# Juvenile Surfclam Survival and Growth to Support Enhancement of Sustainable Fisheries

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# Juvenile Surfclam Survival and Growth to Support Enhancement of Sustainable Fisheries

Final Report

Prepared for:

**New York State Energy Research and Development Authority**

Albany, NY

Morgan Brunbauer

Senior Project Manager

Prepared by:

**Rutgers University, The State University of New Jersey**

New Brunswick, NJ

Daphne Munroe

Professor

Ailey Sheehan

Technician

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# Abstract

Offshore wind leases and areas planned for offshore wind development have the potential to reduce access for surfclam fishermen to catch clams within turbine arrays, some of which overlap with important clam fishing areas (Scheld et al. 2022). To mitigate potential loss of access to commercial fishing grounds, we performed an experiment to assess the feasibility of enhancing surfclam fishing grounds by planting hatchery-produced clams. Surfclams of two size classes, small (24 mm) and large (30.5 mm) nursery-reared clams, were transported from a Maine-based hatchery to an experimental site off the coast of Atlantic City, NJ. This study sought to determine the growth and survival of hatchery-reared surfclams planted in large-scale deployments at natural surfclam habitats in the coastal ocean, and whether survival is improved by planting larger or smaller clams. Additionally, surfclam seed was deployed in two forms: (1) freely in the sediment as they live in the wild, and (2) contained in cages designed to mitigate predation. A science crew and divers executed this project aboard the R/V *Ocean Explorer*. The first deployment took place in October 2023, with two additional sampling efforts in June 2024 and December 2024 to evaluate surfclam performance. Surfclams showed signs of growth and survival in June, and the predation cages effectively excluded predators. The final sampling in December 2024 revealed that the experiment site served as a site for wild seeds to settle.



# Keywords

Atlantic surfclam, enhancement, growth, fisheries



# Acknowledgments

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# Acronyms and Abbreviations

| | |
|---|---|
| CH | chondrophore height |
| CTD | conductivity, temperature, and depth |
| DOPPIO | Data-Assimilative Regional Ocean Model |
| LEO-15 | Long-Term Ecosystem Observatory |
| NJDEP | New Jersey Department of Environmental Protection |
| NYSERDA | New York State Energy Research and Development Authority |
| R/V | research vessel |
| RMI | Research and Monitoring Initiative |
| ROMS | Regional Ocean Modeling System |
| ROSA | Responsible Offshore Science Alliance |
| YSI | EXO Sonde 3 |

# Units of Measurement

| | |
|---|---|
| $^0$C | degree Celsius |
| ± | plus or minus |
| ~ | approximately |
| < | less than |
| > | greater than |
| clams/L | clams per liter |
| clams/m$^2$ | clams per square meter |
| cm | centimeters |
| ft | feet |
| g | grams |
| ha | hectares |
| km | kilometers |
| kN | kilonewton |
| kN/g | kilonewton per gram |
| L | liter |
| lb | pounds |

| | |
|---|---|
| Lg | large |
| m | meters |
| mm | millimeters |
| mm/day | millimeters per day |
| *n* | sample size |
| psu | practical salinity units |
| SD | standard deviation |
| SL | shell length |
| Sm | small |
| µm | micrometer |

# Executive Summary

Existing offshore wind leases and the potential development of future offshore wind leasing may occupy over 8% (22.237 million acres) of the total benthic habitat of the Atlantic outer continental shelf (BOEM and NOAA 2022). In many instances, this development overlaps with commercial fishing areas and could reduce access to economically important species such as the Atlantic surfclam (*Spisula solidissima solidissima*) (Scheld et al. 2022).

To mitigate potential losses of fishing opportunities, the New York State Energy Research and Development Authority (NYSERDA) required developers awarded the 2020 Offshore Wind Solicitation to submit a fisheries mitigation plan, which included options for a commercial fisheries compensation plan (NYSERDA 2022). One possible approach for offshore wind projects that overlap with Atlantic surfclam fishing grounds could be to produce surfclam seed in an aquaculture setting (hatcheries and nurseries). The seed would be deployed on fishing grounds to enhance fishing opportunities outside of offshore wind lease areas. Although a recent study demonstrated that this mitigation strategy may be feasible for surfclams (Gilsinan et al. 2024), many uncertainties remain to fully understand the potential for this strategy to be successful. Primary among those uncertainties is the survival and growth of hatchery-reared surfclams when deployed on fishing grounds on the continental shelf.

## ES.1 Objectives

Through collaboration with State and regional research organizations, and representatives of the commercial fishing industry, a potentially effective fishery enhancement strategy was identified to mitigate impacts on the surfclam fishery. This strategy would supplement the surfclam stock by introducing a stable supply of resilient recruits into the system at a size that supports survival to a fishable condition. Fishery enhancement improves stock productivity and can include mechanisms to enhance or improve habitat or supplement target populations (Taylor et al. 2017). In the case of surfclam enhancement, this strategy would strive to create relatively high-density beds of fishable surfclams in locations that avoid conflicts with offshore wind and are within reasonable access to fishing ports, thereby supporting the fleet's sustainability and productivity.

The field experiments executed herein were built on nearly a decade of experiments conducted at Rutgers University in the Munroe Laboratory that examined hatchery, nursery, and farm grow-out conditions for cultured surfclams (Acquafredda et al. 2019, 2021, 2022, 2025). The Munroe Lab worked with a Maine-based hatchery that supplied surfclams used in this project. Additionally, Captain Tom Dameron, a former surfclam fishing captain, served as a fishing industry advisor for the project. Our approach hypothesized that larger hatchery-reared surfclams would show increased burial success and, subsequently, reduced mortality after deployment compared to smaller hatchery-reared surfclams. This is because as surfclams grow, they become increasingly resilient to predators as they approach or exceed predator refuge body size. However, the improved survival of larger clams is associated with higher production costs because they require additional time and resources to maintain nursery conditions. The hypothesis further proposed that the survival benefits of planting larger clams would outweigh the additional hatchery costs only up to a point where those costs exceed any additional gains in seed survival.

## ES.2 Methods

This study aimed to guide future surfclam fishery enhancement efforts by determining the appropriate size at which hatchery-grown surfclams should be introduced to the marine environment. Surfclams of two size classes, 24 and 30.5 mm, reflecting small- and large-nursery-reared clams, were transported from Casco, ME, and deployed off the coast of Atlantic City, NJ. Over 14 months, the surfclams were monitored to quantify survival and growth. Additionally, sediment composition and environmental parameters were examined at the experiment site.

## ES.3 Outcome

After 7 months, the experiment observed higher growth rates in dead and live surfclams enclosed in predation cages and in the control group than in surfclams dispersed freely in the sediment, although all treatments showed signs of growth and survival from October 2023 to June 2024. We compared size classes within the caged treatment and found no significant difference in growth rates between large and small clams. The predation cages also proved a potentially viable method of excluding predators such as moon snails from penetrating the seed. In December 2024, 14 months following the initial deployment, signs of wild surfclam survival were confirmed; however, hatchery-raised surfclam presence was only observed in the form of single dead shells.

# 1. Introduction

Existing offshore wind leases and the potential development of future offshore wind leasing may occupy over 8% (22.237 million acres) of the total benthic habitat of the Atlantic outer continental shelf (BOEM and NOAA 2022). In many instances, this development overlaps with commercial fishing areas and could reduce access to economically valuable species such as the Atlantic surfclam (*Spisula solidissima solidissima*) (Scheld et al. 2022).

To mitigate potential losses of fishing opportunities, the New York State Energy Research and Development Authority (NYSERDA) required developers awarded the 2020 Offshore Wind Solicitation to submit a fisheries mitigation plan, including options for a commercial fisheries compensation plan (NYSERDA 2022). One possible approach for offshore wind projects that overlap with Atlantic surfclam fishing grounds could be to produce surfclam seed in an aquaculture setting (hatcheries and nurseries). The seed would be deployed on fishing grounds to enhance fishing opportunities outside of offshore wind lease areas. Although a recent study demonstrated that this mitigation strategy may be feasible for surfclams (Gilsinan et al. 2024), many uncertainties remain to fully understand the potential for this strategy to be successful. Primary among those uncertainties is the survival and growth of hatchery-reared surfclams when deployed on fishing grounds on the continental shelf.

The Munroe Lab at Rutgers University, in collaboration with an aquaculture facility in Casco, ME, and a Project Advisory Committee that included Tom Dameron (surfclam fishing captain and fishing industry advisor), Sam Martin (surfclam and scallop fishery representative), Colleen Brust (New Jersey Department of Environmental Protection, or NJDEP), and Reneé Reilly (Responsible Offshore Science Alliance, or ROSA), developed an experiment that examined the growth and survival of hatchery-reared surfclams planted in large-scale deployments at natural surfclam habitats in the coastal ocean. These deployed clams were used to determine whether surfclam survival improves with larger clams, and whether those survival gains outweigh the hatchery costs of culturing to larger sizes.

# 2. Methods

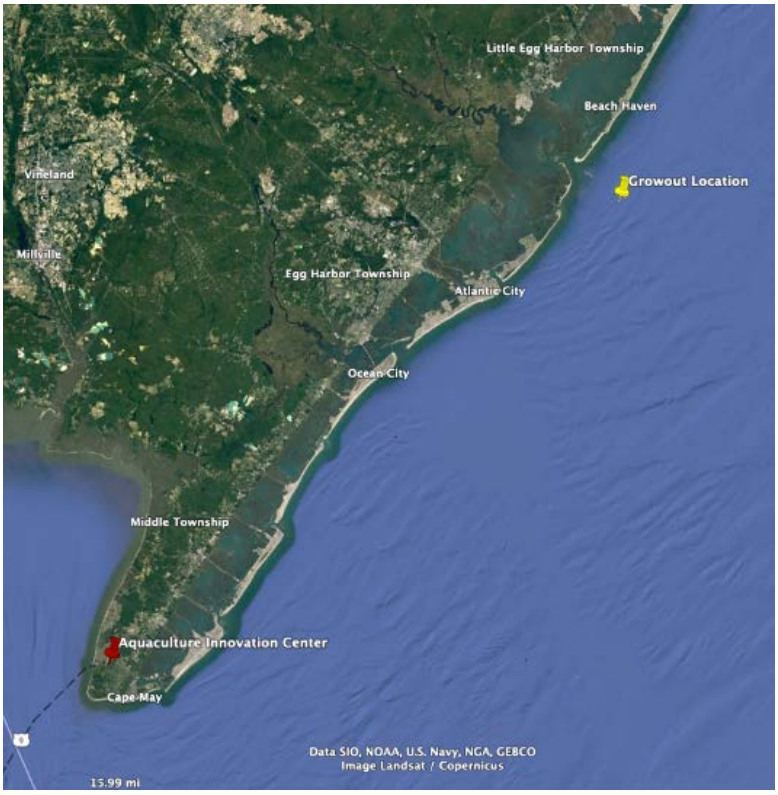
The project included several activities starting with project planning, sourcing and transportation of experimental animals, deploying and sampling the experiment, and processing samples in the laboratory. These activities are described in detail in the following sections.

## 2.1 Project Planning and Surfclam Acquisition

The experiment location was selected in consultation with surfclam industry advisors and the Project Advisory Committee, who provided industry insights and critical feedback to determine the final experiment location. The site selected was located off the coast of Atlantic City, NJ (Figure 1), and was selected based on its suitable bottom type for surfclams, appropriate bottom water temperature conditions, ideal depth for divers to operate for an extended period (approximately 10–12 m), availability of oceanographic data provided by Rutgers University–operated gliders (underwater autonomous vehicles) and historic time series. Locating the experiment somewhere that bottom-tending fisheries in the region could avoid was also imperative. Numerous surfclam observations around the Long-Term Ecosystem Observatory (LEO-15) site off the coast of New Jersey confirmed the suitability of the experiment site (Snelgrove et al. 1999, Weissberger and Grassle 2003, Ma et al. 2006, Quijón et al. 2007). To ensure bottom conditions were suitable for surfclam growth, we also examined bottom temperature near the LEO-15 site using two different data products. We examined bottom temperature from a data-assimilative Regional Ocean Modeling System (ROMS) of the Mid-Atlantic Bight model (DOPPIO) and from recent glider deployments. We analyzed these datasets for seasonal and interannual temperature trends.

**Figure 1. Field Experiment Location**

Location for experiment site off the coast of Atlantic City, NJ (pin in ocean labelled 'growout location').
*Source: Attachment 2 (NYSERDA 2023a).*




## 2.1.1 Transport and Deployment of Surfclams to Project Site

After establishing an experimental site, project subcontractors located in Casco Bay, ME, graded and cleaned surfclams in preparation for transportation to New Jersey in October 2023. In advance of interstate transport, a subsample of the surfclams (approximately 150 animals) was sent to Dr. David Bushek, state shellfish pathologist at Rutgers University, for disease testing. The clams were certified disease-free; Task 4 report, Attachment 1, provides the full histopathology report (NYSERDA 2023b).

Clams were sorted into two size classes, named for convenience as "large" and "small," and kept in mesh bags holding 70 L of clams each (Figure A-1). The large size class was retained on 30.5 mm mesh, with each mesh bag containing an average of 2,256 clams, or 33 clams/L. The small size class was retained on 24 mm mesh, with each bag containing an average of 4,538 clams, or 65 clams/L. Volume counts were used to assign the number of clams of each size to treatment plots during deployment, and tags were attached to each bag to indicate which treatment plot they would be deployed in.

On October 21, 2023, sorted clams were packed for transport in a refrigerated truck. Clams were delivered to a refrigerated holding facility at the Sea Watch dock in Atlantic City, NJ, for storage until deployment, and covered in wet burlap sacks to maintain moisture and clam health. A randomly selected subsample of 130 clams per size group was set aside for an initial lab evaluation of size variability, weight, and shell strength. Shell strength was measured as the force required to break the shell (Johnson 2021) on 50 shells from each size class using an Instron 34SC-1 compression machine.

### 2.1.2 Experiment Deployment

The experiment deployment took place from October 23, 2023, through October 26, 2023, aboard the R/V *Ocean Explorer* with five scuba divers and six science crew. The surfclam transport from the Sea Watch holding facility was timed around weather and vessel safety considerations to ensure marine operations could begin within 24 hours of surfclam arrival at the launch point.

#### *2.1.2.1 Experiment Setup and Sediment Sampling*

The first day of the deployment solely focused on site layout and preparation of experiment materials and took place across three dive missions, each consisting of multiple dives.

During the first mission, divers (two teams of two divers each; Figure A-2) navigated the experiment site using a dive computer GPS to identify the outermost corner points of the experimental plots (Figure 2). To ensure diver safety, divers rotated time in the water, stationing a diver or crew member in a dinghy anchored to the vessel for additional surface monitoring and communication. Each corner point was separated by approximately 49 m, such that the resulting plot encompassed 0.20 ha. The divers first deployed lightweight corner markers at the target waypoints, followed by 150 lb mushroom anchors with temporary large white polyballs to float at the surface for easy identification of each corner above water (Figure A-3). The wind and current slightly offset the final deployment locations from the original target waypoints. Nonetheless, the square plot was delineated, and its size met the original target measurements. The final deployment locations for each corner were confirmed using side scan sonar (Table 1). Finally, the experiment's outside perimeter was set by dropping premeasured 150 ft lines connecting the corner markers.

On the second dive mission, divers installed a pre-spaced and tagged grid of lines within the outside perimeter. At each node in the grid, pre-attached circular metal tags were attached with a unique identifier that allowed divers to orient within the grid; the schematic in Figure 3 shows the node and grid layout. The entire grid was sectioned into six experimental plots labeled S1, S2, S3, L1, L2, and L3, where "S" indicates that this plot was to receive small surfclam size class and "L" indicates plots in which large surfclams were to be deployed.

On a final dive, sediment core samples (7 cm in diameter and 5 cm deep) were collected in pre-labeled jars for analysis and characterization of bottom type at the site. Samples were collected from the boundary around the experimental site (sample size, $n$ = 4) and from within the center of each experimental plot ($n$ = 6). These samples were taken at nodes 4, 9, 11, 13, 22, 28, 37, 39, 41, and 46 (Figures 3 and 6). Core samples were stored in coolers aboard the vessel before transport to the lab for subsequent analysis.

**Figure 2. Schematic of Experiment Grid**

Experiment grid with corner points marked by a circles connected by dotted lines, as seen on vessel sonar. Each corner was spaced about 49 m apart. Numbered solid lines show bottom bathymetry in feet.

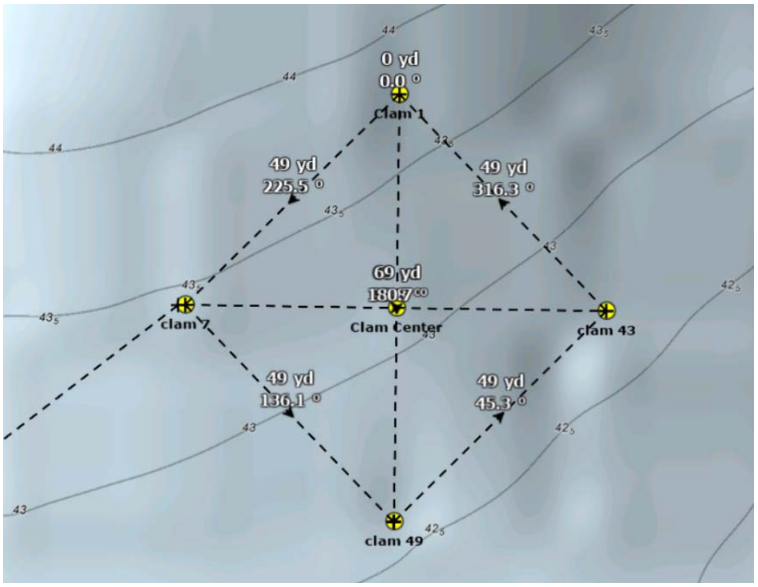


**Figure 3. Layout of Grid Nodes**

Layout of this grid with nodes and size class plot orientation. Plots labeled "L" indicate the large size class and plots labeled "S" indicate the small size class. Nodes with circles outlined indicate corners of the six experimental plots.

*Source: Task 5 Report (NYSERDA 2023c).*

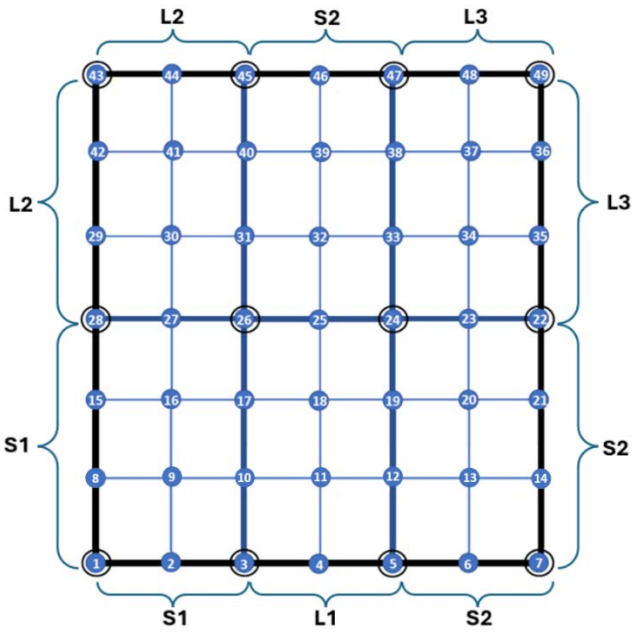



**Table 1. Experiment Coordinates**

Coordinates for experiment corner and center point, with associated grid node number.

| Node | Latitude | Longitude |
|---|---|---|
| 1 | 39°27.2734 | 074°15.0798 |
| 7 | 39°27.2565 | 074°15.1021 |
| 49 | 39°27.2391 | 074°15.0804 |
| 43 | 39°27.2560 | 074°15.0584 |
| 25 | 39°27.2563 | 074°15.0801 |

## *2.1.2.2 Deploying Clams*

After installing the grid, divers dispersed surfclam seed and six predation cages over the second and third deployment days. About 27,228 small clams were seeded per replicate, at an average density of 68 clams/$m^2$, and about 13,536 large clams were seeded per replicate, at an average density of 34 clams/$m^2$. Two dive missions took place on the second day, plus an additional dive to digitally record clam activity. The first mission aimed to plant clams in the S1, L1, and S2 plots, dispersing six bags of clams per plot. The second mission deployed predation cages in the same plots that were seeded in the first mission. Each cage held four rigid rectangular plastic mesh

pouches (bags) with 40 clams per bag of the respective size class of the plot they were deployed in (Figure A-4, Panel A). Bags containing the different size classes of clams were marked with zip ties (Figure A-4, Panels B and C). The S1 and S2 cages were placed at the exterior corner of the grid at nodes 1 and 7 and tied to their nearby mushroom anchors, while the L1 cage was tied to the grid itself. For additional stability on the ocean bottom, a helical anchor was screwed into the bottom and attached to each cage (Figure A-4, Panel D). After the first two missions, the divers used a GoPro digital camera to record footage of the seafloor and clam burial activity, navigating back and forth from nodes 2-27, then 4-25, and finally 6-23.

Clam dispersal continued through the third deployment day over two missions, the first to seed clams in the remaining plots and the second to deploy the remaining predator cages. The divers planted seed in the L2, S3, and L3 plots across three separate dives. The divers then deployed the remaining three predation cages in the same treatment plots, at nodes 43, 46, and 49. Cage 49, located in plot L3, differed from the other five predation cages in that it contained two bags from each size class. All cages were again equipped with helical anchors and anchored to the mushroom anchors at nodes 43 and 49 or the grid at node 46. Video of clam burial activity was not possible during this deployment day because of high turbidity and low visibility.

#### *2.1.2.3 Cape Shore Clams*

On October 24, 2023, the second day of the four-day deployment, a subset of surfclams was transported to Rutgers University's Cape Shore facility in Cape May, NJ. These clams served as the control group and were placed in oyster farm gear (rack-and-bag) to compare their performance in a farm-like environment to that in the ocean at the experimental plot. No size class separation was used when deploying the control group.

#### *2.1.2.4 Oceanography*

The final dive mission on day three of the experiment deployment was to deploy a YSI EXO Sonde 3 to record environmental data throughout the experiment. The sensor was mounted in a metal frame that was attached to the predation cage at node 49 in plot L3 (Figure A-5). The YSI was equipped with four sensors (temperature, salinity, pH, and dissolved oxygen), and recorded a single data point every 2 hours. All sensors were calibrated prior to deployment. A Castaway conductivity, temperature, and depth (CTD) instrument provided additional oceanographic data to capture the water column temperature and salinity at the time of the deployment. Additional CTD casts were made at the 6- and 12-month sampling events.

### 2.1.2.5 Burial Success Assessment

The fourth and final deployment day filmed clam activity within 24 hours following clam dispersal using a GoPro digital camera, and replaced the temporary surface polyballs with subsurface buoys (Figure A-6). A single diver recorded video over two dives. Due to poor visibility, filming attempts were halted until later in the day with the expectation that visibility would improve. Visibility did not improve, and final videos could not be obtained. The large white polyballs at the site corners were replaced with smaller buoys suspended 3 m above the bottom on each of the corner mushroom anchors. This replacement removed all surface-associated floats and lines to minimize risk to sea life, and replaced them with a bottom float that could be located with sonar on subsequent trips to the site.

While divers were unable to gather video data 24–48 hours after clam placement, footage recorded roughly 1 hour after clam deployment was sufficient to evaluate burial behavior. Videos were evaluated at half speed, quarter speed, or frame-by-frame as needed to assess each clam's status. Each clam in the videos was categorized as not buried (lying on its side) or buried (actively burying into the sediment by probing with the foot or being partially or nearly fully buried in sediment).

### 2.1.2.6 Sediment Analysis

Sediment samples returned to the laboratory were stored frozen in labeled jars until processing. Upon processing, samples from each grid location were defrosted and subsampled into two halves. One-half was processed for grain size and organic content, and the other half for meiofauna community identification.

To analyze grain size, each sediment core sample was placed in a pre-weighted tin pan and dried in a drying oven for at least 24 hours at $60^0$C to achieve a consistent moisture-free weight. After removal from the oven, samples were gently homogenized with a mortar and pestle to break apart any remaining clumps. Each sample was weighed and then placed in a Wentworth-grade sieve stack consisting of mesh sizes 2 mm, 1 mm, 500 µm, 250 µm, 125 µm, and 63 µm, with a bottom pan. The size fraction >2 mm was separated by hand into two tin pans: shell fragments and non-shell fragments. The sieve stack was placed on an automatic shaker for 15 minutes, then all sediment pieces from each mesh size were transferred into a pre-labeled and pre-weighed tin pan. Samples were re-dried separately at $60^0$C overnight, then each dried fraction was weighed.

The second half of each subsample was used to evaluate the presence and abundance of juvenile (younger than 1 year old) wild surfclams as well as other meiofauna. Each sample was sorted through a 1 mm mesh sieve, then bivalves were categorized by species and counted. All bivalves were photographed using an Olympus SZX-10 microscope equipped with a Lumenera Infinity 1 digital camera at 10x magnification, and shell lengths were recorded using ImageJ software. Shell images were visually inspected to determine if an individual surfclam was dead prior to capture based on the presence of the periostracum. This was used to approximate the proportion of dead and live wild surfclams.

## 2.2 Surfclam Monitoring

### 2.2.1 6-Month Surfclam Monitoring

Seven months after the initial deployment, on June 15–16, 2024, the R/V *Ocean Explorer* returned to the experiment site to collect samples to evaluate surfclam survival, growth, and overall condition at each of the six experimental plots. Upon arrival at the experiment site, researchers discovered that the corner markers and cages had been dragged offsite, presumably by a fishing vessel.

#### *2.2.1.1 Field Sampling*

Despite the disturbance to the grid, crew members located the locations where surfclams had been distributed using the coordinates recorded from the initial deployment in October 2023 (Table 1). Divers captured GoPro digital camera footage of the seafloor around where marker 49 was originally deployed, followed by two dives to collect live and dead clams. During the first dive, samples lying on the seafloor surface were manually collected into mesh bags. These samples were processed in the field, and both live and dead shells were measured for shell length (SL; longest dimension in mm). Any clams bearing a hatchery mark, a distinct disturbance check in the shell laid down at the deployment site (Beal et al. 1999), were deemed to be from the original deployment in fall 2023, and not a wild clam. Shell length at the time of initial deployment (hatchery mark) and final shell lengths at the time of capture were recorded for each animal collected (mm, Figure A-7). Wild clams were measured for shell length as well, and all processed shells were given a unique shell ID and retained in sample bags. Live clams were stored in coolers in the field for transport to the lab for further processing. Samples were

recovered in the second dive using a suction dredge (Figure A-8) by placing a hose with an attached mesh bag over the seafloor while the dredge was active. Mesh bags were brought to the surface using lift bags, then sorted on deck, bagged, labeled, and stored in coolers for lab processing.

On June 16, 2024, day two of the sampling effort, divers conducted three dives using the suction dredge to collect clams within plot L3. During the first dive, divers excavated sediments from a quadrat approximately 10 cm deep, and excavated a 1 $m^2$ area using an open-bottom aluminum frame that divers pushed into the ocean bottom. Samples that were measured in the field were labeled with a shell ID and retained. Any remaining samples were stored in coolers for lab processing. On both sampling days, predation marks caused by moon snails and any bycatch captured by the dredge were also recorded.

In addition to collecting clams that were distributed freely on the seafloor, divers located and retrieved the predator exclusion cage with the mounted YSI sensor. The cages were also damaged when the site anchors were dragged. With the use of lift bags, the divers delivered the damaged cages to the surface, and a crane hauled the cages onto the deck of the boat (Figure A-9). All bags were sorted through, and both live and dead clams were bagged, labeled, and stored in a cooler for subsequent lab analysis. The YSI was stored in a bucket of water to prevent the sensors from drying out on the return to the lab. Data were offloaded in the lab. Additional profiles of the water column temperature and salinity were recorded using a castaway CTD on both sampling days.

On June 19, 2024, 50 live surfclam samples were taken from the control group held at Rutgers University's Cape Shore for lab processing in addition to the samples retrieved from the experiment site. The 50 samples contained 3 animals from the small size class and 47 from the large size class.

#### *2.2.1.2 Surfclam Laboratory Processing*

In the laboratory, all samples that were not processed in the field were measured for deployment shell length (mm, if applicable) and final shell length (mm). Live clams from the experiment site and the Cape Shore facility were also processed for wet weight, dry weight, gonad condition, and gender. Growth rate was determined by subtracting the hatchery mark length from the final length and dividing by the number of days in the field. Predation marks, when present, were noted and photographed using an Olympus SZX-10 microscope equipped with a Lumenera Infinity 1 digital camera.

#### 2.2.1.3 Sensor Data

The YSI sensor remained hydrated in a calibration cup until June 18, 2024, when the data was offloaded, and a sensor post-calibration was performed. All sensors were cleaned and recalibrated.

### 2.2.2 12-Month Monitoring and Experiment Termination

On December 13, 2024, approximately 14 months after the initial deployment, the R/V *Ocean Explorer* returned to the experiment site to sample the grid for a second and final sampling.

#### 2.2.2.1 Field Sampling

The general location of plot L3 on the experiment grid was determined using the coordinates from the first deployment. Using the suction dredge, divers made multiple attempts to sample clams in this area, using lift bags to bring samples to the surface for sorting on deck. The vessel was repositioned to node 9 to conduct further quadrat sampling with the suction dredge. Surfclam shells were retained for lab processing, and additional bycatch was noted.

#### 2.2.2.2 Lab Processing

In the lab, each shell was assigned a shell ID, and the following metrics were measured: shell length (mm), shell width (umbo to growing edge), shell weight (weight of a single shell valve; g), presence of hatchery mark, hatchery mark length (mm), and hatchery mark width (mm). If a shell was too damaged to obtain accurate measurements, chondrophore height (CH) was measured and converted to shell length using a quadratic model from Chute et al. (2016):

Equation 1. $$\boldsymbol{SL = a + b1\,x\,CH + b2\,x\,CH2}$$

where:

- a = 1.22, $b_1$ = 9.17
- $b_1$ = 9.17
- $b_2$ = -0.12
- CH = chondrophore height (mm)
- SL = shell length

All fragments of damaged shells were also collected and weighed. The interior and exterior of each shell were photographed, as well as all predation holes (if applicable). Larger shells were photographed using an Elmo TT-12 document camera, while smaller shells were photographed with an Olympus SZX-10 microscope equipped with a Lumenera Infinity 1 digital camera.

# 3. Results

Data collected in this project represent environmental conditions in the experiment and growth and mortality processes for the clams used in the experiment. The various results indicated by those data are described in the following sections.

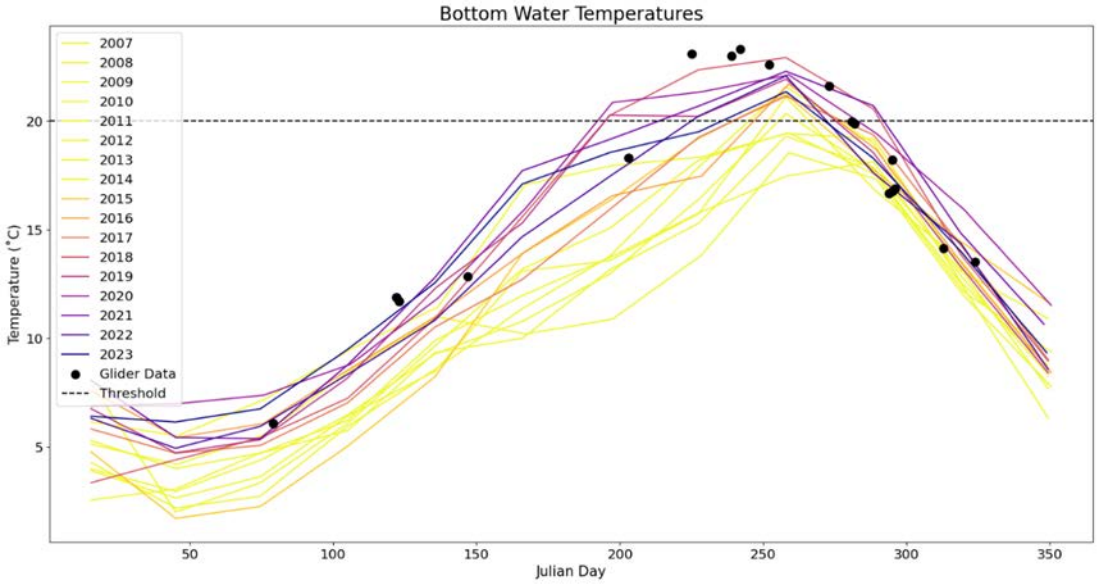
## 3.1 Experiment Site Validation

Data downloaded from the Assimilative Regional Ocean DOPPIO model showed that bottom temperatures near the experimental site from 2007–2023 vary seasonally between 2.5$^0$C and 25.6$^0$C. Peak average bottom temperature typically occurred in September (approximately 22$^0$C), and minimum average bottom temperature occurred in January or February (approximately 1$^0$C, Figure 4) (Bramich 2024). Glider temperature data collected near the bottom along the same bathymetry and within 12 km of the experimental site agreed with the DOPPIO simulated bottom temperature phenology (Figure 4) (Bramich 2024). These temperature conditions are suitable to support surfclams whose optimal temperature tolerance ranges from 2$^0$C to 22$^0$C (Narváez et al. 2015, Munroe et al. 2016, Hornstein et al. 2018, Czaja et al. 2024).

**Figure 4. Bottom Conditions Near the Experimental Site**

Annual average bottom water temperature trend lines colored by year, from DOPPIO showing 2007–2023. The black dots are 22 glider observations of temperatures collected near the bottom along the same bathymetry and within 12 km of the experimental site, shown in Julian days.

*Source: Bramich (2024).*



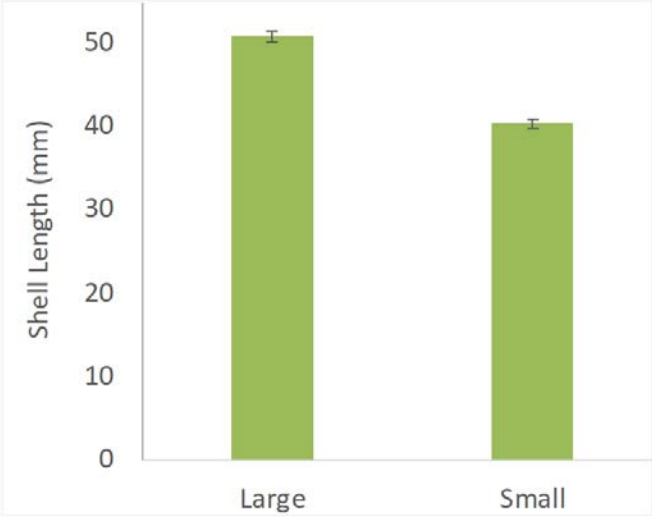
## 3.2 Pre-Deployment Evaluation

Prior to deployment, 130 clams from each size group were measured and weighed in the lab. The small size class had an average shell length of 40.5 mm (median = 40.4 mm, standard deviation (SD) ±3.0 mm) and an average dry tissue weight of 0.80 g (Table 4). The large size class measured 51.0 mm on average (median = 50.5 mm, SD = 3.5 mm) and had an average dry tissue weight of 1.56 g. The large group was significantly larger ($p<0.001$) with shells 20% longer than the small group (Figure 5). Finally, the force required to break shells of the small size class averaged 0.019 kilonewton per gram (kN/g) standardized to shell weight ($n$ = 50), and the large size class averaged 0.0005 kN/g to break ($n$ = 32).

**Figure 5. Pre-Deployment Size Classes**

Median surfclam shell length (mm) of large and small size classes prior to the October 2023 deployment. Error bars show SD.

*Source: Task 4 Report (NYSERDA 2023b).*




## 3.3 Experiment Deployment

Several results were obtained during the deployment of the experiment including characterization of the benthic conditions at the site, and burial success of the animals once deployed. Details of those results are described in the following sections.

### 3.3.1 Field Conditions and Clam Dispersal

On October 23, 2023, the first of four deployment days, bottom water temperature was 15.5$^0$C and the water column was fully mixed. Divers noted varied bottom conditions, with sandy sediment in the area of nodes 1–7, growing muddier around node 29 (Figure 3), and observed marine wildlife such as horseshoe crabs and whelk eggs. Although divers reported poor visibility, they completed three successful missions and installed all grid materials.

On October 24, 2023, water conditions were calm with little to no wind and air temperatures of 12.8$^0$C. Divers reported improved visibility throughout the day and observed clam burial activity, noting that burial began almost immediately following their release on the bottom. Approximately 1 hour after clams were distributed, divers returned to the bottom with handheld GoPro digital cameras and recorded seafloor conditions, including clam burial activity (Figure A-12).

On October 25, 2023, the weather remained sunny and clear with winds increasing to ~10 knots and a sea state of 2–3 ft. The morning dives were hindered by poor visibility caused by the ebbing tide. Divers distributed clams on plots L2, S3, and L3, and noted a thick layer of silt around node 43. The afternoon dives experienced improved visibility during the flood tides, and the predation cages were successfully deployed and anchored.

### 3.3.2 Sediment Analysis

During the fieldwork, an initial visual inspection of recovered sediment revealed a mix of sandy silt, with small surfclam shells appearing in some samples. Laboratory analysis of sediment grain size distribution from samples collected within each treatment plot and at four locations around the perimeter confirmed sediments at the experiment contain sandy silt (Figure 6, Panel B). Coarse sand, sediment sizes >1.00 mm, were more common in plots L2 and S2, while greater proportions of muddy sediments, smaller size sediments <0.063 mm, were present in plot L3 (Figure 6, Panel A). Fine sand (sediment grain sizes between 0.125 and 0.25 mm) was most commonly observed across the experimental site, making up 40%–80% of all samples. An average of 1.2 (±1.23 SD) juvenile (<1 year of age) surfclams were found in each sediment sample (Figure 7), and samples were collected from an area of approximately 30 cm$^2$; therefore, this location contains a density of 400 juvenile clams/m$^2$ on average.

**Figure 6. Sediment Composition and Grain Size Distribution**

Sediment grain size distribution in samples collected during experiment setup. Panel A shows the proportion of sediment size class by dry weight for each sample processed. Panel B shows the sediment composition across the experiment grid, with pie charts indicating where in the grid the sample was collected.

*Source: Task 5 Report (NYSERDA 2023c).*

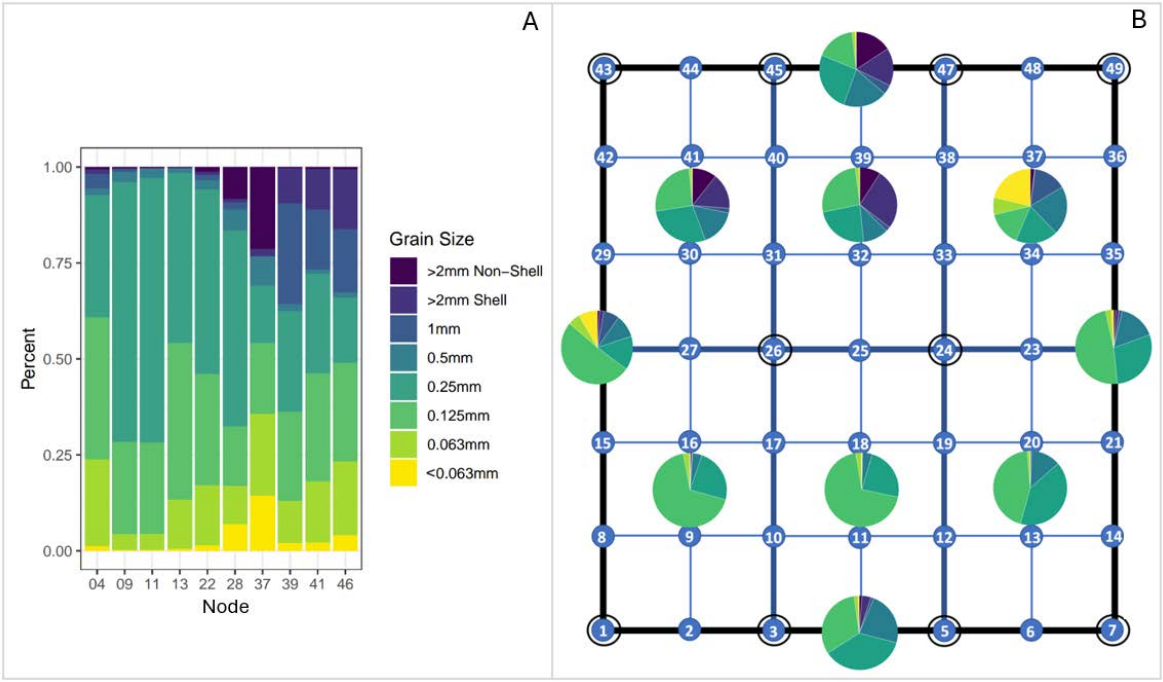
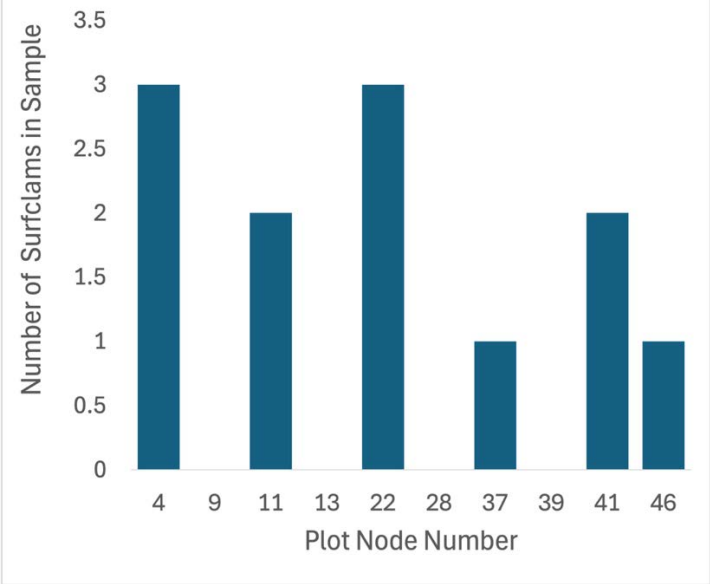



**Figure 7. Juvenile Surfclams in Sediment Samples**

Total number of juvenile (<1 year old) surfclams observed in sediment samples taken from each treatment plot.

*Source: Task 6 Report (NYSERDA 2023d).*



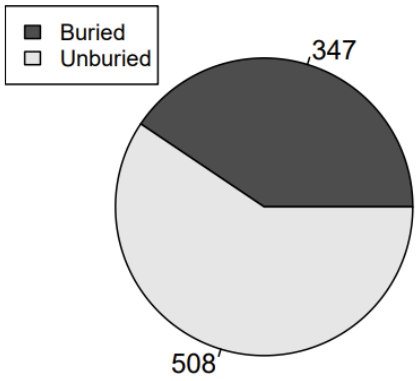
### 3.3.3 Burial Success

Winds remained consistently calm on the fourth and final deployment day at 3–4 knots, with a sea surface temperature of 14.9$^{0}$C, and a sea state of 2–4 ft. Despite poor visibility, several attempts were made to record video of deployment conditions. Limited video was recorded capturing the corner of the grid and cage at node 49 (Figure A-13), but visibility was not adequate to observe the seafloor. While divers were unable to gather video data 24-48 hours after clam dispersal, footage recorded roughly 1 hour after clam deployment was sufficient to evaluate burial behavior. However, a statistical comparison of burial behavior among size classes was unable to be completed because of insufficient sample coverage. An example of the video collected by the divers showing burial behavior can be viewed here (YouTube Link for Surfclam Burial Behavior). These videos confirmed highly active clams on the bottom within 1 hour of deployment from the boat. All clams appeared active and healthy. Burial activity 1-hour post-deployment showed 40% out of 855 total individuals observed actively burying (Figure 8). Any clams that had fully buried prior to video collection were not included in this assessment.

**Figure 8. Burial Behavior of Surfclams**

Proportion of surfclam burial behavior 1 hour after dispersal into the experiment across 855 observed individual clams.

*Source: Task 6 Report (NYSERDA 2023d).*




### 3.3.4 6-Month Sampling

Using the recorded coordinates from the initial deployment, the experiment location was identified. However, once divers deployed, they could not locate anchors, grid nodes, or cages at deployment locations. Grapples and sonar were used to attempt to find the grid.

After extensive searching, the anchors, cord, nodes, cages, and sensor were found tangled to the south of the experiment site. Given the nature of the damage and the distance the experiment gear had moved, researchers assumed that a fishing vessel had dragged it. Although the anchors and lines were dragged off the experiment site, the clams remained in place.

#### *3.3.4.1 Clam Processing*

Divers collected 11 dead, articulated surfclams on the surface of the seafloor, 10 of which were determined to be from the initial deployment due to their hatchery mark, and one live wild surfclam. The suction dredge collected several live clams and articulated shells from the L3 plot location, including clams from our initial deployment and several wild clams. Researchers determined that all sampled clams likely originated from the large size class because their hatchery mark lengths were >30.5 mm. Upon retrieving the YSI, divers noted that the predation cage was inverted and partially buried in the sediment, completely covering the sensor and smothering some of the bags and the clams inside. The cage was stocked with two bags from the small size class and two from the large size class. In total, 43 articulated shells and one live clam were recovered from the large clam bags, and 37 articulated shells and one live clam were recovered from the small clam bags. Given the original stocking density of approximately 40 clams per bag, about half of each size class survived until roughly 1 week before the June sampling.

The largest final shell lengths across all samples were observed for uncaged clams that were recovered live (average = 58.5, SD = ±3.5 mm, maximum = 70 mm; Figure 9, Panel A), whereas uncaged articulated shells were recovered with an average final length of 56.5 mm (SD = ±4.9mm, maximum = 69.4 mm; Table 2). The live wild clams that were recovered had the smallest lengths overall (average = 46 mm, SD = ±5.6 mm; Figure 9, Panel B); however, the sample size was limited ($n$ = 3) compared to the uncaged live clams that we deployed ($n$ = 79). The control clams exhibited higher growth rates than uncaged and caged clams (Figure 9, Panel C), and growth rates of the uncaged and caged clams, the uncaged and control clams, control and caged clams, and the caged small and large size classes significantly differed (Table 3). Among the caged clams, the small size class began the experiment with an average shell length of 41 mm, and the large size class began the experiment with an average length of 48.2 mm. Both size classes completed the experiment with similar average shell lengths (Table 2), and the small size class achieved higher growth rates than the large clams (Figure 10).

Table 4 details wet and dry tissue weight (grams) of all treatments, including the clams processed prior to deployment in October 2023. The large-size uncaged clams increased 70% in mass, and the large-size caged clams increased 106% (Table 4). Male and female clams were present among both the uncaged and control clams, with half partially or fully ripe, while 72% of control clams were spent (Table 5).

**Figure 9. Clam Sizes and Growth**

Panel A shows the shell length distribution of clams deployed freely (uncaged), in the predation cage (caged, both size classes combined), and at the Cape Shore facility (control). Final shell lengths are shaded darker, and shell lengths at the time of deployment are shaded lighter. Articulated (dead) shells are shown in the bars to the left, and live clams are shown in bars to the right. Panel B shows shell lengths of wild clams relative to uncaged, caged, and control clams. Panel C shows growth rates for the uncaged, caged, and control groups for live clams (to the right) and articulated shells (to the left).

*Source: Task 7 Report (NYSERDA 2025).*

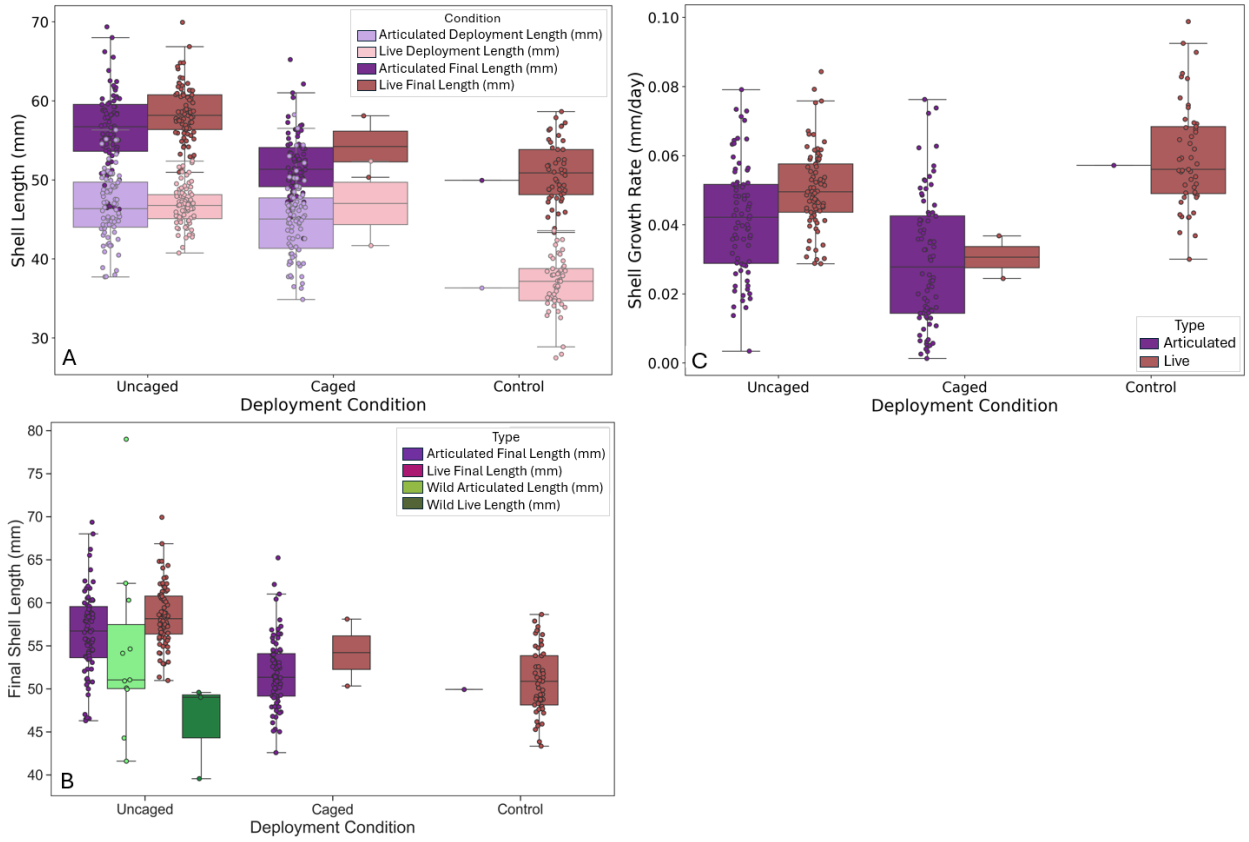


**Table 2. Shell Measurements and Growth Rates**

Shell morphometrics for all clams sampled (wild and experimental) from all deployment conditions (uncaged on the seafloor, predation cage, and control). Caged samples are separated by small (Sm) and large (Lg) size classes.

| Deployment Condition | Live/ Dead | Deployment Mean Shell Length (mm) | Deployment Min Shell Length (mm) | Deployment Max Shell Length (mm) | Final Mean Shell Length (mm) | Final Min Shell Length (mm) | Final Max Shell Length (mm) | Average Growth Rate (mm/day) |
|---|---|---|---|---|---|---|---|---|
| Uncaged | Live; *n*=79 | 46.6 ±2.5 | 40.7 | 52.4 | 58.5 ±3.5 | 51 | 70 | 0.05 ±0.012 |
| | Dead; *n*=76 | 46.7 ±4.3 | 37.7 | 56.3 | 56.5 ±4.9 | 46.2 | 69.4 | 0.042 ±0.016 |
| Uncaged (Wild) | Live; *n*=3 | N/A | N/A | N/A | 46 ±5.6 | 39.6 | 49.6 | N/A |
| | Dead; *n*=11 | N/A | N/A | N/A | 54.4 ±10.1 | 41.6 | 79 | N/A |
| Caged (Sm) | Live; *n*=1 | 41.7 | 41.7 | 41.7 | 50.3 | 50.3 | 50.3 | 0.037 |
| | Dead; *n*=37 | 41 ±2.9 | 34.9 | 46.1 | 51.9 ±3.7 | 45 | 62.1 | 0.046 ±0.012 |
| Caged (Lg) | Live; *n*=1 | 52.35 | 52.35 | 52.35 | 58.1 | 58.1 | 58.1 | 0.024 |
| | Dead; *n*=43 | 48.1 ±3.5 | 39.5 | 58.23 | 51.7 ±4.3 | 42.6 | 65.2 | 0.015 ±0.008 |
| Control | Live; *n*=49 | 36.7 ±3.5 | 27.47 | 43.56 | 50.9 ±3.8 | 43.3 | 58.6 | 0.060 ±0.015 |
| | Dead; *n*=1 | 36.3 | 36.3 | 36.3 | 49.9 | 49.9 | 49.9 | 0.057 |

**Figure 10. Clam Growth by Size Class**

Panel A shows shell length distribution of caged surfclams separated by small and large size classes. Articulated (dead) shells are shown to the right, and live clams are shown to the left. Shell length at initial deployment is shown in lighter shades, and shell length at sampling in June 2024 is shown in darker shades. Panel B shows growth rates of caged surfclams separated by size class.

*Source: Task 7 Report (NYSERDA 2025).*

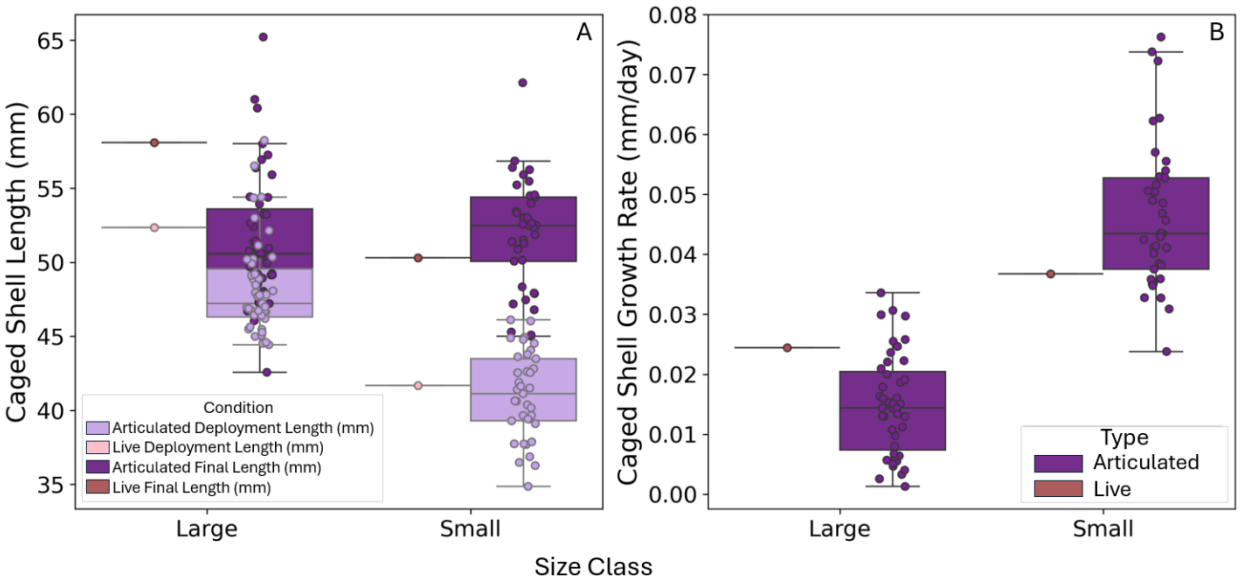



**Table 3. Growth Rate Statistical Results**

Statistical results (p-value) from two-sample t-tests comparing the growth rates between small and large caged clams, all caged clams and control clams, all caged clams and uncaged clams, and uncaged clams and control clams.

| Two-Sample t-Test: Growth Rate | p-Value |
|---|---|
| Caged Small vs. Large | 5.56E-20 |
| Caged vs. Control | 6.46E-18 |
| Caged vs. Uncaged | 9.00E-11 |
| Uncaged vs. Control | 3.80E-07 |

**Table 4. Clam Tissue Weights**

Wet and dry weight (±SD) of surfclams prior to deployment in October 2023, prior to deployment (pre-deployment) and from samples collected in June 2024, 7 months after deployment (post-deployment). Post-deployment weights are categorized by treatment and size (if applicable), while pre-deployment samples are categorized by size.

| Deployment Period | Count (*n*) | Mean Wet Weight | Max Wet Weight | Min Wet Weight | Mean Dry Weight | Max Dry Weight | Min Dry Weight |
|---|---|---|---|---|---|---|---|
| Pre-Deployment: Small | 130 | 5.03 ±1.00 | 7.37 | 3.23 | 0.82 ±0.34 | 3.17 | 0.5 |
| Pre-Deployment: Large | 130 | 11.23 ±1.72 | 15.76 | 7.17 | 1.46 ±2.34 | 2.05 | 0.87 |
| Post-Deployment: Uncaged | 79 | 10.97 ±1.9 | 17.77 | 5.82 | 2.48 ±0.4 | 3.66 | 1.44 |
| Post-Deployment: Uncaged (Wild) | 3 | 5.6 ±1.3 | 6.87 | 4.23 | 1.14 ±0.3 | 0.83 | 1.45 |
| Post-Deployment: Caged (Small) | 1 | 7.29 | 7.29 | 7.29 | 1.4 | 1.4 | 1.4 |
| Post-Deployment: Caged (Large) | 1 | 14.8513 | 14.8513 | 14.8513 | 3.0113 | 3.0113 | 3.0113 |
| Post-Deployment: Control | 49 | 5.39 ±1.1 | 6.05 | 4.12 | 0.84 ±0.11 | 0.92 | 0.72 |

**Table 5. Clam Gender and Gonad Summary**

Summary of gonad condition and gender identification among the live surfclams sampled in June 2024. Clams are categorized by treatment and origin: uncaged hatchery, uncaged wild, caged, and control.

| Deployment Condition | Total Count | N Gonad Spent | N Gonad Partially Ripe | N Gonad Ripe | N Gonad UND | N Male | N Female | N Und |
|---|---|---|---|---|---|---|---|---|
| Uncaged | 79 | 40 | 33 | 6 | 0 | 59 | 10 | 10 |
| Uncaged (Wild) | 3 | 1 | 2 | 0 | 0 | 3 | 0 | 0 |
| Caged (Sm) | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 |
| Caged (Lg) | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| Control | 49 | 36 | 5 | 8 | 1 | 32 | 16 | 2 |

All articulated samples were assessed for signs of predation in the form of a drill hole typical of moon snail predation. Caged dead surfclams did not exhibit evidence of predation (Table 6), while 22% of uncaged articulated shells presented a partial or complete (drilled through the entire shell) drill hole. Additionally, about half of wild articulated shells presented with a complete drill hole. Most shells with a drill hole were between 45 and 63 mm (Figure 13).

**Table 6. Predation Marks**

Summary of predation marks in the form of snail drill holes among articulated (dead) surfclams.

| Deployment Condition | Total Count | Present | Absent | Partial |
|---|---|---|---|---|
| Uncaged (Hatchery) | 76 | 10 | 59 | 7 |
| Uncaged (Wild) | 11 | 5 | 6 | 0 |
| Caged (Sm) | 43 | 0 | 43 | 0 |
| Caged (Lg) | 37 | 0 | 37 | 0 |

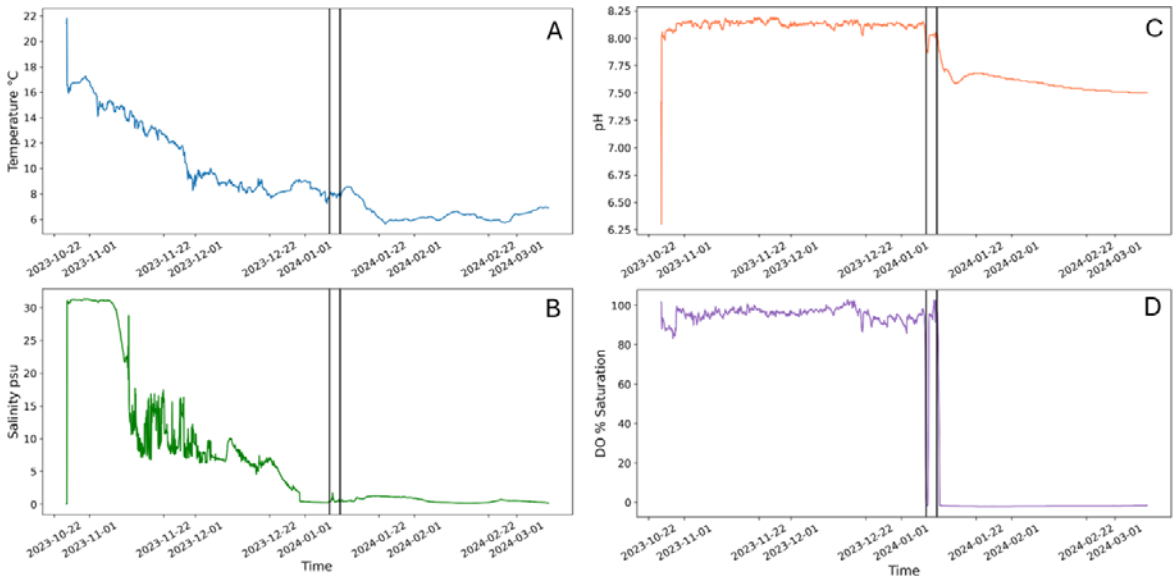
### *3.3.4.2 Oceanography*

The environmental time series collected with the sensor was interrupted in January 2024 when the experiment was disrupted, presumably by a fishing vessel. The predation cage holding the sensor was inverted, burying the YSI (Figure 11). The battery lasted from October 2023 until early March 2024; however, viable data were recorded only for about 2.5 months. This is validated by the complete depletion of dissolved oxygen at the time of disruption (January 2024), shown with vertical lines in Figure 11. The pH and dissolved oxygen levels appear relatively stable throughout the sensor measurements, at pH 8.1 and oxygen saturation >90%. Temperature and salinity both gradually decrease over time, with bottom temperature initially 16$^0$C in October and declining to 8$^0$C in January, and salinity ranging from 20 to 25 psu in October and November and declining to 5–10 psu in December and January.

**Figure 11. Oceanography**

Panel A shows the time series of temperature ($^0$C), Panel B shows salinity (psu), Panel C shows pH, and Panel D shows dissolved oxygen (% saturation). The two vertical lines indicate the estimated timing of predation cage inversion and sensor burial.

*Source: Task 7 Report (NYSERDA 2025).*



### 3.3.5 Final Sampling

Using the recorded coordinates from the initial deployment, the experiment location was identified. However, as described above, anchors, grid nodes, and other orientation markers had been dragged offsite and could not be used to navigate. Although the anchors and lines were dragged off the experiment site, the clams remained in place and sample collection was attempted.

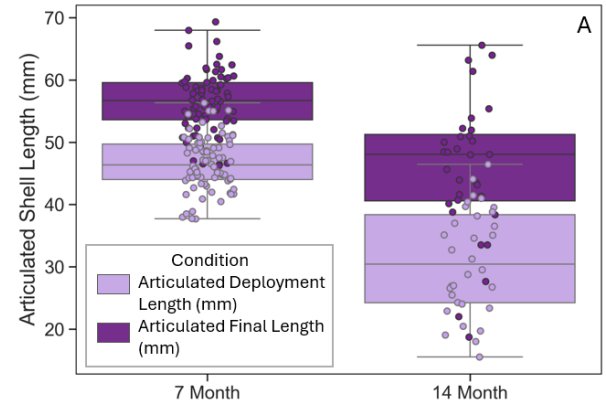
#### *3.3.5.1 Clam Processing*

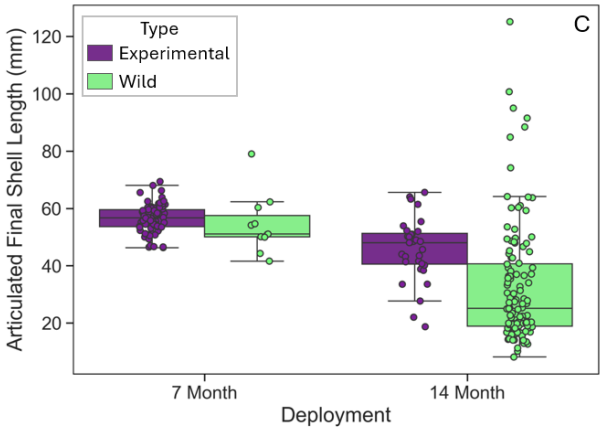
No live surfclams were collected or processed in the lab following the final sampling event in December 2024 (Figure A-10). While three live wild clams were collected, they were estimated to have spawned in spring 2024 because their maximum length was <20 mm, 4 mm smaller than the small size class deployed in the experiment. Across all sample collection attempts, 152 single shell valves were recovered, with one articulated shell pair (length = 22.11 mm). The average final shell length of the shells collected was 34.80 ±20.13 mm, and the average deployment length measured from the hatchery check was 30.95 ±8.43 mm, generating an average growth rate of 0.036 mm/day. Compared with the uncaged, dead shells sampled in June 2024, those collected in December 2024 showed a slightly lower growth rate (0.006 mm/day) (Figure 12, Panel B). While the surfclams sampled in June, 7 months post-deployment, had higher shell lengths (Figure 12, Panel A), a portion of the shells sampled in December, 13 months post-deployment, were collected from an area where the small size class was initially placed, and therefore would represent the smaller size class initially. Additionally, the articulated wild clams sampled in the final deployment exhibited a wide range of shell length, indicating a possible range of ages inhabiting the experiment site. Forty-two shells had drill holes present, with no signs of predation on shells >65 mm (Figure 13).

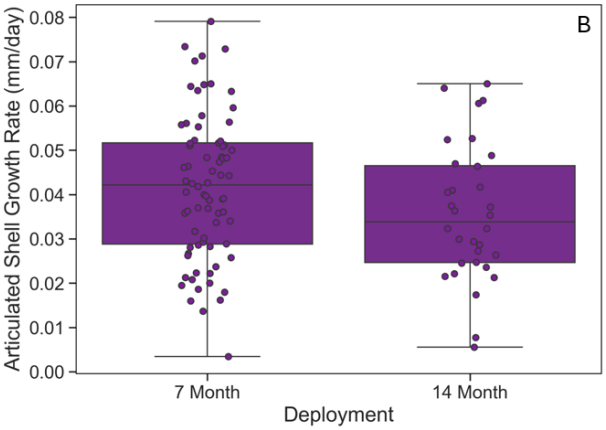
**Figure 12. Clam Growth across Sampling Events**

Panel A shows shell length (mm) at initial deployment (lighter shade) and at time of sampling (darker shade) for articulated (dead) experimental surfclams collected in June 2024 (7 months post-deployment) and December 2024 (14 months post-deployment). Panel B shows growth rates of clams collected 7 and 14 months post-deployment. Panel C shows final shell lengths of experimental (left) and wild clams (right) collected 7 and 14 months post-deployment. Panel D shows average growth and final shell length of articulated surfclam shells collected 7 and 14 months post-deployment.

*Source: Task 7 Report (NYSERDA 2025).*



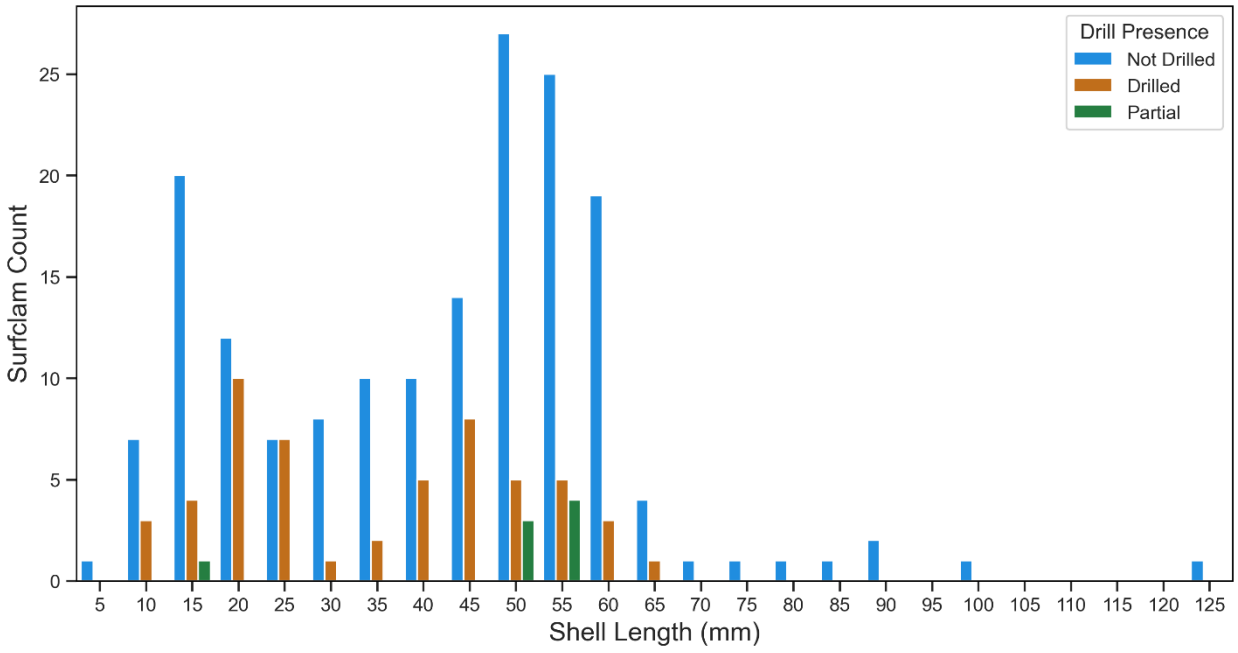




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| Condition | Mean Growth (mm/day) | Mean Shell Length (mm) |
|---|---|---|
| 7 Month: Uncaged | 0.046 | 56.5 |
| 7 Month: Wild | N/A | 54.4 |
| 14 Month: Uncaged | 0.036 | 45.8 |
| 14 Month: Wild | N/A | 32.6 |

**Figure 13. Predation Prevalence**

Evidence of predation present on all articulated (dead) clam shells collected, with shell lengths grouped into 5-mm size bins.



# 4. Discussion

Existing offshore wind leases and the potential development of future offshore wind leasing may occupy over 8% (22.237 million acres) of the total benthic habitat of the Atlantic outer continental shelf (BOEM and NOAA 2022). In many instances, this development spatially overlaps with commercial fishing areas. It could reduce access to economically important species such as the Atlantic surfclam (*Spisula solidissima solidissima*) (Scheld et al. 2022). This project collected data to assess the feasibility of one approach to mitigate lost fishing opportunities in the surfclam fishery due to offshore wind projects that overlap with Atlantic surfclam fishing grounds. The results presented herein support the potential to produce surfclam seed in an aquaculture setting (hatcheries and nurseries) to be planted on fishing grounds to enhance fishing opportunities outside of offshore wind farms. Our results showed that, despite disruption of the planting site in the 6 months between planting the seed and sampling, the clams remained in place and grew well, suggesting that placing hatchery-produced seed in appropriate ocean habitat could support enhanced surfclams populations.

The loss of the experiment grid and cages before the first sampling event limited our ability to statistically assess the performance of the two size classes of surfclams deployed in this experiment. Nonetheless, our ability to recover clams despite disruption to the experimental site suggests that deploying clams to the seafloor is robust to impacts such as fishing gear and anchor dragging. The live and articulated (dead) clams recovered during the sampling events indicate that the sizes of clams used in this experiment will survive and grow at rates comparable to clams kept in protected aquaculture settings. Disarticulation of dead shells can occur quickly, although it varies among species (Trewin and Welsh 1972). The fact that our sampling efforts yielded several articulated shells with final sizes very similar to the live clams collected at the same time suggests that those articulated shells represent animals that died very close to the sampling effort. We noted some evidence of predation on the dead shells, suggesting that predators may have caused some mortality. Mortality could also have resulted from temporarily unfavorable environmental conditions; however, site disruption and sensor loss mean that we do not have adequate environmental observations to confirm this possibility.

The presence of wild surfclams at the experimental site further supports the site's suitability for surfclams. Wild clams do not lay down a hatchery mark, so we could not assess growth over time for wild-caught surfclams as we could for the surfclams deployed for this project. Therefore, no comparison among growth rates of our experimental surfclams and the wild surfclams was possible. In general, the small size class exhibited slightly higher growth rates than the large size class. This phenomenon is expected, with smaller animals typically growing faster and growth rate slowing as animals age. This size-varying growth could be used advantageously in enhancement efforts with the caveat that we noted evidence of predation on size classes of clams up to about 60 mm shell length. Results of this experiment indicate that enhancement of surfclam beds using hatchery-raised surfclams is possible with the sizes used for this project. Future experiments should test the effects of stocking density and varying sizes on the survival and growth of clams used for enhancement. This project has leveraged funding from the NJDEP Research and Monitoring Initiative (RMI) for a project underway to address the effects of varying planting density.

# 5. Future Considerations

To expand the scope of the experiment, future studies could implement multiple grids that encompass various stocking densities and multiple size classes. Increasing the number of grids could cover a greater range of environments and increase the probability of maintaining an intact experimental site in the event of a disturbance. If spatial capacity is limited, the number of plots and predation cages per grid could be decreased, while maintaining multiple grids. Expanding replication in future studies should further support the relevance of the results and mitigate impacts of fishery displacement or stock enhancement for surfclams.

While avoiding vessel paths that could disrupt the experiment site is not guaranteed, additional precautions such as secondary anchors could be considered. Deploying an anchor or other indicator of grid location separate from the grid setup could help locate both size classes should the experiment be disturbed, in addition to prerecorded coordinates. Improved anchoring could help ensure environmental data relevant to the organismal response to bottom water and climatic conditions are collected to further our understanding of how surfclams placed on the bottom will perform in fishery mitigation or enhancement endeavors.

Environmental factors such as limited visibility can hinder a diver's ability to navigate the experiment site. Adaptations to future experiments that aim to evaluate survival and growth of surfclams in the open ocean should consider the possibility of outside interference, evaluate various stocking densities and size classes while expanding the extent of the deployment site, and use tools to aid divers in conditions with poor visibility.

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# Appendix A. Field Experiment Figures

## A.1 Full Timeline of Experiment Deployment, October 2023–December 2024

**Figure A-1. Clam Transportation**

Clam transportation to R/V *Ocean Explorer*. Mesh bags denote size class with colored tag.

*Source: Task 4 Report (NYSERDA 2023b).*



**Figure A-2. Pre-Dive Check**

Divers preparing to deploy experiment.



**Figure A-3. Polyball Deployment**

White polyball used to identify the corner of the experiment grid.



**Figure A-4. Deploying Predation Cages**

Panel A shows the stocking of predation cages with surfclams; Panel B shows the cages being equipped with zip ties; Panel C shows the attachment of a tag identifying the assigned deployment grid; and Panel D shows the cage being prepared for deployment into water.

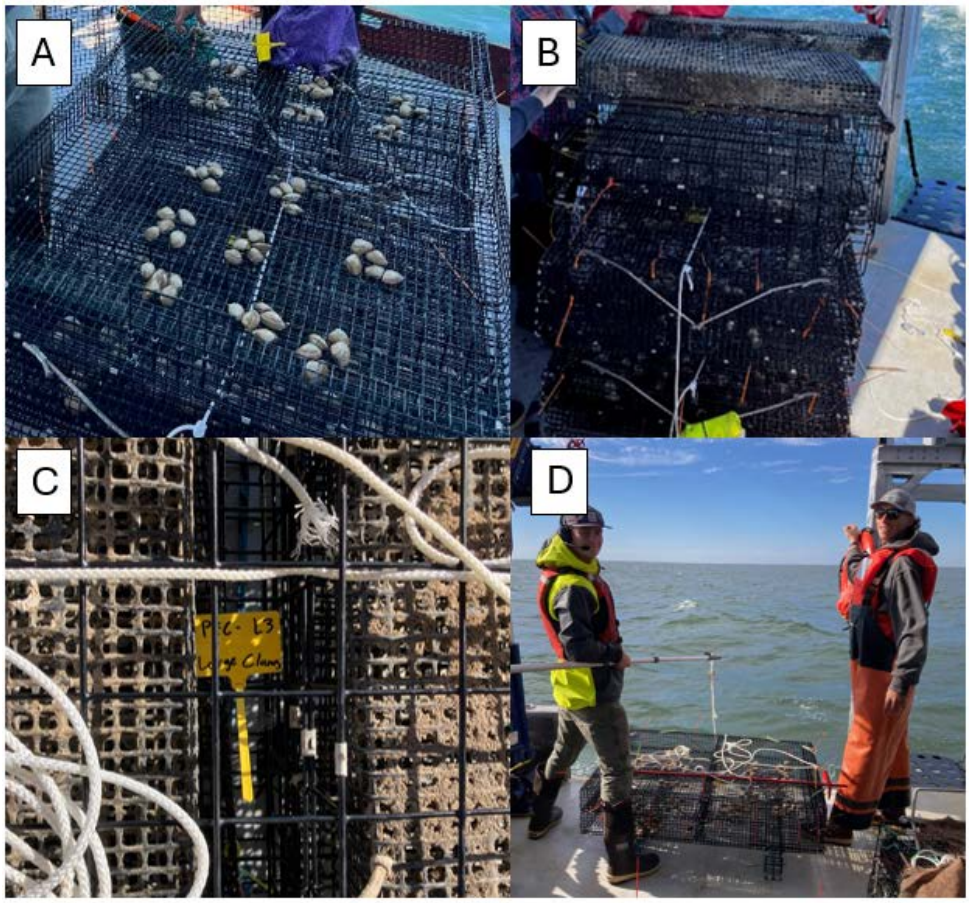


**Figure A-5. YSI Deployment**

YSI sensor attached to predation cage in preparation for deployment.

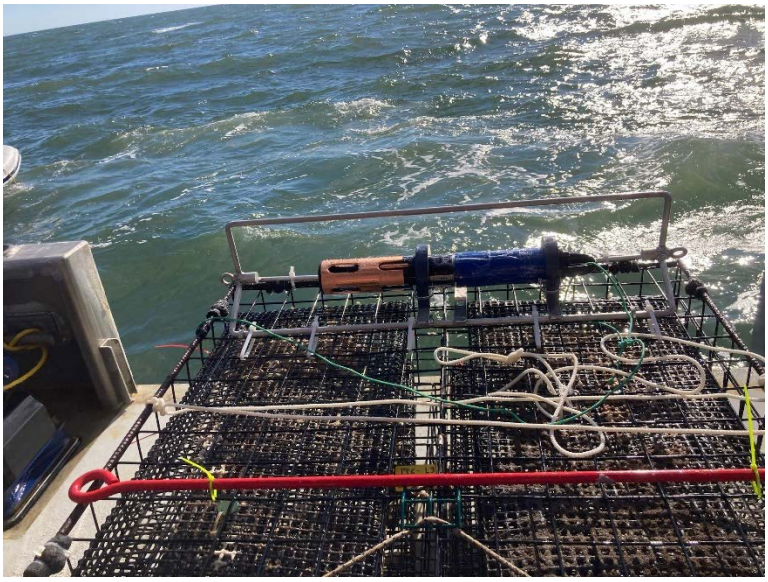


**Figure A-6. Polyball Replacement**

Replacement of the white polyball with a subsurface buoy on the fourth and final deployment day of the experiment setup.

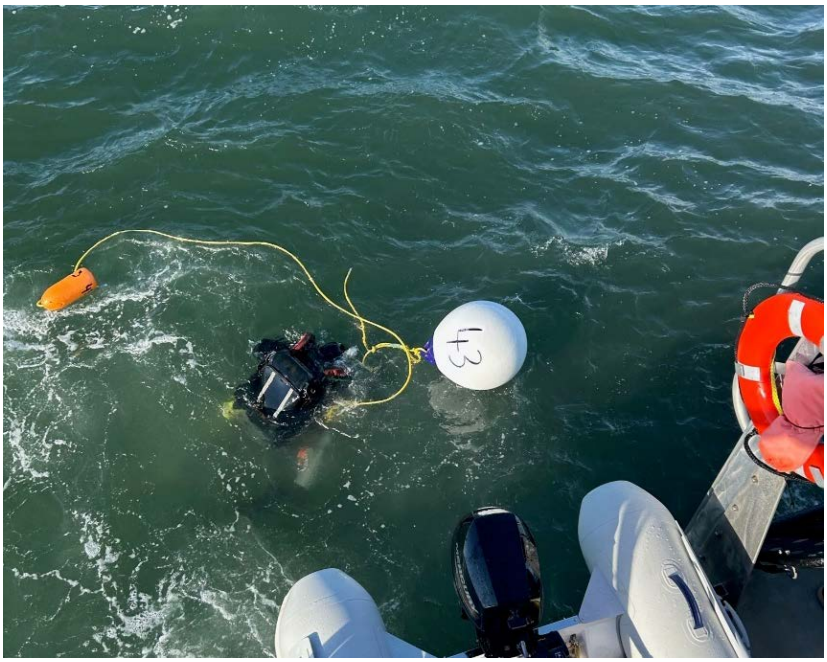


**Figure A-7. Surfclam Retrieval, June 2024**

Surfclams collected in the June 2024 deployment. The length at time of deployment can be identified by darker coloring on shell (indicated with a line overlaid on the photo).




**Figure A-8. Suction Dredge, June and December 2024**

Suction dredge used for sampling surfclams in June and December 2024 deployments.

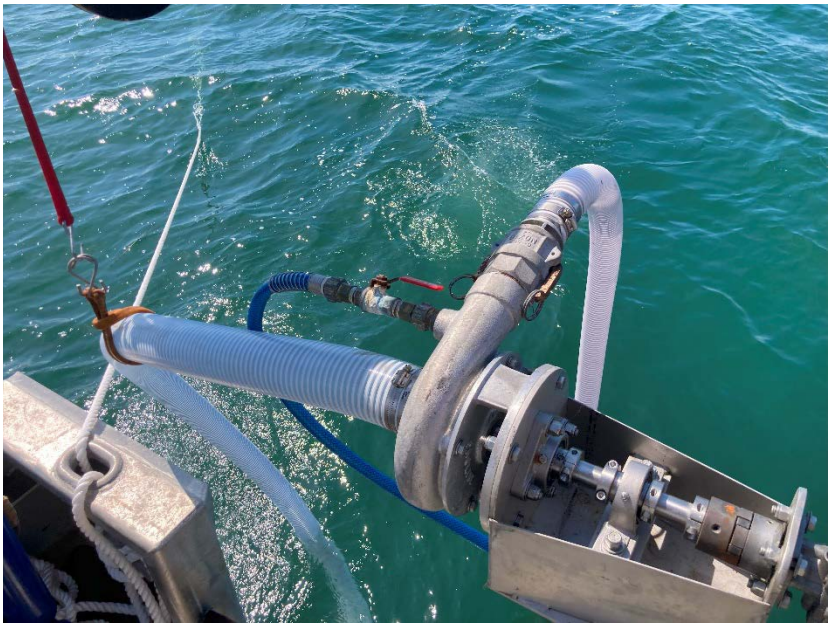


**Figure A-9. Predation Cage and YSI Retrieval**

Predation cage with attached YSI sensor retrieved from experiment after 7.5 months.




**Figure A-10. Deployment Sample, December 2024**

Catch from dredge sample with live bycatch from December 2024 deployment.



**Figure A-11. GoPro Footage after Surfclam Dispersal, October 2023**

Panel A shows GoPro footage of surfclams deployed in a predation cage captured on the second deployment day in October 2023, and Panel B shows the burial behavior of surfclams approximately 1 hour after dispersal.

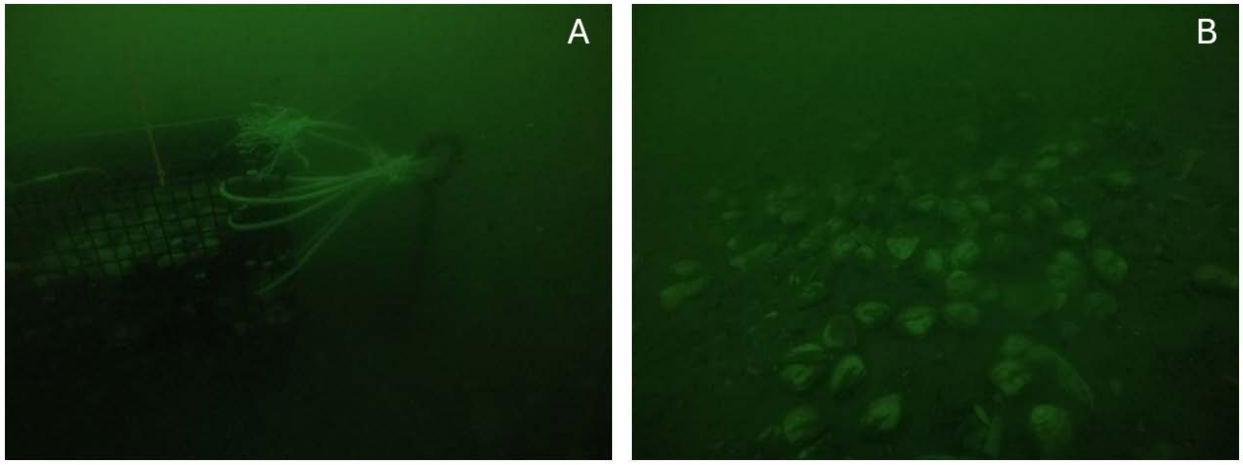



**Figure A-12. GoPro Footage of Predation Cage, October 2023**

Panel A shows GoPro footage captured during mission two of deployment day four in October 2023, showing a predation cage anchored at corner point 49 on the experiment grid.



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**New York State Energy Research and Development Authority**

17 Columbia Circle
Albany, NY 12203-6399

**toll free:** 866-NYSERDA
**local:** 518-862-1090
**fax:** 518-862-1091

info@nyserda.ny.gov
nyserda.ny.gov




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