Resource monitoring for Atlantic surfclam (*Spisula solidissima*) at the Coastal Virginia Offshore Wind development site

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Dominion Energy - Commercial Offshore Wind
2700 Cromwell Drive
Norfolk, VA 23509

Submitted by:

David Rudders[1], Roger Mann[1], Sarah Borsetti[2], Daphne Munroe[2], Alexandra McCarty[3], Reece Aponte[1], Ailey Sheehan[2], Sophia Piper[2], Hails Tanaka[2], Tom Dameron[4]

Affiliations:
1. Virginia Institute of Marine Science
2. Haskins Shellfish Research Laboratory – Rutgers University
3. Cherrystone Aquafarms
4. Oceanside Marine LLC

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Executive Summary

Development of offshore wind capacity along the East Coast of the United States continues to progress with plans for more than one thousand turbines planned coastwide over the next decade (BOEM 2022). In many instances, the construction and operation of turbines spatially overlap with other ocean uses, such as commercial fishing. While the impact on fishing is likely variable across regions and species, it is imperative to characterize these impacts across the spatiotemporal scale associated with the life cycle of the development.

Located 27 miles off the coast of Virginia Beach, Virginia, the Coastal Virginia Offshore Wind (CVOW) 3,000-megawatt project will be built in water depths ranging from 18 to 42 meters (m), and the seafloor is primarily sandy benthic habitat. These bottom habitats are potentially suitable for Atlantic surfclams (*Spisula solidissima solidissima*) and have historically supported a commercial fishery in the area. Until recently, fishery efforts off the coast of Virginia along the southern edge of the surfclam range were low. However, commercial surfclam fishing efforts off Virginia resumed in 2021 with the fishery harvesting surfclams to the east of the CVOW site.

Given the spatial overlap between the Atlantic surfclam resource and the offshore wind lease, Dominion Energy worked with project Principal Investigators (PIs) to develop and execute a survey, in alignment with ROSA Offshore Wind Project Monitoring Framework and Guidelines (ROSA 2021), to characterize Atlantic surfclam abundance, and document spatial distribution and population structure.

This surfclam survey observed relatively high total biomass and density of surfclams within and around the CVOW lease area; total biomass observed here was more than double that observed in lease areas off New Jersey in the central portion of the fishing stock. However, the surfclams collected in and around the CVOW lease were almost exclusively smaller than 120mm throughout the surveyed area, meaning that the exploitable biomass (the biomass of surfclams >120mm) was relatively low. A spatial pattern in abundance was evident with highest biomass in the south, and biomass gradually decreasing northward. For example, surfclam biomass in the southern control was over 50 times higher than that observed in the northern control.

Surfclams observed during this survey represented age classes from < 1 year old (collected in benthic grabs) through 9 years old. Age classes 1 through 6 are consistently observed suggesting that recruitment of surfclams has been consistent over the past 5 to 6 years. Additionally, the genetic patterns observed in this survey indicated that a mix of *S.s.solidissima* and *S.s.similis* was widely distributed throughout the CVOW lease and adjacent areas.

Introduction

Development of offshore wind capacity along the East Coast of the United States continues to progress with plans for more than one thousand turbines planned coastwide over the next decade (BOEM 2022). In many instances, the construction and operation of turbines spatially overlap with other ocean uses. Commercial fishing is one such activity that, in some cases, will interact with offshore wind development. While the impact on fishing is likely variable across regions and species, it is imperative to characterize these impacts across the spatiotemporal scale associated with the life cycle of the development.

Located 27 miles off the coast of Virginia Beach, Virginia, the Coastal Virginia Offshore Wind (CVOW) project occupies a lease site of approximately 112,799 acres and will ultimately contain 176 turbines with associated substations and transmission cabling (Figure 1). Water depth in the lease area ranges from 18 to 42 m, and the seafloor is primarily sandy benthic habitat. The project will provide up to 3,000 megawatts of power to Virginia and North Carolina when fully built and operational.

The Atlantic surfclam (*Spisula solidissima solidissima*) is an economically valuable clam species that supports a major federally managed fishery. In 2022, the fishery landed 42.5 million pounds (lbs). of surfclams worth $37.1 million dollars in New Jersey alone[*]. The fishery operates year-round from the Mid-Atlantic and New York Bight through Georges Bank. Until recently, fishery effort off the coast of Virginia along the southern edge of the surfclam range was low. However, commercial surfclam fishing efforts off Virginia resumed in 2021 with sustained surfclam harvesting to the east of the CVOW site.

The location of surfclam harvest grounds, key ports, and processing facilities relative to offshore wind farm areas, as well as the use of specialized dredge gear will increase operational risks of fishing within wind farms, make the Atlantic surfclam fishery particularly vulnerable to displacement from offshore wind lease areas once built (Scheld et al., 2022). Given the spatial overlap between the Atlantic surfclam resource and the offshore wind lease, Dominion Energy worked with project Principal Investigators (PIs) to develop and execute a survey, in alignment with ROSA Offshore Wind Project Monitoring Framework and Guidelines (ROSA 2021), to characterize baseline resource conditions and characterize the surfclam population in the CVOW lease before construction began. One year of pre-construction data was collected at the CVOW site with the objectives of estimating Atlantic surfclam abundance and documenting spatial distribution and population structure. This study design allows for an initial resource assessment, and the survey setup also allows for a before-after control-impact (BACI) design if sampling continues after lease development.

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[*] NOAA Fisheries Office of Science and Technology, Commercial Landings Query, Available at: www.fisheries.noaa.gov/foss, Accessed 04/15/2024

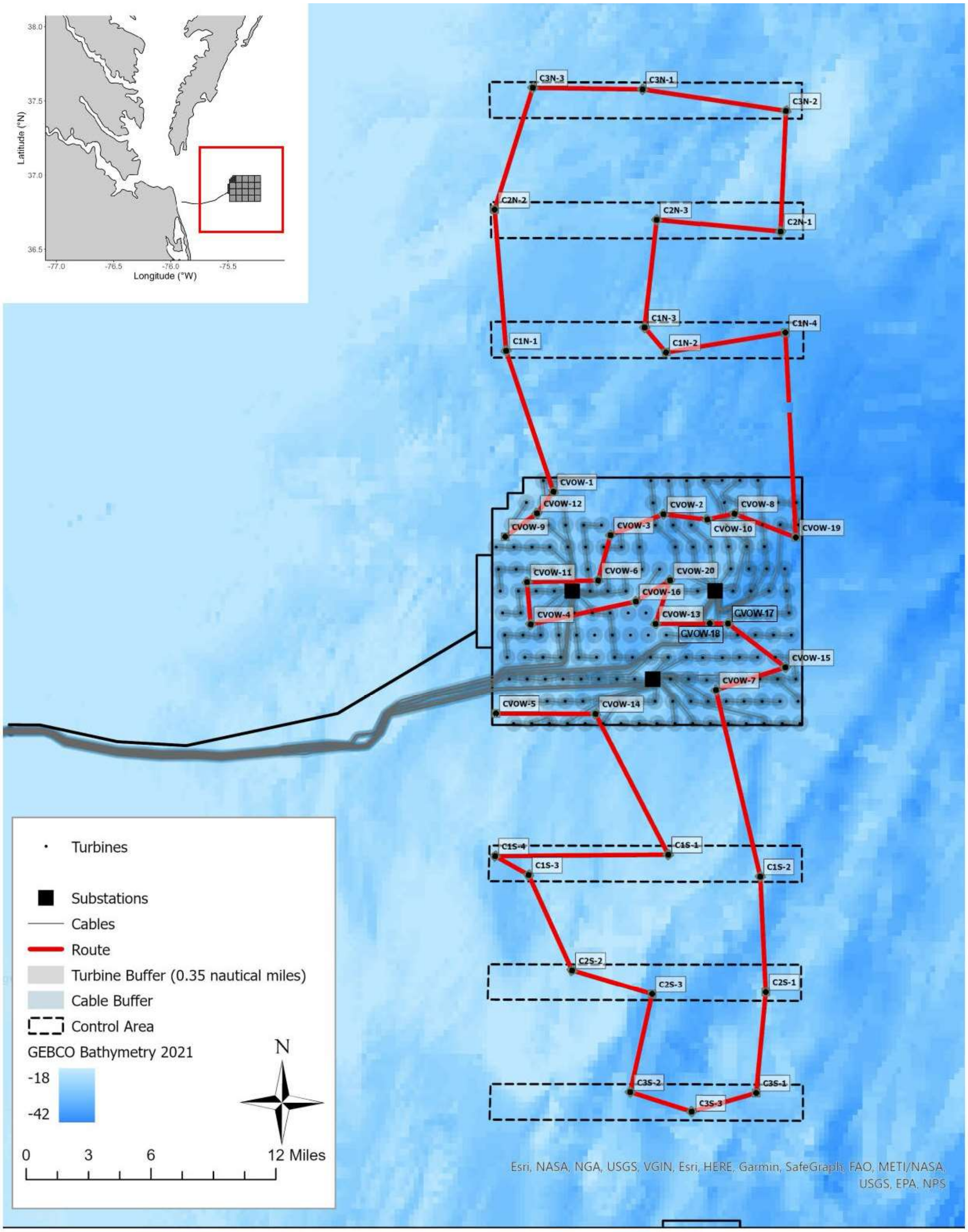


Figure 1. *Survey region offshore of Virginia Beach, which includes the CVOW lease (solid line), control areas (dotted line), sample locations (numbered points), and the vessel track (red line). Each control area (dotted line) is spaced five miles apart, with the first control area five miles to the north and south of the lease. The two subsequent control areas are ten and fifteen miles to the north and south of the lease.*

Sampling

Thirty-eight survey stations were sampled within both lease and control areas (Figure 1) on June 19-20, 2023, on an industry vessel (*F/V* Joey D). Samples were collected using a newly designed hydraulic sampling dredge. A hydraulic dredge uses high-pressure water jets to penetrate the sediment as it is dragged along the seafloor. Hydraulic dredges are used to collect both epifauna and infauna, making it the most effective tool for sampling benthic animals like Atlantic surfclams (Munroe et al. 2023). The novel surfclam dredge used for this survey is 2.5 meters (m) wide with a bar spacing of 2 centimeters (cm). This bar spacing is closer than that of a standard commercial dredge (typically about 3.5 cm) enabling capture of surfclams > 60 mm in length, whereas commercial dredges typically retain surfclams > 90 mm. This modified bar spacing allows the dredge used in this study to sample the breadth of the population present in a more representative manner than would be possible with a commercial dredge. Additional details on the survey dredge specifications and its capture efficiency and selectivity are provided in Munroe et al. (*In Review*).

Sample station locations were randomly determined in advance of the CVOW surfclam survey. Stations were located such that they avoided existing and future locations of cables and any other hard structure such as scour protection and turbine foundations. To accommodate these constraints, pre-selected survey stations were identified in all locations that did not overlap an offset buffer around each turbine of 0.35 nautical miles (nm) to allow buffer around scour protection and the turbine base, and a 0.15 nm buffer on either side of buried cables. These offsets from future cables and hard structures provide a spatial sampling location constraint that would exist after construction takes place in the event future sampling locations would not be placed over rocks or cables, thereby supporting statistical comparison of before construction data to post-construction data, should such a survey be deemed necessary. A subset of survey stations was then randomly selected from the total potential stations and standardized dredge tows made at each station. Each dredge tow sampled the bottom for 5 minutes at a vessel speed of 2.5-3.0 knots. Sensors on the dredge were used to estimate bottom contact and the start and end location (latitude/longitude) of each tow. Vessel position data during each tow was continuously recorded to provide an estimate of the position of the dredge on the bottom. The tow start/end locations and the dredge width were used to calculate the area of bottom that was sampled for a given tow. To avoid bias caused by gear saturation, dredge tows were cut short if the dredge filled up before 5 minutes. Additionally, sensors attached to the dredge measured water temperature and dredge manifold pressure. Average tow distance for all tows was approximately 486 m (standard deviation [*SD*] = 122). Station depth ranged from approximately 15 to 37 m.

The catch from each tow was sorted by species and deposited in bushel baskets so that the volume of the entire surfclam catch could be measured for each tow. Volumetric subsamples of the catch from each tow were taken, and all animals in the bushel subsample were counted and measured. The counts from the volumetric subsample were scaled up using the total catch volume to estimate the total number of surfclams for a given tow. Catch per unit effort (CPUE), for both volume and count, was standardized by tow duration (Figures 2 and 3). Surfclams were found at all stations within the lease and control-south and all but two stations in the control-north. Catch was highest in the control-south (median catch was 3,940 surfclams per tow) and lowest in the control-north (median catch was 8 surfclams per tow); catch in the lease area was intermediate (median catch was 125 surfclams per tow).

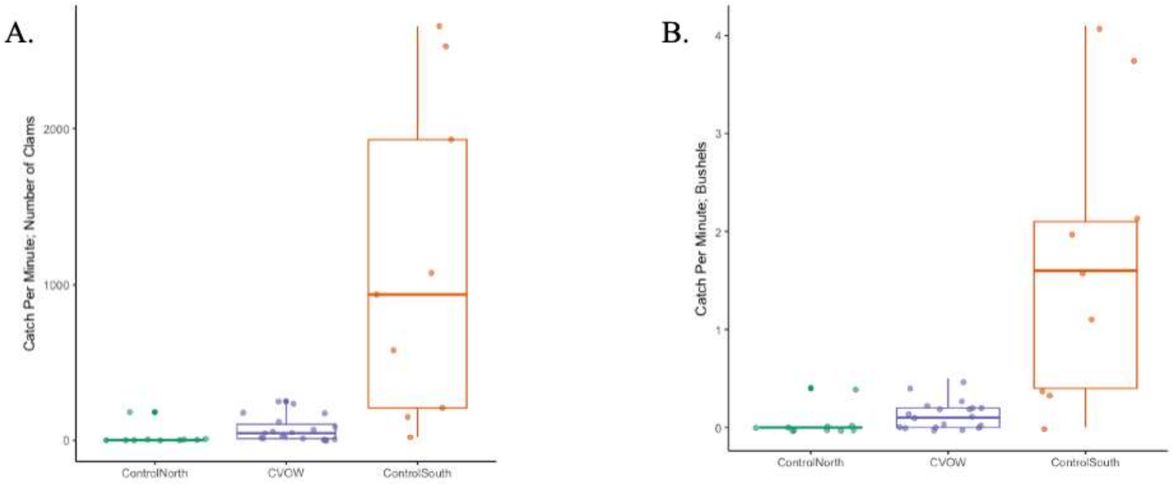


Figure 2. *Catch per unit effort in minutes in the lease (purple) and control stations (north- green; south - orange). The center line in each box plot represents the median value. The lower and upper box boundaries represent the 25th and 75th percentiles and the whiskers extend 1.5 times the interquartile range beyond the edge of the box. Overlayed points in each area show the observed data. A. Catch in number of surfclams B. Catch in bushels.*

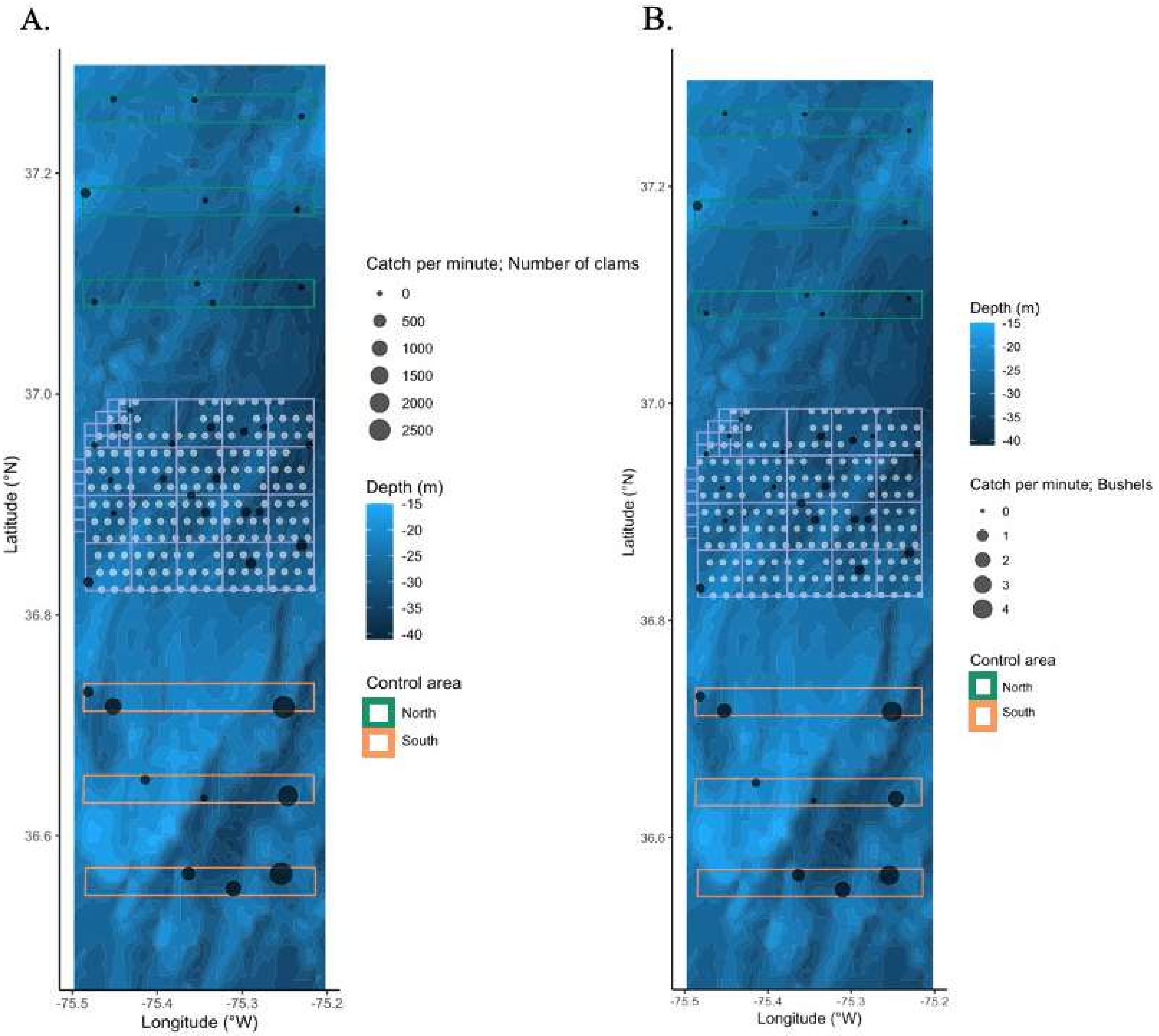


Figure 3. *Catch per unit effort (black circles) in the lease (purple outline) and control stations (north- green outline; south- orange outline). The size of the black circles corresponds to the catch per minute in number of surfclams (A) and in bushels (B). Proposed turbine locations within the lease have been included (gray).*

Swept area calculation

Using information from a GPS receiver (model: GlobalSat BU-353-S4, accuracy of 5 m) and ArcGIS, an estimate of bottom area swept per tow was calculated. During the survey, a StarODDI sensor logged at 15 second intervals to collect additional details related to the tow (date, time, temperature, depth, tilt along the X, Y, and Z axis, and roll in degrees). Tilt along the X-axis was used to find the true start and end times, which were merged with the timestamps from the GPS data (Figure 4). Using ArcGIS, the point-to-line function was used to connect the consecutive coordinate in a tow to calculate the tow distance (in meters). The tow distance was then multiplied by the width of the dredge (2.5 m) to estimate the area swept during a given survey tow. Tow specific swept area was used to standardize abundance and biomass estimates for each tow.

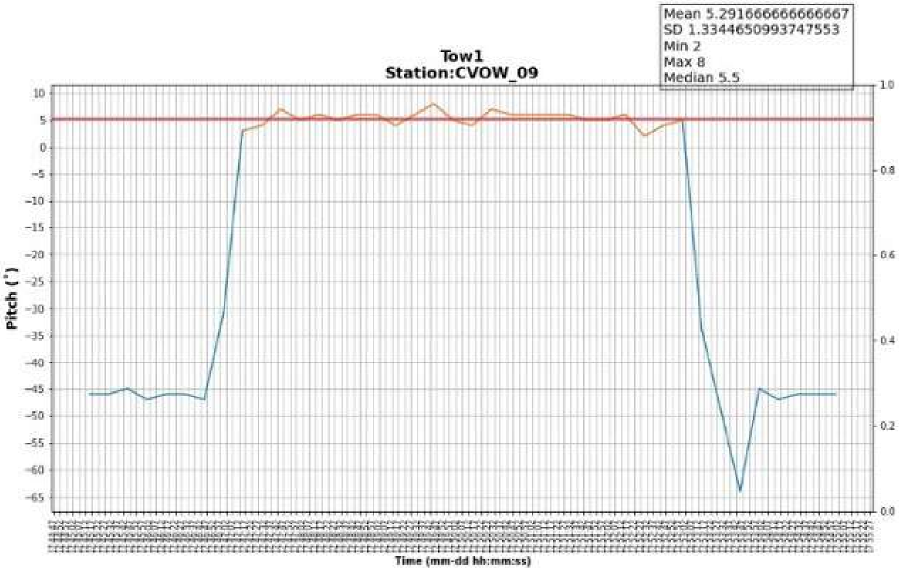


Figure 4. *Example of dredge tilt variable continuously recorded for a single tow with StarODDI and used to evaluate true start and end time of the dredge tow.*

Biomass Estimation

The entire catch at each station from the surfclam dredge was placed in bushel baskets (Figure 5) to quantify total catch. For catches larger than half a bushel, a randomly selected quarter bushel subsample of surfclams (or more) was selected and length measurements of all individual surfclams in the subsample were made. For catches less than half a bushel, shell length of all individual surfclams caught were measured. Because of the smaller sizes and therefore greater number of surfclams per bushel, a < 1 bushel subsample was required due to time constraints of measurements at each station. Length measurements were used to determine the size frequency of the catch for a given tow. This is done by expanding the total count of the subsample and measured subsample size frequency to the total catch. This provided an estimate of the number and size of surfclams caught at each station. The total count of surfclams and observed length frequencies were used to estimate the meat weight of the surfclams in each tow using an established allometric weight-at-length relationship for surfclam (Marzec et al. 2010). The allometric relationship used was confirmed to apply to surfclams in this portion of the stock in a recent study that measured and weighed surfclams caught in the fishery nearby the CVOW lease area (Wisner et al., 2023).

Figure 5. *Example of a partially full bushel of surfclams collected in this survey.*

Swept area biomass (kilograms [kg]/meter squared [m^2]) was calculated for each survey tow within the CVOW lease and controls (north and south) as follows:

$$Swept\ Area\ Biomass = \frac{biomass}{tow\ distance * dredge\ width} * [1 + (1 - efficiency)] \qquad \text{Eq. 1}$$

Mean and median swept area biomass were calculated by survey area (lease and controls). Both the mean and median swept area biomass estimates were then used to scale up the estimates to provide an estimate of biomass for lease and control areas (Table 1). The swept area biomass values were expanded to the footprint of each survey area (lease footprint – 112,799 acres or 456,481,358 m^2; north and south controls – 48,960 acres or 198,134,091 m^2 each). No selectivity was applied to these biomass estimates, and two dredge efficiency estimates (k) were applied to the data (k = 1, k = 0.65). Efficiency reflects how effectively the dredge catches the surfclams it encounters. An efficiency of one (1) assumes the dredge catches all the surfclams in its path and a k = 0.65 assumes the dredge catches 65% of surfclams in its path. The specific efficiency and selectivity of this dredge was evaluated using depletion experiments and by direct comparison to an established survey dredge used in federal management of surfclam stocks (Munroe et al., *In Review*). The dredge used in this survey performs similarly to the federal survey dredge with an estimated efficiency of 0.65, although it was demonstrated to catch both smaller (< 90 mm) and larger (> 145 mm) surfclams with greater efficiency than the dredge used for federal surveys (Munroe et al., *In Review*). Neither gear has perfect efficiency (k = 1) and therefore the biomass estimates using that value are likely underestimates of the true population. The southern control had the largest biomass, the northern control had the smallest biomass, and the lease area had an intermediate biomass.

Table 1. *Biomass estimates for the CVOW lease and control areas. Biomass was estimated in two ways (from the mean and median swept area biomass) and for two dredge efficiencies (k=1 and k=0.65).*

Survey Area	Biomass (metric tons[†]) – from mean swept area biomass	Biomass (metric tons) – from median swept area biomass	Efficiency (k)
Control – north	65.9	5.8	1
Lease	577.1	331.5	
Control – south	4,137.8	3,149.1	
Control – north	89.0	7.8	0.65
Lease	779.1	447.5	
Control – south	5,586.0	4,251.3	

Fishable biomass, characterized by individuals larger than 120 millimeters (mm), was calculated for the CVOW lease area (Table 2). However, the Atlantic surfclam minimum size limit (120 mm) has been suspended annually due to federal regulation (CFR 50, 648.75 (b)(3)) which allows the industry to harvest surfclams smaller than 120 mm. There were no surfclams collected within the control sites that met the minimum size limit for commercial harvest; therefore, fishable biomass could not be calculated for these areas.

Table 2. *Fishable biomass estimate for the CVOW lease area using both efficiency estimates.*

Site	Fishable biomass (metric tons) – from mean swept area biomass	Efficiency
CVOW	4.9	1
	6.6	0.65

Abundance Estimation

Surfclam counts from each subsample were scaled up using the total catch volume to estimate the total number of surfclams for a given tow. Surfclam abundance per tow was standardized by swept area. No size selectivity was applied to these abundance estimates, and two dredge efficiency estimates (k) were applied to the data (k = 1, k = 0.65) (Table 3). The highest abundance of surfclams was found in the southern control and lowest at the northern control. Similar to biomass, the lease had an intermediate abundance of surfclams.

Table 3. *Surfclam abundance estimates for the CVOW lease and control areas for two dredge efficiencies (k=1 and k=0.65).*

Survey Area	Mean abundance (surfclam/m^2)	Median abundance (surfclam/m^2)	Efficiency (k)
Control – north	0.1	0.01	1
Lease	0.3	0.2	
Control – south	4.0	3.3	
Control – north	0.1	0.01	0.65
Lease	0.4	0.2	
Control – south	5.4	4.5	

[†] 1 metric ton = 2,204.6 pounds

Catch Composition

Shell length of all surfclams in the subsample was measured (n = 3,564) (Table 4, Figure 6). Analysis of Variance (ANOVA) showed a difference between the average shell length of surfclams in the three areas sampled (p = 0.002). The post hoc Tukey's Honestly Significant Difference (HSD) test showed that surfclams at the lease area stations were smaller than those found at the control areas (control-north: Lease, p = 0.02; control-south: Lease, p = 0.01).

Table 4. *Overview of surfclam shell length (mm) found during the survey including the average shell length (mm) plus/minus the standard deviation, median shell length (mm), and range in shell lengths (mm) observed at each survey area.*

Survey area	Average shell length (mm)	Median shell length (mm)	Range in shell length (mm)
All stations	77.6 ± 13.1	79.4	22.1 – 138.6
All controls	78.5 ± 13.6	80.9	22.1 – 115.0
Control-north	79.0 ± 10.7	79.0	42.0 – 115.0
Lease	77.0 ± 12.7	78.0	29.1 – 138.6
Control-south	78.3 ± 14.3	81.3	22.1 – 108.5

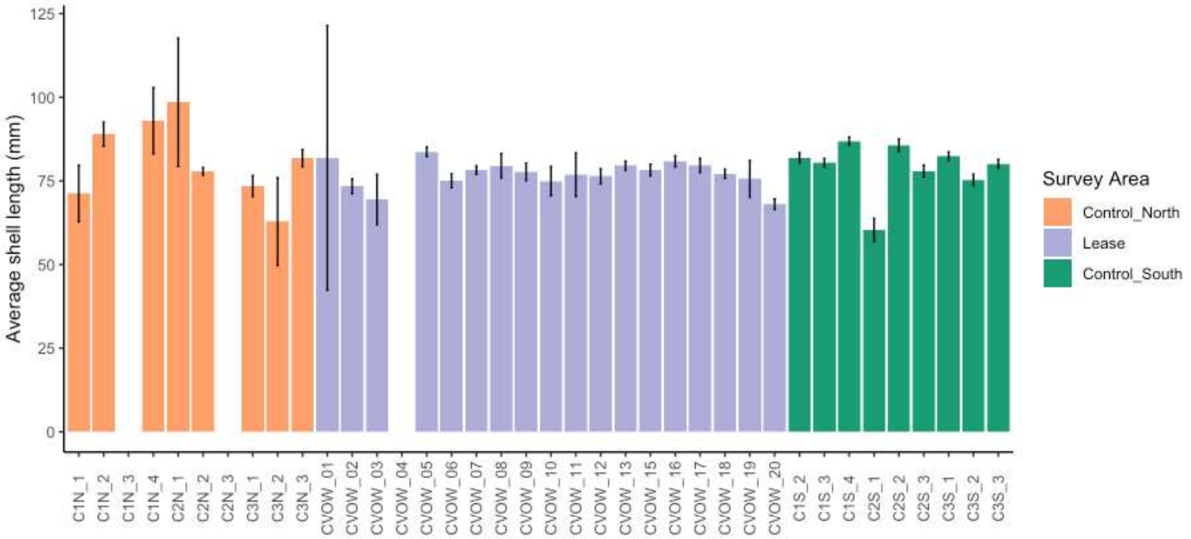


Figure 6. *Average shell length (mm) by survey area and associated 95% confidence interval arranged by station from north to south (control-north, orange; lease, purple; control-south, green). Two stations had zero catch (C1N-3 and CVOW-04) and station C2N-3 caught seven surfclams but all were unmeasurable due to breakage.*

Environmental data: Environmental conditions were collected simultaneously with biological samples collected at each station using a Castaway CTD. Environmental data collected during the surfclam survey represent single-point measurements, thereby describing the environment during sampling and not representative of the habitat throughout the entire year. Surfclam biology is closely tied to bottom water temperature ranges and are not reported here. Generally, warmer temperatures are assumed to constrain the sizes surfclams can grow to because metabolism scales with temperature (Munroe et al., 2016). The CTD provided a profile of the water column at each station and provided information on temperature and conductivity/salinity in the bottom waters at the time of sampling.

Temperature data were subset by depth to analyze the bottom temperature at the time of the survey where surfclams were collected. Over the entire survey area (lease and controls), average bottom temperatures ranged from 14.3-16.8°C (mean [*M*] = 15.7°C, *SD* = 0.73) (Table 4; Figure 7A). Control-north sites displayed the largest range in average bottom temperatures with a difference of 2.4°C, while the control-south sites recorded a difference of 0.48°C. Sites within the lease had a difference in average bottom temperature of 2.2°C, ranging from 14.6-16.8°C (*M* = 15.4°C, *SD* = 0.58).

Salinity data were also subset based on the same depth range used for the average bottom temperature. Across the survey areas, salinity ranged from 32.5-33.7 parts per thousand (ppt) (*M* = 33.0 ppt, *SD* = 0.27) (Table 5; Figure 7B). The highest salinity reading was recorded in the control-south area, while the lowest reading was found in the control-north area. The largest range in salinity occurred within the lease area, going from a minimum of 32.5 ppt to a maximum of 33.5 ppt (*M* = 32.9 ppt, *SD* = 0.16).

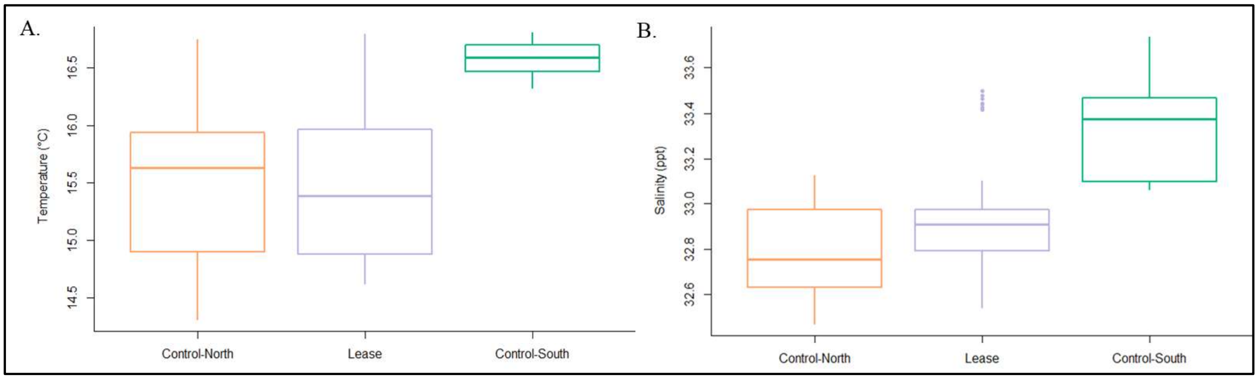


Figure 7. *A. average bottom temperature (°C) and B. salinity (ppt) for each survey area, control-north (orange), lease (purple), and control-south (green). The center line in each box plot represents the median value. The lower and upper box boundaries represent the 25th and 75th percentiles and the whiskers extend 1.5 times the interquartile range beyond the edge of the box.*

Table 5. *Average bottom temperature (°C) and salinity (ppt) range and mean values for each survey area, control-north, lease and control-south.*

Survey Area	Temperature (°C)			Salinity (ppt)		
	Min	Max	Mean	Min	Max	Mean
Control-north	14.3	16.7	15.4	32.5	33.1	32.8
Lease	14.6	16.8	15.4	32.5	33.5	32.9
Control-south	16.3	16.8	16.6	33.1	33.7	33.3

Aging:

Obtaining age composition of the catch can help inform our understanding of recruitment frequency in the study area, and length-at-age is important for deriving growth parameters for the surfclam population. Ages of surfclams can be reliably determined from annular rings laid down in the shell (Jones et al., 1978; Ropes and O'Brien 1978) and age information is an important part of the federal survey process (Chute et al., 2016). At stations where surfclams were encountered, ten to twenty surfclam shells were retained and returned to the laboratory for aging. These shells were cleaned, sectioned, sanded, and polished for aging. Individual age and length data for surfclams sampled were used to determine age frequency in the population. If sampling continues after construction, this growth curve could also then be compared.

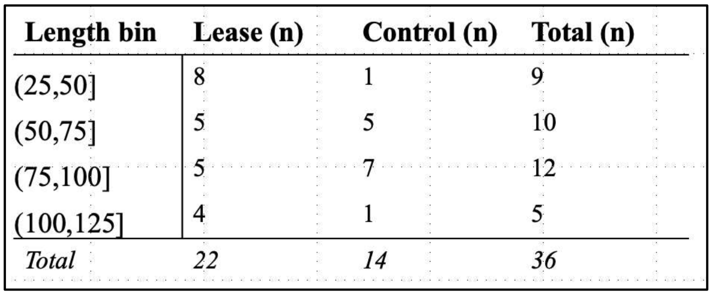
In total, 306 surfclams were retained for aging. Higher surfclam abundance was observed in the lease area and control-south, and this is reflected in the number of surfclam shells that were collected for aging from that survey area. Surfclam shells were collected at 29 stations (16 lease sites and 13 control sites) (Table 6). The distribution of surfclam shells retained is reflective of average shell sizes observed at each survey area (see Table 4) and therefore is a representative sample of surfclams in the whole region.

***Table 6**. Distribution of surfclam shells retained for aging (by survey area), count of stations where surfclam shells were collected, total count, average length of shells plus/minus the standard deviation and median length of shells.*

Survey Area	Stations	Number of surfclams collected for aging	Average shell length (mm)	Median shell length (mm)
Control - north	4	30	76.8 ± 11.2	75.5
Lease	16	115	73.2 ± 14.7	74.0
Control - south	9	161	79.0 ± 7.7	79.0
All stations	*29*	*306*	*75.7 ± 12.4*	*77.0*

Age structure of a sampled population can be estimated by summarizing the relationship between age and length for a subsample (described below) and then applying this summary to the entire sample (n = 306). This summary subsample is referred to as an age-length key. Construction of age-length keys and the procedure for assigning ages to individual samples (which have length measurements) are described in Isermann and Knight (2005). A subsample of n surfclams to be aged is selected from the entire sample by randomly selecting surfclams from each length interval (rather than a simple random selection of all surfclams). This subsampling protocol divided shells into two groups, lease and control surfclam shells, to allow shells selected for aging to be balanced by location. Shells were then binned into four separate 25-mm length increments (Table 7). Using guidelines employed in fish population studies, Lusk et al. (2021) and Coggins et al. (2013) suggested 10 individuals/length bin. These numbers provide a near-optimal performance in accuracy and precision of growth estimates. Five shells were randomly selected from each station type for each length bin (if available). For some of the length bins, there were not enough shells for a survey area, and in those cases, shells were randomly selected from the other survey area to get to ten animals (if available). This resulted in 36 shells to be aged (Table 7). The length frequency of the aged subsample was a reflective sample of the total measured sample (Figure 8).

***Table 7.** Subset of surfclam shells selected to be aged by length bin and survey area.*



Length bin	Lease (n)	Control (n)	Total (n)
(25,50]	8	1	9
(50,75]	5	5	10
(75,100]	5	7	12
(100,125]	4	1	5
Total	*22*	*14*	*36*

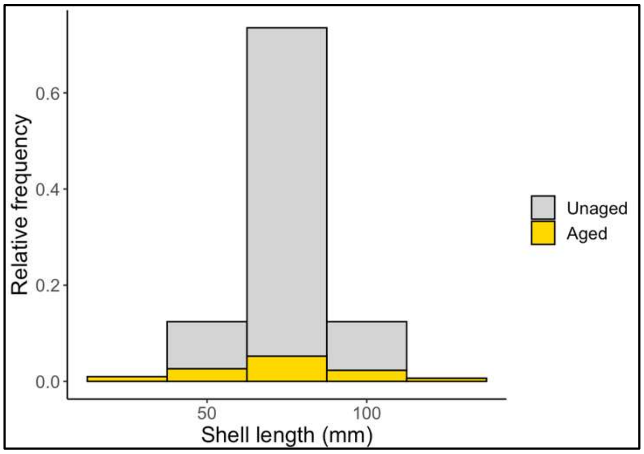


***Figure 8**. Relative length frequency (mm) of all shells retained for aging (gray) and those selected to be aged (yellow).*

Aging Methods

In total, 36 shells were selected for the aging process. The right valve of each animal was used for aging unless damage to the shell prevented an accurate reading. A line was drawn across the longest portion of the chondrophore (Figure 9) and then extended across the entire valve to use as a guideline when sectioning the shell. Before sectioning the shell, each one was filled with modeling clay to add support and prevent breakage. Approximately 27 of the total 36 shells were cut with a tile saw along the guideline, and the remaining 9 shells from the smallest length bin (i.e., 25 mm to 50 mm) were sectioned using an otolith saw to further reduce the chance of any breakage.

***Figure 9.** Surfclam shell processing for aging the chondrophore. (Left) Surfclam valves prepared for sectioning. Dotted line indicates where the surfclam shell is cut. (Middle) Sectioning of surfclam using a tile saw. (Right) Sectioned chondrophore with annual rings marked.*

The sectioned shells were sanded and polished to ensure growth lines were clearly visible under a microscope. The sanding process started with 200-grit sandpaper and worked up to 600-grit, leveling and smoothing the length of the sectioned shell and chondrophore. After progressively working through the sandpaper grits, the chondrophores were viewed under a microscope to ensure growth lines were visible. If the growth lines were visible, the shell would be set aside for aging. If the growth lines were difficult to find, the process would be repeated.

After the sanding and polishing process was complete, shells were imaged under an Olympus SZX12 Stereo Microscope in combination with the DP73 Digital Camera and Olympus cellSens imaging software. The section from each shell that had the largest portion of the chondrophore present was used when imaging. The section was securely mounted so that the length of the shell and chondrophore were level under the microscope lens. Using the cellSens imaging software, the chondrophore was displayed on a computer screen, which allowed for adjustments to the focus or contrast of the image and ensured a clear picture of the growth lines along the chondrophore (Figure 9). The completed chondrophore images were then examined with ImageJ to age each shell. Protocols designed by Redmond (2019) were followed to ensure the aging of each animal was done accurately and consistently.

Age-Length Curve

The subsample of aged shells was used to build a relationship between age and length. This relationship was then applied to estimate the age of the remaining 270 surfclams retained for aging (length sample). Each surfclam in the length sample was assigned to one of the 25 mm length increments (used above). Age was assigned to a surfclam based on its length category and the proportion of surfclams in that category of each age as determined by the age sample. Assignment of age to surfclam in the length sample was based on the probability of each age given the length category that the surfclam belongs to, as derived from the age-sample.

Once all surfclams in the length- sample were assigned an age, both the age and length samples were used to develop an age-length curve (Table 8; Figure 10). The von Bertalanffy model was used to describe Atlantic surfclam growth as:

$$L_t = L_\infty (1- e^{-k(t-t0)}) \qquad \text{Eq. 2}$$

Where L_t is the total shell length at age t (mm), L_∞ is the theoretical asymptotic maximum length (mm), k is the growth coefficient (year^{-1}), and t_0 is the theoretical age (years) at which length is zero.

Growth parameters from this study were then compared to parameters estimated using NOAA NEFSC Atlantic surfclam stock survey data (2010-2019) from the Southern Virginia survey region (Días et al., 2024) (Table 8; Figure 10).

***Table 8**. Estimated growth parameters calculated using the von Bertalanffy growth equation. Parameters provided from published literature for the NOAA NEFSC Atlantic surfclam stock Southern Virginia subregion and from this study. Parameters include asymptotic length (L_∞, mm), growth coefficient (k; year^{-1}), and the theoretical age (t_0; years) at which length is zero. 95% upper and lower confidence intervals included.*

Reference	Year	Target population	Growth parameters	Estimates	95% LCI	95% UCI
This study	2023	CVOW lease & associated controls	L_∞	84.6	81.1	98.5
			K	0.6	0.2	0.8
			t_0	-1.0	-3.3	-0.2
Días et al., 2024	2010-2019	Southern Virginia	L_∞	101.0	95.5	106.6
			K	0.7	0.7	1.4
			t_0	0.5	0.2	0.8

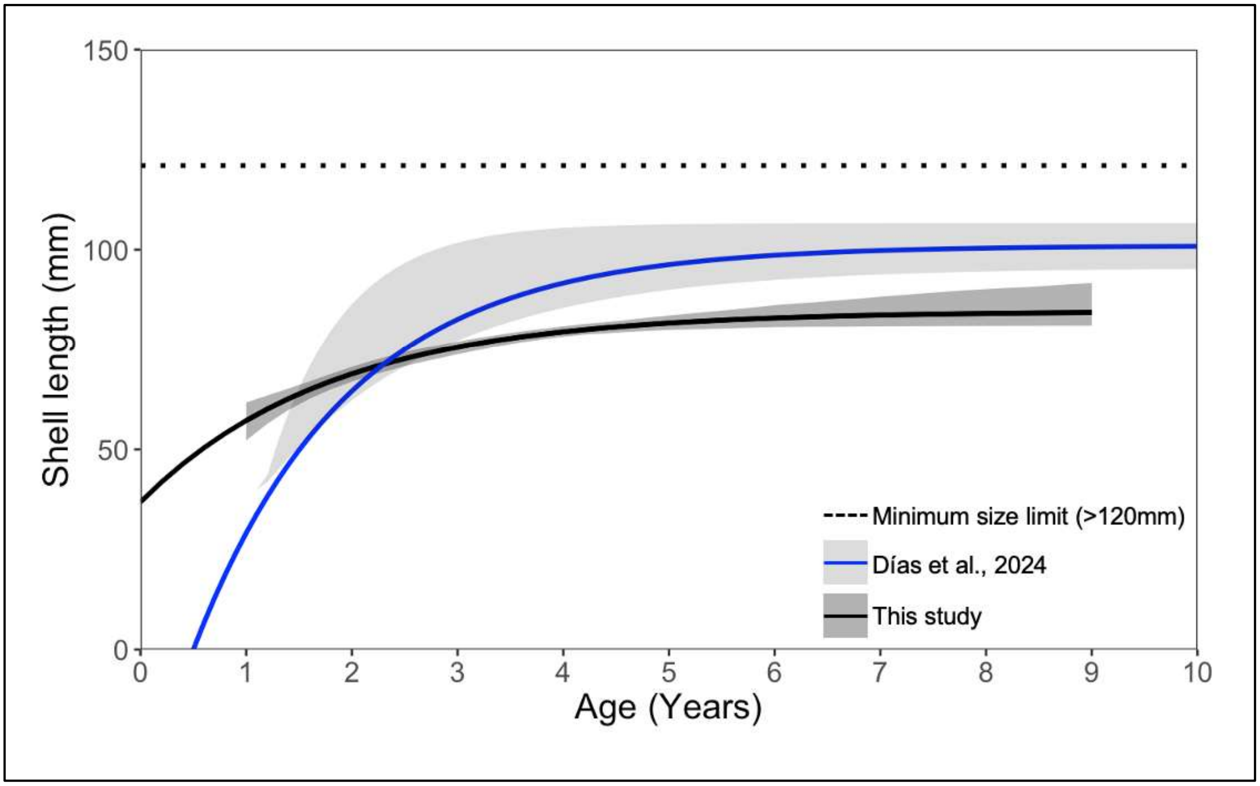


***Figure 10.** Age-length curve for this study (black line), Días et al. (2024) (blue line) and 95% confidence interval. Minimum size limit (> 120 mm) for the surfclam fishery is represented with the dotted line.*

Genetics

When available, five surfclams per station were retained for genetic analysis. A total of 155 tissue samples (~2 to 3 mm^2 of mantle) were collected, preserved in 95% ethanol, and returned to the laboratory from 15 lease and 14 control stations. The shells of these individuals were also retained. DNA was successfully extracted from all samples and assessed for quality and quantity, and standardized concentrations were sent to Dr. Matthew Hare at Cornell University to assess population structure. Dr. Hare's lab has optimized an assay to distinguish between subspecies (*S.s. similis*) and the Atlantic surfclam (*S.s. solidissima*) (Hare et al. 2010). Analysis revealed that 129 samples were *S.s. similis* and 26 were *S.s. solidissima*. There was no statistically significant difference in mean shell length between the two subspecies (Figure 11, t(29.21) = 1.03, $p = 0.3$) nor difference in shell length between survey areas (lease and control) (Figure 11, One-way ANOVA $F_{(2,151)} = 0.90$, $p = 0.41$).

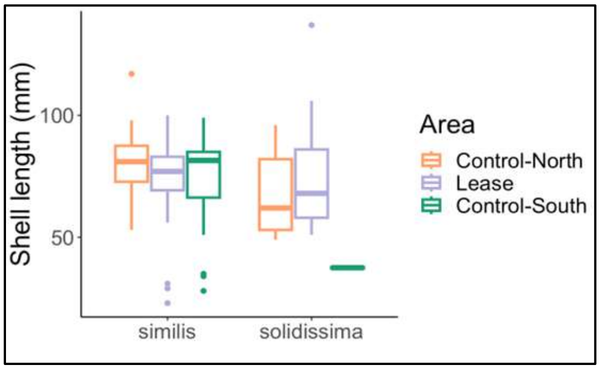


Figure 11. *Shell length (mm) for S.s. similis and S.s. solidissima tissue samples collected at the 15 lease (Lease, purple) and 14 control stations (Control-north, orange; Control-south, green).*

However, there was a statistically significant difference in abundance among subspecies between survey areas (Figure 12) (chi-square test, $p = 0.04$). This is likely due to the varying depth and temperature of the sampled sites. There was a statistically significant difference in mean sampling depth (t(40.02) = -3.59, $p < 0.001$) and temperature between the two species (t(38.30) = 5.52, $p < 0.001$), where *similis* was more commonly found at shallower and warmer sites (27.5 m and 15.9ºC), while *solidissima* was found at deeper and colder sites (30.1 m and 15.1ºC).

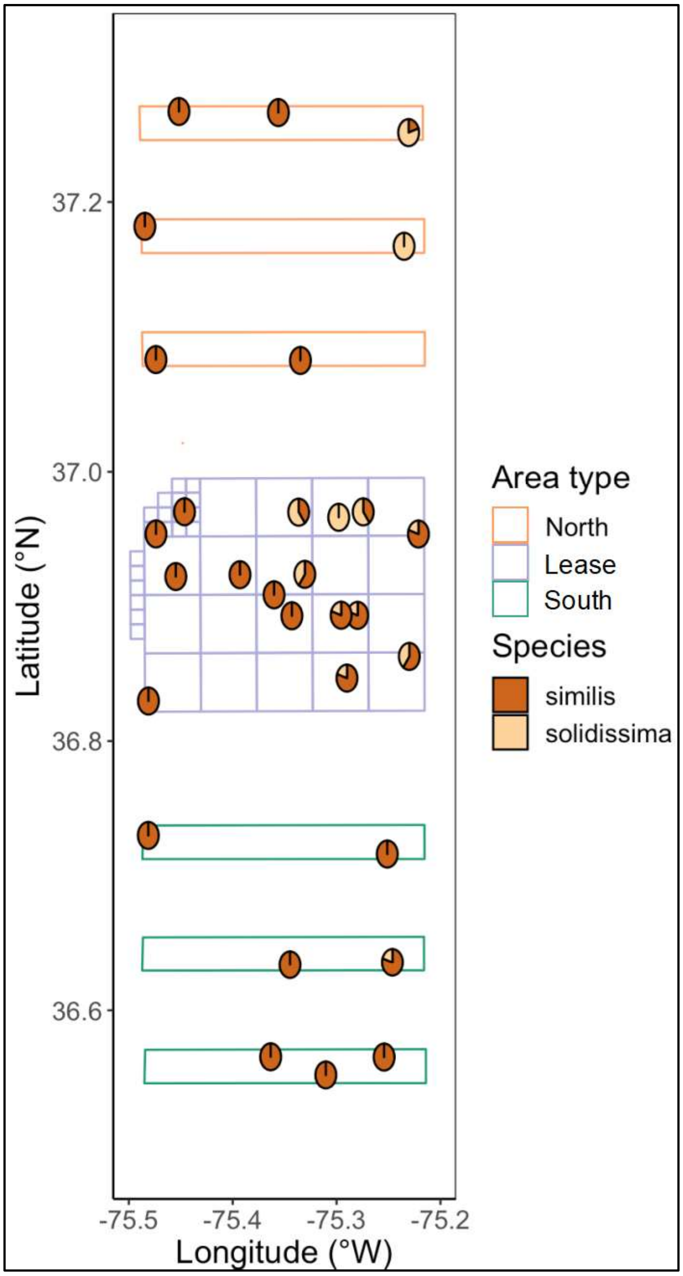


Figure 12. *Proportion of surfclam samples that were* *<u>S.s. similis</u>* *and* *<u>S.s. solidissima</u>* *by station in the three survey areas, control-north (orange), lease (purple), and control-south (green).*

Benthic Grab Sampling

A Petersen grab sampler was deployed at each station to collect a 0.1-m^2 bottom sediment sample (Figure 13). The sample was placed on a sieve table with 2.0 mm mesh and washed through the screen (Figure 13). All benthic meiofauna and any shell hash material were retained in a bag, labeled, and frozen. Frozen samples were returned to the laboratory, where meiofauna were sorted and identified.

The grab samples mainly consisted of sand and shell hash, but pebbles were present at a few of the stations. The sandy stations ranged from fine sand to coarse sand. Many stations had a mix of sediment types (e.g., semi-coarse sand, fine sand, and shell hash at one station). Juvenile surfclams were present in these samples, along with other bivalves including Tellinids and the genus *Astarte*. Surfclams collected in grab samples represent new recruits and are between 1.5-25 mm shell length and < 1 year of age. Juvenile surfclams counts varied by survey area but surfclams were present in both the control and lease areas indicating that there has been recent recruitment in the region. The highest count of juvenile surfclams were found in the northern control but the largest juveniles were found in the southern control (Table 9).

Figure 13. *(Left) Peterson grab sample collection. (Right) Benthic sediment sample is collected and placed into a bin. Sample is then sieved through mesh and retained for lab processing.*

Table 9. *Number of live juvenile surfclams collected with the Petersen grab sampler including the average count per grab plus/minus the standard deviation, median count per grab, range in count per grab observed at each survey area, and the average shell length (mm).*

Survey Area	Number of grab samples	Average surfclam count	Median surfclam count	Range in count	Average shell length (mm)
Control - north	10	6.8 ± 7.1	3.0	0-20	5.5 ± 2.2
Lease	18	1.5 ± 2.3	0.0	0-7	5.9 ± 2.0
Control - south	9	3.6 ± 4.1	2.0	0-13	7.2 ± 5.5

Bycatch

During sampling processing of each dredge tow qualitative information regarding presence of non-target species or bycatch caught was noted. Bycatch included molluscs, arthropods, chordates, and echinoderms (Table 10).

Table 10. *Bycatch species observed in dredge tows.*

Phylum	Class	Species	Common Name
Mollusca	Gastropoda	*Busycon carica*	Knobbed Whelk
		Busycotypus canaliculatus	Channeled Whelk
		Euspira heros	Moon Snail
	Bivalvia	*Mercenaria campechiensis*	Southern Quahog
		Arctica islandica	Ocean Quahog
		Astarte castanea	Chestnut Astarte
		Placopecten magellanicus	Atlantic Sea Scallop
	Cephalopoda	*Octopoda* spp.	Octopus
Arthropoda	Crustacea	*Paguroidea* spp.	Hermit Crab
		Majoidea spp.	Spider Crab
		Cancer borealis	Jonah Crab
		Ovalipes ocellatus	Lady Crab
		Callinectes sapidus	Blue Crab
	Chelicerata	*Limulus polyphemus*	Horseshoe Crab
Chordata	Chondrichthyes	*Raja eglanteria*	Clearnose Skate
	Actinopterygii	*Centropristis striata*	Black Sea Bass
		Hippoglossina oblonga	Fourspot Flounder
		Prionotinae spp.	Sea Robin
		Astroscopus guttatus	Star Gazer
Echinodermata	Asteroidea	*Asterias rubens*	Common Starfish

Summary

This surfclam survey observed relatively high total biomass and density of surfclams within and around the CVOW lease area; total biomass observed here was more than double that observed in lease areas off New Jersey in the central portion of the fishing stock. However, the surfclams collected in and around the CVOW lease were almost exclusively smaller than 120mm throughout the surveyed area, meaning that the exploitable biomass (the biomass of surfclams >120mm) was relatively low. A spatial pattern in abundance was evident with highest biomass in the south, and biomass gradually decreasing northward. For example, surfclam biomass in the southern control was over 50 times higher than that observed in the northern control. The latitudinal biomass pattern across the surveyed area is coincident with slightly higher temperature and salinity in the southern control; however, this slight change in bottom water conditions is unlikely to explain the difference in biomass. More likely, the differences in biomass are driven by benthic habitat type, food availability, and stochastic patterns in recruitment, although we cannot test these directly with the information collected in this survey.

Surfclams in this survey represented age classes from < 1 year old (collected in benthic grabs) through 9 years old. Age classes 1 through 6 are consistently observed, suggesting that recruitment of surfclams has been consistent over the past 5 to 6 years. The absence of older age classes suggests that recruitment prior to 2017 may have failed, or that surfclams are generally not surviving past 6 years of age in this area. The patterns of genetics observed in this survey indicated that a mix of *S.s.solidissima* and *S.s.similis* was widely distributed throughout the CVOW lease and adjacent areas. These results were unanticipated given that *S.s.similis* has, to date, been identified in shallower habitats, such as backbay ponds in Massachusetts, Georgia, and Long Island Sound (Hare et al., 2010) and are not expected to occupy the same deep water habitats as *S.s.solidissima*.

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