredging, much of the Harbor bottom consists of soft sediment that provides limited attachment points and refuge. The addition of hard, vertically structured substrate increases oyster survival, growth, recruitment, and habitat complexity, and supports higher biodiversity of invertebrates and fish.

Since 2010, Billion Oyster Project and partners have piloted a range of restoration structures, including gabions, reef balls, shell, oyster castles, cages, and concrete structures, often directly seeded with juvenile oysters to compensate for low natural recruitment. By seeding reef structures in advance, Billion

Oyster Project simultaneously adds substrate and multiple oyster cohorts, maximizing restoration efficiency under site-specific conditions.

Data and lessons learned from these pilot projects, as reported previously, inform project design, monitoring protocols, and adaptive management strategies for large-scale restoration in an urban estuary.

Project Objectives

Billion Oyster Project restoration projects aim to:

- Conduct pre-installation monitoring to characterize baseline site conditions.
- Install appropriately sized reef footprints and spat densities informed by site conditions and pilot data.
- Deploy seeded and unseeded reef substrate to support reef development and habitat enhancement.
- Implement post-installation monitoring and adaptive management to evaluate project performance over time.
- Phase installations over multiple years to introduce multiple oyster age classes.

Additional detail on the scientific rationale, restoration design, and adaptive management framework is provided in previous Billion Oyster Project Annual Monitoring Reports.

Regional Waterbodies

Billion Oyster Project leads ongoing oyster restoration projects and an active pipeline of proposed oyster restoration projects to advance its goal to restore a self-sustaining oyster population within five regional waterbodies in New York City: 1) Upper Harbor Region, 2) Lower Harbor/Raritan Bay, 3) Hudson River, 4) Jamaica Bay, and 5) Western Long Island Sound (**Figure 1**).

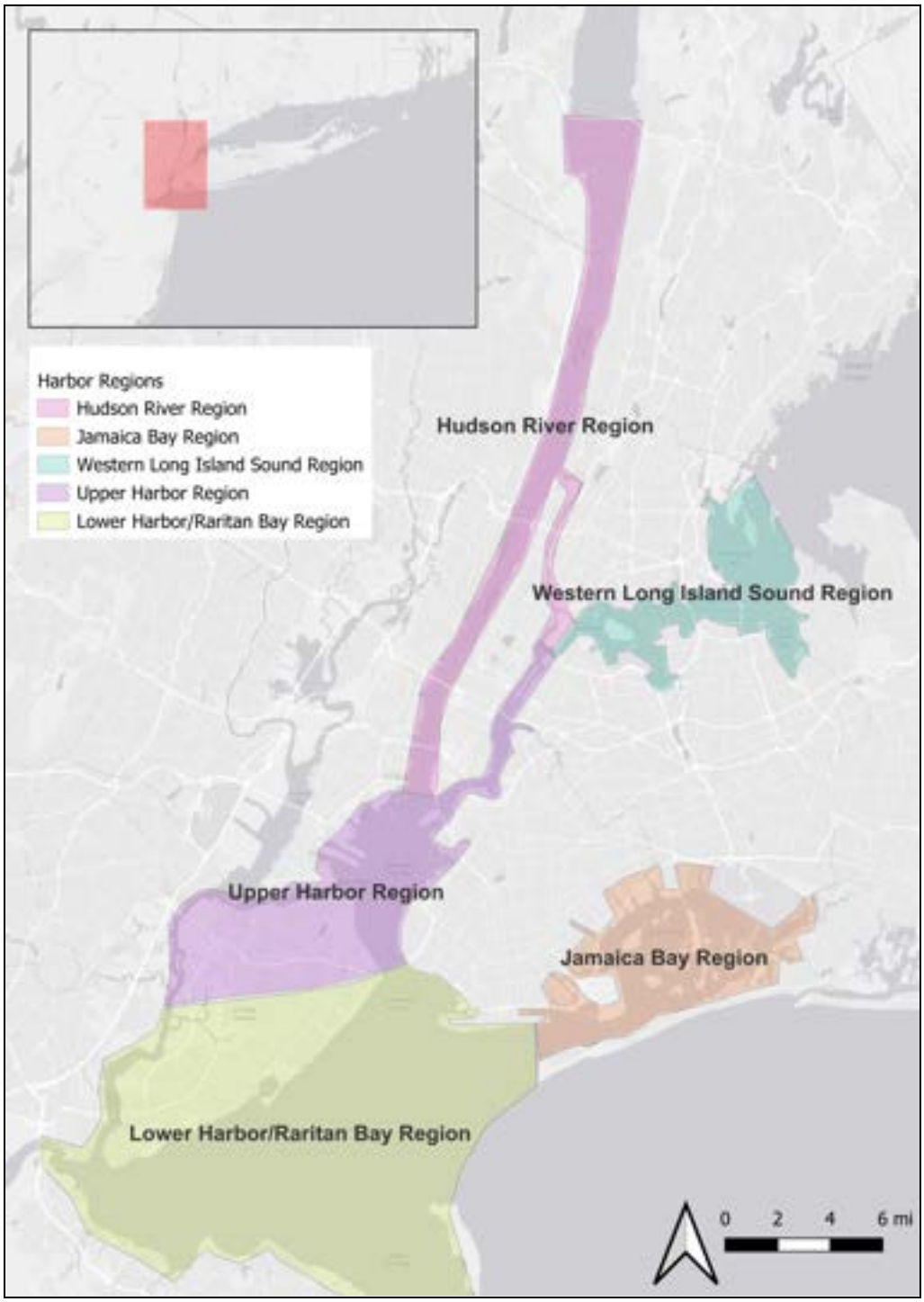

Figure 1. Map of regional waterbodies in the New York Harbor.

Summary of Sites

Table 3 summarizes the restoration sites in New York Harbor that Billion Oyster Project is actively monitoring. While the majority of the post-installation monitoring is occurring in restoration sites located within the Upper and Lower Harbor, Billion Oyster Project is working on expanding the restoration of other regional waterbodies, specifically large-scale restoration in the Western Long Island Sound and Hudson River.

Table 3. Summary of active restoration sites in 2025 included in this report.

Waterbody	Site	Structure	Structure Placement	Status of Site
Upper Harbor	Brooklyn Bridge Park	Cabinet Reef (**BBPC**)	On-bottom	Post-Installation
		Gabion (**BBPG**)		
		SEAPA Nursery (**BBPN**)	Off-bottom	
		Bay Ball Reef (**BBP**)	On-bottom	Installation in 2024 & 2025
	Bush Terminal Park (**BTP**)	Cabinet Reef	On-bottom	Post-Installation
		Deepwater Cabinet		
	Brooklyn Navy Yard (**BNY**)	SuperTray Nursery	Off-bottom	Post-Installation
	Governors Island Ecodock (**GIE**)	SuperTray Nursery	Off-bottom	Post-Installation Annual Structure Removal
Lower Harbor & Raritan Bay	Coney Island Creek (**CIC**)	Cabinet Reef	On-bottom	Post-Installation Annual Structure Removal
	Great Kills Harbor (**GKH**)	SuperTray Nursery	Off-bottom	Post-Installation
	Living Breakwaters (**LBW**)	Breakwater	On-bottom	Installation in 2025
Jamaica Bay	Bayswater Point State Park (**BW**)	Bagged Shell Reef	On-bottom	Post-Installation
	Head of Bay (**HOB**)	Shell Reef	On-bottom	Post-Installation
	Paerdegat Basin (**PB**)	Cabinet Reef	On-bottom	Post-Installation
Western Long Island Sound	Soundview Park (**SV**)	Shell Reef	On-bottom	Post-Installation
		Bay Ball Reef	On-bottom	Installation in 2024
	SUNY Maritime (**SM**)	SuperTray Nursery	Off-bottom	Installation in 2025

Restoration Background

This section provides a brief introduction to the oyster sources, structures, and methodology used for monitoring activities at our restoration sites. An explanation of the grading metric is also provided to identify the key metrics used to assess oyster performance and health.

Larval Sources

As Billion Oyster Project's demand for larvae grew, the organization expanded its sourcing to include multiple hatcheries. Coordinating with several independent hatcheries proved complex, leading Billion Oyster Project to work mainly with Atlantic Aqua Farms, an operator of multiple hatcheries along the East Coast. This streamlined communication by establishing a single point of contact, which improved efficiency and coordination. The list of larvae suppliers for 2025 are listed in **Table 4**.

Once larvae are obtained from approved hatcheries, larvae are directly set to cured shells (recycled from partner restaurants) or reef substrates in the Remote Setting Facility on Governors Island. After two to four weeks in the setting facility, the seeded structures are then deployed to permitted restoration sites. Wild oyster larvae may also recruit to restoration sites and set to the developing reef. For more information on the oyster life cycle and our shell collection process, please refer to Billion Oyster Project's website.

Table 4. Summary of hatcheries and quantity of larvae procured in 2025.

Larvae Supplier	Location	Number of Eyed Larvae Procured
Muscongus Bay Aquaculture	Bremen, ME	58,000,000
Oyster Seed Holdings	Hudgins, VA	20,000,000
Mobjack Bay Lease Holdings	Gloucester, VA	40,000,000
Mook Sea Farm	South Bristol, ME	70,000,000

Oyster Structures

Billion Oyster Project applies oyster restoration structures to each site based on site-specific conditions, project objectives, and our evolving understanding of best management practices for oyster restoration in a heavily urbanized city. The current structures are included in **Table 5**.

Table 5. On-bottom and off-bottom structures used for oyster restoration.

Structure Figure and Description	
	**SuperTrays** UV-resistant aquaculture plastic trays measuring 2’ x 2’. SuperTrays are stackable, filled with spat-on-shell, and may be bridled together using a ⅜ inch polypropylene line to facilitate setting in the remote setting facility or suspension from floating docks or piers.
	**SEAPA Cages** 20L baskets are typically used in aquaculture to grow oysters, these structures are filled with spat-on-shell and suspended off-bottom in stacks of two to three to form nurseries. Billion Oyster Project uses SEAPA cages with the following dimensions: 2.5’ x 8” x 6”.
	**Bagged Shell** Individual plastic mesh bags that hold approximately 600 shells and 0.3 cubic yards of material. Individual bags are submerged in the intertidal area, which can be accessed via wading during low tide and secured with PVC pipes that are inserted on the outer edge of the plot.
	**ECOncrete® Disks** ECOncrete® disks provide a substrate for biofouling marine organisms, including oysters. Each disk is approximately 10-12 lbs and has a diameter of approximately 10 inches. The disks can interlock when stacked on top of each other, the stack is then stabilized by placing a shaft anchor through the middle of each disk.
	**Cabinet Reef** Welded rebar frames that contain mesh files filled with oysters. Cabinet reefs facilitate hands-on programming by students and community members. Billion Oyster Project uses two sizes of cabinets, a 4’ x 2’ x 2’ welded rebar frame with 14 mesh files, and a 10’ x 2’ x 2’ with 28 mesh files.
	**Gabion** Welded steel structures filled with spat-on-shell. Once installed, they act as surrogate reef structures in the absence of natural oyster reefs while the juvenile oysters grow, and create a three-dimensional habitat for benthic species. Billion Oyster Project has used three sizes of gabions (large: 4’ x 2’ x 2’).
 	**Bay Ball** Reef balls of varying sizes are used to mimic the structure and function of a natural oyster reef. Bay ball refers to a particular size of reef ball designed by the Reef Ball Foundation and used at Billion Oyster Project sites. Bay ball units weigh up to 500 lbs each. These units may be cast with a footer to minimize subsidence in soft sediment and may be installed unseeded or seeded with juvenile oysters. They are typically deployed with the assistance of a marine contractor.

Monitoring Methodology

As described in previous Billion Oyster Project Annual Monitoring Reports, monitoring methods are standardized across sites and adapted as reefs develop. The summary below highlights the core approaches used to assess oyster performance and associated ecological communities in 2025. Full methodological detail is provided in prior reports, and available upon request.

Oyster Performance

Oyster performance is assessed using one of two established monitoring protocols (clump monitoring or quadrat monitoring) depending on restoration structure, oyster aggregation, and reef maturity. Clump monitoring is typically used for recent spat-on-shell installations where oysters are loose and unaggregated, while quadrat monitoring is used once oysters have cemented to one another and formed cohesive reef structures, such as on reef balls or older installations. Many sites transition from clump to quadrat monitoring over time as reef development progresses.

Live and dead box oysters (oysters with both valves intact) are counted at each site. Shell height is measured from the umbo to the shell margin to the nearest millimeter, and oysters are classified as live or dead based on standard visual and tactile indicators. Oyster density (oysters per square meter) is calculated using quadrat data only, where the sampled area is known.

Wild recruitment is assessed by counting oysters with shell heights less than 25 mm at least one year post-installation or during targeted wild oyster surveys. Oysters below this size threshold are assumed to be naturally recruited. Wild oyster surveys are typically conducted in the fall, following the reproductive season, along fixed-length transects.

Annual percent mortality is calculated as the proportion of dead box oysters relative to the total number of live and dead box oysters sampled, with site-level estimates summarized across replicate quadrats and reported with 95% confidence intervals. Annual percent recruitment is calculated as the proportion of juvenile oysters (<25 mm). Site-level population estimates are updated annually by accounting for observed mortality and recruitment. As documented in previous reports, early post-installation mortality is expected, with mortality rates anticipated to stabilize as reefs mature and recruitment becomes more consistent.

Benthic Species Characterization

Benthic infaunal communities are characterized during pre-restoration site investigations using sediment grab samples. Sampling layout and intensity is adapted to site size and conditions and conducted in wadable or non-wadable areas as appropriate. Sediment samples are sieved in the field and processed in a laboratory, where organisms are identified to the lowest practical taxonomic level and weighed. These data are used to characterize baseline benthic community composition, diversity, abundance, and biomass, allowing an evaluation of ecological changes associated with oyster reef restoration.

Epibenthic Species Characterization

Epibenthic communities associated with restored reef structures are characterized using quadrat-based photographic surveys conducted during oyster monitoring events. For each restoration structure monitored, one oyster monitoring quadrat is randomly selected for epibenthic assessment. This approach allows epibenthic data to be collected concurrently with oyster performance metrics while minimizing additional disturbance to the reef. Photographs are analyzed by taxonomic experts, and representative

voucher specimens are collected and preserved when necessary for species confirmation. Epibenthic organisms are identified to the lowest practical taxonomic level, and data are used to assess species presence and community composition on restored reef substrates.

Mobile Species Characterization

Mobile species associated with restored oyster reefs are assessed using a combination of trapping, seining, and passive observation, depending on site conditions and accessibility. Sampling is conducted primarily during the field season (spring through fall), with observational data collected during routine monitoring visits. Captured organisms are identified to species, counted, photographed for verification, and measured when appropriate (typically fish and crabs). Organisms are released back to the site following processing. Passive observations include species found utilizing reef structures for foraging, refuge, or shelter during monitoring activities. These data are used to evaluate species richness, abundance, and habitat use associated with restored oyster reefs.

Grading Metrics

To assess the performance and health of oyster restoration at each site, several metrics are used to evaluate oyster growth, mortality, and recruitment with assigned qualitative grades. 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. 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 (i.e., recruitment, reproduction, disease). The three metrics are described in **Table 6**.

Table 6. List of oyster performance and health metrics used to assess oysters at restoration sites.

Metric Category	Parameter and unit of measurement	Explanation	What indicates good oyster performance?	Available Grades
Growth	Shell height (unit: mm)	Oyster growth is assessed by measuring the total shell height from the umbo to the outermost edge.	Mean shell height increases within the growing season and between years.	Positive Stable or Slow Negative
Mortality	Annual mortality is calculated by the number of dead box oysters sampled divided by the total number of live and dead box oysters sampled (unit: %)	Oysters naturally have a high mortality as spat and after the initial period of high mortality, mortality should eventually stabilize.	Annual mortality stabilizes after the initial mortality.	Low Stabilizing High
Recruitment	Multiple peaks on size frequency histograms	Size frequencies are calculated based on the total number of sampled oysters that are classified into specific size groups.	More than one peak on the size-frequency histogram indicates the recruitment of new oysters.	Consistent Low but consistent Low but variable or None NA (no available data)
	New spat (oysters <25 mm one year post-installation) = new recruitment	Mature oysters produce larvae that are pelagic and swim in the water for two to three weeks. After, the larvae transition to the bottom, settling onto hard substrates such as oyster shells or rocks.	The presence of naturally recruited wild oyster spat.	

Growth and Recruitment

Oysters are expected to survive and grow over time, 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, size-frequency distributions 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 of oysters present in a single sample, multiple peaks, not necessarily of equal size, may be visible.

Mortality

Like growth, oyster mortality 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.

Juvenile oysters, called spat, attach to hard substrate in high densities. At small sizes, spat are especially vulnerable to predation and environmental stressors. The spat grows quickly over the first 1–2 years of life, but as they grow they must also compete for space and food. As a result, survival to adulthood is expected to be low. 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 and may rise again as oysters die of old age or disease.

Upper Harbor Region

The Upper Harbor Region spans from Randall's Island in the north, extending south down the East River, to include Manhattan, Queens, and Brooklyn shorelines until the Verrazano Narrows (**Figure 2**). This very active waterway is the most urbanized of the four regional waterbodies with a shoreline dominated by vertical seawalls, riprap revetments, and piers. Fast currents move through deepened navigational channels. As the Hudson River and East River meet in the Harbor and Narrows, oyster larvae from wild populations in the Hudson near Tappan Zee and Western Long Island Sound region may recruit to substrate in Upper Harbor. It is therefore critical to add substrate to restoration sites in this region. Smaller bays and coves between piers and waterfront parks are potential protected locations for restoration. **Table 7** summarizes the restoration sites and installation details in this regional waterbody.

Figure 2. Map of restoration sites within the Upper Harbor Region.

Table 7. Summary of restoration structures and installation details of each site in the Upper Harbor Region.

Site	Structure	Installation Date	Larvae Source	Mean shell height at installation (mm)	Number of oysters installed
Brooklyn Bridge Park	SEAPA Cage Nursery	8/28/2020	Muscongus Bay, ME	2-5	215,280
	Cabinet Reef	9/8/2021		2-5	185,071
	Gabions	8/30/2021		2-5	588,861
	Reef Balls	8/23/2024		2-5	13,400,000
		7/23/2025		2-5	7,600,000
Brooklyn Navy Yard	SuperTray Nursery	Fall 2014	NYHS Hatchery	~5	226,000
		Spring 2015	Muscongus Bay, ME	~5	3,500,000
		4/10/2017		29.5	7,500
Bush Terminal Park	Deepwater Cabinets	6/28/2016	Muscongus Bay, ME	~2	387,781
	Cabinet Reef	6/28/2016	Muscongus Bay, ME	~2	581,671
		8/22/2018	Muscongus Bay, ME; NYHS Hatchery	~5	180,000
	Bagged Shell Reef	8/23/2018		~5	133,986
Governors Island Ecodock	SuperTray Nursery	6/9/2025	Oyster Seed Holdings, VA	2-5	1,150,274

Brooklyn Bridge Park

Project Summary

As of 2025, Billion Oyster Project maintains and monitors several installations in Brooklyn Bridge Park near Brooklyn Bridge Park Marina and Pier 4 with direct support from New York Harbor School students and interns, local students, and community groups. The project provides insight into oyster performance using on and off-bottom restoration techniques, including larger scale on-bottom restoration at the site. In addition, the project offers public engagement opportunities that reconnect people to the waterbodies surrounding New York Harbor, as well as to the wildlife thriving along the shorelines and in the shallows.

Data trends from 2025 indicate that conditions are supportive of larger-scale oyster restoration:

- Oyster growth was positive across most structures.
- The SEAPA Cage Nursery experienced low annual mortality; however, on-bottom structures experienced significant mortality, with bay ball mortality increasing from spring to fall, likely due to elevated predation pressure from the oyster drill (*Urosalpinx cinerea*).
- Recruitment remains present but low across all structures.

Site Overview

Billion Oyster Project has been conducting oyster restoration at the Brooklyn Bridge Park Marina (formerly ONE°15 Marina) since 2020 with the initial installation of 29 SEAPA cages as an oyster nursery (**Figure 3**). In 2021, Billion Oyster Project expanded the site to include a field station with three removable oyster cabinets adjacent to Pier 4 Beach and a subtidal reef composed of five on-bottom gabions located offshore of Bird Island.

In spring 2022, monitoring revealed significant mesh degradation of the files within the cabinet structures, likely due to prolonged exposure to saltwater and frequent removal for onshore educational programming. Billion Oyster Project conducted a final monitoring of the structures in spring 2025 and subsequently removed all structures and oysters, disposing of them in an upland facility in May 2025.

In 2024, Billion Oyster Project received regulatory approval to install a two-phase, two-acre reef composed of 240 bay balls (210 seeded with 42 million spat) between Pier 4 Beach and Pier 3. Phase 1 began in 2024 with the installation of 75 bay balls (67 seeded with 13.4 million juvenile oysters) across clusters A-G. Phase 1 was completed in 2025 with the addition of 45 bay balls (38 seeded with 7.6 million spat) across clusters G-K. **Table 8** provides an overview of all Billion Oyster Project restoration structures at the Brooklyn Bridge Park site.

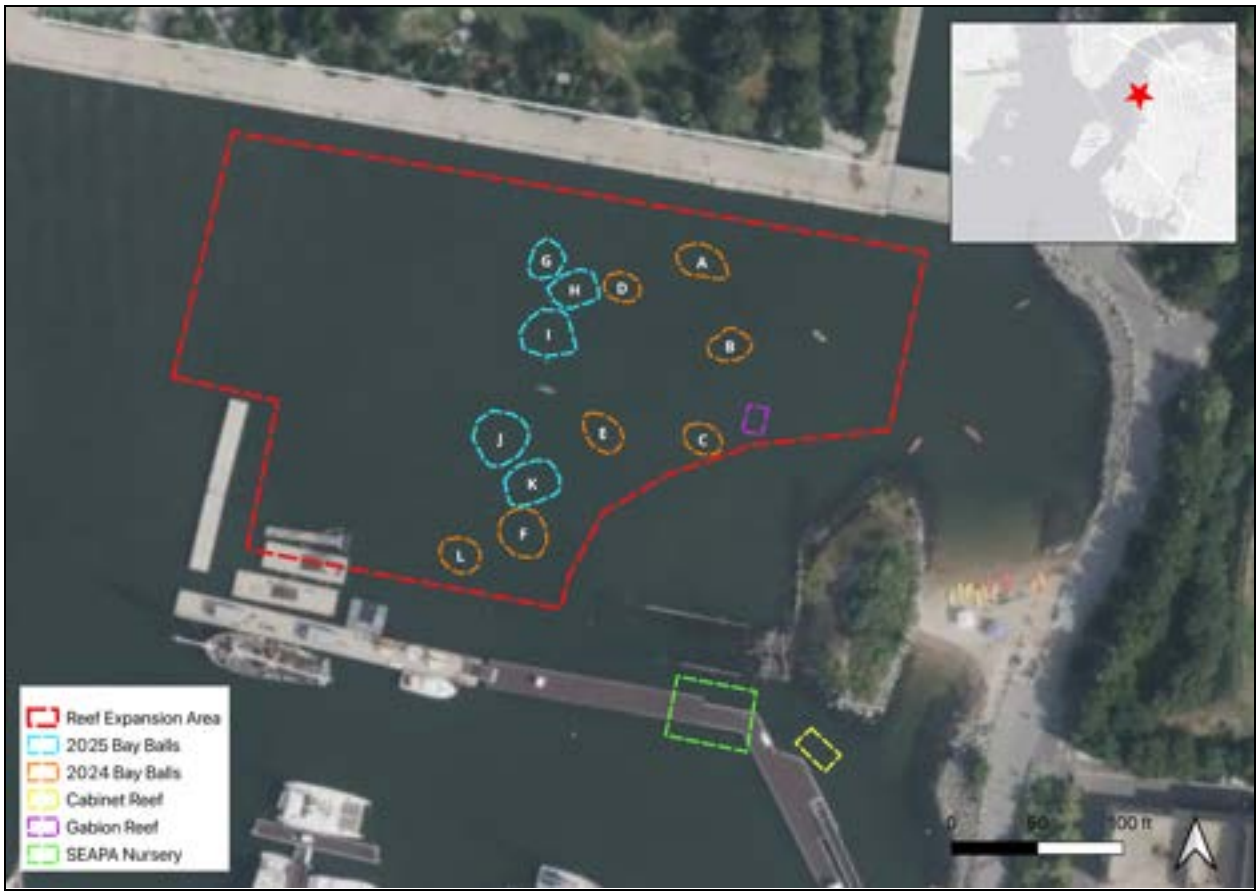

Figure 3. 2025 as-built site map of Brooklyn Bridge Park with oyster reef structures. The cabinet reef was removed in May 2025.

Table 8. Summary of structures installed and spat introduced at Brooklyn Bridge Park.

Structure Name	Year Installed	Quantity of Structures	Spat Introduced	Monitoring Frequency
SEAPA Cage Nursery	2020	29	215,280	Biannual
Cabinets Reef*	2021	3	185,071	
Gabion Reef	2021	5	588,861	Annual
Bay Balls	2024	75	13,400,000	Biannual
	2025	45	7,600,000	

*All cabinet reef structures were removed in May 2025.

Oyster Performance

Brooklyn Bridge Park SEAPA Cage Nursery

Billion Oyster Project monitors the SEAPA cage nursery biannually because of its accessibility and the community engagement opportunities associated with routine site maintenance. Monitoring is conducted using a clump-based method, in which a random subset of 30 oyster clumps from each cage (each clump containing at least one live oyster or dead box) is assessed for growth, mortality, and recruitment.

Growth: Positive

The oysters in the SEAPA nursery show a positive trend in oyster growth as the overall size frequency expands horizontally (**Figure 4**). In total, 1593 oysters were monitored in 2025 and 1864 oysters in 2024. Live oysters exhibited positive growth from a mean shell height of 70.4 mm (SD = 26.8, N = 1595) in 2024 to 80.1 mm (SD = 24.9, N = 1400) in 2025, while the mean shell height of dead box oysters was 71.8 mm (SD = 24.5, N = 193) in 2025 (**Table 9**). Oysters typically show increased size by the fall monitoring period, having benefited from warmer summer waters that enhance feeding. In contrast, growth is slower during the spring monitoring period due to reduced metabolic activity over the cold winter months.

Mortality: Low

Annual mortality of the SEAPA nursery is low, compared to the other structures at Brooklyn Bridge Park, fluctuating between 10.4% to 14.4% and this year's annual mortality (12.1%, N = 1593) continues to fall between the range (**Table 9**). The height of the hanging SEAPA cages could limit predation from oyster drills that were more evident in the cabinet reefs.

Recruitment: Low but consistent

Continuing the trend of low recruitment from previous years, no recruitment (oysters less than 25 mm in shell height) was observed in this year's fall monitoring (**Table 9**). However, we did find spat in the bags of blank shell bags that were deployed monthly to assess whether recruitment of wild or restored oysters is occurring around the SEAPA nursery. In July, four spat were observed (out of a sample size of 617 blank shells), with a mean shell height of 19.0 mm (SD = 5.6). In August, 12 spat were recorded (out of N = 650 blank shells), with a mean shell height of 2.8 mm (SD = 2.9).

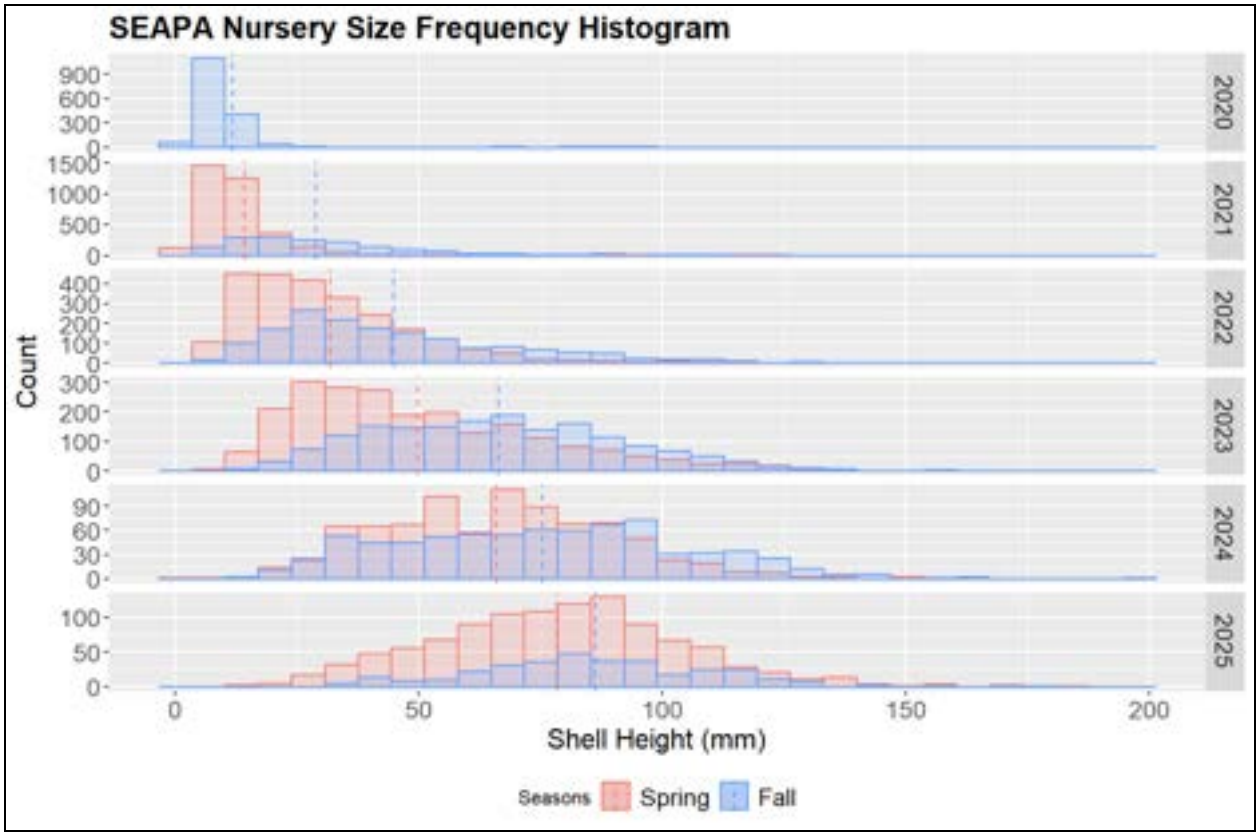

Figure 4. Size frequency histogram of live oysters in SEAPA nursery, 2020-2025. The dashed line represents the seasonal mean shell height.

Table 9. Summary of oyster performance at Brooklyn Bridge Park SEAPA nursery.

Year	Sample Size	Mean Shell Height (SD) of Live Oysters (mm)	Mean Shell Height (SD) of Dead Box Oysters (mm)	% Mortality	% Recruitment
2020	1770	11.8 (15.0)	8.9 (12.5)	4.8%	<1 year old
2021	5564	18.7 (17.0)	16.1 (12.2)	9.7%	<1 year old
2022	4495	37.0 (22.0)	28.1 (16.8)	8.7%	22.2%
2023	4430	57.0 (26.5)	51.2 (24.3)	10.4%	3.6%
2024	1864	70.4 (26.8)	71.5 (26.2)	14.4%	2.0%
2025	1593	80.1 (24.9)	71.8 (24.5)	12.1%	0%

Brooklyn Bridge Park Cabinet Reef

Similar to the SEAPA nursery, the cabinet reef was monitored using clump-based assessments, as oysters within the files had not grown sufficiently through the mesh to allow for quadrat-based monitoring. Because the cabinet reef is located in the intertidal zone adjacent to Pier 4 Beach, the files are only accessible during low tide and must be monitored using waders.

Since the previous year's annual monitoring, field staff observed substantial mortality across the cabinet reef. Following spring 2025 monitoring, Billion Oyster Project elected to remove all remaining structures

and associated oysters due to their declining condition. Of the 22 remaining files assessed before removal, only two live oysters were observed out of a total of 12 oysters counted.

Growth: Slow

The overall growth trend of the cabinet reef is positive as the overall size frequency expands horizontally, but slowly with fluctuations annually (**Figure 5**). In total, 12 oysters were monitored in the cabinet reef in 2025 and 114 oysters in 2024. Analysis of data indicates a steady positive growth trend. The mean shell height of live oysters increased from 16.5 mm (SD = 6.5, N = 500) at the time of installation in 2021 to 30.3 mm (SD = 8.8, N = 25) in 2024, and decreased to 28.5 mm (SD = 2.1, N = 2) in 2025 (**Table 10**). Dead box oysters had a mean shell height of 39.4 mm (SD = 15.0, N = 10).

Mortality: High

Compared to other structures at this site, mortality in the cabinet reefs is greater and continues to increase annually. These oysters are also frequently handled by Billion Oyster Project staff, community groups, and student groups that remove these oysters from files during interactive programming and monitoring events. This stress may contribute to the increasing percent mortality from 78.0% (N = 114) in 2024 to 83.3% (N = 12) in 2025 (**Table 10**). Oyster drill predation is also a likely cause of mortality due to their presence and prevalence during monitoring events.

Recruitment: Low but consistent

There is a consistent occurrence of smaller (<25 mm), and, therefore, younger oysters at the site. Recruitment decreased from 24.6% (N = 114) in 2024 to 16.7% (N =12) in 2025 (**Table 10**). Out of the 12 oysters that were sampled, two were likely recruits based on their small size.

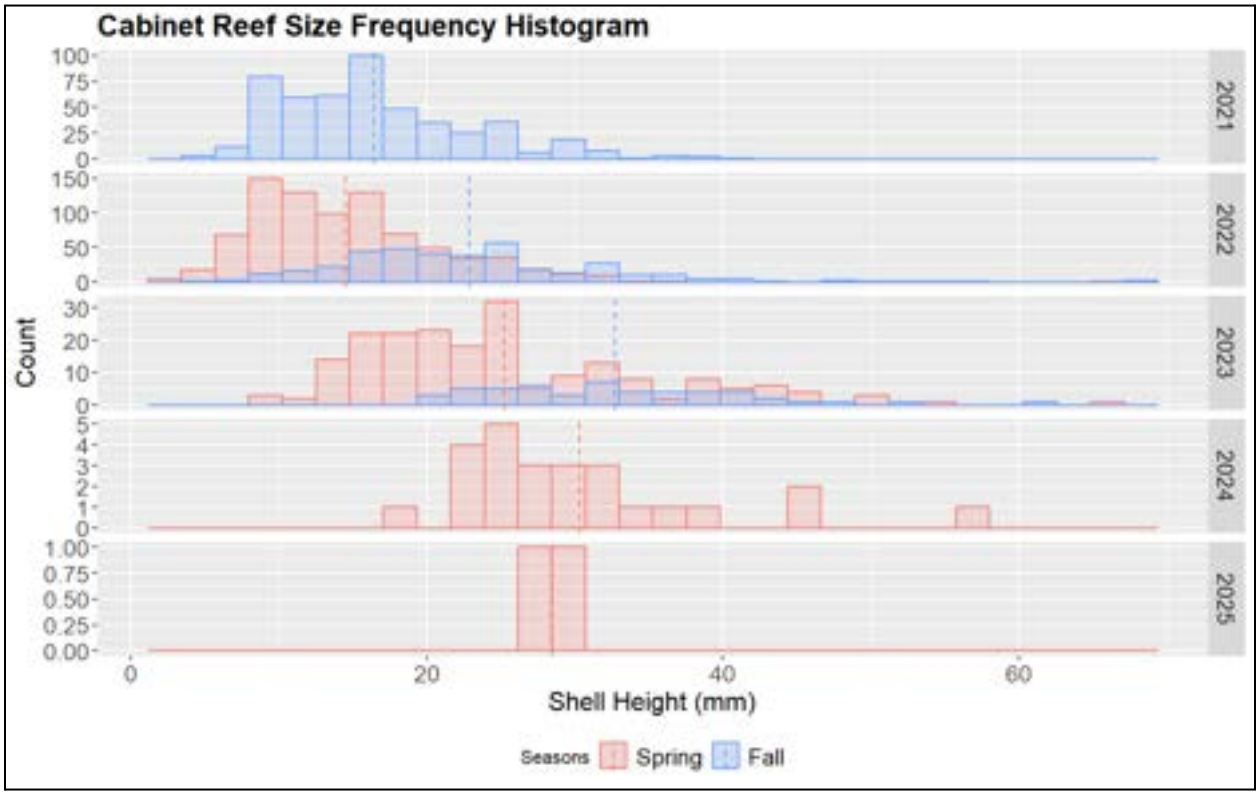

Figure 5. Size frequency histogram of live oysters in cabinet reef, 2021-2025. The dashed line represents the seasonal mean shell height.

Table 10. Summary of oyster performance at the Brooklyn Bridge Park cabinet reef. NA indicates no calculation for percent recruitment as the data is difficult to discern between restored and wild oysters.

Year	Sample Size	Mean Shell Height (SD) of Live Oysters (mm)	Mean Shell Height (SD) of Dead Box Oysters (mm)	% Mortality	% Recruitment
2021	621	16.5 (6.5)	14.6 (5.8)	19.5%	<1 year old
2022	1877	17.1 (8.2)	23.2 (9.4)	35.8%	<1 year old
2023	1093	26.8 (10.1)	27.7 (9.3)	76.9%	NA
2024	114	30.3 (8.8).	32.7 (10.0)	78.1%	NA
2025	12	28.5 (2.1)	39.4 (15.0)	83.3%	16.7%

A closer examination of cabinet reef oyster growth over time shows that sampled oysters in this structure consistently failed to exceed a maximum shell height of 70 mm (**Figure 5**). This contrasts with oysters on other reef substrates, which typically reached or surpassed this size within the first one to two years post-installation. Coupled with high mortality rates and persistent recruitment, this pattern suggests that while the files effectively attracted new spat, they also exposed oysters to elevated predation pressure, likely from oyster drills. As a result, each incoming recruitment cohort was repeatedly removed before individuals could reach larger size classes or contribute to spawning, creating a cycle of continual recruitment followed by predation-driven attrition.

Brooklyn Bridge Park Gabion Reef

Monitoring of the gabion reef was conducted using clump-based assessments, as oysters within the structures have not grown sufficiently through the mesh to support quadrat monitoring. Due to their subtidal placement, access to the gabions is only possible via diving. Over time, the top lids of the gabions have exhibited increasing signs of structural degradation, particularly in areas frequently handled by divers during monitoring. Based on observed deterioration at this site and similar degradation documented at other gabion installations, Billion Oyster Project proposes to remove the gabion reef during the next field season.

Growth: Positive

Similar to the other structures, the oysters in the gabion reef show a positive trend in oyster growth as the overall size frequency expands horizontally (**Figure 6**). In total, 238 oysters were monitored in 2025 and 264 oysters in 2024. The mean shell height of live oysters increased from 38.4 mm (SD = 14.2, N = 196) in 2024 to 52.9 mm (SD = 17.6, N = 194) in 2025 (**Table 11**). Dead box oysters had a mean shell height of 46.7 mm (SD = 11.3, N = 44).

Mortality: Stabilizing

Annual mortality was stable between 25% and 27% in the last two years and declined to 18.4% (N = 238) in 2025 (**Table 11**). This decline could be attributed to the installation of bay balls in proximity of the gabions, acting as an alternative food source for oyster drill predation. In addition, oysters in the subtidal gabions are only handled once per year and accessible only to divers.

Recruitment: Low but consistent

Out of 238 oysters monitored in 2025, 2.1% (N = 238) of the oysters monitored were recorded as recruits, which is a decrease compared to 2024, when the percent recruitment was 14.8% (N = 264) (**Table 11**).

These percentages of recruitment suggest that wild recruitment was occurring to the gabions but has declined this year.

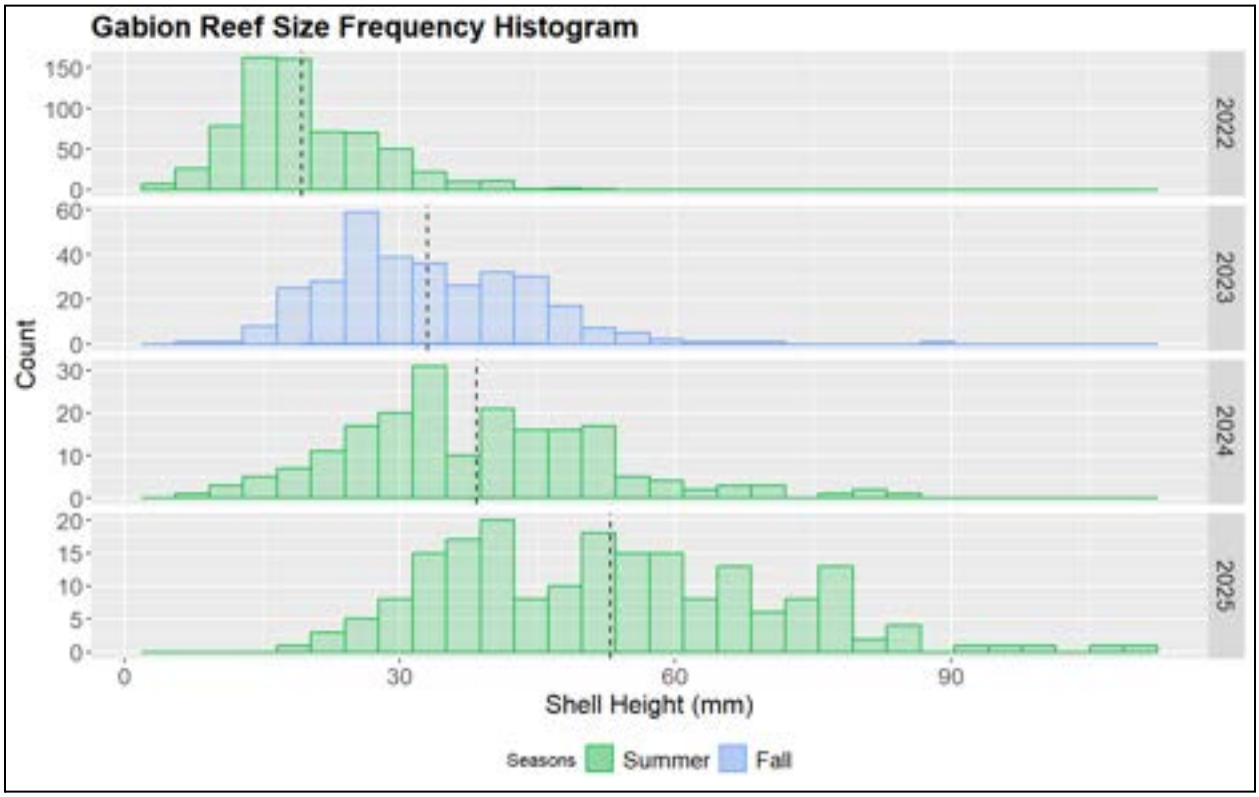

Figure 6. Size frequency histogram of live oysters in gabion reef, 2022-2025. The dashed line represents the annual mean shell height.

Table 11. Summary of oyster performance at Brooklyn Bridge Park gabion reef. NA indicates no calculation for percent recruitment as data is difficult to discern between restored and wild oysters.

Year	Sample Size	Mean Shell Height (SD) of Live Oysters (mm)	Mean Shell Height (SD) of Dead Box Oysters (mm)	% Mortality	% Recruitment
2021	NA	NA	NA	NA	<1 year old
2022	761	19.3 (7.5)	21.5 (8.9)	11.8%	<1 year old
2023	437	33.0 (10.9)	26.9 (9.8)	26.8%	NA
2024	264	38.4 (14.2)	38.0 (14.7)	25.8%	14.8%
2025	238	52.9 (17.6)	46.7 (11.3)	18.5%	2.1%

Brooklyn Bridge Park Bay Ball Reef

In 2025, Billion Oyster Project conducted biannual monitoring of the 2024 cohort of the first phase of the Brooklyn Bridge Park Project Oyster Reef Expansion at Pier 4. From each of the 2024 cohort clusters, two bay balls were randomly selected to be the recurrently monitored bay balls, and one bay ball was selected for randomized monitoring. During monitoring events, the bay balls were lifted onto the deck of an A-frame vessel, and quadrat monitoring was used to assess size, density, mortality, and recruitment within four randomized quadrats. During spring monitoring, 20 seeded and three unseeded bay balls were monitored. During fall monitoring, 18 seeded and five unseeded bay balls were monitored.

Growth: Positive
Oyster growth showed a positive trend between spring and fall monitoring periods (**Figure 7**). Mean shell height increased from 12.6 mm (SD = 4.4, N = 2,588) in spring to 26.8 mm (SD = 11.6, N = 745) in fall (**Table 12**). Live oysters had a mean shell height of 12.1 mm (SD = 4.4, N = 1,879) in spring and 38.0 mm (SD = 12.0, N = 138) in fall, while dead box oysters averaged 13.9 mm (SD = 5.0, N = 709) in spring and 24.3 mm (SD = 9.9, N = 603) in fall (**Figure 7**).

Mortality: High
Spring monitoring recorded 2,588 oysters across 23 bay balls, with a percent mortality of 27.4% (**Table 12**). Among the 20 seeded bay balls, only one showed no oysters in any of the four sampled quadrats, while four others had at least one quadrat with no observed oysters. Mortality on seeded bay balls was 26.7% (N = 2518), consistent with expectations of elevated mortality within the first year post-restoration. Early losses likely reflect a combination of predation (e.g., oyster drills, crabs, and oyster toadfish), sedimentation, and fouling by organisms such as colonial ascidians.

Fall monitoring documented 745 oysters across 23 bay balls, with mortality increasing to 81.5% (**Table 12**). Of the 18 seeded bay balls assessed, three had no oysters in any sampled quadrats, and eight others had one or more quadrats without oysters. Mortality on seeded bay balls was similarly high (81.4% of 741 oysters). Oysters in smaller size classes are particularly susceptible to predation, a pattern supported by frequent observations of oyster drills on both seeded and unseeded bay balls. High spring densities may also have intensified competition for space and resources, contributing to elevated fall mortality. Continued long-term monitoring will be essential to evaluate recruitment, survival trajectories, and overall reef development across both seeded and unseeded structures.

Recruitment: NA
While it is still too early to infer long-term recruitment trends on the bay balls, spring 2025 monitoring documented shell heights ranging from 1 to 35 mm and a total of 70 oysters on unseeded bay balls, indicating recruitment of wild spat since installation (**Table 12**). Distinguishing between hatchery-set spat that settled and subsequently died and wild recruits that settled and died is difficult; this ambiguity complicates interpretation of recruitment on seeded substrates. As a result, unseeded bay balls provide a more accurate and representative measure of natural recruitment for this substrate type. Of the three unseeded bay balls monitored, no recruitment was observed on two, while the third supported 70 oysters across three of four quadrats. Mean shell height of recruited oysters on unseeded bay balls was 13.4 mm (SD = 2.6, N = 3), and percent mortality was 51.4% (**Table 12**).

Fall monitoring recorded shell heights ranging from 6 to 68 mm on seeded bay balls and four oysters on unseeded bay balls, suggesting that oysters spawned during the summer successfully settled on the reef (**Table 12**). Of the five unseeded bay balls monitored, no recruitment was observed on four; the fifth contained four recruits within a single quadrat. Mean shell height of these recruits was 13.5 mm (SD = 3.1, N = 4), and all were dead box oysters (**Table 12**).

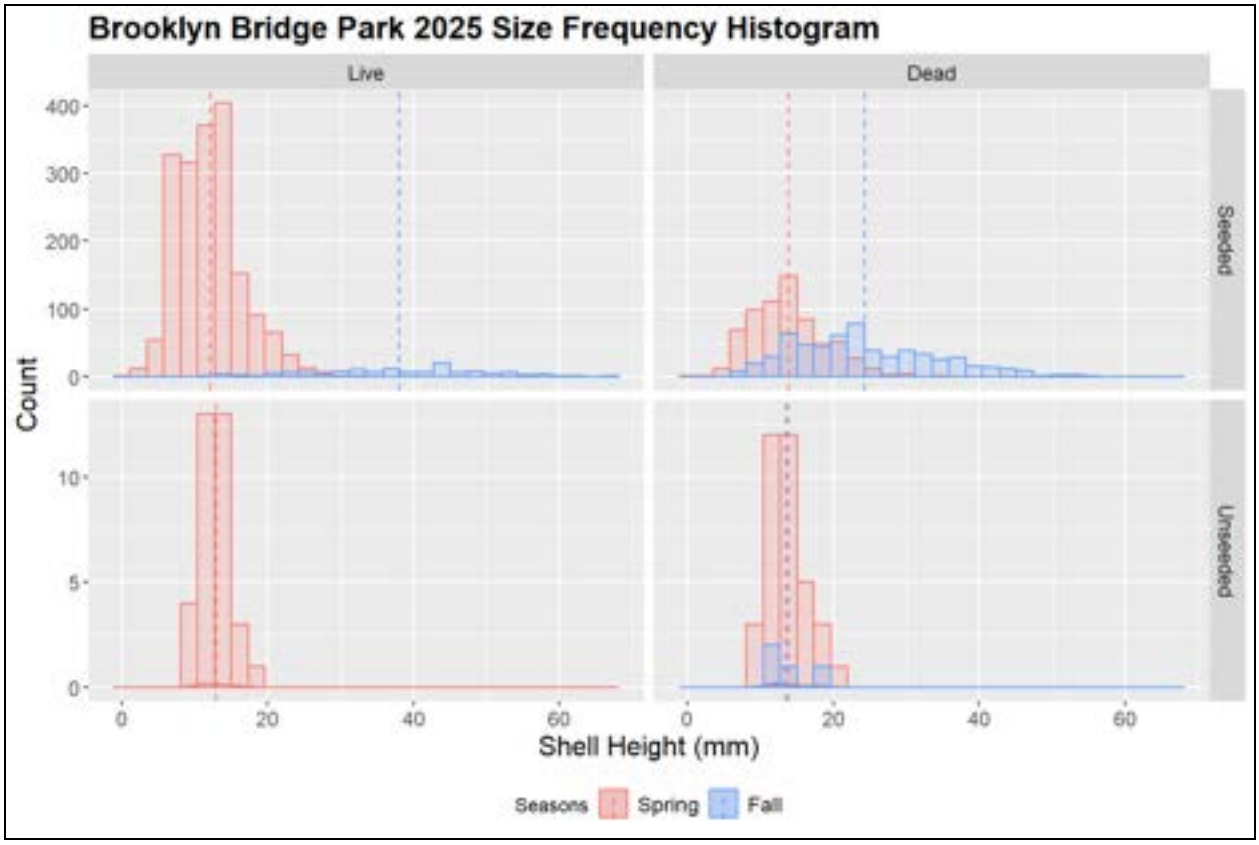

Figure 7. Size frequency histogram of seeded (top) and unseeded (bottom) bay ball oysters during spring (left) and fall (right) monitoring in 2025; dashed line represents the mean shell height.

Table 12. Summary of oyster performance at Brooklyn Bridge Park bay ball reef. NA indicates data is not available.

Season	Structure Status	Sample Size of Bay Balls	Number of Observed Oysters	Mean Shell Height (SD) of Live Oysters (mm)	Mean Shell Height (SD) of Dead Box Oysters (mm)	% Mortality
Spring	Seeded	20	2518	12.1 (4.4)	13.9 (5.0)	26.7%
	Unseeded	3	70	13.0 (2.4)	13.9 (2.8)	51.4%
	All	23	2588	12.6 (4.4)	13.9 (4.9)	27.4%
Fall	Seeded	18	741	38.0 (12.1)	24.3 (9.9)	81.2%
	Unseeded	5	4	NA	13.5 (3.1)	100.0%
	All	23	745	38.0 (12.1)	24.2 (9.9)	81.5%

Oyster Density on Bay Balls

For each bay ball, oyster density was quantified using four randomly placed 0.04 m^2 quadrats on the surface of the structure. The sample size (N) in this section refers to the number of quadrats, rather than the number of bay balls. Oyster density could not be calculated for the SEAPA cage nursery, cabinet reef, or gabions, as monitoring was conducted using the clump method (30 clumps) rather than quadrat sampling.

For bay balls, average quadrat mortality was calculated by first determining the percent mortality within each 0.04 m² quadrat across all bay balls, then computing the mean and corresponding 95% confidence interval (CI). The CI provides a measure of precision and indicates the range within which the true average quadrat-level mortality is likely to fall. This metric reflects mortality at the quadrat scale, rather than across all individual oysters pooled together, and allows for an estimate of variance[1].

Spring Monitoring

Across all bay balls, the mean live oyster density was 510.6 oysters per square meter (SD = 791.4, N = 92). When both live and dead box oysters were included, the mean density was 708.4 oysters per square meter (SD = 881.8, N = 92) (**Table 13**). It is important to note that all oysters observed were less than one year old. As individuals grow and additional recruitment occurs throughout the field season, overall density is expected to decline due to space and resource competition, predation, disease, and natural senescence, unless recruitment is sufficient.

A comparison of densities between 20 seeded and 3 unseeded bay balls during spring monitoring should be interpreted cautiously, given the substantial difference in sample sizes. Seeded bay balls supported an average of 576.6 live oysters per square meter (SD = 826.0, N = 80) and 790 total oysters (live and dead box) per square meter (SD = 908.7, N = 80). In contrast, unseeded bay balls, which effectively represent natural recruitment per square meter, contained an average of 70.8 live oysters (SD = 196.8, N = 12) and 164.6 total oysters per square meter (SD = 360.8, N = 12) (**Table 13**).

Fall Monitoring

Across all bay balls, the mean live oyster density decreased to 37.5 oysters per square meter (SD = 97.0, N = 92). When both live and dead box oysters were included, the mean density was 226.4 oysters per square meter (SD = 375.3, N = 92), reflecting the high presence of dead box oysters on many structures (**Table 13**).

A comparison between the 18-seeded and 5 unseeded bay balls during fall monitoring should be interpreted cautiously, due to the difference in sample sizes. Seeded bay balls supported an average of 46.0 live oysters per square meter (SD = 105.7, N = 75) and 271.0 total oysters (live and dead box) per square meter (SD = 402.7, N = 75). In contrast, unseeded bay balls, representing natural recruitment, contained an average of 0 live oysters and 29.4 total dead box oysters per square meter (SD = 18.2, N = 17) (**Table 13**).

These preliminary results highlight the potential effectiveness of seeding in enhancing oyster density. The decline in live, total, and recruitment densities from spring to fall is expected, as mortality is typically high during the first year post-installation, when oysters are small and susceptible to predation and environmental stress. Overall, quadrat mortality increased substantially between sampling events, from 51.0% (CI = 7.2%, N = 92) in the spring to 93.4% (CI = 3.6%, N = 92) in the fall (**Table 13**). Seeded quadrat mortality rose from 44.8% (CI = 7.2%, N = 80) to 92.0% (CI = 4.4%, N = 75), while unseeded quadrat mortality increased from 92.5% (CI = 10.2%, N = 12) to 100.0% (CI = 0.0%, N = 17) over the same period (**Table 13**).

[1] The overall percent mortality calculated across all quadrats and the average mortality using quadrats as replicates are often not identical. This is due to the fact that individual quadrats may have mortality greater than or less than the overall percent mortality, thus shifting the per-quadrat average up or down from the overall percent. Thus, quadrat mortality provides additional insight into the variance of mortality on the reef.

As stated previously, the high mortality rates may be due to the fact that smaller oysters are more susceptible to predation, a pattern supported by field observations of oyster drills on both seeded and unseeded bay balls. Additionally, the high oysters densities recorded in spring may have intensified competition for space and resources, contributing to the elevated mortality observed in fall. Continued long-term monitoring will be essential to assess future recruitment dynamics, survival trajectories, and overall reef development across both seeded and unseeded structures.

Table 13. Oyster density, standard deviation (SD), quadrat mortality, and 95% confidence interval (CI) of bay ball reef.

Season	Structure Status	# of Quadrats	Live Oyster Per Square Meter (SD)	Total Oyster Per Square Meter (SD)	Quadrat Mortality (CI)
Spring	Seeded	80	576.6 (826.0)	790.0 (908.8)	44.8% (7.2%)
	Unseeded	12	70.8 (196.8)	164.6 (360.8)	92.5% (10.2%)
	All	**92**	**510.6 (791.4)**	**708.4 (881.7)**	**51.0% (7.2%)**
Fall	Seeded	75	46.0 (105.8)	271.0 (402.7)	92.0% (4.4%)
	Unseeded	17	NA	29.4 (18.2)	100% (0%)
	All	**92**	**37.5 (97.0)**	**226.4 (375.2)**	**93.4% (3.6%)**

Site-wide Oyster Population Estimates

The annual population estimates across all structures at Brooklyn Bridge Park can be found in **Table 14**. This estimate is calculated using annual percent mortality and percent recruitment data. Because the cabinet reef was fully monitored and quantified before its removal, the actual count of live oysters from that assessment is included in the table alongside the estimates for the remaining structures. No mortality or recruitment data were collected for the bay balls installed in 2025: monitoring for these structures will begin in spring 2026. Incorporating the available estimates and the observed cabinet reef count, the total projected oyster population at the site in 2025 is approximately 10.5 million oysters (**Table 14**).

Given the variability in percent mortality observed between the spring and fall monitoring events for the bay balls, population estimates for this substrate can be presented as a range. The spring-derived estimate represents the higher end of the range, while the fall-derived estimate represents the lower end, reflecting increased mortality later in the season. Using this mortality range, the 2025 bay ball population estimate spans from approximately 2.5 million oysters (fall monitoring mortality = 81.5%) to 9.7 million oysters (spring monitoring mortality = 27.4%). Incorporating these bay ball estimates with those from the other substrates yields a total projected 2025 site-wide oyster population ranging from approximately 10.5 million to 17.8 million oysters.

Table 14. Estimated population dynamics across all structures at Brooklyn Bridge Park. Rows highlighted in blue show the most recent population estimates based on 2025 data. NA indicates data is not available.

Structure	Year	Start Estimate	Annual % Mortality	Post Mortality Estimate	Annual % Recruitment	Population Estimate
SEAPA Cage Nursery	2020	**215,280**	4.8%	215,280	<1 year old	215,280
	2021	215,280	9.7%	194,309	<1 year old	194,309
	2022	194,309	8.7%	177,407	22.2%	216,831
	2023	216,831	10.4%	194,267	3.6%	201,338
	2024	201,338	14.4%	172,282	2.0%	175,779
	2025	175,779	12.1%	154,483	0.0%	**154,483**
Cabinet Reef	2021	**185,071**	19.5%	149,010	<1 year old	149,010
	2022	149,010	35.8%	95,662	<1 year old	95,662
	2023	95,662	76.9%	22,143	NA	22,143
	2024	22,143	78.1%	4,856	NA	4,856
	2025	4,856	83.3%	809	16.7%	**2**
Gabion Reef	2021	**588,861**	NA	588,861	<1 year old	588,861
	2022	588,861	11.8%	519,219	<1 year old	519,219
	2023	519,219	26.8%	380,206	NA	380,206
	2024	380,206	25.8%	282,274	14.8%	323,974
	2025	323,974	18.5%	264,080	2.1%	**269,627**
Bay Ball	2024 (2024 cohort)	**13,400,000**	NA	NA	<1 year old	**13,400,000**
	2025 (2024 cohort)	13,400,000	81.5%	2,482,148	<1 year old	**2,482,148**
	2025 (2025 cohort)	**7,600,000**	NA	7,600,000	NA	**7,600,000**
Installed Estimate		**21,989,212**	**Total Population Estimate**			**10,506,260**

Epibenthic Species Characterization

During the fall bay ball monitoring event, epibenthic data were collected in the form of quadrat photographs. For every bay ball retrieved (both seeded and unseeded), one of the four quadrats used for oyster monitoring was randomly selected for inclusion in epibenthic monitoring. Dr. Allison Fitzgerald of New Jersey City University processed the photographs and voucher specimens that were collected and preserved in 95% ethanol. Dr. Fitzgerald's analysis indicated at least 14 non-oyster epibenthic taxa are inhabiting the bay balls at Brooklyn Bridge Park. The full epibenthic analysis report is available upon request.

Mobile Species Characterization

On behalf of Billion Oyster Project, a consulting team (AKRF, Princeton Hydro, and Monmouth University) conducted seasonal fish sampling of the bay balls, deploying both minnow and seabass traps, as well as collecting seasonal eDNA samples. The full report from AKRF, is available upon request. In brief, 12 fish taxa and 12 invertebrate taxa were collected at the restoration site by trapping. eDNA complemented trapping by detecting rare or transient species and species unlikely to be caught because of their behavior

or their size compared to the trap opening. Fifty-seven teleost fish Amplicon Sequence Variants (ASVs), corresponding to distinct species or taxonomic groups, were detected by eDNA analysis.

Billion Oyster Project staff conducted additional mobile species monitoring efforts, including spring seining at Pier 4 Beach, minnow-trap deployments at the SEAPA cage nursery, and fish observations around reef structures throughout the spring, summer, and fall. These sampling efforts allow us to characterize how fish utilize restored oyster habitats. Public participation further strengthens this work, with New York Harbor School students and community volunteers assisting with trap deployment and retrieval, seining surveys, and field observations. Data collected in 2025 indicate a fish species richness of 12 across the three structures. Skilletfish (*Gobiesox strumosus*) were particularly abundant around the bay balls, while spring seining near the cabinet reef revealed high numbers of Atlantic silversides (*Menidia menidia*). Both trapping and observations also indicate notable abundances of skilletfish and cunner (*Tautogolabrus adspersus*) around the SEAPA cage nursery (**Appendix, Figure A1**), suggesting that these oyster habitats provide healthy, structurally complex environments that support a diverse and productive fish community.

Recommended Restoration Action

Gabion Reef Removal
In anticipation of the final monitoring event in 2026, Billion Oyster Project plans to remove the subtidal gabion reef at Brooklyn Bridge Park, after which oysters will be disposed of at an upland facility. The salinity of the water accelerates corrosion of metal structures at a much higher rate than concrete structures, such as bay balls, and as metal components degrade, they become sharp and increasingly hazardous to replace and repair compared to the plastic SEAPA cages. Lessons learned from the degradation of previously installed metal reef structures have led Billion Oyster Project to transition to alternative structures. Bay balls are a preferred structure because they can withstand long-term saltwater exposure without degrading. In addition, the goal of the gabion reef installation was to inform large-scale restoration at the site. With Phase 1 of the large-scale bay ball installation completed, these structures are no longer needed.

Reseeding and Phase 2 Installation
While no specific management action is proposed at this time, these findings underscore the need to evaluate reseeding approaches, including potential expansion of the SEAPA cage nursery (currently permitted for 30 cages) and the installation of additional seeded reef balls through Phase 2 within the Phase 1 project footprint to increase proximity to and improve performance of the existing population at the site. Billion Oyster Project will use Year 1 outcomes to engage NYSDEC in discussions on appropriate adaptive measures and to refine Phase 2 design options should high mortality persist and warrant intervention.

Bush Terminal Park

Project Summary

As of 2025, Billion Oyster Project maintains and monitors several installations in Bush Terminal Park Eastern Lagoon (**Figure 8**). The Sunset Park Field Station supports oysters in two structures (community cabinet reefs at two different depths) to provide insight into oyster health and performance using on-bottom restoration techniques, progressing towards the implementation of larger scale on-bottom restoration adjacent to the site. The bagged shell reef installed in 2018 was removed in 2024 due to high mortality and sedimentation of the site. The installations at Bush Terminal Park also provide hands-on education and engagement opportunities with students and community groups that reconnect people to the water bodies surrounding New York Harbor, as well as to the wildlife thriving along the shorelines and in the shallows.

Trends from 2016-2025 data indicate conditions are supportive of larger-scale oyster restoration:

- The overall growth trends positively with some fluctuations of mean shell height across some years that may be attributed to recruitment, small sample sizes, and eventual mortality of older oysters.
- Annual mortality stabilizes for cabinet reefs (50-60%) but increases for deepwater cabinets.
- Recruitment is highest one year post-installation but decreases over time, suggesting the need for reseeding.

Site Overview

In 2016, the Billion Oyster Project (Billion Oyster Project) installed five cabinet structures in the eastern lagoon. Two of these cabinets (hereafter referred to as deepwater cabinets), containing approximately 530,548 spat-on-shell, were installed near the northern edge of the lagoon at depths accessible only by divers. The remaining three cabinets (hereafter referred to as the cabinet reef), containing approximately 969,452 spat-on-shell, were installed at shallower depths along the southern shoreline of the lagoon and are accessible via wading.

In 2018, following evidence of positive growth during the first two years post-installation, Billion Oyster Project augmented the cabinet reef with an additional five cabinets containing approximately 180,000 spat-on-shell. That same year, Billion Oyster Project also deployed 96 bags of shell adjacent to the cabinet reef, including 66 bags seeded with approximately 133,986 spat-on-shell and 30 unseeded bags (**Table 15**).

In 2024, Billion Oyster Project removed the bagged shell reef due to excessive sedimentation at the site. Oysters within the bags were observed to be buried in anoxic sediments, as indicated by the darkened coloration of the shells. Removal efforts prioritized minimizing sediment disturbance and did not involve heavy machinery; staff removed as many bags as feasible under these constraints. Remaining bags are heavily buried, and the site will continue to be monitored to determine whether additional bags become exposed over time.

Figure 8. Map of Sunset Park Field Station at Bush Terminal Park.

From 2016 to 2023, Billion Oyster Project conducted monitoring of the cabinet reef and bagged shell reefs biannually and shifted to annually from 2024, while the deepwater cabinets have been monitored annually by divers. Frequency of monitoring and activities at the cabinet reef and deepwater cabinets are listed in **Table 15**. During monitoring events, Billion Oyster Project staff documented fish and invertebrate species inhabiting the oyster shells within the structures and conducted seining surveys around the reef. Results are included in the **Appendix, Figure A2**.

Table 15. Summary of structures installed and spat introduced to the eastern lagoon of Bush Terminal Park.

Structure Name	Year Installed	Quantity of Structures	Spat Introduced	Monitoring Frequency
Deepwater Cabinets	2016	2	387,781	Annual
Cabinet Reef	2016	3	581,671	Biannual
	2018	5	180,000	
Bagged Shell Reef	2018	96	133,986	

Oyster Performance

Bush Terminal Park Deepwater Cabinets

Data from 2016 are excluded because the field team did not distinguish oyster status (live or dead) and

only video monitoring was conducted in 2017 for deepwater cabinets. No data collection occurred in 2020 and 2021 due to the COVID-19 pandemic and related site access restrictions.

Measuring oyster shell height underwater has proven difficult especially when visibility is low in such an urban environment. Given the low sample size when assessed underwater in previous years and increasing mortality, Billion Oyster Project decided to remove the files from the deepwater cabinets for monitoring in 2025. Removing the files from the deepwater cabinet to monitor was not recommended in the past due to many of the oysters having grown through the files in high density ("reefing"), which would kill many oysters if forcefully removed.

Growth: Positive

Oyster growth trends positively but with fluctuations where the mean shell height decreased in 2019, 2023, and 2024 (**Figure 9**). The mean shell height of live oysters increased from 104.7 mm (SD = 19.5, N = 21) in 2024 to 160.7 mm (SD = 92.4, N = 141) in 2025 (**Table 16**). The mean shell height of dead box oysters increased from 115.1 mm (SD = 26.3, N = 21) in 2024 to 150.1 mm (SD = 40.4, N = 141) in 2025 (**Table 16**).

Mortality: High

Despite seeing a slight decrease in mortality the previous year, mortality continues to increase in 2025. Annual mortality increased from 71.4% (N = 21) in 2024 to 92.9% (N = 141) in 2025 (**Table 16**). This could be attributed to growing oysters competing for space, natural aging, accumulating disease loads, and mortality of oysters.

Recruitment: None

Although recruitment was observed in 2018, 2019, and 2021 post-installation, no recruitment has been observed since 2023. Even with an increase in sample size (N = 141) in 2025 compared to previous years, no recruits were observed (**Table 16**).

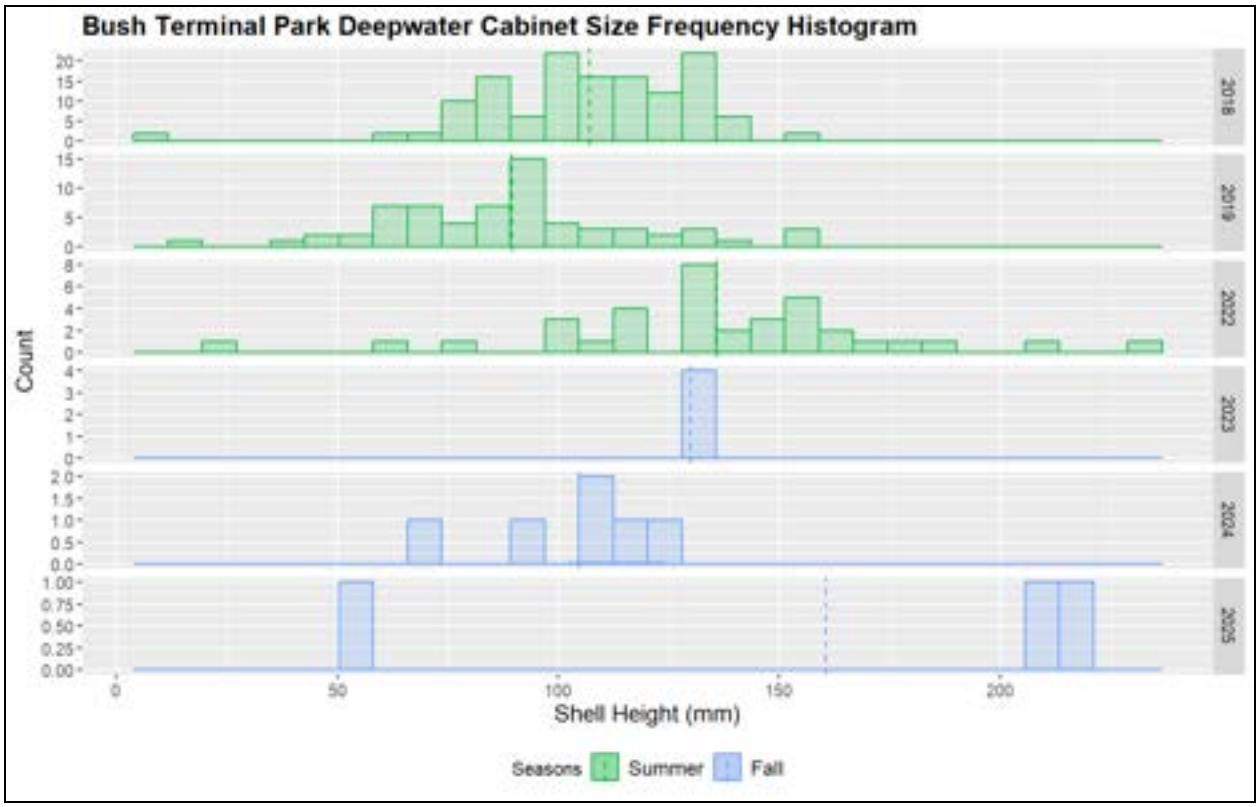

Figure 9. Size frequency histogram of live oysters in Bush Terminal Park deepwater cabinet. The dashed line represents the seasonal mean shell height.

Table 16. Summary of oyster performance at Bush Terminal Park deepwater cabinet. SD indicates standard deviation and NA indicates no available data.

Year	Sample Size	Mean Shell Height (SD) of Live Oysters (mm)	Mean Shell Height (SD) of Dead Box Oysters (mm)	% Mortality	% Recruitment
2016	975	NA	NA	NA	<1 year old
2017	***No monitoring***				
2018	140	107.1 (24.0)	114.0 (26.4)	4.3%	1.4%
2019	76	89.5 (28.2)	70.7 (34.0)	14.5%	1.3%
2020	***No monitoring***				
2021	***No monitoring***				
2022	78	135.9 (39.0)	119.3 (40.8)	53.9%	1.3%
2023	35	130.0 (0.0)	123.8 (12.3)	88.6%	0.0%
2024	21	104.7 (19.5)	115.1 (26.3)	71.4%	0.0%
2025	**141**	**160.7 (92.4)**	**150.1 (40.4)**	**92.9%**	**0.0%**

Bush Terminal Park Cabinet Reef

Data from 2016 are excluded because staff did not distinguish oyster status (live or dead). No data collection occurred in 2021 due to the COVID-19 pandemic and related site access restrictions. Due to structure maintenance of the cabinet reefs, the two cohorts (2016 and 2018) are mixed and assessed

together for monitoring in 2025.

Growth: Positive
Oyster growth trends positively after the installation of the 2018 cohort until 2021 when it decreased until 2023 when it increased again (**Figure 10**). The mean shell height of live oysters from both cohorts increased from 111.7 mm (SD = 45.8, N = 126) in 2024 to 123.2 mm (SD = 39.2, N = 296) in 2025 (**Table 17**). The mean shell height of dead oysters from both cohorts increased from 77.96 mm (SD = 37.7, N = 126) in 2024 to 110.5 mm (SD = 37.7, N = 296) in 2025 (**Table 17**).

Mortality: Stabilizing
Annual mortality of the cabinet reef oysters mostly increased until 2021 where it started to stabilize between 50% to 70%. Annual mortality slightly decreased from 59.5% (N = 126) in 2024 to 54.4% (N = 296) in 2025 (**Table 17**). This trend aligns with expectations, as mortality typically increases and then stabilizes over time due to frequent handling during engagement activities and the increasing sedimentation, which ultimately contributes to oyster mortality.

Recruitment: Low but variable
Recruitment among both cohorts occurred annually since installation except in 2022. Recruitment decreased from 0.8% (N = 126) in 2024 to 0.3% (N = 296) in 2025 (**Table 17**).

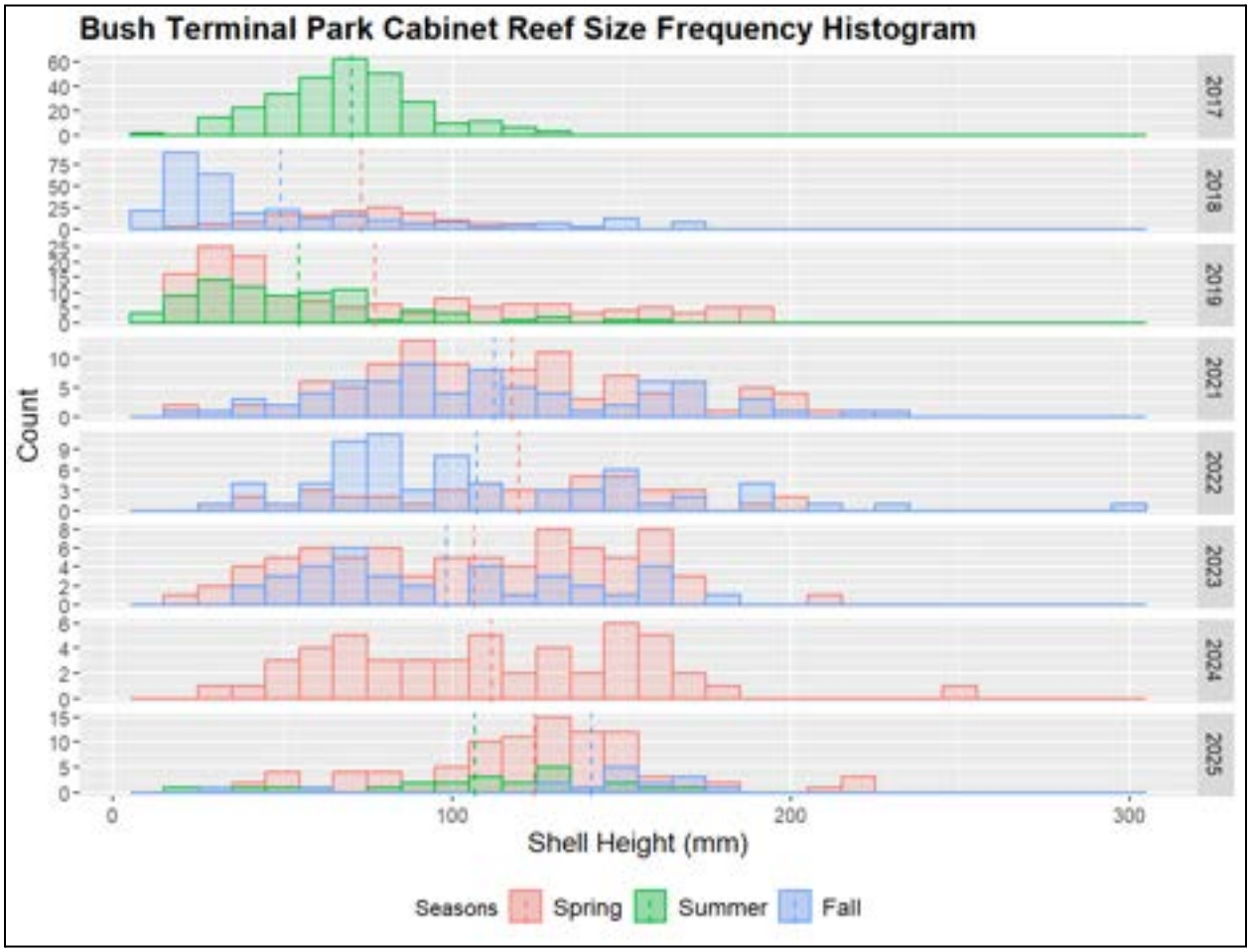

Figure 10. Size frequency histogram of live oysters in Bush Terminal Park cabinet reef (2016 and 2018 cohorts). The dashed line represents the seasonal mean shell height.

Table 17. Summary of oyster performance at Bush Terminal Park cabinet reef. NA indicates no available data. SD indicates standard deviation and NA indicates no available data.

Year	Sample Size	Mean Shell Height (SD) of Live Oysters (mm)	Mean Shell Height (SD) of Dead Box Oysters (mm)	% Mortality	% Recruitment
2016	1783	NA	NA	NA	<1 year old
2017	312	70.3 (21.4)	43.6 (22.1)	8.7%	2.9%
2018	528	56.8 (38.1)	49.5 (20.2)	18.6%	<1 year old
2019	254	69.2 (47.1)	87.0 (72.5)	11.8%	11.0%
2020	***No monitoring***				
2021	379	115.6 (46.0)	83.0 (31.3)	51.7%	0.8%
2022	245	112.3 (48.7)	85.6 (34.3)	54.3%	0.0%
2023	356	103.8 (42.4)	70.9 (34.9)	68.3%	2.8%
2024	126	111.7 (45.8)	78.0 (37.7)	59.5%	0.8%
2025	296	123.2 (39.2)	110.5 (37.7)	54.4%	0.3%

Oyster Population Estimates

The annual population across all structure types at Bush Terminal Park is presented in **Table 18**, which highlights the variability in annual mortality and recruitment that is likely influenced by frequent handling and sedimentation in the cabinet reef. However, the actual population estimate is not fully represented due to small sample sizes and gaps in data from certain years. Annual mortality could not be calculated for the cabinet reefs and deepwater cabinets in 2016 because oyster status (live or dead) was not recorded. Annual mortality and recruitment could not be calculated for deepwater cabinets in 2020 and 2021 as well as for cabinet reefs in 2020 because of the COVID pandemic. The total population at Bush Terminal Park is estimated at 7,965 oysters, where 111 oysters are from the deepwater cabinets and 7,854 oysters are from the cabinet reefs (**Table 18**).

Table 18. Estimated population dynamics across all structures at Bush Terminal Park. Rows highlighted in blue show the most recent population estimates based on 2025 data. NA indicates data is not available.

Structure	Year	Start Estimate	Annual % Mortality	Post Annual Mortality Estimate	Annual % Recruitment	Population Estimate
Deepwater Cabinets	2016	387,781	NA	387,781	<1 year old	387,781
	2017	387,781	NA	387,781	NA	387,781
	2018	387,781	4.3%	371,162	1.4%	376,464
	2019	376,464	14.5%	321,976	1.3%	326,212
	2020	326,212	NA	326,212	NA	326,212
	2021	326,212	NA	326,212	NA	326,212
	2022	326,212	53.9%	150,560	1.3%	152,490
	2023	152,490	88.6%	17,427	0.00%	17,427
	2024	17,427	71.4%	4,979	0.00%	4,979
	2025	4,979	97.78%	111	0.00%	**111**

Structure	Year	Start Estimate	Annual % Mortality	Post Annual Mortality Estimate	Annual % Recruitment	Population Estimate
Cabinet Reef	2016	581,671	NA	581,671	<1 year old	581,671
	2017	581,671	8.7%	531,334	2.9%	546,661
	2018	726,661	18.6%	591,788	<1 year old	591,788
	2019	591,788	11.8%	521,892	11.0%	579,423
	2020	579,423	NA	579,423	NA	579,423
	2021	579,423	51.7%	279,774	0.8%	281,989
	2022	281,989	54.3%	128,909	0.0%	128,909
	2023	128,909	68.3%	40,918	2.8%	42,067
	2024	42,067	59.5%	17,027	0.8%	17,162
	2025	17,162	54.4%	7,827	0.3%	**7,854**
					Total Estimated Population	**7,965**

Mobile Species Characterization

On behalf of Billion Oyster Project, a consulting team (AKRF and Princeton Hydro) conducted seasonal fish sampling with minnow and seabass traps in an area outside of the lagoons, where future oyster restoration is being investigated and designed. This will serve as a baseline assessment of mobile species prior to restoration. The full pre-installation report from AKRF, including sampling effort and seasonal and gear-type comparisons, is available upon request. In brief, seven fish taxa and six invertebrate taxa were collected at the site by trapping.

Recommended Restoration Actions

In response to oyster performance trends observed in the 2016–2018 cohorts and consistent with Billion Oyster Project's restoration strategy of adding seeded substrate and multiple oyster cohorts, Billion Oyster Project is currently permitting a multi-phase oyster reef restoration project within a 1.3-acre footprint in the southern half of the basin between Bush Terminal Park lagoons and Pier 5. The project is informed by comprehensive pre-installation surveys, including hydrographic and sediment characterization, and is designed to create subtidal oyster reef habitat that complements documented nearshore wild eelgrass beds along the northern perimeter of the basin.

The project will be implemented in two phases. Each phase will include the installation of one 90 cubic yard shell mound reef and 120 bay balls, of which 110 will be seeded and 10 left unseeded to support comparisons of wild oyster and epibenthic recruitment. Each phase will introduce approximately 22 million juvenile oysters. Phase 1 is targeted for installation in 2026, with Phase 2 planned for 2029. The phased approach allows Billion Oyster Project to evaluate oyster performance, recruitment, and habitat development over time in a more open, tidally influenced setting than the adjacent lagoons, while using standardized substrates with greater vertical relief to support long-term reef development.

Brooklyn Navy Yard (Wallabout Basin)

Project Summary

As of 2025, Billion Oyster Project maintains and monitors a floating nursery in Brooklyn Navy Yard (Wallabout Basin) with support from New York Harbor School students and interns.

Trends from 2025 data show:

- Oyster growth is stable.
- Annual mortality is relatively low.
- Recruitment is observed.
- Consistent monitoring is needed to verify current trends.

Site Overview

The oyster nursery at the Brooklyn Navy Yard (Wallabout Basin) utilizes a floating longline system designed to accommodate adult oysters. The oysters are contained in SuperTrays, with each stack suspended from a single float (**Figure 11**). However, due to a dissolved oxygen gradient in the water column, oyster growth slows with increasing distance from the surface.

Figure 11. Map of Brooklyn Navy Yard nursery.

In 2015, approximately 3.5 million young spat were introduced to this nursery (**Table 19**). In 2017, an additional 7,500 oysters were added (**Table 19**). Monitoring was conducted with New York Harbor School

students via vessel in the fall of 2025 to assess oyster performance. During monitoring, invertebrates such as boring sponges (*Cliona celata*) and blue crabs (*Callinectes sapidus*) were recorded, but no vertebrate species were observed.

Table 19. Summary of structures installed and oyster introduced at Brooklyn Navy Yard (Wallabout Basin).

Structure Name	Year Installed	Quantity of Structure	Oyster Introduced	Monitoring Frequency
SuperTray Nursery	2015	NA*	3,500,000 (Spat)	Annual
	2017		7,500 (Adult)	

*The quantity of structures cannot be determined as oysters transferred to the nursery from other sites were consolidated with the existing cohort to maximize space.

Oyster Performance

Growth: Stable

Oyster growth at the Brooklyn Navy Yard Nursery is relatively stable. The mean shell height of all cohorts increased from 2023 to 2024, decreased from 82.8 mm (SD = 25.9, N = 169) in 2024 to 69.3 mm (SD = 28.8, N = 430) in 2025 (**Figure 12, Table 20**). This decline in mean shell height may be attributed to the larger sample size in 2025, which likely included a greater proportion of juvenile oysters from later cohorts. The presence of recruits may have contributed to lowering the overall mean shell height across the sample.

Mortality: Low

Annual mortality in 2025 was the lowest observed over the past three years at 17.0%, decreasing by half from the 33.1% mortality recorded in 2024 (**Table 20**). Continued monitoring is necessary to confirm and better understand growth and mortality trends at this site over time.

Recruitment: Low but variable

Annual recruitment in the nursery fluctuates, with up to 16.0% of sampled oysters observed as recruits in 2023 and 0.0% in 2024. Recruitment was present in 2025, representing 3.5% of the sample (**Table 20**). Billion Oyster Project has occasionally observed wild oysters on the bulkheads surrounding Wallabout Basin; however, continued monitoring is needed to assess long-term recruitment trends.

Table 20. Summary of oyster performance at Brooklyn Navy Yard SuperTray nursery. NA indicates data are not available. Data from 2018 to 2022 are excluded due to no monitoring during those years.

Year	Sample Size	Mean Shell Height (SD) of Live Oysters (mm)	Mean Shell Height (SD) of Dead Box Oysters (mm)	% Mortality	% Recruitment
2017	404	NA	NA	NA	<1 year old
2023	286	47.8 (21.2)	39.5 (19.9)	28.0%	16.4%
2024	169	82.8 (25.9)	72.1 (29.3)	33.1%	0.0%
2025	430	69.3 (28.8)	56.4 (22.2)	17.0%	3.5%

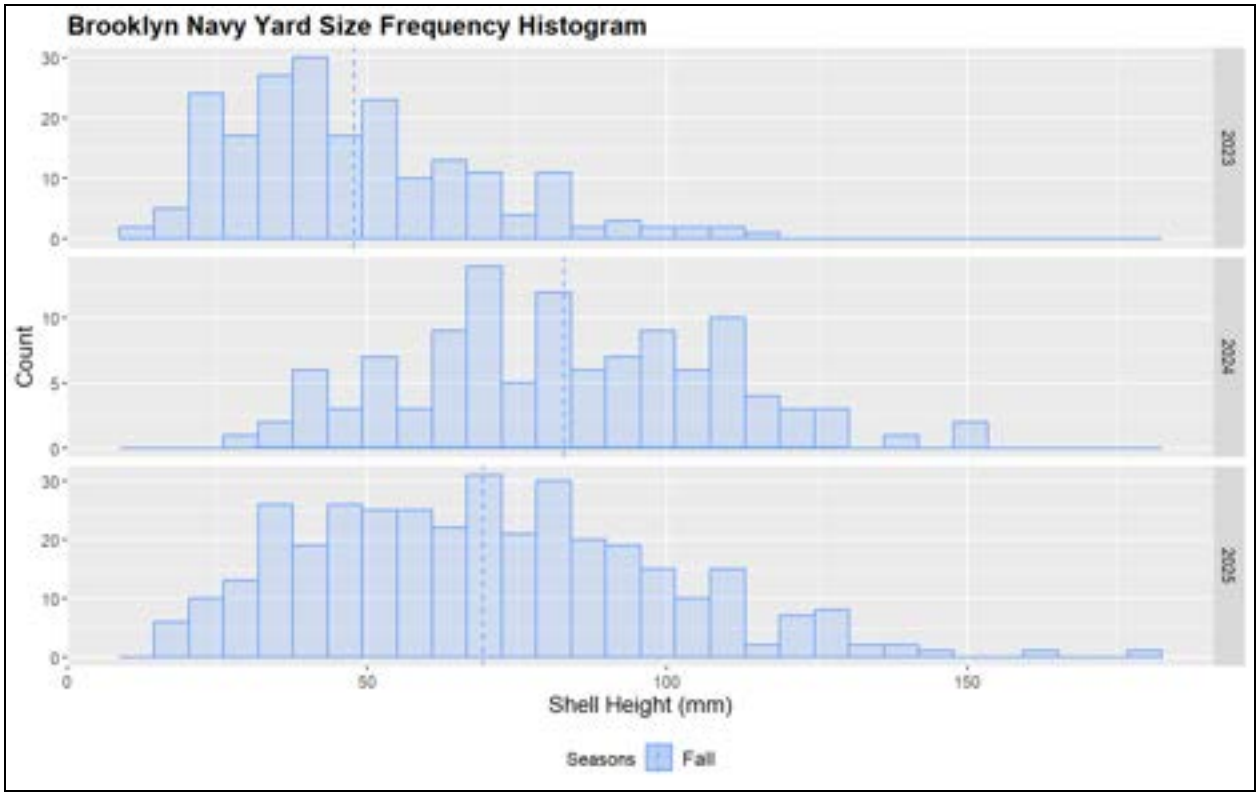

Figure 12. Size-frequency histogram of live oysters in Brooklyn Navy Yard, 2023-2025. The dashed line represents the mean shell height.

Oyster Population Estimates

The current population estimate for Brooklyn Navy Yard cannot be determined. Unfortunately, oysters at this site were not monitored regularly, and oysters from other sites were occasionally transferred to the nursery and consolidated with the existing cohort.

Recommended Restoration Actions

The Brooklyn Navy Yard nursery will continue to serve as a floating nursery, with ongoing annual monitoring of oyster performance and data analysis of trends. We anticipate stable mortality levels and fluctuating annual recruitment. The Brooklyn Navy Yard nursery benefits from its off-bottom configuration because it experiences little or no sedimentation and predation; water flow is also favorable for oyster growth and reproduction. However, water quality in Wallabout Basin poses challenges to future restoration efforts.

Governors Island Ecodock

Project Summary

As of 2025, Billion Oyster Project continues to maintain and monitor the SuperTray nursery in Governors Island Ecodock with support from New York Harbor School students and interns and local students.

Trends from 2025 data and and observations of the site from past years show:

- Positive growth between installation and monitoring dates.
- Stable mortality among years.

Site Overview

The Governors Island nursery is located within the Ecodock, a floating dock at Pier 101 on Governors Island, serving as a temporary nursery for oysters reared at the MAST Hatchery (**Figure 13**). Oysters grow in stacks of SuperTrays suspended from the dock until they are ready for deployment to other restoration sites. The nursery supports the cultivation of approximately 1 million oysters, from newly set spat to individuals up to two years old.

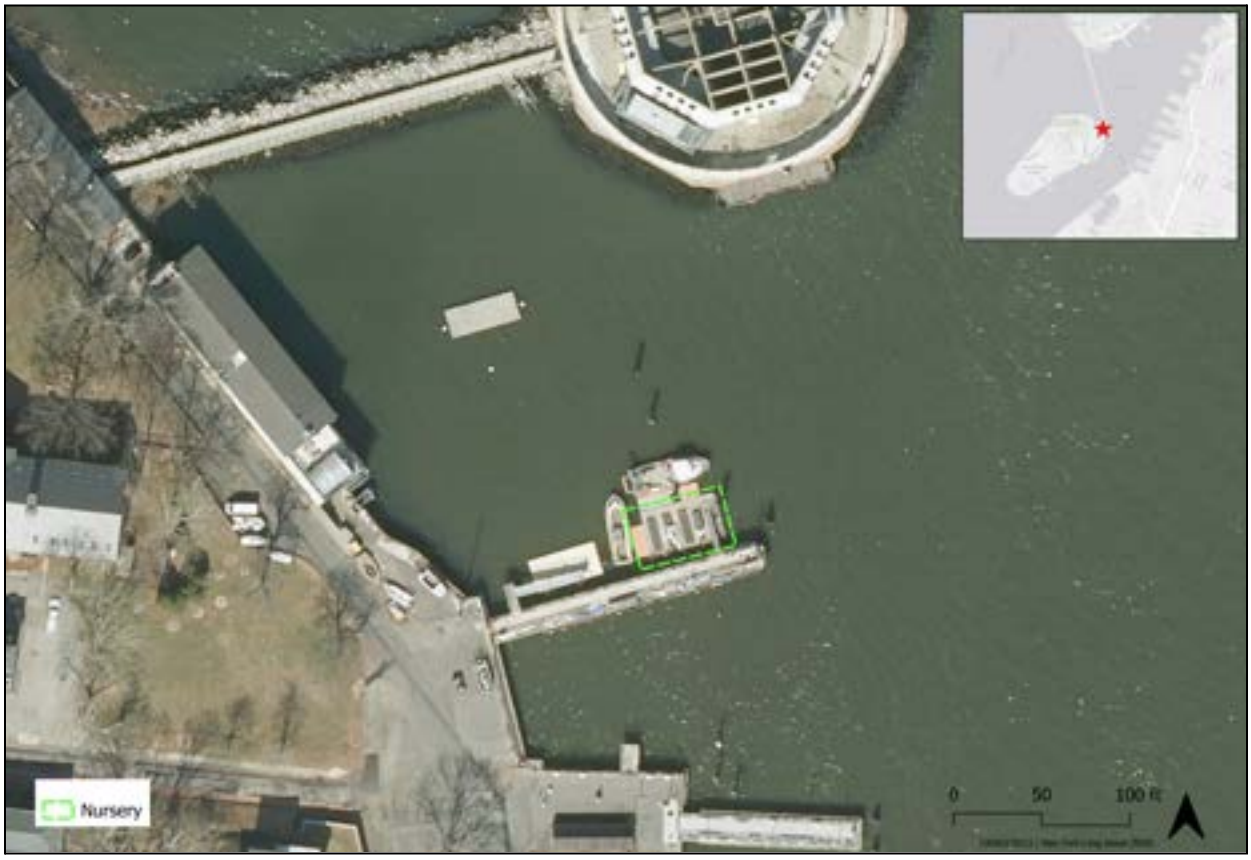

Figure 13. Map of the Governors Island Ecodock nursery site.

The frequent movement of oysters within the nursery and their eventual transfer to other restoration sites pose challenges for conducting regular monitoring activities and maintenance. However, annual monitoring is conducted each fall to assess their growth. Approximately 1,150,000 spat-on-shell were introduced in 2025 (**Table 21**).

Fish trapping was conducted by Billion Oyster Project staff and NYHS interns, in spring, summer and fall 2025, using minnow traps. Skilletfish, blenny, blackfish, flounder, striped bass and cunner were observed, as detailed in the **Appendix, Figure A2**.

Table 21. Summary of structures installed and spat introduced to the Governor Island Ecodock Nursery.

Structure Name	Year Installed	Quantity of Structures	Spat Introduced	Monitoring Frequency
SuperTray Nursery	2025	60	1,150,274	Annual

Oyster Performance

Because a new cohort is installed and monitored each year, it's difficult to infer multiyear trends on oyster performance at this site.

Growth: Positive

The 2025 cohort exhibited a positive growth trend, increasing from a mean shell height of 3–5 mm at installation on June 9th to 17.6 mm (SD = 7.9, N = 715) during monitoring on September 15th for live oysters (**Figure 14, Table 22**). Between installation and the monitoring date, a growth rate of 0.18 mm/day was observed, highlighting continued growth over the three-month period.

Mortality: Low

Annual mortality of the 2025 cohort was low, averaging around 7.6%, and is the lowest recorded among all cohorts, with the previous lowest recorded for the 2018 cohort at 8.2%. However, it is important to note that monitoring occurred three months after cohort installation, giving the oyster spat limited time for mortality to occur, so this low value is expected (**Table 22**).

Recruitment: NA

Recruitment could not be quantified because the installation was less than one year old.

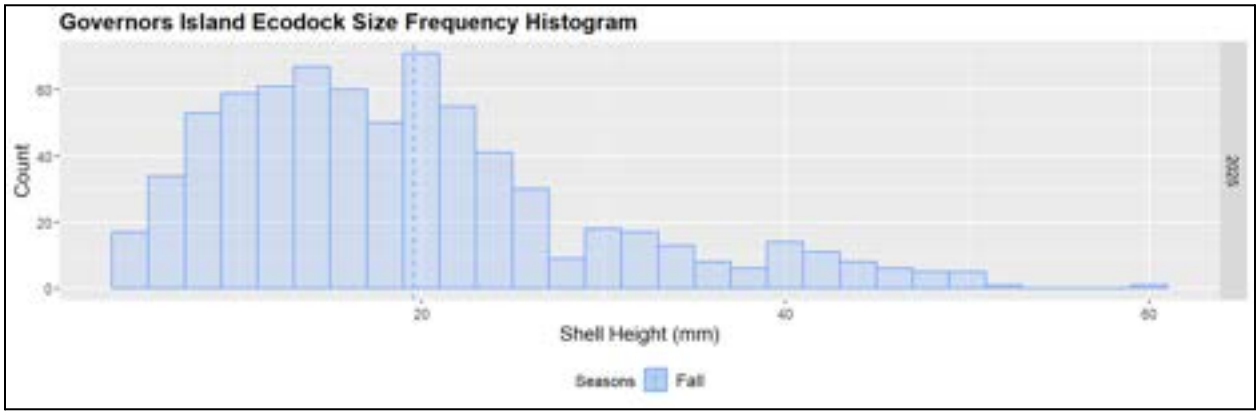

Figure 14. Size-frequency histogram of live oysters in Governors Island Ecodock, 2025. The dashed line represents the mean shell height.

Table 22. Summary of oyster performance at Governor Island Ecodock SuperTray Nursery. NA indicates data is not available.

Year	Sample Size	Mean Shell Height (SD) of Live Oysters (mm)	Mean Shell Height (SD) of Dead Box Oysters (mm)	% Mortality	% Recruitment
2025	715	17.6 (7.9)	11.4 (7.2)	7.6%	<1 year old

Oyster Population Estimates

The current population estimate for Governors Island Ecodock cannot be determined as remaining cohorts are consolidated together to maximize space on the Ecodock.

Recommended Restoration Actions

Governors Island Ecodock will continue to serve as a short-term holding bay for juvenile oysters before they are transferred to restoration sites or used in the Oyster Research Station and Oyster Research Tank programs. Due to this function and the frequent addition of new cohorts each year, it can be challenging to track oyster performance at the Governors Island Ecodock. As a result, understanding multi-year oyster performance trends is not a goal of this site.

Lower Harbor & Raritan Bay

The Lower Harbor & Raritan Bay Regions extend from the Verrazano Narrows to the south shore of Staten Island, Raritan Bay, Sandy Hook New Jersey, and the south Brooklyn waterfront to the opening of Jamaica Bay near Breezy Point (**Figure 15**). There are vertical seawalls, riprap revetments, and piers, but it is slightly less urbanized than the Upper Harbor Region. There are also major navigational channels as shipping traffic moves to and from the Upper Harbor or the Arthur Kill via Raritan Bay. Like most other regions, oyster restoration relies on the addition of substrate and multiple cohorts of oysters. **Table 23** summarizes the restoration sites and installation details in this regional waterbody.

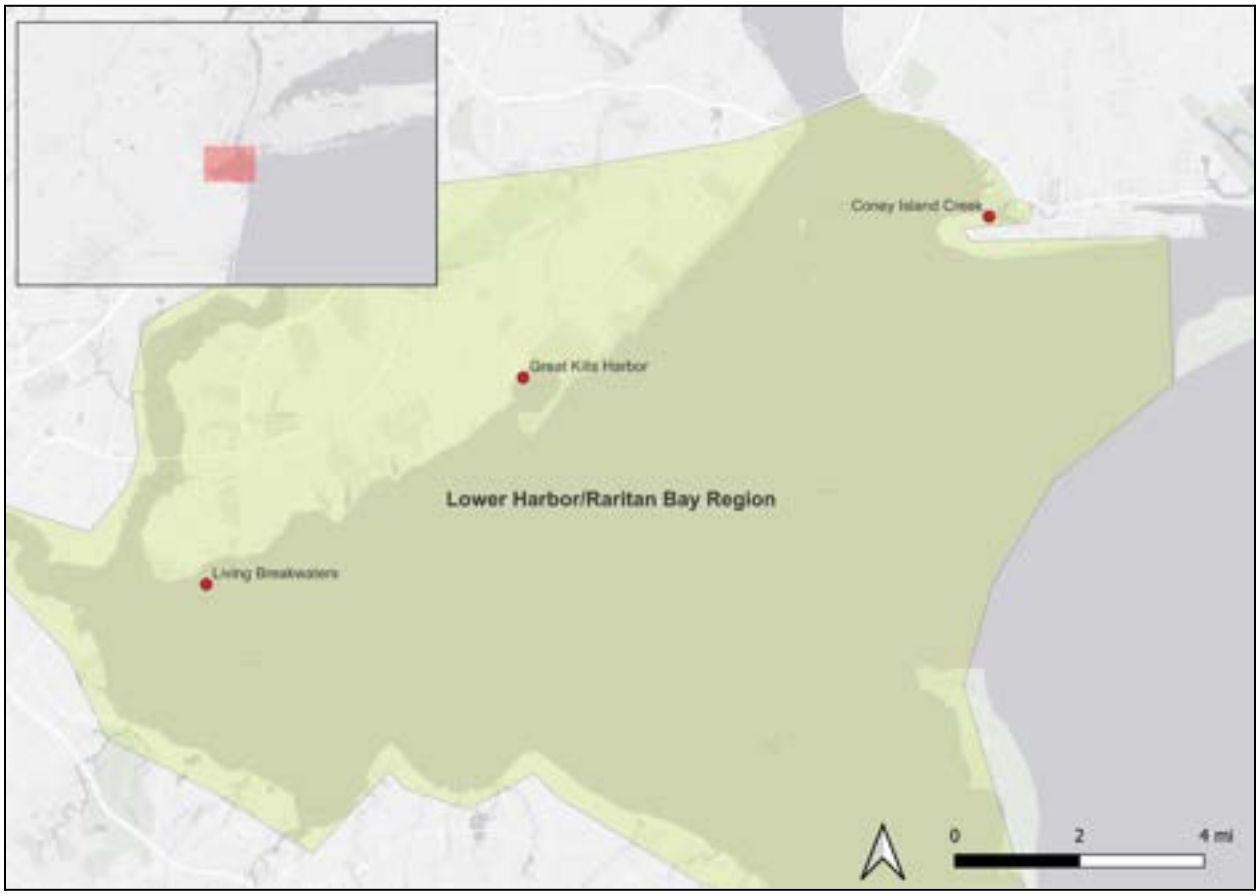

Figure 15. Map of restoration sites within Upper and Lower New York Harbor.

Table 23. Summary of restoration structures and installation details of each site in the Lower Harbor and Raritan Bay.

Site	Structure	Installation Date	Larvae Source	Mean shell height at installation (mm)	Number of oysters installed
Coney Island Creek	Cabinet Reef	6/23/2025	Muscongus Bay, ME	~5	40,000
Great Kills Harbor	SuperTray 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
Living Breakwaters	Breakwaters	7/2/2025	Mobjack Bay Lease Holdings, VA Mook Sea Farm, ME Muscongus Bay, ME	2-5	70,000,000

Coney Island Creek

Project Summary

The project area is located in a cove on the southern shore of Coney Island Creek, adjacent to Kaiser Park and near an old fishing pier along the shoreline (**Figure 16**). The project aims to provide insight into oyster performance in a degraded waterbody. Two cabinets filled with spat-on-shell are installed, monitored, and removed within the same calendar year before November 30th in compliance with NYSDEC permit conditions. Data from this project will inform future oyster restoration projects in Coney Island Creek as long-term clean-up efforts advance.

Trends from 2025 data and and observations of the site from past years show:

- Positive growth between installation and removal dates.
- Consistent mortality among years.

Site Overview

Coney Island Creek experienced significant degradation due to historical filling, dredging, and industrial activity. A combined sewer outfall is located to the east of the project site, near Shore Parkway and W. 15th Street. Despite these challenges, a small population of wild oysters has been observed on rocks in the intertidal zone beneath the fishing pier. Notably, Coney Island Creek is under evaluation by the EPA for Superfund designation due to its history of pollution. Consequently, Billion Oyster Project is restricted to the application of temporary on-bottom structures at this site, with all oysters and structures required to be removed upon permit expiration.

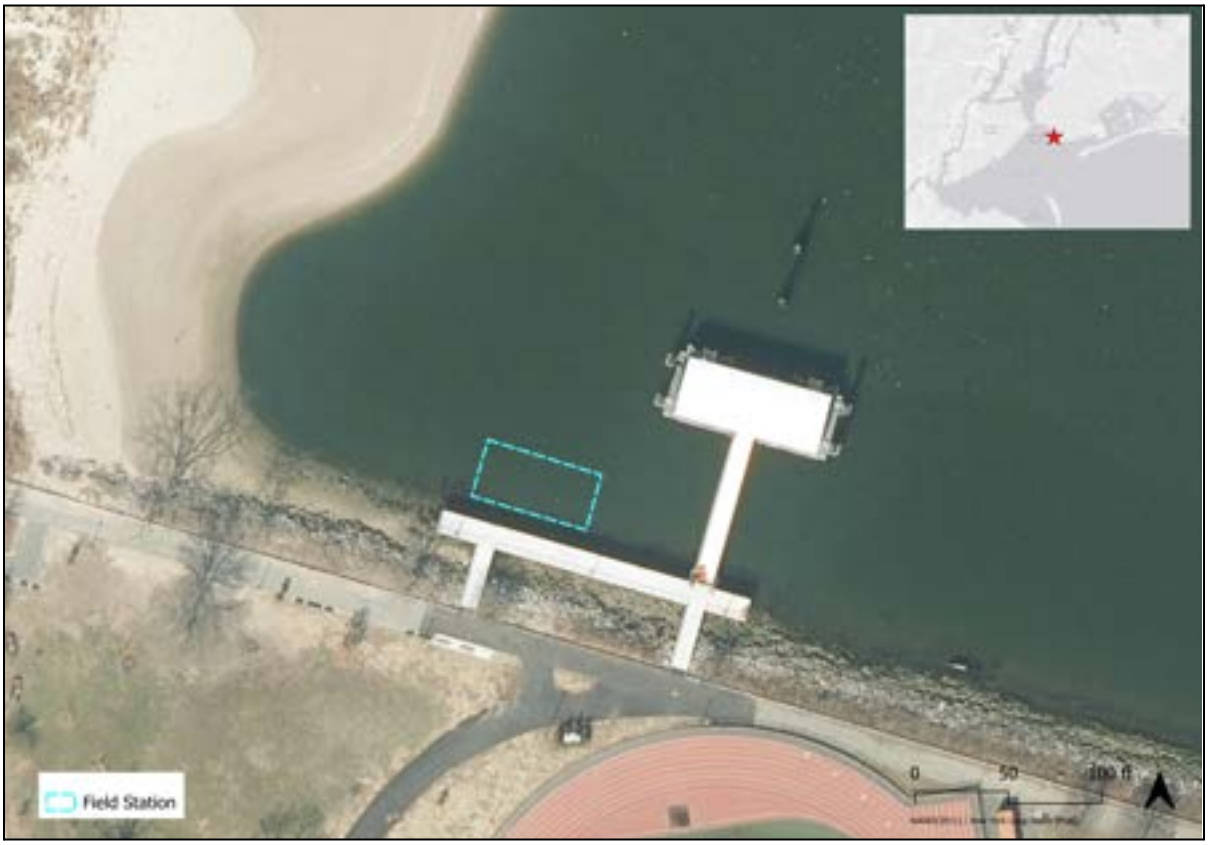

Figure 16. Map of cabinet reef location at Coney Island Creek.

In 2018, one cabinet was placed on the bottom near the fishing pier in Kaiser Park (**Figure 16**). The cabinet, which is submerged at all times, was equipped with a locking mechanism to prevent poaching. Oyster monitoring at the site allowed determination of when oysters reached market size, at which point the larger oysters were removed.

In 2021, Billion Oyster Project observed significant degradation of the 2018 cabinet's mesh inserts. The cabinet was replaced with two, 10' x 2' x 2' welded 1/2" rebar oyster cabinets, each equipped with new files and oysters. At the end of 2021, Billion Oyster Project requested a permit renewal; but the pending Superfund designation and regulatory reviews resulted in an adjusted permit condition that requires annual removal of introduced oysters On December 20, 2022, Billion Oyster Project staff removed two cabinets and all files from the site and relocated the oysters to the Governors Island Reef.

In coordination with NYSDEC in 2024, Billion Oyster Project reinstalled two cabinets one with 10 and the other 11 files, and approximately 159,152 spat-on-shell (**Table 24**). The reef was removed on November 13, 2024, in compliance with permit conditions.

Similarly, in June 2025, Billion Oyster Project reinstalled two cabinets, each containing 10 files seeded with approximately 40,000 spat-on-shell (**Table 24**). These structures were removed on August 12, 2025, in accordance with permit conditions.

Billion Oyster Project conducted oyster performance monitoring annually since 2018, except between 2021-2022 when the cabinet reef was conducted biannually in the spring and fall. No oysters were installed in 2023 therefore no monitoring was conducted that year.

Table 24. Summary of structures installed and spat introduced at Coney Island Creek.

Structure Name	Year Installed	Quantity of Structures	Spat Introduced	Monitoring Frequency
Cabinet Reef	2018	2	92,000	Annual
	2020	2	14,223	
	2021	2	117,772	
	2024	2	159,152	
	2025	2	40,000	

Oyster Performance

Since Billion Oyster Project removes each cohort at the end of each calendar year, it's difficult to infer multiyear trends on oyster performance at this site.

Growth: Positive

The 2025 cohort exhibited a positive growth trend from installation to removal, similar to previous to previous cohorts (**Figure 17**). The mean shell height of 5 mm at installation in June to a live oyster mean shell height of 25.0 mm (SD = 7.0, N = 1727) and a dead box mean shell height of 20.1 mm (SD = 6.12, N = 1727) at removal in August (**Table 25**).

Mortality: Low

Annual mortality of the 2025 cohort was considered low at 10.7% (N = 1727), compared to previous cohorts (**Table 25**). This low mortality could be attributed to the short deployment period of two months compared to the longer deployment periods of previous cohorts.

Recruitment: NA

Recruitment could not be quantified because the installation was less than one year old. Any recruits that may have settled prior to the fall monitoring period would be difficult to distinguish from installed individuals based on size.

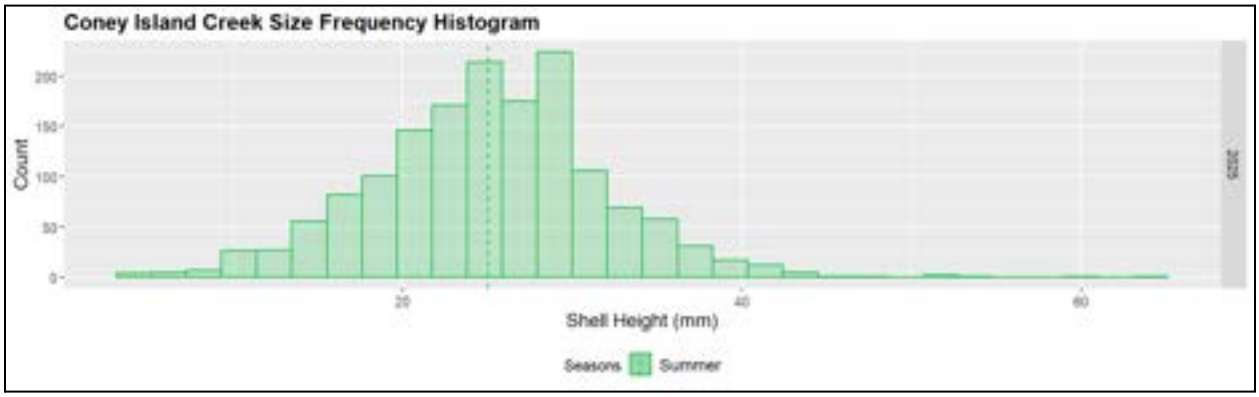

Figure 17. Size-frequency histogram of live oysters in Coney Island Creek cabinet reefs, 2025. The dashed line represents the seasonal mean shell height.

Table 25. Summary of oyster performance of 2025 cohort at Coney Island Creek cabinet reef.

Year	Sample Size	Mean Shell Height (SD) of Live Oysters (mm)	Mean Shell Height (SD) of Dead Box Oysters (mm)	% Mortality	% Recruitment
2025	1727	25.0 (7.0)	20.4 (6.1)	10.7%	NA

Oyster Population Estimates

The current population estimate for Coney Island Creek is zero, as all cohorts were removed before the end of the year.

Recommended Restoration Actions

Billion Oyster Project removed the cabinets from the site and does not plan to restock oysters to Coney Island Creek at this time.

Great Kills Harbor

Project Summary

As of 2025, Billion Oyster Project maintains and monitors the SuperTray nursery in Great Kills Harbor Richmond County Yacht Club, with support from local students, and community members.

Trends from 2018-2025 data indicate the need for intervention based on

- Stabilizing oyster growth.
- The lack of recruitment and high mortality.
- Observed increasing presence of boring sponge that is also likely contributing to high mortality.

Site Overview

Billion Oyster Project established the Great Kills Harbor nursery beneath a pier, accessible via the floating docks of the Richmond County Yacht Club (**Figure 18**). Three cohorts of oysters were introduced in 2016, 2017, and 2019. All cohorts were placed in stacks of three SuperTrays, which were accessible during low tide or using a block and tackle for monitoring and maintenance.

Figure 18. Map of Great Kills Harbor Nursery at Richmond County Yacht Club pier.

Table 26 summarizes the quantity of structures and oysters installed at Great Kills Harbor. In 2016, Billion Oyster Project introduced approximately 15,836 one-year old oysters across two stacks (6 trays) to the nursery. In 2017, twelve more stacks (36 trays) were added, containing approximately 141,327

spat-on-shell. In 2019, six additional stacks (18 trays) were introduced with approximately 200,000 spat-on-shell.

Table 26. Summary of structures installed and oyster introduced to the Great Kills Harbor Nursery.

Structure Name	Year Installed	Quantity of Structures	Oyster Introduced	Monitoring Frequency
SuperTray Nursery	2016	6	15,836 (Adults)	Annual
	2017	36	141,327 (Spat)	
	2019	18	200,000 (Spat)	

In spring 2025, monitoring for all cohorts was conducted, and 15 SuperTrays were removed to initiate site closure due to consistently high annual mortality observed over the years. During this monitoring event, Billion Oyster Project staff occasionally observed various fish and invertebrate species inhabiting the oyster shells within the structures, including goby, blackfish, and pipefish. A detailed list of fish species observed during routine monitoring can be found in the **Appendix, Figure A2**.

Oyster Performance

Data from 2016-2017 are excluded from the size frequency graph because shell height and oyster status were not collected in tandem (**Figure 19**). Without this synchronized data, trends in oyster growth or status during these years could not be reliably analyzed or included in the graph. Additionally, no data was collected in 2020 due to the COVID-19 pandemic and related restrictions.

Growth: Stable

Oysters from all cohorts at Great Kills Harbor have shown positive growth since installation, reaching a mean shell height of live oysters of 144.8 mm (SD = 24.3, N = 622) in 2024, and stabilizing at a mean shell height of 142.7 mm (SD = 29.3, N = 468) in 2025 (**Figure 19, Table 27**). This stabilization likely reflects mortality of larger oysters, resulting in a lower mean shell height compared to the previous year.

Mortality: High

Annual mortality has remained consistently high since 2018, two years after installation of the first cohort, fluctuating between 36.0% and a peak of 80.1% in 2024. In 2025, mortality decreased to 57.9% (**Table 27**). This decrease may be attributable to the lower sample size collected in 2025 (N = 468) compared to 2024 (N = 622), which may have included fewer dead oysters; it may also indicate increased resilience to site conditions as oysters aged.

Recruitment: None

Recruitment was observed annually from 2018, one year after installation of the 2017 cohort, except in 2021, and no recruitment was observed in 2025 (**Table 27**).

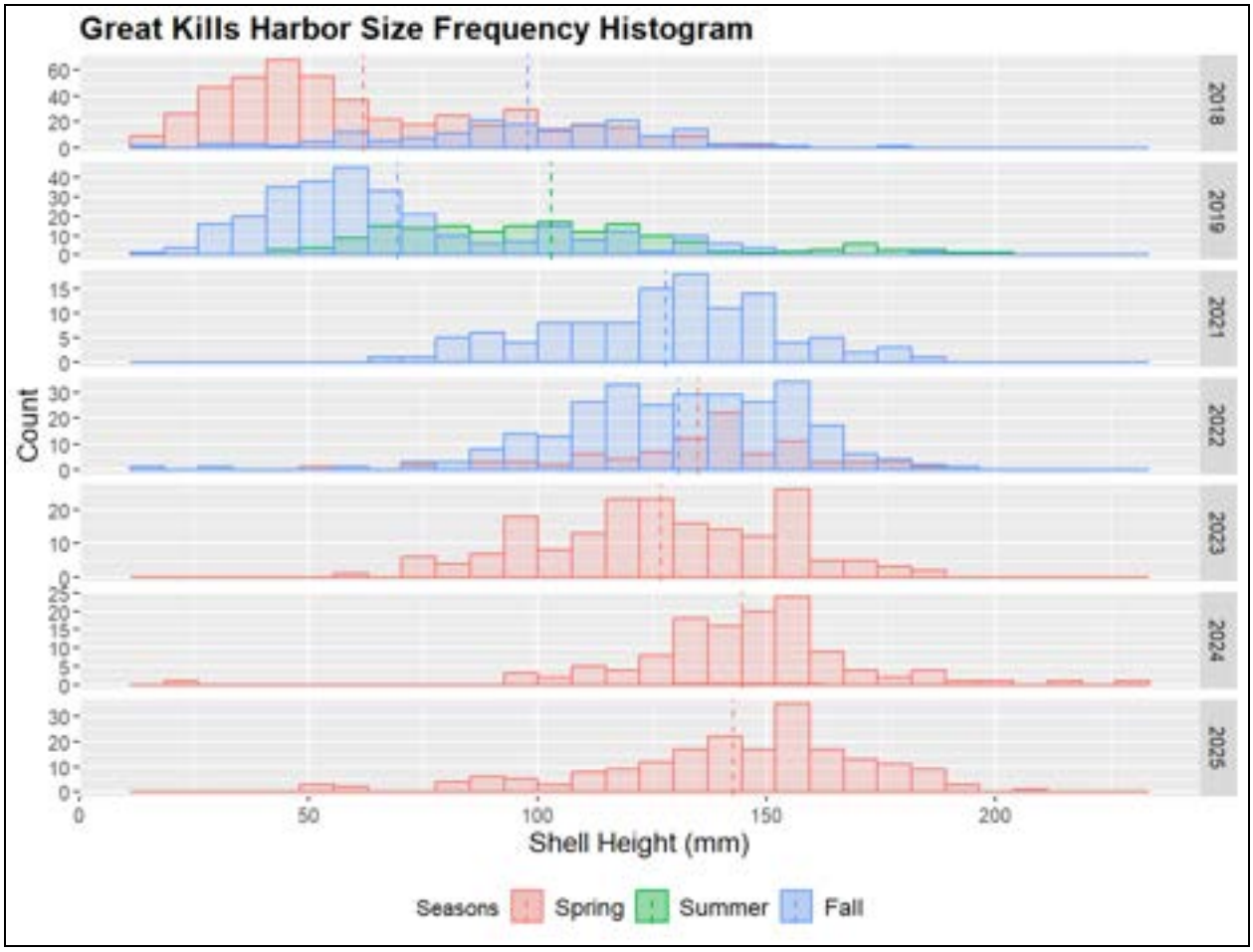

Figure 19. Size-frequency histogram of live oysters across all cohorts in Great Kills Harbor Nursery, 2018-2025. No data was collected in 2020 due to the COVID-19 pandemic. The dashed line represents the seasonal mean shell height.

Table 27. Summary of oyster performance at Great Kills Harbor SuperTray nursery. NA indicates data is not available.

Year	Sample Size	Mean Shell Height (SD) of Live Oysters (mm)	Mean Shell Height (SD) of Dead Box Oysters (mm)	% Mortality	% Recruitment
2016	2841	NA	NA	NA	<1 year old
2017	2328	NA	NA	NA	<1 year old
2018	1026	71.4 (34.3)	57.9 (29.5)	37.1%	6.0%
2019	727	81.8 (36.0)	86.0 (24.3)	36.0%	0.4%
2020	***No monitoring***				
2021	353	127.9 (24.6)	97.7 (27.2)	67.7%	0.0%
2022	900	131.9 (25.2)	116.3 (23.5)	59.4%	0.1%
2023	359	127.0 (25.9)	115.1 (28.0)	48.2%	0.3%
2024	622	144.8 (24.3)	125.1 (27.6)	80.1%	0.2%
2025	**468**	**142.7 (29.3)**	**133.2 (27.6)**	**57.9%**	**0.0%**

Oyster Population Estimates

The total population at Great Kills Harbor nursery is estimated at 1,120 oysters (**Table 28**). The current oyster population estimates in **Table 28** may not accurately reflect the true population size due to a lack of data collection in 2020, which was impacted by the COVID-19 pandemic. As a result, percent mortality and recruitment for that year were not considered, potentially affecting the accuracy of the estimates.

The low population estimate observed can be attributed to high annual percent mortality, likely exacerbated by the presence of disease at the site, as well as low recruitment levels. Despite this, Billion Oyster Project staff noted a high biodiversity of fish and invertebrates at the site (**Appendix, Figure A2**). However, the presence of boring sponge on oyster shells further underscores the challenges in fostering a sustainable and thriving oyster population at this location.

Table 28. Estimated population dynamics of Great Kills Harbor Nursery. Rows highlighted in blue show the population estimate as of 2025 based on annual mortality and annual recruitment. NA indicates data is not available.

Year	Start Estimate + Installation	Annual % Mortality	Post Mortality Estimate	Annual % Recruitment	Population Estimate
2016	15,836	NA	15,836	<1 year old	15,836
2017	15,836 + 141,327	NA	157,163	<1 year old	157,163
2018	157,163	37.1%	98,801	6.0%	104,675
2019	104,675 + 200,000	36.0%	194,875	0.4%	195,679
2020	195,679	NA	195,679	NA	195,679
2021	195,679	67.7%	63,194	0.0%	63,194
2022	63,194	59.4%	25,629	0.1%	25,657
2023	25,657	48.2%	13,293	0.3%	13,330
2024	13,330	80.1%	2,657	0.2%	2,662
2025	2,662	57.91%	1,120	0.00%	**1,120**

Recommended Restoration Actions

Due to elevated annual mortality, Billion Oyster Project removed 15 SuperTrays in 2025 and will complete the removal of this nursery in 2026. Billion Oyster Project acknowledges the valuable opportunities this nursery has provided for community engagement in restoration and research initiatives. Oyster Research Stations will remain at the site for stewardship by local community groups.

Living Breakwaters

Project Summary

In 2025, Billion Oyster Project piloted the first in situ oyster larval setting in New York City along a 50-foot section of the leeward side of Breakwater D within the Living Breakwaters system. This pilot is intended to inform future oyster installations across multiple breakwaters and evaluate the feasibility of in situ setting in a high-energy coastal environment.

Results from 2025 indicate that in situ larval setting can successfully initiate oyster recruitment on Living Breakwaters infrastructure, particularly within intertidal habitat features. Post-trial monitoring confirmed successful larval settlement, early spat growth and survival, and the presence of wild recruitment along several breakwaters.

Site Overview and Trial Description

The project site is part of the Living Breakwaters system along the south shore of Staten Island, New York, which consists of eight nearshore breakwaters (A–H) designed to reduce wave energy, protect the shoreline, and enhance marine habitat (**Figure 20**).

Figure 20. Overall site plan of the Living Breakwaters. An in situ trial was conducted on Breakwater D in 2025.

The in situ larval setting trial was conducted in July 2025 along the leeward side of Breakwater D to take advantage of reduced wave energy and increased larval retention. Approximately 7 million

pediveliger-stage oyster larvae from two commercial hatcheries were acclimated on site and released at slack high tide within an enclosed 50-foot section of the breakwater (**Table 29**). A turbidity curtain was deployed for several days post-release to retain larvae, and mesh bags of clean shell were used as proxy substrates to quantify settlement.

During the trial period, Billion Oyster Project conducted daily site visits to assess enclosure integrity and record water quality conditions, which were generally suitable for larval settlement. Following removal of the enclosure, shell bags were retrieved for grow-out and enumeration, and follow-up monitoring was conducted to document settlement, early survival, and growth. Findings from this pilot will inform adaptive management and the design of future in situ setting efforts across the Living Breakwaters system.

Table 29. Summary of oyster introduced to the Living Breakwaters.

Structure Name	Year Installed	Linear ft along Breakwater side	Oyster Introduced	Monitoring Frequency
Breakwater	2025	50	7,000,000	Annual

Oyster Performance

Post-trial monitoring confirmed that the in situ larval setting trial at Breakwater D was successful, as evidenced by direct observation of oyster spat on intertidal settlement surfaces and to supplement direct observations on the breakwater, four bags of clean shell were deployed within the turbidity curtain during the trial as proxy settlement substrates, which provided successful settlement on bagged shell proxy substrates. In early September, one of the four bags was successfully recovered and transferred to an off-bottom nursery at Pier 101 on Governors Island for examination.

Growth: Positive

A total of 150 of 600 blank shells deployed were recovered and evaluated on September 10, 2025. Of these, 12 shells (8%) contained at least one oyster spat, with 13 total spat documented. Only one mortality was observed among the recovered spat. Live spat ranged in size from 7 mm to 39 mm, with a mean shell height of 21.7 mm at the time of assessment.

Mortality: NA

Current data are insufficient to quantify overall setting survival rates across the full range of substrates on Breakwater D. Field observations suggest higher settlement in intertidal tide pools relative to subtidal armor units, though additional monitoring is required to confirm this pattern. Follow-up surveys planned for spring 2026 will support improved estimates of settlement success, survival, and spatial distribution of oysters resulting from the 2025 in situ trial.

Recruitment: Low but consistent

Based on a wild oyster survey conducted on 5 of the breakwaters (D, E, F, G, and H) via kayak in September 2025, a total of 313 wild oysters was observed with a mean shell height of 64.4 mm (SD = 14.7). Most of the live recruits were found on the windward side of the breakwaters (8 transects sampled) compared to the leeward side (2 transects sampled), which indicates the presence of a wild oyster population in the area.

Oyster Population Estimates

Because the oyster population was only recently established and post in situ monitoring was postponed until spring 2026, there is currently no estimate of oyster population size at the Living Breakwaters.

Recommended Restoration Actions

Overall, the 2025 trial demonstrates that in situ larval setting can successfully initiate oyster recruitment on the Living Breakwaters infrastructure, particularly within intertidal habitat features. The results provide a proof of concept and inform upcoming 2026 trials, including the need for refined monitoring approaches, improved proxy substrates, and repeat trials to build a robust dataset for evaluating long-term performance and scalability of this method within the Living Breakwaters system.

The team will conduct two additional in situ trials in July 2026, repeating the methods and procedures for deploying the turbidity curtain, collecting water quality data, and acclimating and releasing oyster larvae. Applying lessons learned from the 2025 trial, the team will use divers to assess trial success or failure via presence/absence surveys in fall 2026, and return to the breakwaters in spring 2027 to assess spat density, size, and mortality. The team will use a different, retrievable proxy substrate that may yield more representative insight into the setting rate than the bagged shell. ECOncrete® disks or a similar-sized, temporary off-bottom structure will be deployed atop the breakwater structures within the intertidal zone of the enclosed trial areas. The structures will be retrieved upon the conclusion of each trial and held off-bottom on Governors Island to allow spat to grow out for 8-10 weeks for more accurate counting in the summer and fall of 2026. They will be routinely hauled up for surveys during the fall months to assess density. Results will then be compared to in situ monitoring data collected onsite in spring 2027.

Jamaica Bay

The Jamaica Bay Region encompasses 16,000 acres of surface waters and 3,000 acres of islands and marshes (NYC DEP). The tidal inlet to Jamaica Bay is in the west between Manhattan Beach (Brooklyn) and Breezy Point on the Rockaway Peninsula (Queens). The Bay extends eastward to JFK Airport and Bayswater Point and to Brooklyn and Queens shorelines in the north. Given the single inlet to the Bay, this region is somewhat disconnected from other regional waterbodies. Except for the navigational channels, the Bay is relatively shallow with an average depth of 13 feet. A significant portion of the shoreline is public parkland (New York City Parklands, New York State Parklands, or National Park Service-owned parklands) and remains undeveloped. Future oyster restoration in this regional waterbody will require collaboration with these governmental landowners. Current oyster restoration sites within the Jamaica Bay waterbody include Head of Bay, Paerdegat Basin, and Bayswater Point State Park (**Figure 21**, **Table 30**). Based on data from these sites, there is strong potential for the successful recovery of oyster populations but the addition of substrate and recurrent reseeding with cohorts of oysters are necessary interventions in this waterbody.

Figure 21. Map of restoration sites within Jamaica Bay.

Table 30. Summary of restoration structures and installation details of each site within Jamaica Bay.

Site	Structure	Installation date	Larvae source	Size at installation (shell height, mm)	Number of oysters installed
Head of Bay (**HOB**)	OysterGro	09/01/2016	Merry Oysters, MA Island Creek Oysters, MA	~120	35,200
		11/08/2017 12/08/2017			9,300
	Shell Reef	2018	Merry Oysters, MA Island Creek Oysters, MA	~130	40,000*
		06/16/2023	Oyster Seed Holdings, VA	~10	15,353,000
		07/31/2024		~45	50,000
		06/07/2025	Mook Sea Farm, ME Muscongus Bay, ME	~5	14,400,000
Paerdegat Basin **(PB)**	Cabinet Reef	7/27/2018	Muscongus Bay, ME	~5	480,000
Bayswater Point State Park (**BW**)	Bagged Shell Reef	7/20/2020	Muscongus Bay, ME	~5	30,514
		9/14/2020		2-5	414,749

* Adult oysters were transferred from the floating “donor reef” to the on-bottom “receiver reef” in 2018.

Bayswater Point State Park

Project Summary

As of 2025, Billion Oyster Project maintains and monitors the bagged shell reef installation in Bayswater Point State Park with support from local students and volunteers. This project provides insight into oyster health and performance using the shallow nearshore environment of Jamaica Bay, Queens, NY. A secondary objective of the project compares the performance of bags constructed from natural fibers, such as coir or coconut, with those made from plastic mesh. The experimental bags contain either unseeded shell or seeded shell material.

Trends from 2020-2025 data indicate

- Gradual increase of oyster size and consistent recruitment annually.
- Stabilizing annual mortality relative to the mortality elsewhere in Jamaica Bay.
- The need to reconsider the structure design at this site to minimize mortality.

Site Overview

The Bayswater Point State Park project is located at Motts Point in Joseph Sanford Jr. Channel, eastern Jamaica Bay (**Figure 22**). This site features a sandy beach shoreline bordered by salt marsh and forest.

Figure 22. Map of Bayswater State Park Bagged Shell Reef.

In summer 2020, Billion Oyster Project staff, project partners, and volunteers constructed an on-bottom reef consisting of 96 coir and plastic mesh bags filled with seeded or unseeded shells (**Table 31**). Each bag measures approximately 24" x 6". The bags were secured to the reef perimeter by threading a wire through them and anchoring it to the substrate with steel stakes. The reef remains permanently submerged and can only be accessed during low tide.

Table 31. Summary of structures installed and spat introduced at Bayswater Point State Park.

Structure Name	Year Installed	Quantity of Structures	Spat Introduced	Monitoring Frequency
Bagged Shell Reef	2020	96	445,263	Biannual

Billion Oyster Project conducted biannual monitoring at the site between 2020 to 2023 and shifted to annual monitoring from 2024. In 2025, Billion Oyster Project conducted monitoring activities at the site with volunteers in April and engaged with a local school group in November. During the monitoring event, Billion Oyster Project staff documented fish and invertebrate species inhabiting the oyster shells within the bagged shells and conducted seining surveys around the reef. Results are presented in the **Appendix, Figure A2.**

Oyster Performance

Growth: Positive

A general increasing trend in oyster growth was observed as the mean shell height continued to increase (**Figure 23**). The mean shell height of live oysters increased from 62.8 mm (SD = 27.4, N = 227) in 2024 to 77.8 mm (SD = 32.2, N = 174) in 2025 (**Table 32**). The mean shell height of dead box oysters increased from 44.0 mm (SD = 18.9, N = 227) in 2024 to 46.3 mm (SD = 23.7, N = 174) in 2025 (**Table 32**).

Mortality: Stabilizing

Annual percent mortality at this site increased within the first three years post-installation and then slightly decreased in recent years. This elevated mortality is likely attributable to the frequent handling of oysters for programmatic activities and moderate sedimentation at the site, which caused oysters to become partially buried. During monitoring, Billion Oyster Project staff and volunteers observed the darkened coloration of oyster shells, indicating prolonged exposure to anoxic sediment as well as evidence of boring sponges, indicating susceptibility to diseases as they age. Annual mortality decreased from 76.2% in 2024 to 70.7% in 2025, ranging between 70% to 80% in the last three years (**Table 32**).

Recruitment: Low but consistent

Recruitment - as indicated by the occurrence of oysters less than 25 mm in height - has remained consistent annually post-installation. Since peak recruitment observed in 2022, annual recruitment has been decreasing. Annual recruitment decreased from 11.9% in 2024 to 9.8% in 2025 (**Table 32**). Billion Oyster Project needs to continue monitoring recruitment at Bayswater to better understand annual trends and the influence of frequent handling and sedimentation. As additional oyster restoration projects in Jamaica Bay are permitted and implemented, these trends may change as larval availability increases.

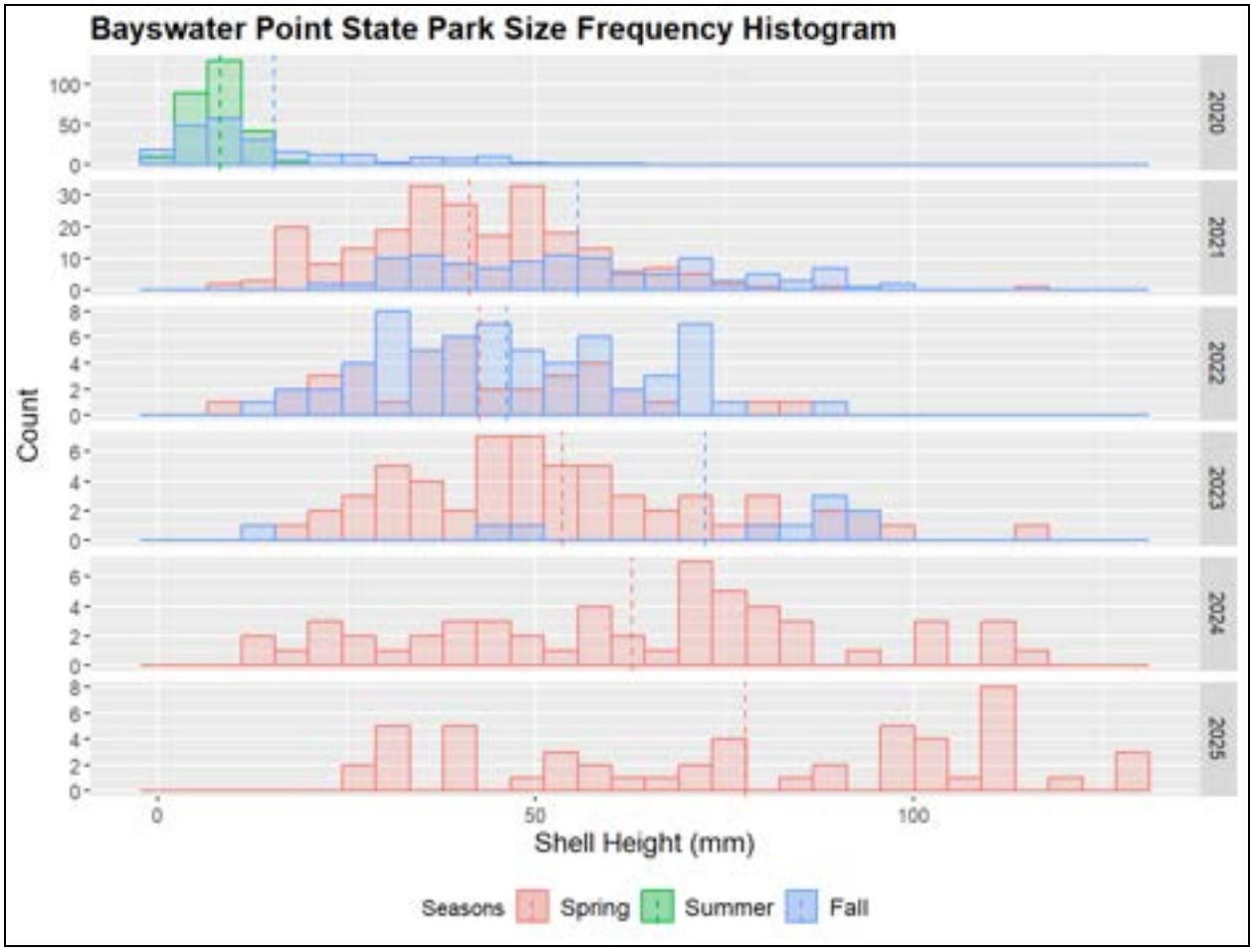

Figure 23. Size-frequency histogram of live oysters in Bayswater Point State Park bagged shell reef, 2020-2025. The dashed line represents the seasonal mean shell height.

Table 32. Summary of oyster performance at Bayswater Point State Park bagged shell reef. SD indicates standard deviation.

Year	Sample Size	Mean Shell Height (SD) of Live Oysters (mm)	Mean Shell Height (SD) of Dead Box Oysters (mm)	% Mortality	% Recruitment
2020	559	11.6 (10.1)	8.2 (10.9)	9.1%	<1 year old
2021	511	46.0 (18.1)	40.8 (15.3)	33.5%	3.1%
2022	327	44.9 (17.2)	39.8 (15.9)	68.8%	12.6%
2023	325	56.3 (23.0)	47.0 (18.2)	78.8%	11.9%
2024	227	62.8 (27.4)	44.0 (18.9)	76.2%	11.9%
2025	**174**	**77.8 (32.2)**	**46.3 (23.7)**	**70.7%**	**9.8%**

Oyster Population Estimates

The annual population estimates for the Bayswater State Park bagged shell reef can be found in **Table 33**. Billion Oyster Project has not added new cohorts of oysters to the Bayswater site since 2020. The persistently high yet stable mortality at Bayswater is likely due to sedimentation, which has further reduced the estimated population to 1,848 oysters. Despite this, recruitment continues to occur annually.

Table 33. Estimated population dynamics of Bayswater Point State Park Bagged Shell Reef.

Year	Start Estimate	Annual % Mortality	Post Mortality Estimate	Annual % Recruitment	Population Estimate
2020	414,749	9.1%	376,910	<1 year old	376,910
2021	376,910	33.5%	250,781	3.1%	258,659
2022	258,659	68.8%	80,683	12.6%	90,815
2023	90,815	78.8%	19,281	11.9%	21,583
2024	21,583	76.2%	5,134	11.9%	5,745
2025	5,745	70.7%	1,684	9.8%	**1,848**

Recommended Restoration Actions

Monitoring data collected between 2020 and 2025 demonstrate that oysters at Bayswater Point State Park are surviving to reproductive size and that natural recruitment occurs annually at the site. In addition, the site supported Billion Oyster Project programming focused on engaging and educating the community about Jamaica Bay and oyster restoration. Collectively, these outcomes meet the primary objectives of the original project. However, monitoring also indicated persistently high mortality in recent years (70-80% annually), primarily due to sedimentation and frequent handling. Without substantial design modifications to address these stressors, elevated mortality is expected to continue.

As the project objectives have been met and additional experimental value under the current design is limited, Billion Oyster Project recommends removing the bagged shell reed at Bayswater Point State Park. Billion Oyster Project will complete one final monitoring event, remove all remaining oysters and reef materials, and dispose of all materials in an upland facility in accordance with permit requirements in 2026. A site close-out report will be submitted to NYSDEC documenting the final monitoring results, removal activities, and material disposal. Lessons learned for this project will inform future restoration design and site selection in Jamaica Bay.

Head of Bay

Project Summary

As of 2025, Billion Oyster Project maintains and monitors four shell reefs installed in Head of Bay, with support from New York Harbor School diving students and interns. This project aims to support a persistent, multi-cohort oyster population through phased installations and adaptive management of four non-contiguous, adjacent shell reefs. In 2025, Billion Oyster Project reseeded the site by installing approximately five million spat-on-shell across Reefs 2 and 3 and ten million spat-on-shell across Reefs 1 and 4.

Trends from 2025 data indicate that

- Oyster growth met performance expectations across multiple cohorts, with substantial early growth from oyster installed in summer 2025.
- Mortality remained variable across reefs and cohorts, relatively low for the 2016-2017 cohort, higher for the 2023 cohort, and the lowest annual mortality was observed on the newly established reef.
- Natural recruitment was low or absent, following trends observed in previous years. Recruitment could not be reliably quantified during fall monitoring due to size overlap with newly installed spat-on-shell.
- Oyster density varied among reefs, with higher density observed in Reefs 1 and 4, which consisted primarily of newly installed spat-on-shell. Reefs 2 and 3, which had a greater diversity of cohorts and received fewer spat-on-shell in 2025, had lower densities.

Site Overview

In 2016, the New York City Department of Environmental Protection (DEP), in partnership with Billion Oyster Project and the Hudson River Foundation, began the “Developing a Self-Sustaining Oyster Population in Jamaica Bay, New York City” project on a one-acre site in Head of Bay (**Figure 24**). The project encompasses approximately one acre of subtidal habitat and includes four constructed oyster reefs. These reefs were established to support the development of a self-sustaining eastern oyster (*Crassostrea virginica*) population capable of serving as a larval source for Jamaica Bay. The project aligns with broader regional goals, including targets outlined in the Hudson-Raritan Estuary Comprehensive Restoration Plan (USACE 2016) and the Jamaica Bay Watershed Protection Plan (NYC DEP 2018), by promoting oyster reef restoration and contributing to estuarine habitat complexity and water quality enhancement.

The Head of Bay pilot project was initiated in 2016 by the New York City Department of Environmental Protection, in partnership with the Billion Oyster Project (Billion Oyster Project) and the Hudson River Foundation. It initially included four unseeded, on-bottom “receiver reefs” made of recycled shell and crushed porcelain, paired with a floating longline of 105 OysterGro units stocked with adult oysters to act as a larval source (“donor reef”). Since the initial pilot, the longline donor reef has been removed, the on-bottom receiver reef has been stocked with both adult oysters and spat-on-shell, and Billion Oyster Project has continued to work at and monitor the site with involvement from New York Harbor School diving students and interns (**Table 34**). 2025 represents the most recent installation of oysters on reefs 2 and 3, totaling 5 million oysters on 16 cubic yards (CY) of shell.

Table 34 provides a summary of installations at the Head of Bay site since 2016. Monitoring at the site was switched from biannual to annual to evaluate oyster performance in 2022.

Figure 24. Map of Head of Bay site showing the centerline of the receiver reefs constructed in 2016.

Table 34. Summary of structures installed and oysters introduced to Head of Bay.

Year	Reef(s)	Activity	Materials	Monitoring Frequency
2016	On-bottom receiver reefs 1-4 & Floating donor reef	Initial Construction	4 receiver reefs: cured oyster shell & crushed porcelain; Donor reef: 105 OysterGro units with 35,000 adult oysters	Biannual
2017	Donor reef	Addition of adult oysters	9,300 adults added to OysterGro units	
2018 - 2019	Reefs 2 and 3	Donor reef removal & adult oyster redistribution	~40,000 adults moved to Reefs 2 and 3	
2023	Reefs 2 and 3	Spat-on-shell installation	15.3 million spat on 36 CY shell	Annual
2024	Reefs 2 and 3	Adult oyster installation	50,000 adults	
2025	Reefs 2 and 3	Spat-on-shell installation	5 million oysters on 11 CY shell	
	Reefs 1 and 4	Spat-on-shell installation	10 million oysters on 22 CY shell	

In 2025, Billion Oyster Project conducted spring monitoring on Reefs 2 and 3 and fall monitoring on all four reefs. Oyster performance metrics (i.e., shell height, mortality, recruitment) were assessed using quadrat excavation sampling. At each reef, divers swam along an established east-west transect and collected samples at 16 quadrats per reef, each 20-ft intervals with a 0.0929 m^2 (1 ft^2) quadrat. Because oyster distribution across the reefs was patchy and some quadrats contained no oysters, clump monitoring was conducted, with divers collecting approximately 30 oyster clumps per reef along the sample transect line for surface processing. All oysters within each quadrat and clumps were returned to the reef and evenly redistributed to maintain reef structure and function.

During spring 2025 monitoring, divers collected exploratory reef height observations at Reef 2 and Reef 3. These measurements were not conducted using a standardized protocol and are not presented quantitatively. Observations indicated variable reef height with areas of both shell and sediment prior to the June 2025 spat-on-shell installation. Additionally, a diverse array of invertebrate species was recorded during monitoring, while only a single vertebrate species, the oyster toadfish (*Opsanus tau*), was observed during the fall monitoring.

Oyster Performance

Growth: Positive

The live mean shell height of the 2016–2017 cohort on Reef 2 increased slightly from 147.3 mm (SD = 24.6, N = 34) in 2024 to 147.8 mm (SD = 24.7, N = 28) in spring 2025. In contrast, on Reef 3, the live mean shell height of the same cohort decreased from 135.5 mm (SD = 25.9, N = 18) in 2024 to 113.9 mm (SD = 35.5, N = 48) in spring 2025 (**Figure 25**, **Table 35**).

The 2023 cohort exhibited substantial growth across both reefs. On Reef 2, live mean shell height increased from 57.4 mm (SD = 14.8, N = 480) in 2024 to 104.9 mm (SD = 32.4, N = 127) in spring 2025. Similarly, on Reef 3, mean shell height increased from 56.2 mm (SD = 11.3, N = 105) in 2024 to 86.8 mm (SD = 23.5, N = 117) in spring 2025 (**Table 35**).

The cohort installed in summer 2025 also demonstrated measurable growth, increasing from an initial live mean shell height of <2 mm at installation to 50.8 mm (SD = 14.3, N = 927) on Reef 1 and 53.11 mm (SD = 10.1, N = 260) on Reef 4 in less than five months (**Table 35**). It is important to note that the maximum shell height detected in Reef 1 was 107 mm, and 85 mm in Reef 4. This suggests that samples from Reefs 1 and 4 likely contained oysters from an older cohort, as the maximum shell height from Reefs 2 and 3 after the 2023 installation was between 77 mm and 78 mm. Continued monitoring will be necessary to characterize long-term growth trends for this newly established cohort.

Fall growth data from Reefs 2 and 3 show a decrease in mean shell height relative to spring monitoring, driven by the installation of spat-on-shell during summer 2025. Mean shell heights of 58.9 mm (SD = 28.9, N = 268) on Reef 2 and 57.8 mm (SD = 22.1, N = 185) on Reef 3 indicate that fall samples were dominated by newly installed spat, with values comparable to those observed on Reefs 1 and 4 (**Table 35**). Given the presence of multiple cohorts on Reefs 2 and 3, distinguishing among cohorts during fall monitoring remains challenging.

Mortality: Stabilizing

Annual percent mortality of the 2016–2017 cohort on Reef 2 decreased from 29.4% (N = 34) in 2024 to

17.9% (N = 28) in spring 2025. In contrast, percent mortality for this cohort on Reef 3 increased from 16.7% (N = 18) in 2024 to 20.8% (N = 48) in spring 2025 (**Table 35**).

For the 2023 cohort, annual percent mortality declined on both reefs. On Reef 2, mortality decreased from 63.3% in 2024 to 59.1% in spring 2025, while on Reef 3, it decreased more substantially, from 81.0% (N = 105) in 2024 to 55.6% (N = 117) in spring 2025 (**Table 35**).

The cohort installed in summer 2025 exhibited relatively low mean percent mortality during its first monitoring period, with 13.8% (N = 927) on Reef 1 and 13.1% (N = 260) on Reef 4 (**Table 35**). Continued monitoring will better characterize mortality trends for this newly established cohort.

Recruitment: None

No recruitment was observed in the spring monitoring this year (**Table 35**). Any recruitment in Reefs 2 and 3 from the fall monitoring is difficult to discern due to the comparably small size of new recruits and recently-installed oysters.

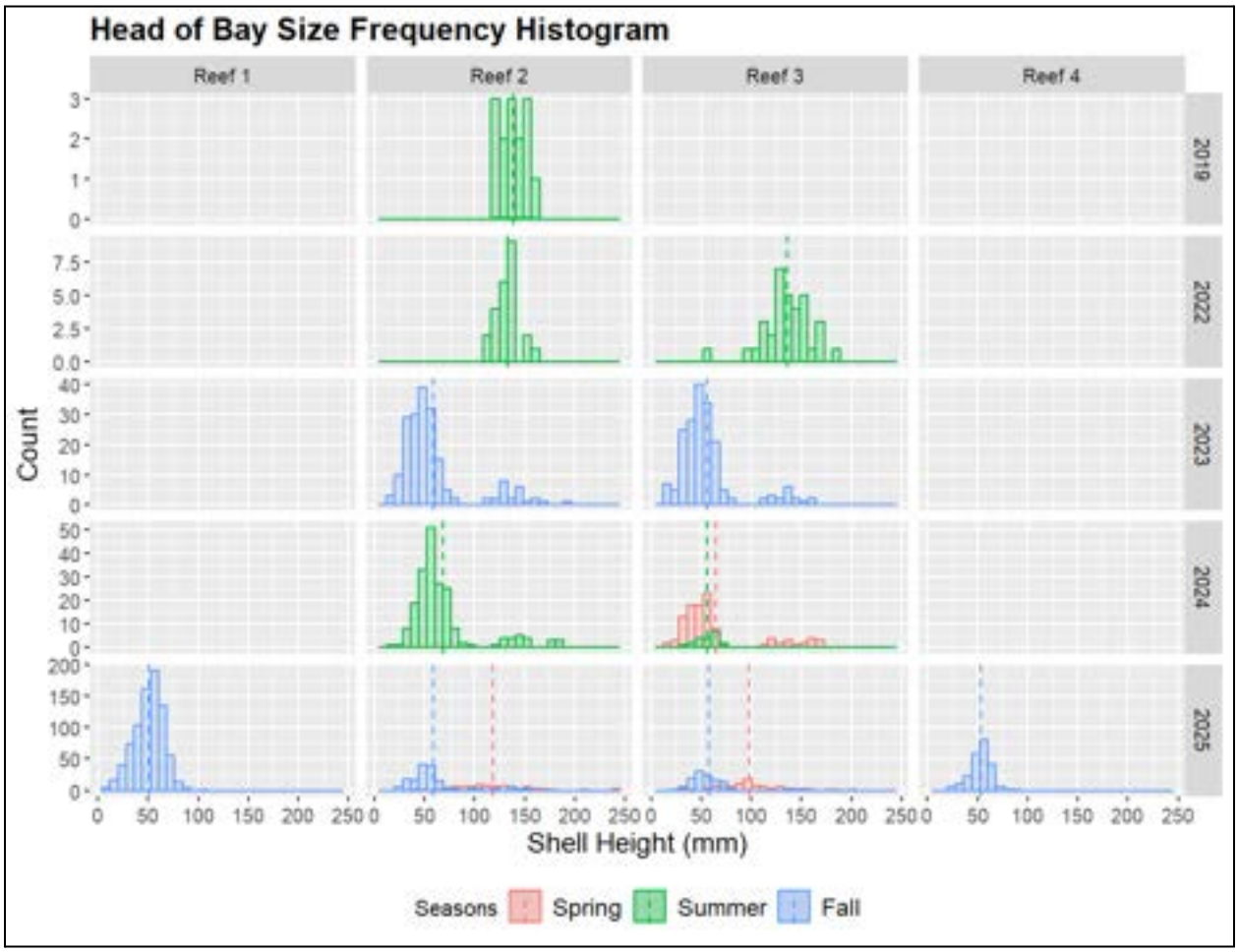

Figure 25. Size frequency histogram of Head of Bay shell reefs, 2019-2025; dashed line represents seasonal mean shell height.

Table 35. Summary of oyster performance at Head of Bay shell reefs. SD indicates standard deviation and NA indicates no calculation for percent recruitment as data is difficult to discern between restored and wild oysters.

Reef	Cohort	Season	Sample Size	Mean Shell Height (mm) of Oysters (SD)		% Mortality	% Recruitment
				Live Oysters	Dead Box Oysters		
1	**2025**	**Fall 2025**	**927**	**50.8 (14.3)**	**35.4 (10.5)**	**13.8%**	<1 year old
2	2016-2017	Summer 2019	21	138.6 (12.8)	121.3 (25.8)	33.3%	0.0%
		Fall 2023	30	139.0 (18.1)	131.4 (11.6)	16.7%	0.0%
		Summer 2024	34	147.3 (24.6)	140.5 (21.5)	29.4%	0.0%
		Spring 2025	**28**	**147.7 (24.7)**	**154.2 (19.5)**	**17.9%**	0.0%
	2023	Fall 2023	172	46.5 (12.9)	37.4 (11.7)	4.1%	<1 year old
		Summer 2024	480	57.4 (14.8)	45.8 (15.1)	63.3%	2.3%
		Spring 2025	**127**	**104.9 (32.4)**	**71.4 (20.0)**	**59.1%**	0.0%
	All Cohorts	Fall 2025	268	58.9 (28.9)	57.9 (36.8)	41.4%	NA
3	2016-2017	Fall 2023	20	134.6 (13.9)	111.0 (22.6)	10.0%	0.0%
		Spring 2024	18	135.5 (25.9)	130.0 (11.5)	16.7%	0.0%
		Spring 2025	**48**	**113.9 (35.5)**	**105.5 (36.9)**	**20.8%**	0.0%
	2023	Fall 2023	171	47.2 (13.1)	36.0 (8.8)	2.3%	<1 year old
		Spring 2024	312	53.2 (27.8)	46.6 (18.3)	70.8%	<1 year old
		Summer 2024	105	56.2 (11.3)	46.0 (11.4)	81.0%	1.9%
		Spring 2025	**117**	**86.8 (23.5)**	**67.1 (23.9)**	**55.6%**	0.0%
	All Cohorts	Fall 2025	185	57.8 (22.1)	55.1 (34.0)	35.7%	NA
4	**2025**	**Fall 2025**	**260**	**53.1 (10.1)**	**36.5 (9.8)**	**13.1%**	<1 year old

Oyster Density

For each shell reef, oyster density was quantified using 16 randomly placed 0.0929 m² quadrats on the surface of the structure. The sample size (N) reported in this section refers to the number of quadrats sampled, not the number of individual oysters. Oyster density could not be calculated for the 2016–2017 and 2023 cohorts in 2023 because monitoring during that year was conducted exclusively using clump-based methods. In addition, quadrat-based density estimates were not available for the 2016–2017 cohort on Reefs 2 and 3 after 2022, as subsequent monitoring relied on clump monitoring only.

For the 2025 cohort, oyster density could not be calculated for Reefs 2 and 3 during the fall monitoring because multiple cohorts were present and could not be reliably distinguished. As a result, only total oyster density across all cohorts was calculated for these reefs (**Table 36**). Recruitment density was not calculated for any data collected less than one year post-installation.

Average quadrat mortality was calculated by first determining percent mortality within each 0.0929 m² quadrat across each shell reef, followed by computation of the mean and corresponding 95% confidence interval (CI). The CI provides an estimate of precision and represents the range within which the true

mean quadrat-level mortality is likely to occur. This approach characterizes mortality at the quadrat scale rather than across pooled individual oysters and allows for a more robust assessment of spatial variability in mortality across the reef.

Table 36. Oyster density, standard deviation (SD), quadrat mortality, and 95% confidence interval (CI) of Head of Bay shell reefs.

Reef	Cohort	Season	# of Quadrats	Live Oyster Per Square Meter (SD)	Total Oyster Per Square Meter (SD)	Quadrat % Mortality (CI)
1	2025	Fall 2025	11	587.1 (570.7)	685.0 (624.3)	29.5% (16.5%)
2	2016-2017	Summer 2022	2	0.0 (0.0)	16.2 (7.6)	100.0% (0.0%)
	2023	Spring 2025	12	26.9 (38.0)	63.7 (58.1)	54.2% (22.5%)
	All Cohorts	Fall 2025	11	38.2 (52.2)	102.8 (128.1)	67.8% (19.0%)
3	2016-2017	Summer 2022	5	25.8 (24.8)	43.1 (26.4)	42.9% (34.6%)
	2023	Spring 2024	9	46.7 (60.9)	168.6 (209.1)	54.5% (26.0%)
	2023	Spring 2025	10	22.6 (37.4)	60.3 (81.9)	72.2% (20.1%)
	All Cohorts	Fall 2025	9	34.7 (76.6)	78.9 (135.1)	62.8% (27.3%)
4	2025	Fall 2025	7	103.0 (93.8)	123.0 (106.9)	18.6% (11.6%)

Oyster Population Estimates

As of 2025, the estimated oyster population across all cohorts at Head of Bay is approximately 13.8 million individuals, based on annual mortality and recruitment data collected from initial installation through the most recent monitoring period (**Table 37**). Population estimates for Reefs 2 and 3 are pooled because exact deployment counts are not available for each reef individually; the same approach applies to Reefs 1 and 4.

Annual percent mortality was calculated as the number of dead box oysters observed across both reefs divided by the total number of oysters sampled from those reefs in a given year. Annual percent recruitment was calculated as the number of oysters less than 25 mm shell height observed one year post-installation divided by the total number of oysters sampled from both reefs in that year. Annual mortality typically declines following spat-on-shell installations, while recruitment cannot be reliably calculated immediately after installation because restored oysters and wild recruits are similar in size during the monitoring period.

Given that adult oyster installations represent a negligible proportion relative to spat-on-shell deployments, the majority of the estimated population is likely composed of individuals originating from spat-on-shell installations. Because cohorts on Reefs 2 and 3 cannot be reliably distinguished, population estimates can be presented as a range derived using either pooled or cohort-specific percent mortality and recruitment rates. Using this approach, the estimated oyster population at the site ranges from approximately 12.8 million to 14.4 million individuals.

The observed reduction in population size is primarily attributed to elevated annual mortality and low recruitment, patterns commonly observed in restored oyster reefs. These estimates should be interpreted

as approximate due to the lack of exact oyster deployment counts across all spat-on-shell and adult installations as well as missing mortality and recruitment rates between 2019 and 2023.

Table 37. Estimated population dynamics of Head of Bay shell reefs. NA indicates data is not available.

Reefs	Year	Start Estimate + Installation	Annual % Mortality	Post Mortality Estimate	Annual % Recruitment	Population Estimate
1 and 4	2025	10,000,000	13.7%	8,635,215	<1 year old	**8,635,215**
2 and 3	2018-2019	40,000	NA	40,000	NA	40,000
	2023	40,000 + 15,300,000	3.2%	14,848,047	<1 year old	14,848,047
	2024	14,818,331 + 50,000	68.0%	4,766,711	2.2%	4,872,637
	2025[A]	4,872,637	57.4%	2,076,862	2.3%	**2,124,457**
	2025[B]	5,000,000	39.1%	3,046,358	<1 year old	**3,046,358**
					Total Estimated Population	**13,806,030**

A = population estimates for 2016-2017 and 2023 cohort; B = population estimates for 2025 cohort

Recommended Restoration Actions

To support the creation of a self-sustaining oyster population at Head of Bay, Billion Oyster Project recommends the following actions:

Reseeding in Response to Oyster Performance

Billion Oyster Project will focus future installations of spat-on-shell on areas with low oyster density to sustain population size and reproductive potential, especially on Reefs 2 and 3. Future efforts should manage multiple cohorts to maintain a mix of size classes and reproductive capacity, since natural recruitment remains limited.

Continued Monitoring and Reef Assessment

Billion Oyster Project will maintain annual monitoring of oyster growth, mortality, density, and recruitment across all reef components at Head of Bay. Billion Oyster Project will implement systematic assessments of reef height, spatial extent, and substrate coverage to track changes in reef size and structural stability and to identify areas that may require supplemental shell or substrate. Visual surveys will be used to evaluate reef subsidence, displacement, or erosion in order to maintain three-dimensional habitat complexity over time.

In 2026, Billion Oyster Project will conduct side scan sonar surveys to obtain an updated assessment of reef footprint, reef height, and overall spatial configuration of the constructed reefs. These data will complement in-water monitoring efforts and provide a site-wide perspective on reef condition.

Monitoring data will be used to inform future management decisions, including the timing, location, and scale of additional seeding, as well as potential interventions to enhance recruitment or reduce stressors. These actions will help sustain reef structure and oyster abundance, support long-term ecological function, and advance Head of Bay towards restoration success.

Paerdegat Basin

Project Summary

As of 2025, Billion Oyster Project maintains and monitors the cabinet reef at Paerdegat Basin Sebago Canoe Club installed in 2018. The installations also provide hands-on education and engagement opportunities with students and community groups that reconnect people to the water bodies surrounding New York Harbor, as well as to the wildlife thriving along the shorelines and in the shallows.

Trends from 2018-2025 data indicate

- Oyster growth trends positively.
- Annual mortality increases while annual recruitment decreases.
- The need to reconsider the structure design at this site to minimize mortality.

Site Overview

The project site is located on the northeast shoreline of the Paerdegat Basin, adjacent to the Sebago Canoe Club (**Figure 26**). The installation is situated below mean low water on the southeastern side of the club's gangway. The total area of the project site is approximately 0.1 acres, with a combined total footprint of installed material of less than 100 square feet.

Figure 26. Map of Paerdegat Basin cabinet reef.

In July 2018, Billion Oyster Project staff installed a total of five 10' x 2' x 2' oyster cabinets made of welded 1/2" rebar and containing approximately 480,000 spat-in-shell (**Table 38**). One cabinet was placed

closer to shore to facilitate monitoring events, while access to the four remaining subtidal cabinets from the shore is possible only during the lowest of low tides.

Table 38. Summary of structures installed and spat introduced at Paerdegat Basin.

Structure Name	Year Installed	Quantity of Structures	Spat Introduced	Monitoring Frequency
Cabinet Reef	2018	5	480,000	Biannual

Billion Oyster Project conducted biannual monitoring at the site between 2020 to 2023 and shifted to annual monitoring in 2024. In total, Billion Oyster Project conducted annual monitoring and training in April and collected sediment for benthic characterization in September. During monitoring, Billion Oyster Project documented fish and invertebrate species inhabiting the cabinet reef and conducted seining surveys around the reef. Results are presented in the **Appendix, Figure A2**.

Oyster Performance

Growth: Positive

Live oysters in the cabinet reef continue to exhibit consistent positive growth since installation as the mean shell height increased (**Figure 27**). The mean shell height of live oysters increased from 91.4 mm (SD = 26.4, N = 356) in 2024 to 96.9 mm (SD = 20.8, N = 283) in 2025 (**Table 39**). The mean shell height of dead box oysters increased from 76.8 mm (SD = 31.6, N = 356) in 2024 to 83.2 mm (SD = 24.1, N = 283) in 2025 (**Table 39**).

Mortality: Stabilizing

Annual mortality stabilized around 30% in past years but increased from 30.06% (N = 356) in 2024 to 60.1% (N = 283) in 2025 (**Table 39**). This increase in mortality could be attributed to natural senescence where older oysters are dying out and structure degradation in soft sediment where the cabinet reef is sinking and files becoming more buried in the sediment.

Recruitment: Low but variable

Since installation, recruitment is low to absent each year and only peaked in 2020. Between 2023 and 2024, recruitment decreased from 0.8% (N = 356) in 2024 to 0% (N = 283) in 2025 (**Table 39**). These low rates are likely attributable to the small population size of the 2018 cohort and lack of larval supply from elsewhere

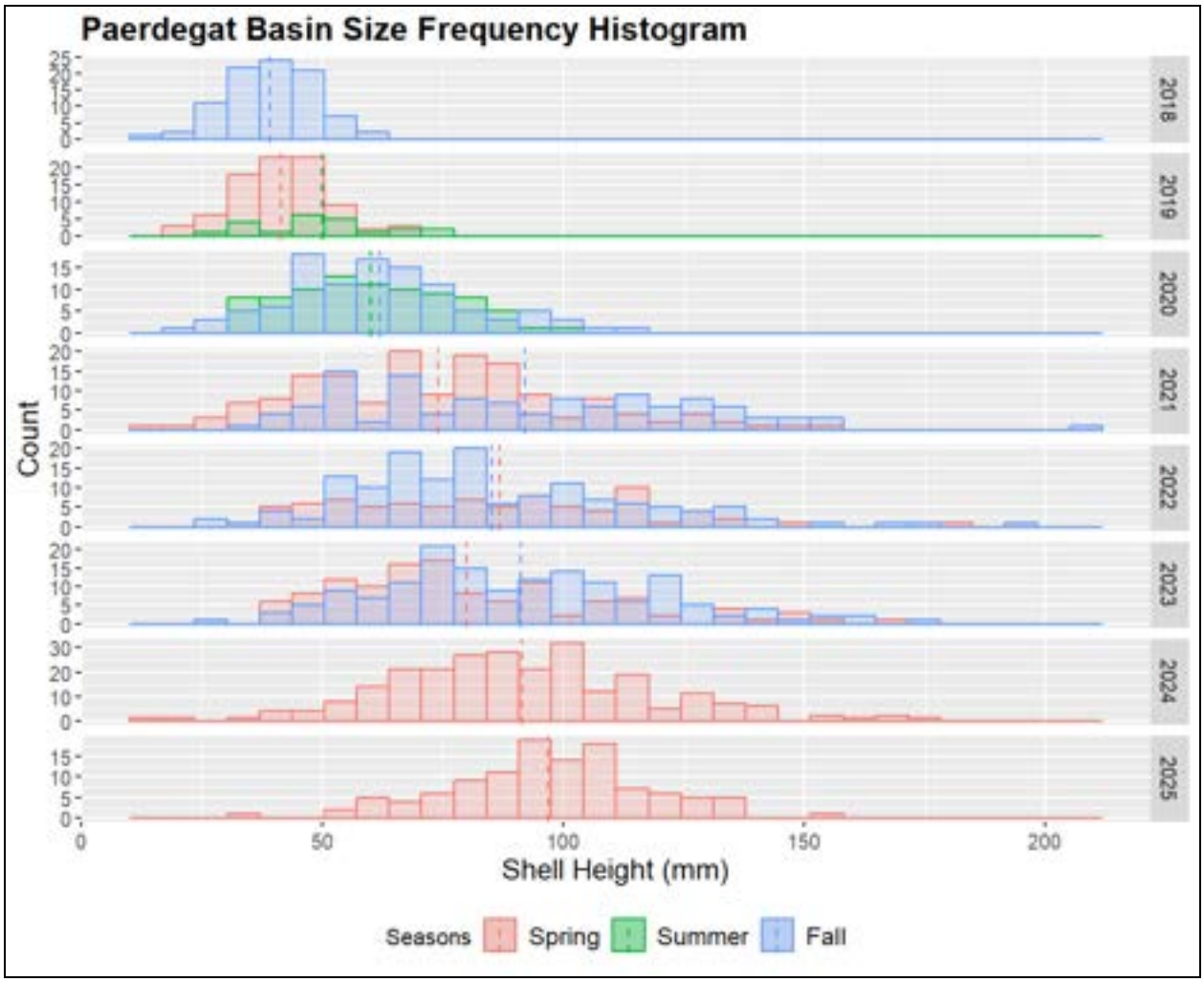

Figure 27. Size-frequency histogram of live oysters in Paerdegat Basin cabinet reefs, 2018-2025. The dashed line represents the seasonal mean shell height.

Table 39. Summary of oyster performance at Paerdegat Basin cabinet reef. SD indicates standard deviation and NA indicates data is not available.

Year	Sample Size	Mean Shell Height (SD) of Live Oysters (mm)	Mean Shell Height (SD) of Dead Box Oysters (mm)	% Mortality	% Recruitment
2018	90	39.1 (9.0)	NA	0.0%	<1 year old
2019	117	0.0 (11.0)	36.0 (7.6)	6.9%	0.0%
2020	267	61.1 (17.9)	53.1 (14.8)	29.2%	1.4%
2021	390	81.8 (31.7)	60.8 (25.2)	30.0%	0.0%
2022	324	85.8 (30.7)	61.7 (21.0)	30.6%	0.5%
2023	509	86.3 (28.9)	68.7 (26.6)	45.8%	0.4%
2024	356	91.4 (26.4)	76.8 (31.6)	30.1%	0.8%
2025	**283**	**96.9 (20.8)**	**83.2 (24.1)**	**60.1%**	**0.0%**

Oyster Population Estimates

The annual population estimates of the Paerdegat Basin cabinet reef can be found in **Table 40**. The initial oyster population introduced to Paerdegat Basin in 2018 was small and Billion Oyster Project has not added new cohorts to the site since installation. The population size at this site is estimated to be 24,044 oysters in 2025, reflecting the increased mortality and low recruitment this year (**Table 40**).

Table 40. Estimated population dynamics of Paerdegat Basin Cabinet Reef.

Year	Start Estimate	Annual % Mortality	Post Mortality Estimate	Annual % Recruitment	Population Estimate
2018	480,000	0.0%	480,000	<1 year old	480,000
2019	480,000	6.8%	447,179	0.0%	447,179
2020	447,179	29.2%	316,543	1.4%	321,065
2021	321,065	30.0%	224,745	0.0%	224,745
2022	224,745	30.6%	156,073	0.5%	156,838
2023	156,838	45.8%	85,044	0.4%	85,372
2024	85,372	30.1%	59,713	0.8%	60,216
2025	60,216	60.1%	24,044	0.0%	**24,044**

Mobile Species Characterization

On behalf of Billion Oyster Project, a consulting team (AKRF and Princeton Hydro) conducted seasonal fish sampling, deploying both minnow and seabass traps, to four areas throughout the basin, where future oyster restoration is being investigated and designed, to serve as a baseline assessment of mobile species. The full pre-installation report from AKRF, including sampling effort and seasonal and gear-type comparisons, is available upon request. In brief, 12 fish taxa and 11 invertebrate taxa were collected at the site by trapping.

Recommended Restoration Actions

As Billion Oyster Project transitions from pilot-scale installations to the implementation of a basin-scale restoration effort, Billion Oyster Project will scale back existing installations and remove the cabinet reef at the Sebago Canoe Club. Removal of all cabinets and associated materials will occur following completion of final monitoring in 2026. Live oysters from the cabinets may be transferred to existing off-bottom SEAPA cages

Billion Oyster Project is currently permitting a multi-phase project totaling approximately 2.81 acres of oyster reef habitat in Paerdegat Basin. Billion Oyster Project is seeking to permit Phase 1 consisting of 0.37-acres seeded and unseeded substrate designed to further our understanding of recruitment trends in Jamaica Bay and better define the minimum target stocking density required to maintain positive population density.

Western Long Island Sound

The Western Long Island Sound region extends from City Island and Pelham Bay in the Bronx in the northeast, to Little Neck Bay and Flushing Bay, Queens in the south, to the head of the East River near Randall's Island in the west (Figure 28). Soft shorelines and salt marshes are more prevalent in the eastern portion of this region, transitioning to industrial and hardened shorelines west of the Whitestone Bridge. Consistent wild recruitment at planned and active restoration sites throughout this region indicates the presence of a larval source, likely commercialoyster farms further east along the Long Island Sound shoreline, with the highest densities of wild oysters documented in areas with hard substrate and low wind and wave energy. The shallow gradient and soft shorelines present opportunities to incorporate shoreline protection into designs to reduce erosion and restore or protect wetlands. Together, these conditions enhance the potential for successful restoration outcomes in the region, where Billion Oyster Project has installed various types of restoration structures and spat-on-shell (**Table 41**).

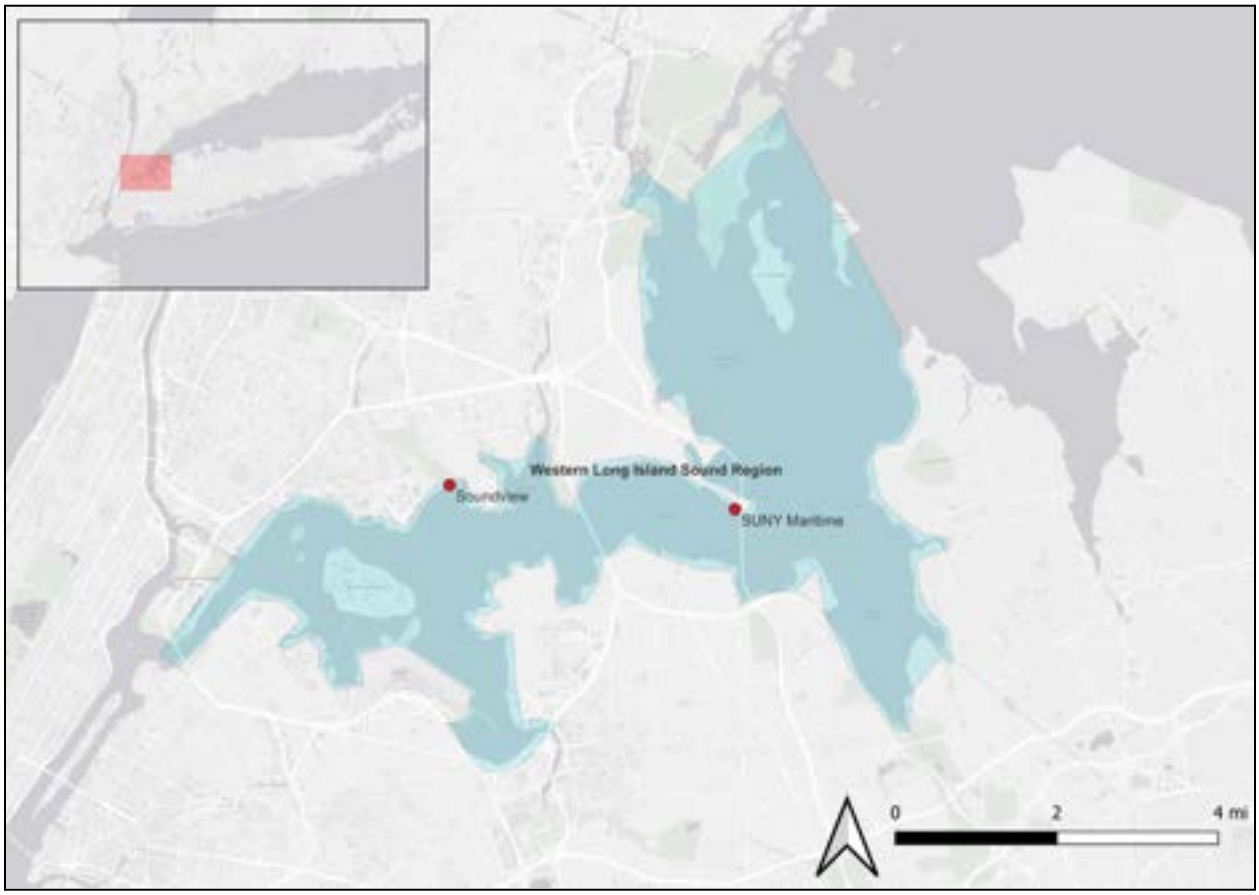

Figure 28. Map of restoration site within Western Long Island Sound.

Table 41. Summary of restoration structures and installation details of each site within Western Long Island Sound.

Site	Structure	Install date	Larvae source	Size at installation (shell height, mm)	Number of oysters installed
Soundview Park (SV)	Shell Reef	07/24/2020, 07/27/2020	Muscongus Bay, ME	~5	9,000,000
		09/2/2020		Adult	200,000
		08/10/2021		~5	7,300,000
		08/8/2022 - 08/12/2022		~5	1,500,000
	Cabinet Reef	08/18/2020		~5	200,000
	Gabion	07/17/2020, 08/20/2020		~5	2,793,101
		08/08/2022 - 08/12/2022		~5	>1,500,000
	Reef Balls	6/17/2024 - 6/28/2024	Oyster Seed Holdings, VA Muscongus Bay, ME	>10	8,900,000
SUNY Maritime (SM)	SuperTray	06/9/2025	Oyster Seed Holdings, VA	~5	595,765

Soundview Park

Project Summary

The Soundview Oyster Habitat Restoration Project expanded upon the success of previous research projects at the site, which identified Soundview as an optimal location for large-scale reef restoration in New York Harbor. This project provides insight into oyster health and performance using on-bottom restoration techniques. The installations also provide hands-on education and engagement opportunities with students and community groups that reconnect people to the waterbodies surrounding New York Harbor, as well as to the wildlife thriving along the shorelines and in the shallows. As of the end 2025, Billion Oyster Project maintains and monitors shell reefs and reef balls installed in the eastern portion of the Soundview project area after removing the gabion reef in the central and western project area in June 2024.

In 2025, Billion Oyster Project monitored oyster performance across both reef components through spring and fall surveys. Oysters exhibited strong growth and survival across the site (**Table 42**):

- On the shell mound reef, mean shell height increased to 94 mm, confirming that site conditions support oyster growth. Mortality (55%) remained within expected ranges for mid-stage restoration reefs.
- On bay balls, mean shell height reached 80 mm, and annual mortality ranged from 7% (spring) to 45% (fall). Bay balls supported both restored and wild-set oysters, with unseeded units showing some natural recruitment.
- The total oyster population at the site is estimated between 5.4 million and 9.2 million individuals in 2025.

Site Overview

The Soundview Oyster Habitat Restoration Project, led by Billion Oyster Project with funding from NYSDEC, restored five acres of oyster reef habitat near Soundview Park at the mouth of the Bronx River (**Figure 29**). This large-scale restoration effort built upon earlier research that identified Soundview as an optimal site for oyster reef restoration in New York Harbor.

Construction began in the summer of 2020. The initial reef installation included approximately 600 cubic yards (CY) of unseeded shell, 200,000 adult oysters deployed atop the shell reefs, and 12.6 million spat-on-shell (**Table 42**). The spat-on-shell was deployed in several formats: 15 cubic yards of loose shell, 169 gabions, and four community cabinets. The gabions were constructed using welded 1/2" flat bar frames (4' x 2' x 2') with 1” galvanized mesh inserts, each capable of holding up to 100,000 spat-on-shell and weighing approximately 350 pounds. The community cabinets, also 4' x 2' x 2', contained 14 mesh files hung from rebar hangers, each cabinet supporting about 100,000 spat-on-shell and weighing approximately 200 pounds.

In 2021, Billion Oyster Project supplemented the initial installation with an additional 7.3 million spat-on-shell added to the shell reefs (**Table 42**). In 2022, 3.0 to 3.4 million spat-on-shell were deployed, including 12 gabions and additional loose spat-on-shell (**Table 42**).

In 2023, monitoring revealed a significant degradation of the gabions’ mesh. In response, Billion Oyster Project removed the damaged gabions from the western and central reef areas in spring 2024.

In late June 2024, Billion Oyster Project installed 240 bay balls—both seeded and unseeded—in the eastern reef area to protect two shell reefs (**Figure 29**). Additionally, 75 cubic yards of unseeded shells was added to create a tenth shell reef. In total, 8.9 million oysters were introduced to 80 of the bay balls as part of this latest phase of restoration (**Table 42**).

In 2025, no new structures were installed, and no reseeding occurred. The total project area spans five acres, with 0.96 acres designated for the reef footprint. All loose shells were placed below mean low water, while gabions and bay balls were installed below mean lower low water.

Invertebrates were observed during bay ball and shell reef monitoring. Notably, lion's mane jellyfish (*Cyanea capillata*), and mud snails (*Nassarius obsoletus)*. However, only one vertebrate species, a goby (*Gobiidae* spp.), was recorded during summer shell reef monitoring. Additional species, including blue crabs and other fishes, were observed by divers during underwater monitoring, further emphasizing the ecological role of oyster reefs in supporting local marine communities.

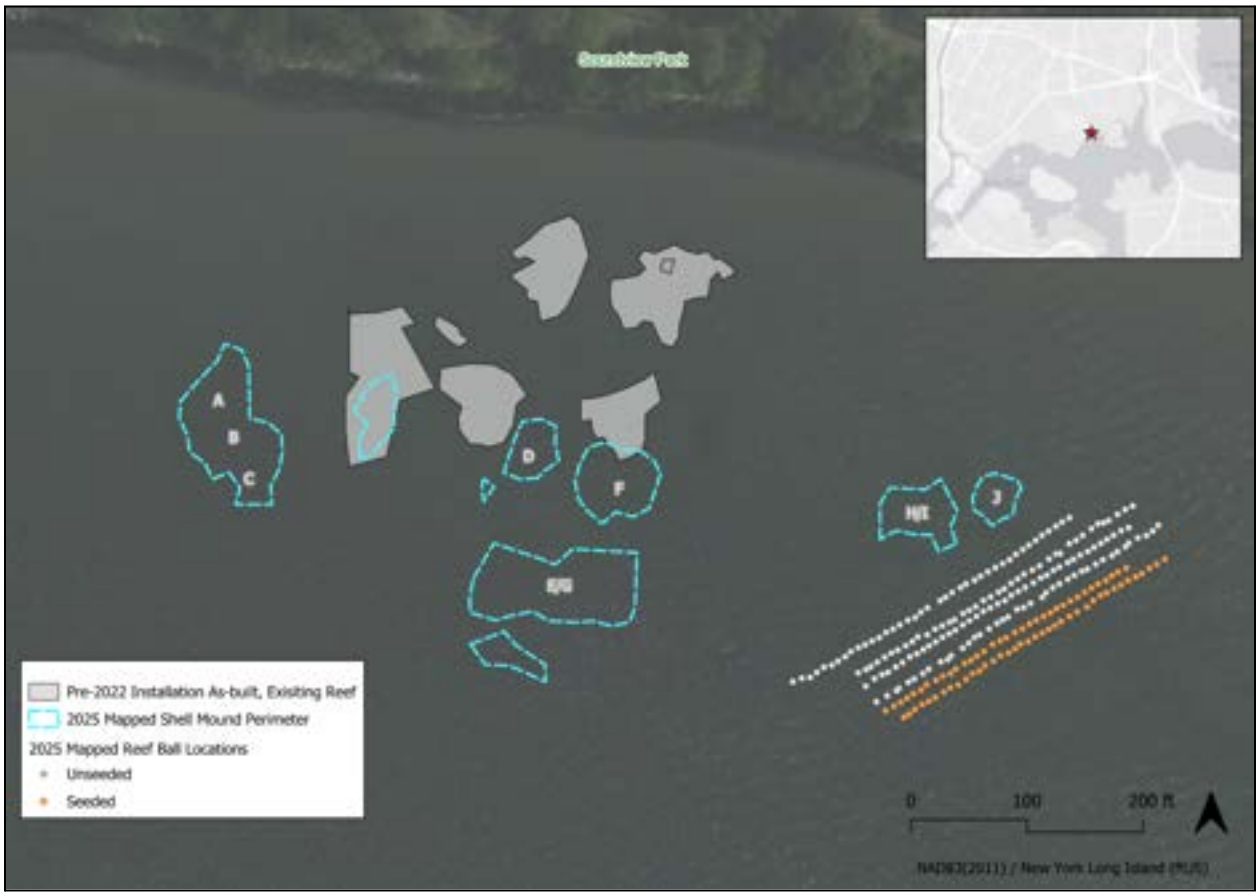

Figure 29. 2024 as-built site map of the Soundview Park oyster reef.

Table 42. Summary of structures installed and oyster introduced at Soundview Park.

Structure Name	Year Installed	Quantity of Structures	Oysters Introduced	Monitoring Frequency
Gabion*	2020	181	2,793,101	Annual
	2022		>1,500,000	
Shell Reef	2020	NA	9,000,000	
	2020	NA	200,000 (Adults)	
	2021	NA	7,300,000	
	2022	NA	1,500,000	
Reef Balls	2024	80 seeded 160 unseeded	8,900,000	

*All gabion structures were removed in June 2024 but the oysters and shell materials from the gabions were placed on the shell reef.

Oyster Performance

Soundview Park Shell Mound Reef

Growth: Positive

Mean shell height of live oysters across the shell mound reef increased from 93.9 mm (SD = 16.9, N = 53) in 2024 to 94.1 mm (SD = 14.4, N = 178) in 2025 (**Figure 30**, **Table 43**). This increase aligns with existing growth trends observed across the nine seeded shell mounds, indicating that site conditions are supportive of oyster growth.

Mortality: High

Annual mortality increased from 39.6% (N = 53) in 2024 to 58.4% (N = 178) in 2025 (**Table 43**). This increase may be influenced by several environmental factors, including a reduction in chlorophyll-a availability, which dropped from an average of 70 µg/L in 2023 to 30 µg/L in 2024 (NYC DEP, 2025). Reduced food availability could have contributed to the higher mortality observed in 2025 compared to 2024. Additional monitoring over time is necessary to determine whether this trend persists.

Recruitment: Low but variable

In 2022, several shell mounds were reseeded with 1,500,000 spat-on-shell. None of the shell mounds have been reseeded since 2022, and no recruitment was observed on any of the shell mound reefs during the 2024 monitoring season (**Figure 30**). However, during the 2025 monitoring, a single oyster with a shell height of 37 mm was observed on the unseeded shell mound J (which was installed in June 2024) and is evidence that recruitment is occurring on this substrate at this site.

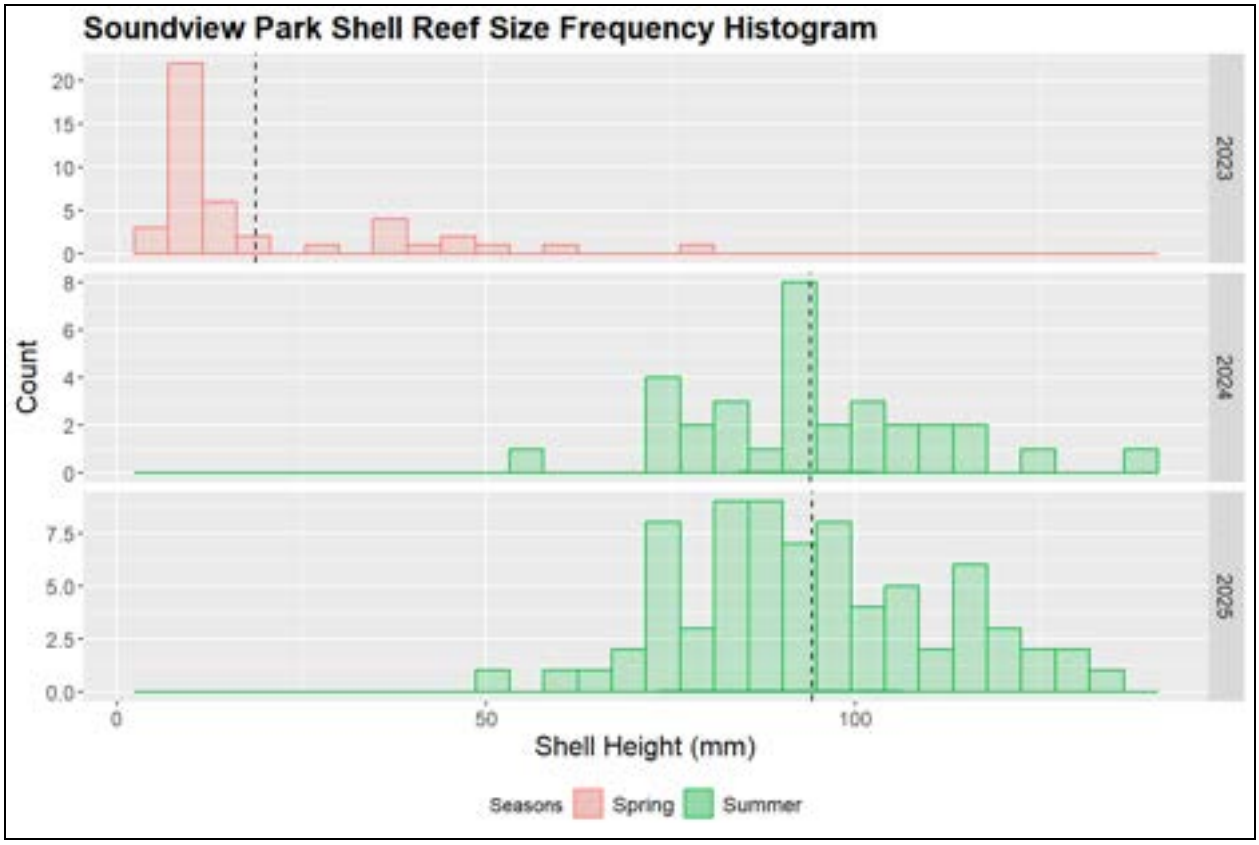

Figure 30. Size frequency histogram of live oysters in Soundview Park shell reefs, 2023-2025; dashed line represents seasonal mean shell height.

Table 43. Summary of oyster performance (sample size, mean shell height, and standard deviation (SD), and percent mortality) of Soundview Park shell reefs. For data prior to 2023, refer to Soundview Final Report 2018-2022.

Year	Sample Size of Oysters	Mean Shell Height (SD) of Live Oysters (mm)	Mean Shell Height (SD) of Dead Box Oysters (mm)	% Mortality	% Recruitment
2023	87	18.70 (17.62)	28.88 (18.51)	49.43%	0.00%
2024	53	93.91 (16.91)	73.81 (14.63)	39.62%	0.00%
2025	**178**	**94.09 (17.43)**	**79.25 (25.30)**	**58.43%**	**0.00%**

Soundview Park Bay Balls

Annual monitoring was conducted to evaluate oyster performance and overall reef health. Oyster performance was assessed in spring using low-tide wade surveys and in fall using dive-based monitoring. During spring monitoring, six seeded and nine unseeded bay balls were assessed; at a low tide of −1.48 ft, only the upper third of each bay ball was exposed, so six quadrats per bay ball were used. In fall, limited low-tide access prompted the use of dive-based monitoring to assess oyster performance at high tide. This non-destructive approach allowed evaluation of entire bay balls and provided greater scheduling flexibility compared to shore-based surveys. However, dive-based monitoring required careful timing to optimize visibility and was more time-intensive per oyster. As a result, only one quadrat per bay ball was assessed in fall, compared to six quadrats per bay ball during spring wade surveys.

Growth: Positive
Oyster growth showed a positive trend from spring to fall for both seeded and unseeded bay balls (**Figure 31**). Since the installation of oysters smaller than 5 mm in 2024, mean shell height increased from 52.2 mm (SD = 13.7, N = 794) in spring to 80.5 mm (SD = 25.0, N = 96) in fall (**Table 44**).

On seeded bay balls, live oysters grew from a mean shell height of 53.4 mm (SD = 12.8, N = 763) in spring to 83.1 mm (SD = 24.7, N = 91) in fall, while dead box oysters averaged 49.8 mm (SD = 13.1, N = 763) in spring and 45.9 mm (SD = 9.9, N = 91) in fall (**Table 44**). The decrease in mean shell height of dead oysters likely reflects the smaller sample size or additional mortality among smaller individuals by fall.

On unseeded bay balls, live oysters averaged 26.3 mm (SD = 7.8, N = 31) in spring and 57.4 mm (SD = 14.7, N = 5) in fall (**Table 44**), indicating continued growth among naturally recruited oysters.

Mortality: Stabilizing
Spring monitoring recorded 794 oysters across 15 bay balls, with a percent mortality of 7.3% (**Table 44**). This relatively low mortality may reflect the early timing of the monitoring event, when less time had elapsed for mortality to occur, as well as the placement of quadrats near the tops of bay balls, where oysters may be less vulnerable to marine predators due to periodic exposure at low tide. Mortality on the six seeded bay balls was similarly low at 7.6% and no dead box oysters were observed on the nine unseeded bay balls, resulting in a mortality rate of 0.0% (**Table 44**).

Fall monitoring documented 96 oysters across 15 bay balls, with a percent mortality of 49.0% (**Table 44**). Among the nine unseeded bay balls assessed, only five live oysters were observed, all on a single bay ball within Transect F. This pattern does not necessarily indicate increased mortality since spring, but likely reflects limited spatial coverage associated with single-quadrat sampling and reduced underwater visibility during dive-based monitoring, which hindered identification of live oysters. To improve data resolution and robustness, Billion Oyster Project plans to increase the number of quadrats per bay ball during future dive monitoring efforts.

Recruitment: NA
Spring monitoring documented 31 live recruits across nine unseeded bay balls, with a mean shell height of 26.3 mm (SD = 7.8) (**Table 44**). This total likely underestimates recruitment, as more than half of each bay ball was not visible at low tide. Nonetheless, the presence of recruits on bay balls installed nine months prior to monitoring indicates active wild oyster recruitment in the area.

Fall monitoring recorded five live recruits across nine unseeded bay balls, with a mean shell height of 57.4 mm (SD = 14.7) (**Table 44**). The lower number of observed recruits relative to spring likely reflects reduced underwater visibility and lower sampling effort (six quadrats per bay ball in spring versus one in fall). Continued monitoring of unseeded bay balls is needed to better characterize recruitment patterns at the site.

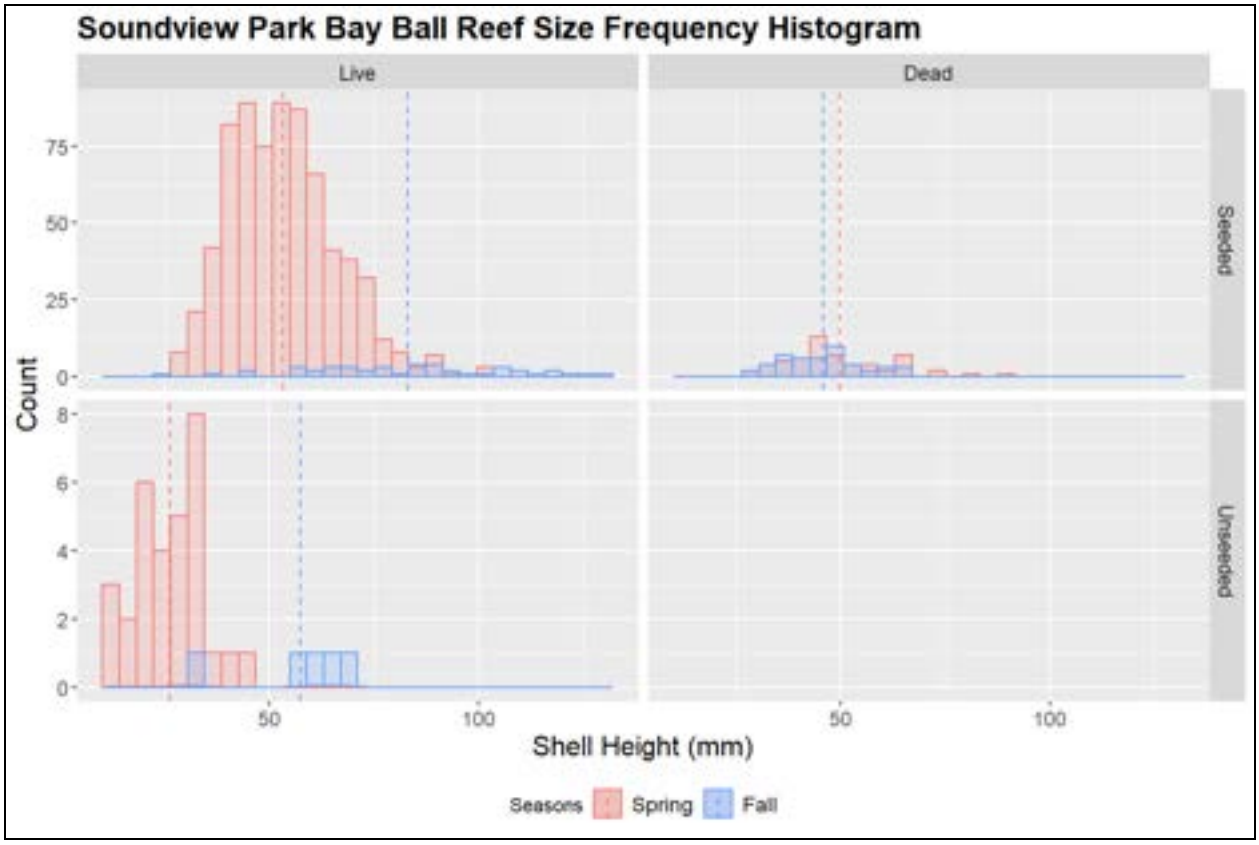

Figure 31. Size frequency histogram of seeded (top) and unseeded (bottom) bay balls during spring wade monitoring and fall dive monitoring in 2025 at Soundview Park; dashed line represents seasonal mean shell height.

Table 44. Summary of oyster performance (sample size, mean shell height and standard deviation (SD), percent mortality) of Soundview Park bay ball reef spring wade monitoring and fall dive monitoring in 2025.

Season	Structure Status	Sample Size of Bay Balls	Number of Observed Oysters	Mean Shell Height (SD) of Live Oysters (mm)	Mean Shell Height (SD) of Dead Box Oysters (mm)	% Mortality
Spring 2025 Wade Monitoring	Seeded	6	763	53.4 (12.8)	49.8 (13.1)	7.6%
	Unseeded	9	31	26.3 (7.8)	NA	0.0%
	All	**15 total**	**793**	**52.2 (13.7)**	**49.8 (13.1)**	**7.3%**
Fall 2025 Dive Monitoring	Seeded	6	91	83.1 (24.7)	45.9 (9.9)	51.7%
	Unseeded	9	5	57.4 (14.7)	NA	0.00%
	All	**15 total**	**96**	**80.5 (25.0)**	**45.9 (9.9)**	**49.0%**

Oyster Density

Oyster density was quantified using 0.04 m^2 quadrats on the surface of the structure. The sample size (N) in this section refers to the number of quadrats that had live or dead box oysters present, rather than the number of bay balls, and the number of quadrats per structure is determined by the monitoring lead staff and site conditions. Average quadrat mortality was calculated by first determining the percent mortality within each 0.04 m^2 quadrat across all bay balls, then computing the mean and corresponding 95% confidence interval (CI). The CI provides a measure of precision and indicates the range within which the

true average quadrat-level mortality is likely to fall. This metric reflects mortality at the quadrat scale, rather than across all individual oysters pooled together, and allows for an estimate of variance.

Soundview Park Shell Mound Reef

Quadrat monitoring of the shell mound reef has been conducted since its construction in 2020. However, the use of both quadrat and clump monitoring methods on the different mounds across years has made it difficult to establish consistent trends in oyster density over time. To address this, Billion Oyster Project standardized its 2025 monitoring approach by using 0.0929 m² quadrats — a larger quadrat size than that used for bay balls, but more practical for divers to handle underwater.

It is important to note that because of low underwater visibility during low tide, some quadrats for Shell Mounds D and A/B/C were not randomly selected, as divers had difficulty collecting oysters within each quadrat for surface monitoring. A total of 26 quadrats were assessed in 2025 but only 16 quadrats had live or dead box oysters present across all shell mound reefs. Nevertheless, results show a marked decrease in total oyster cover on the shell mound reefs, and in live oyster density, dropping from 49.2 live oysters per square meter (SD = 47.7, N = 7) in 2024 to 41.7 live oysters per square meter (SD = 50.5, N = 16) in 2025. Recruitment was only observed in 2023, when 206.3 live recruits per square meter (SD = 412.5, N = 4) were recorded, whereas no recruits were detected in 2025 (**Table 45**). Overall, quadrat mortality remained relatively stable across years, with values of 52.7% (CI = 42.2%, N = 4) in 2023, decreasing to 48.0% (CI = 25.2%, N = 7) in 2024, and rising again to 67.2% (CI = 14.5%, N = 16) in 2025 (**Table 45**).

Table 45. Oyster density, standard deviation (SD), quadrat mortality, and 95% confidence interval (CI) of Soundview Park shell reefs.

Year	# of Quadrats	Live Oyster Per Square Meter (SD)	Total Oyster Per Square Meter (SD)	Recruit Per Square Meter (SD)	Quadrat Mortality (CI)
2023	4	275.0 (423.8)	543.6 (679.9)	206.3 (412.5)	52.7% (42.2%)
2024	7	49.2 (47.7)	81.5 (66.3)	0.0 (0.0)	48.0% (25.2%)
2025	**16**	**41.7 (50.5)**	**93.5 (97.5)**	**0.0 (0.0)**	**67.2% (14.5%)**

Soundview Park Bay Balls

Spring Monitoring

Across all bay balls sampled via wading, a total of 90 quadrats were assessed but only 57 quadrats had live or dead box oysters present. The mean live oyster density was approximately 322.8 live oysters per square meter (SD = 258.8, N = 57) (**Table 46**). When including both live and dead oysters, the mean increased to 348.3 oysters per square meter (SD = 280.1, N = 57).

When comparing seeded and unseeded bay balls (N = 6 and N = 9, respectively), seeded bay balls exhibited a mean of 489.6 live oysters (SD = 171.4, N = 36) and 529.9 total live and dead box oysters per square meter (SD = 182.6, N = 36), while unseeded bay balls had a mean of 36.9 live oysters (SD = 15.0, N = 21). The same mean was observed when counting both live and dead oysters, as no dead oysters were recorded on the unseeded bay balls (**Table 46**). Given that the bay balls were installed less than a year before spring 2025 monitoring, it would be difficult to distinguish between the seeded and recruited oysters to calculate recruitment density on the bay balls, as both would be similar in size. Recruitment is

typically more accurately assessed in the fall dive monitoring.

Fall Monitoring

Across all bay balls sampled via diver, a total of 15 quadrats were assessed but only 6 quadrats on the seeded bay balls had live and dead box oysters present, none were found in the unseeded bay ball quadrats. Seeded bay balls exhibited a mean of 183.3 live oysters per square meter (SD = 111.4, N = 6) and 379.2 total (live and dead) oysters per square meter (SD = 146.1, N = 6). In comparison, no oysters observed on the quadrats placed on unseeded bay balls (**Table 46**). Divers observed 5 live oysters outside of the quadrats placed on unseeded bay balls. Recruitment was observed only on seeded bay balls, with a mean of 4.2 oysters per square meter (SD = 10.2, N = 6).

Table 46. Oyster density, standard deviation (SD), quadrat mortality, and 95% confidence interval (CI) of Soundview Park bay ball reef.

Season	Seeded/ Unseeded	# of Quadrats	Live Oyster Per Square Meter (SD)	Total Oyster Per Square Meter (SD)	Quadrat Mortality (CI)
Spring 2025 Wade Monitoring	Seeded	36	489.6 (171.4)	529.9 (182.6)	7.4% (1.8%)
	Unseeded	21	36.9 (15.0)	36.9 (15.0)	0.0%
	All	**57**	**322.8 (258.8)**	**348.3 (280.1)**	**4.7% (1.5%)**
Fall 2025 Dive Monitoring	Seeded	6	183.3 (111.4)	379.2 (146.1)	39.5% (32.5%)
	Unseeded	0*	NA	NA	NA
	All	**6**	**183.3 (111.4)**	**379.2 (146.1)**	**39.5% (32.5%)**

*A total of 9 unseeded bay balls were assessed but none of the quadrats contained live or dead box oysters.

These preliminary results highlight the potential effectiveness of seeding in enhancing oyster density. The observed decline in live and total densities from spring to fall is expected, as mortality is typically high during the first year post-installation, when oysters are small and particularly susceptible to predation and environmental stressors. Overall, quadrat mortality increased between sampling events, from 4.7% (CI = 1.5%, N = 57) in the spring to 39.5% (CI = 32.5%, N = 6) in the fall (**Table 46**). Seeded quadrat mortality rose from 7.4% (CI = 1.8%, N = 36) to 39.5% (CI = 32.5%, N = 6) (**Table 46**).

As stated previously, the high mortality rates may be due to the fact that smaller oysters are more susceptible to predation. Additionally, the higher oyster densities observed in spring may have intensified competition for space and resources, contributing to the increased mortality recorded in fall. Continued long-term monitoring will be essential to assess future recruitment dynamics, survival trajectories, and overall reef development across both seeded and unseeded structures.

Oyster Population Estimates

Annual population estimates across the reef substrates, calculated using annual mortality and recruitment data, are presented in **Table 47**. Although the gabion reefs were removed in 2024, any recovered oysters were transferred to the shell mound reef and, therefore, may be included in the population estimates.

Shell Mound Reef

The 2023–2024 report included population estimates only for 2023–2024, as annual percent mortality could be calculated from existing data. Earlier monitoring (2020–2022) focused solely on live oysters and therefore did not fully capture mortality trends since the 2020 installation. To address this gap, we applied the mean 2023 percent mortality (49.4%) to estimate populations for the missing years. This rate was chosen because it likely reflects mortality one year post-installation, consistent with seeding and reseeding efforts in 2020–2022. Using this approach, the projected 2024 population across all shell mounds decreased from approximately 5.5 million (based on 2023–2024 data) to about 1.2 million oysters (**Table 47**). This remains a conservative estimate, assuming similar mortality from 2020–2022. With the inclusion of 2025 data, the projected shell mound population is approximately 487,000 oysters (**Table 47**). Billion Oyster Project will continue refining analytical methods and monitoring approaches to fill data gaps and develop a long-term dataset that better captures mortality and recruitment trends.

Bay Balls

A single annual average for percent mortality and recruitment was not calculated for 2025 because the spring and fall surveys differed in sample size and methods. Instead, we report a range of population estimates to capture this variability. The spring wade monitoring provides the upper bound, while the fall dive monitoring reflects the lower bound due to higher observed mortality. Based on these data, the 2025 oyster population on bay balls is estimated to range from approximately 4.8 million (fall: 49.0% mortality, 5.2% recruitment) to 8.6 million oysters (spring: 7.3% mortality, 3.9% recruitment) (**Table 47**).

Sitewide

Incorporating these estimates from the shell mound reef and bay balls, the total projected oyster population at the site in 2025 ranges from approximately 5.4 million to 9.2 million oysters (**Table 47**).

Table 47. Estimated population dynamics across all structures at Soundview Park. NA indicates data is not available.

Structure	Year	Start Estimate + Installation	Annual % Mortality	Post Mortality Estimate	Annual % Recruitment	Population Estimate
Shell Reef	2020	9,200,000	49.4%*	4,652,874	<1 year old	4,652,874
	2021	4,652,874 + 7,300,000	49.4%*	6,045,131	<1 year old	6,045,131
	2022	6,045,131 + 1,500,000	49.4%*	3,815,929	<1 year old	3,815,929
	2023	3,815,929	49.4%	1,929,895	<1 year old	1,929,895
	2024	1,929,895 + 181,111 (gabion)	39.6%	1,274,570	0.0%	1,274,570
	2025	1,274,570	58.2%	532,871	0.6%	**532,871**
Bay Balls	2024	8,900,000	NA	8,900,000	<1 year old	8,900,000
	Fall 2025	8,900,000	49.0%	4,542,708	5.2%	**4,779,308 - 8,571,972**
	Spring 2025	8,900,000	7.3%	8,249,874	3.9%	
					Total Estimated Population	**5,312,179 - 9,104,843**

* Using mean percent mortality from 2023 (49.43%) to estimate annual mortality for the missing years (2020-2022).

Recommended Restoration Actions

Reseeding the Shell Mound Reef

Billion Oyster Project recommends reseeding as an adaptive management measure to support long-term reef development in a recruitment-limited system. Reseeding will increase oyster density, introduce overlapping age classes, and improve reproductive success by counteracting low-density effects on fertilization. This approach is consistent with accepted restoration practice in recruitment-limited estuaries and is expected to buffer against ongoing mortality, environmental variability, and episodic stressors.

Shell Mound J, installed in 2024, but without any spat on shell, should be prioritized for initial spat-on-shell seeding. The remaining nine shell mounds should receive additional cohorts at least once every other year to maintain population density and overlapping reproductive age classes. Longer intervals between reseeding events may reduce reproductive interaction among cohorts and limit population growth.

Install Bay Balls to Protect Shell Mounds

To address localized exposure and minor displacement, additional bay balls are recommended adjacent to Shell Mounds E/G to attenuate wave energy and stabilize existing shell mounds. Additional bay balls along the eastern portion of the reef footprint are also recommended to reduce the risk of future dispersion of Shell Mounds A/B/C.

Continue monitoring existing bay balls that were meeting most performance criteria in 2025.

SUNY Maritime

Project Summary

In 2025, Billion Oyster Project installed a floating nursery at SUNY Maritime and will maintain and monitor it with support from SUNY Maritime College students and Billion Oyster Project Ambassadors. This floating nursery was installed following the removal of the previous nursery at this site in 2021 due to pier construction.

Trends from 2025 data indicate:

- Positive growth between installation and monitoring dates.
- Expected mortality rate of approximately 23%, consistent with early-stage oyster development.

Site Overview

A total of 30 SuperTrays in stacks of three were installed as an oyster nursery, each stack is suspended to a line attached to the pier (**Figure 32**).

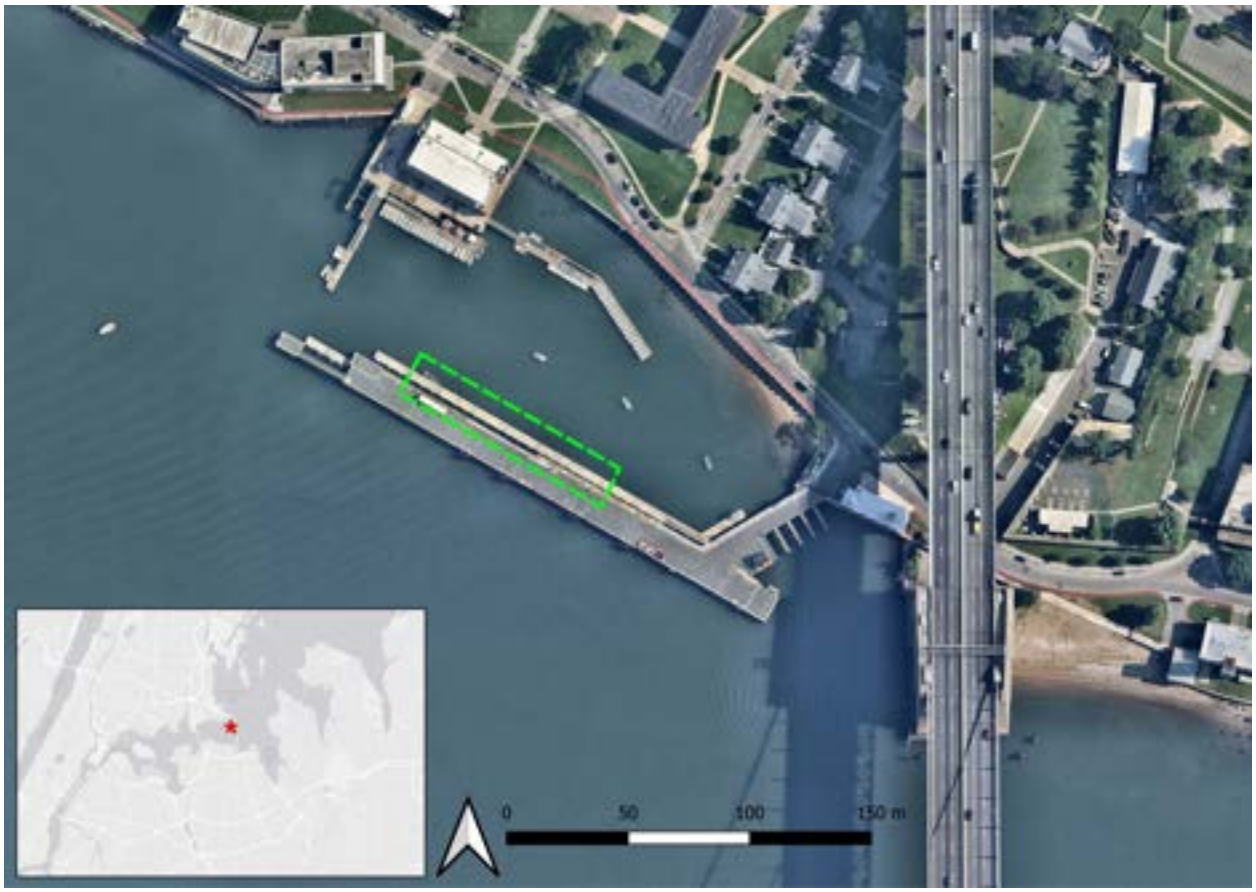

Figure 32. Map of SUNY Maritime nursery.

In 2025, approximately 595,000 million juvenile spat were introduced to this nursery (**Table 48**). Monitoring was conducted in fall 2025 with SUNY Maritime College students and faculty on the pier to assess oyster performance. During this monitoring event, Billion Oyster Project staff observed various fish and invertebrate species inhabiting the oyster shells within the structures, including skilletfish,

blackfish, cunner, goby, feather blenny and rock gunnel. A detailed list of fish species observed during fall monitoring can be found in the **Appendix, Figure A2**. Invertebrates included the presence of two Forbes sea stars (*Asterias forbesi*). These sea stars are feeding on various mollusks and are known to aggregate around bivalve beds such as oyster, mussel, and clam reefs where food is readily available. The presence of this species indicates that the oyster reef is functioning as an effective habitat and food source, supporting marine biodiversity and fostering shelter and reproduction (iNaturalist; Sealifebase).

Table 48. Summary of structures installed and spat introduced to the SUNY Maritime Nursery.

Structure Name	Year Installed	Quantity of Structures	Spat Introduced	Monitoring Frequency
SuperTray Nursery	2025	30	595,765	Annual

Oyster Performance

Growth: Positive

The 2025 cohort exhibited a positive growth trend, increasing from a mean shell height of 3–5 mm at installation on June 9th, to 30.2 mm (SD = 12.0, N = 756) during monitoring on November 21st for live oysters (**Figure 33, Table 49**). Between installation and the monitoring date, a growth rate of 0.18 mm/day was observed, highlighting continued growth over the five-month period.

Mortality: Stabilizing

Annual mortality of the 2025 cohort averaged approximately 22.9%, which is expected during the first few months of oyster growth and indicates overall survival and successful establishment of this cohort. (**Table 49**).

Recruitment: NA

Recruitment could not be quantified because the installation was less than one year old. Any recruits that may have settled prior to the fall monitoring period would be difficult to distinguish from installed individuals based on size.

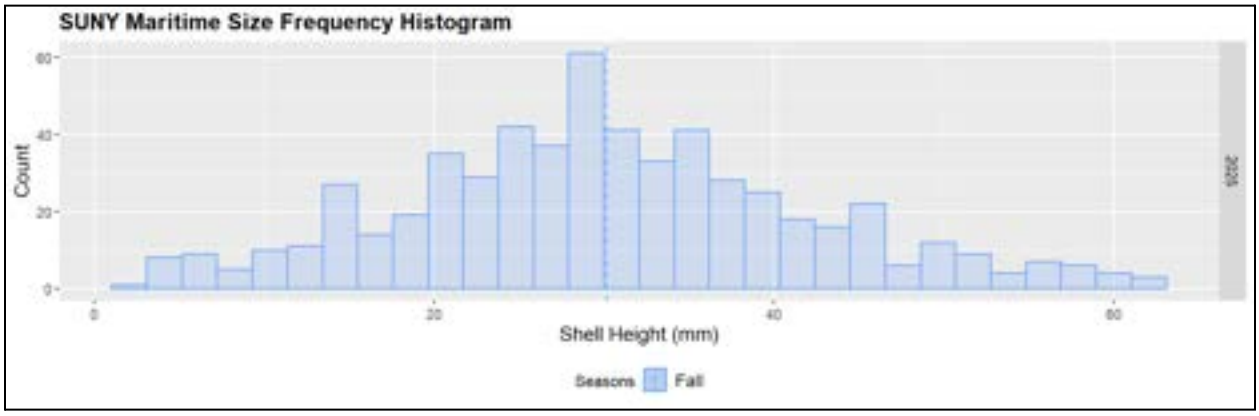

Figure 33. Size-frequency histogram of live oysters in SUNY Maritime, 2025. The dashed line represents the mean shell height.

Table 49. Summary of oyster performance at SUNY Maritime SuperTray nursery. NA indicates data is not available.

Year	Sample Size	Mean Shell Height (SD) of Live Oysters (mm)	Mean Shell Height (SD) of Dead Box Oysters (mm)	% Mortality	% Recruitment
2025	756	30.2 (12.0)	19.5 (10.1)	22.9%	<1 year old

Oyster Population Estimates

Taking into account the starting population and percent mortality, the total projected oyster population estimate at SUNY Maritime is 459,433 oysters (**Table 50**).

Table 50. Estimated population dynamics of SUNY Maritime SuperTray Nursery.

Cohort	Year	Start Estimate	Annual % Mortality	Post Mortality Estimate	Annual % Recruitment	Population Estimate
2025	2025	595,765	22.9%	459,433	<1 year old	**459,433**

Recommended Restoration Actions

The SUNY Maritime nursery will continue to serve as a floating nursery, with ongoing annual monitoring of oyster performance and data analysis of trends. We anticipate stable mortality levels and fluctuating annual recruitment. The SUNY Maritime nursery benefits from its off-bottom configuration because it experiences little or no sedimentation; previous cohort data suggest that the site is also favorable for oyster growth.

Pre-Installation

This section provides an overview of the site performance criteria that Billion Oyster Project conducts as part of the pre-restoration site investigation for an intertidal/subtidal oyster reef proposal. The purpose of all new projects is to (1) create a permanent oyster reef habitat informed by the research conducted in the pre-installation phase, (2) collect data on oyster performance and health and the success of restoration techniques of large-scale projects post-installation, and (3) continue to provide public engagement opportunities that reconnect people to the New York Harbor waterfront. Each project will also guide future oyster restoration practices at other sites in New York Harbor.

Pre-installation activities are organized into three major research areas: (1) oyster health & performance, and (2) estuarine community utilization, and 3) bottom type mapping and habitat conditions (**Table 51**). Billion Oyster Project, partner experts, and community scientists will work together to characterize the changes in oysters and benthic communities. Data collected for estuarine community utilization, bottom type mapping, and habitat conditions will be used to inform design and permitting of the site.

Table 51. Pre-installation activities for new sites.

Research Area	Protocol	Parameters	Frequency	Method
Wild Oyster Health and Performance	Recruitment	Spat Count	Annually, once in Fall	Lodge et al. 2017
	Disease (optional)	Disease Intensity & Prevalence	Once, late Summer or Fall	Levinton et al. 2013 (Tissue Inspection)
	Reproduction (optional)	Gonad Condition Sex Ratio	Once in Summer	Levinton et al. 2013 (Tissue Inspection)
Estuarine Community Utilization	Benthic Characterization	Biodiversity Abundance	Once, late Summer or Fall	Taghon et al. 2018 (Van Veen or Petite Ponar Grab Samples & Sieving)
	Epibenthic Characterization	Biodiversity Abundance	Once, late Summer or Fall	Fitzgerald et al. 2020 (Diver w/ Clearwater Box)
	Mobile Characterization	Biodiversity Abundance	Traps Annually, thrice per year Spring, Summer, & Fall Seining Annually eDNA Annually (optional)	Able et al. 2005, Baggett et al. 2024 (draft conceptual fish monitoring plan), Kumar et al. 2022 (eDNA for turbid waters), McCann et. al, 2018 *(Exploring eDNA)*
Bottom Type Mapping and Habitat Conditions	Mapping	Hydrographic Surveys	Once	Side-scan Sonar Multibeam Sonar
	Bottom Type Characterization	Sediment Characterization	Once	Van Veen or Petite Ponar Grab Samples & Sieving

2025 Pre-Installation Activities

Table 52 summarizes the pre-installation activities completed in 2025 at Bush Terminal Park, Flushing Bay, Paerdegat Basin, and Hudson Reef. Billion Oyster Project was unable to conduct any pre-installation activities at Four Sparrow Marsh in 2025. Following the abundant wild oysters observed during the 2024 wild oyster surveys at the Western Long Island Sound sites, Billion Oyster Project collected wild oysters from Flushing Bay for laboratory testing to assess disease load and reproductive maturity. Data collected from these pre-installation activities can be requested through Billion Oyster Project's website.

Table 52. Pre-installation activities completed 2025. NA indicates the pre-installation activity was not needed or completed prior to 2025.

Pre-Installation Activity	Bush Terminal Park	Flushing Bay	Paerdegat Basin	Hudson Reef	Turtle Cove	Powell's Cove	Pugsley Creek
Wild Oyster Survey	Completed	Completed	NA	Ongoing	Completed	Completed	Completed
Disease (Wild Oyster)	NA	Completed	NA	NA	NA	NA	NA
Reproduction (Wild Oyster)	NA	Completed	NA	NA	NA	NA	NA
Mobile Characterization	Completed	Completed	Completed	Completed	Completed	Completed	Completed
Benthic Characterization	NA	NA	Completed	2026	NA	NA	NA
Hydrographic Surveys (Side-scan and Multi-beam)	NA	NA	Completed	Completed	NA	NA	NA
Hydrologic Study	NA	Completed	NA	NA	NA	NA	NA
Wave/Fetch Analysis	NA	Completed	NA	NA	NA	NA	NA
Bottom Type Characterization	NA	NA	NA	2026	NA	NA	NA

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Appendix

2025 Fish Biodiversity Data

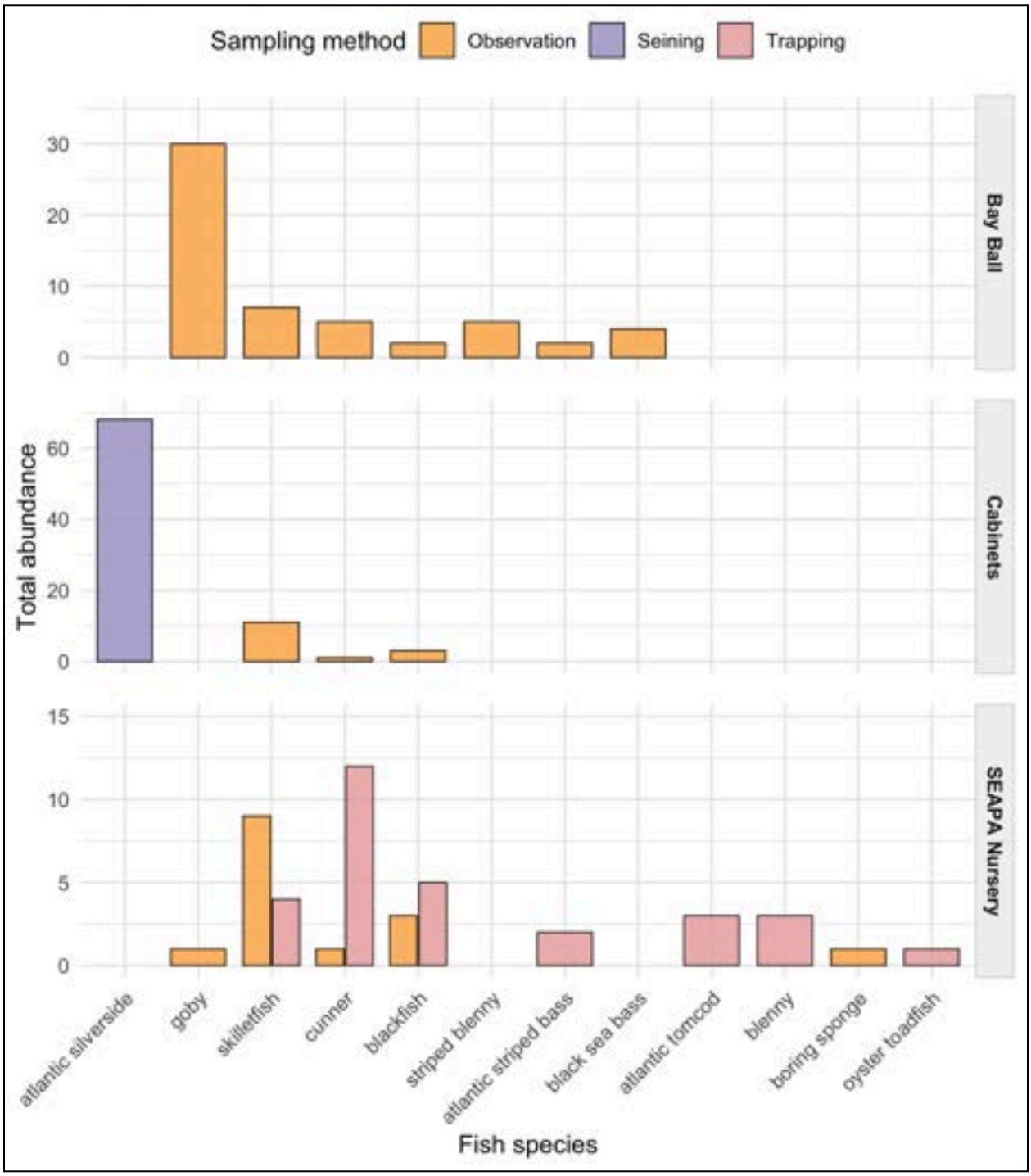

Figure A1. Fish abundance sampled during observations, seining and trapping, aggregated across spring, summer, and fall 2025 at Brooklyn Bridge Park cabinet reef, SEAPA nursery, and bay ball reef. Number of sampling days N = 24.

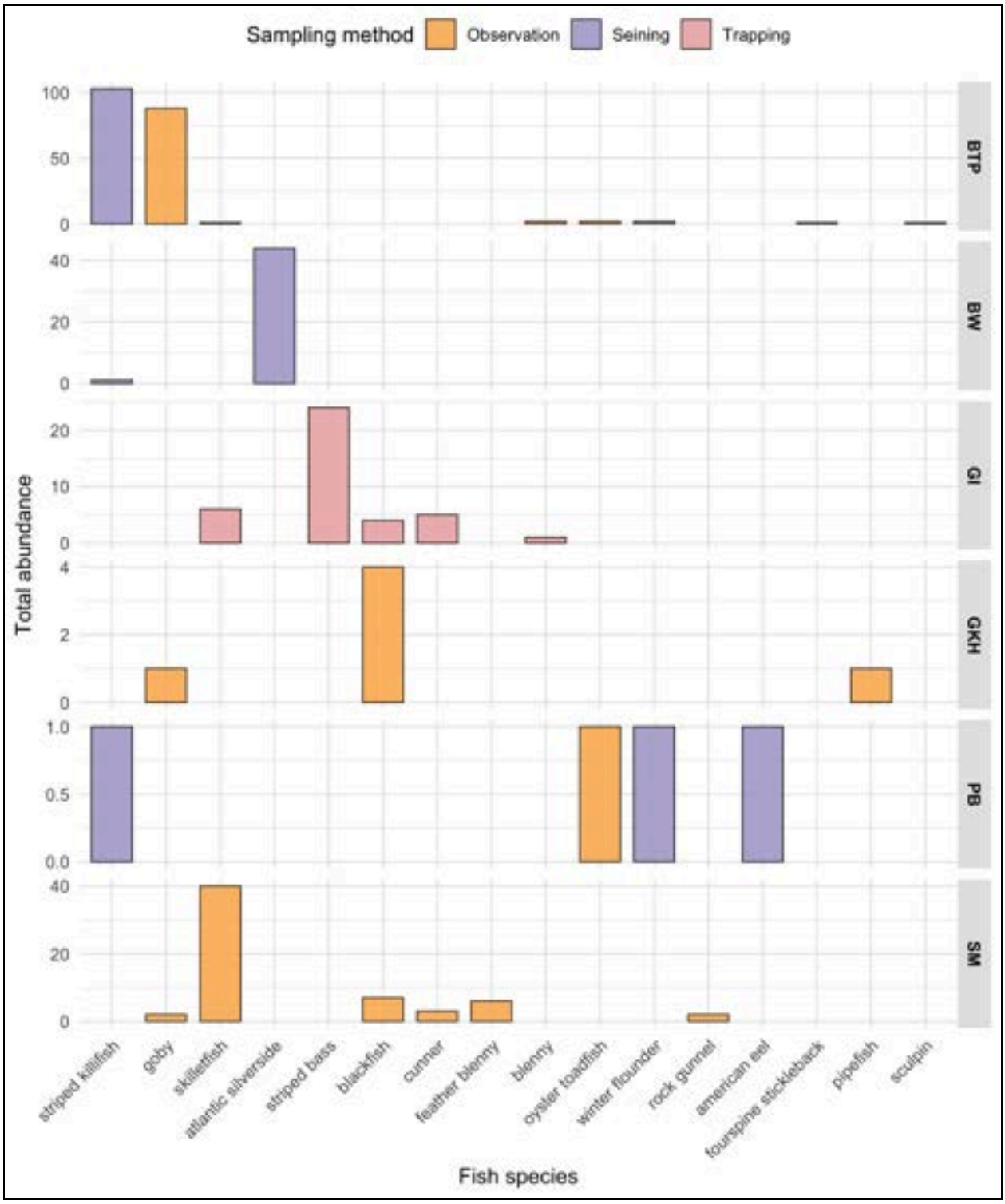

Figure A2. Fish abundance sampled during observations, seining and trapping, aggregated across spring, summer, and fall 2025 at Bush Terminal Park (N = 6), Bayswater Point State Park (N = 1), Governors Island (N = 13), Great Kills Harbor (N = 1), Paedergat Basin (N = 1), and SUNY Maritime (N = 1). N = Number of sampling days.