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INVENTORY OF NEW JERSEY'S ESTUARINE SHELLFISH RESOURCES: HARD CLAM STOCK ASSESSMENT

RARITAN AND SANDY HOOK BAYS (Survey Year 2014)

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Abstract

The New Jersey Marine Fisheries Administration - Bureau of Shellfisheries ("Bureau"), conducted a hard clam [*Mercenaria mercenaria* (Linnaeus 1758)] stock assessment in Raritan and Sandy Hook Bays in Monmouth County, New Jersey. Two prior comprehensive surveys were completed in 1983 and 2000. The Bureau sampled 108 stations in Raritan Bay and 98 stations in Sandy Hook Bay using a hydraulic clam dredge and estimated each bay's standing stock and relative distribution of hard clams. Work was conducted between September 4, 2014 and October 14, 2014. The survey resampled stations that were sampled during the previous two surveys. The standing stock of hard clams in Raritan Bay for 2014 was estimated at 839.1 million clams. That estimate represents an approximately 39% increase in the standing stock compared with the 601.7 million clams estimated from the 2000 survey. The standing stock of hard clams in Sandy Hook Bay for 2014 was estimated at 355.1 million clams, representing a 4% increase from the standing stock of 342.7 million clams in 2000.

A stock estimate was also calculated for the designated depuration harvest zones that span Sandy Hook Bay and portions of Raritan Bay. The estimate for all of the harvest zones in 2014 was 931.1 million clams, representing a 27% increase from the 2000 estimate of 735.2 million clams.

Statistical analysis indicated a significant increase in hard clam abundance for Raritan Bay when comparing stations sampled in 2014 to those same stations sampled in 2000. There was no statistical difference in abundance for Sandy Hook Bay. The mean length of hard clams for Raritan Bay collected in 2014 was 69.6mm and was a statistically significant increase in length from the mean length of 65.7mm in 2000. The mean length of clams in Sandy Hook Bay in 2014 was 64.9mm and was a statistically significant decrease from the mean length of 68.4mm in 2000. There was no significant difference in recruitment indices (the percentage of clams sized 30-37mm collected at each station compared with all clams >37mm collected at the same station) between the two surveys for Sandy Hook Bay, but there was a significant decrease in recruitment in Raritan Bay. Analysis showed no significant difference in mortality estimates for Raritan Bay between the two surveys but a significant increase in mortality was found for Sandy Hook Bay in 2014 when compared with 2000.

Introduction

The Raritan and Sandy Hook Bay complex is located in Monmouth County, New Jersey (Figure 1). Although one waterbody, the pier at U.S. Naval Weapons Station Earle is commonly used to distinguish the two bays, with Raritan Bay to the west of the pier and Sandy Hook Bay to the east.

The first modern comprehensive survey of hard clams in Raritan and Sandy Hook Bays was performed in 1983 by the Bureau as part of its Estuarine Shellfish Research and Inventory Program (McCloy and Joseph 1984). The primary purpose of that survey, as well as the one performed in 2000 (Celestino 2003b) and 2014, was to determine the standing stock, distribution, and relative abundance (density) of hard clams in the bay. The survey completed in 2014 is nearly identical to the surveys performed in 1983 and 2000. Quantitative and qualitative comparisons were made between the surveys where appropriate.

Raritan and Sandy Hook Bays are the center of New Jersey's commercial hard clamming industry. All clamming is performed within the depuration harvest zones designated by the NJDEP's Bureau of Marine Water Monitoring. Two depuration plants serve the industry at this time.

Materials and Methods

Study Site

All field work was conducted in the Raritan and Sandy Hook Bays, Monmouth County, New Jersey (Figures 1-3). The Hudson-Raritan Estuary spans the states of New York to the north and New Jersey to the south. The Hudson River and Arthur Kill feed into the estuary from the north, the Raritan River from the west, and the Navesink and Shrewsbury Rivers from the south. The estuary opens to the Atlantic Ocean on the east. All sampling within the estuary was limited to New Jersey state waters.

Sampling

A total of 206 stations (Raritan: 108, Sandy Hook: 98) were quantitatively sampled between September 4, 2014 and October 14, 2014. All stations were sampled with a hydraulic clam dredge that was deployed from the research vessel *Zephyrus*, a 42-foot long, Chesapeake dead rise style vessel. The dredge was equipped with a 12" – wide blade that cut 4" in to the substrate and a stainless steel cage with bars spaced to retain clams 30mm and larger. Although clams less than 30mm were occasionally obtained, clams less than 30mm were not included in any statistical analyses. Water was jetted through nozzles to either loosen the substrate ahead of the knife or to push sediment to the back of the dredge. The forward nozzles, located above the knife, were opened when towing through harder, sandy substrates to loosen the sediments. The rear nozzles, positioned towards the back of the dredge cage, were opened while towing through softer, muddy substrates, to help prevent the knife from becoming clogged with sediment and to expel sediment through the back of the cage. Occasionally, both sets of nozzles were opened when towing through "sticky" sediments, where the sand/mud substrate needed to be both loosened and expelled.

Water was supplied to the nozzles through a 3" hose attached to a hydraulically powered Berkeley irrigation water pump on the deck of the vessel. At 35-40 pounds of pressure per square inch, the pump delivered approximately 300-500 gallons of water per minute. The dredge was deployed and retrieved using a 3/8" stainless steel wire cable attached to the main haul back winch on the vessel. Towing was accomplished using a 3/4" polypropylene graduated line.

The 2014 survey closely followed the previously established protocols from the 1983 survey (see McCloy and Joseph 1984) and those of the 2000 survey (see Celestino 2003b). McCloy and Joseph (1984) established a grid system that placed stations at ½ - mile intervals in Raritan Bay and central Sandy Hook Bay, while stations along the shallow and near-shore areas of Sandy Hook Bay were set at ¼ - mile intervals. Stations sampled in 2014 were identical to those sampled in 2000 except where it was not feasible due to recent obstructions, changes in bathymetry, or submerged telecommunication/electric cable areas, in which case the station was relocated as close to the original station as possible.

Stations were located using a Garmin GPS 4210 chart plotter. Water quality parameters (salinity, temperature, pH, and dissolved oxygen) were determined in the field at the first and last stations sampled each day using a YSI-Professional Plus multimeter.

Water depth was determined using the Garmin GPS 4210 chart plotter. The towline length was set at a length-to-depth ratio of 4:1, plus an additional 15' of length to account for the distance from the tow bit to the water line. Nozzle selection was determined using the qualitative sediment data collected in 2000 (ex. "sand" or "mud"). In instances where it appeared that the dredge was not fishing properly, nozzles were adjusted and the tow was repeated. At each station qualitative substrate information was updated. One 100' tow was attempted at each station, although 100' was not always achievable due to submerged obstructions, high percentages of clay, or subsurface currents. Once the dredge was deployed from the vessel and the tow line became taught, vessel speed was adjusted using a trolling valve.

A graduated distance measuring line with a weight attached to the end was deployed perpendicularly to the vessel and released gradually as the vessel moved forward. When the 100' mark was achieved, the dredge was hauled back while the vessel was kept as stationary as possible to avoid sampling additional area. Additional length was added to the distance line to account for water depths and the angle of the line to the bottom.

After the dredge was retrieved, the dredge was either washed by towing it briefly at the surface to expel remaining sediment, or brought on board the vessel immediately if washing was not necessary. The contents of the dredge were deposited on the culling table and sorted. All live hard clams were counted and lengths were measured to the nearest millimeter. Empty, paired hard clam valves, referred to hereafter as boxes, were also enumerated and measured to the nearest millimeter.

Horseshoe crabs (*Limulus polyphemus*) and blue crabs (*Callinecdes sapidus*) were sexed and measured to the nearest millimeter. Other associated species, including surf clams (*Spisula solidissima*), soft clams (*Mya arenaria*), and blue mussels (*Mytilus edulis*) were noted for

presence. Observations of live submerged aquatic vegetation and macroalgae collected in the dredge (if any) were also noted.

Hard Clam Analysis

Statistical analyses were performed for the years 2000 and 2014 only; no statistical comparison was made with 1983 data, since that data was previously compared with the year 2000 data in Celestino (2003b). Only clams sized 30mm and greater were included in the statistical analyses. Although the dredge was not designed to retain clams smaller than 30mm, a fair number of small seed clams were found, and that information is provided in summary form only.

Abundance and Distribution

Hard clam abundance, expressed as number of clams per square foot, was calculated for the catch per tow at each station. All data were adjusted for the dredge's overall mean efficiency of 88.0% (±7.7%) by increasing raw abundances by a factor of 1.137 (100 ÷ 88) (see Celestino 2003a)[1]. For the purpose of understanding relative abundance and distribution of *Mercenaria*, the following categories were employed: none (0.00 clams/ft^2), occurrence (0.01 - <0.20 clams/ft^2), moderate abundance (0.20 - <0.50 clams/ft^2) and high abundance (≥0.50 clams/ft^2). Each station was assigned a category once the data had been adjusted for dredge efficiency. This category system was employed in previous studies by the Bureau. Figures were produced that visualize the distribution of the different densities of hard clams throughout the bay.

For the purpose of estimating the standing stock of hard clams, stations were categorized according to the same classification intervals established in prior surveys: (0.00 clams/ft^2), (0.01 - <0.06 clams/ft^2), (0.06 - <0.12 clams/ft^2), (0.12 - <0.50 clams/ft^2), (0.50 - <1.0 clams/ft^2), (1.0 - <2.0 clams/ft^2) and (≥2.0 clams/ft^2). Adjacent stations of the same density category were grouped together in polygons using ESRI ArcMap v10.3.1. The mean density of clams was calculated for each polygon and multiplied by the area of the polygon to get an estimate of the standing stock for that particular area. All areas were summed for a total stock estimate of the bay.

A standing stock estimate was also calculated exclusively for the designated depuration harvest zones, using the above classification intervals and methods. The commercial harvest of shellfish is limited to work within these zones and must be performed under a special depuration harvest permit issued by the Bureau of Marine Water Monitoring.

A t-Test for paired means where $\alpha=0.05$ was conducted on hard clam density data for individual stations that were sampled in both surveys. The null hypothesis was that there was no difference in densities of clams between the two surveys. Data for n= 206 paired stations were analyzed.

[1] This study was performed with a different vessel, the *R/V Jennings* (née *Notata*). The same dredge was used in this study and all subsequent sampling events. The Bureau plans to perform an efficiency study with the new vessel as soon as possible. The outcome of the study may require a slight revision of this data.

Population Age/Size Structure

All clams collected that were 30mm and greater were measured for length and graded in to the following commercial size classifications: sublegals (30-37mm), littlenecks (38-55mm) cherrystones (56-76mm) and chowders (>76mm). A composite (sum of all clams measured) length-percent-frequency distribution graph and length-frequency graph were produced, where lengths were combined into three-millimeter groupings (starting at, but not including clams obtained at 29mm). This three-millimeter bin system was employed in previous estuarine inventories. Length-percent-frequency plots were produced for each depuration zone.

A paired t-Test where $\alpha=0.05$ was used to analyze mean clam lengths between 2000 and 2014, where paired data were available (n=94 stations where ≥1 clam was collected in both survey years for Raritan Bay; n=93 stations for Sandy Hook Bay). The null hypothesis was there was no change in mean clam lengths between the two surveys.

Recruitment

The percentage of sublegal clams collected at each station was calculated as a measure of recruitment at each station. Sublegal clams (30-37mm) collected represented a single year class and thus were expected to recruit into the fishery at the legal length of 38mm the following year. The recruitment index per station was calculated as

$$\left\{\frac{\text{no. of clams collected between 30 and 37mm at station } i}{\text{total no. of clams collected at station } i}\right\} \text{ x } 100\%$$

If no live clams were collected, recruitment = NA as 0÷0 is undefined. The result from each station was binned and plotted, except those stations where recruitment was undefined.

Statistical analysis was performed for paired stations where abundances were ≥0.20 clams/ft^2 in both survey years (n=37 pairs of stations for Raritan Bay; n=51 pairs for Sandy Hook Bay). The null hypothesis was that there was no change in recruitment between the two survey years, where $\alpha=0.05$.

Mortality

Natural mortality was calculated for each station using the number of boxes relative to the station's entire sample of boxes and live hard clams.

$$\left\{\frac{\text{no. of boxes at station } i}{\text{no. of boxes at station } i + \text{no. of live clams at station } i}\right\} \text{ x } 100\%$$

The calculation was independent of age, size, or gender of *Mercenaria mercenaria*. If no live clams or boxes were collected, mortality = NA as 0÷(0+0) is undefined. The result from each station was binned and plotted, except those stations where recruitment was undefined.

A paired t-Test for means (n=103 pairs of stations for Raritan Bay; n=95 pairs for Sandy Hook Bay) where α=0.05 was used to compare mortality indices between the two survey years 2000 and 2012. The null hypothesis was that there was no difference in mortality percentages between the two surveys.

Submerged Aquatic Vegetation (SAV)

Vascular vegetation was not collected at any of the stations, nor was it during each of the two prior surveys. Therefore, no analysis was performed. Macroalgae was observed and recorded, but the data are not provided in this report.

Results

Description of the Study Site

Sediment type in both bays ranged from hard sand to soft mud, and included cobble, gravel, and shell. Tables 1a (Raritan Bay) and 1b (Sandy Hook Bay) below summarize the water quality characteristics of each bay, respectively.

Table 1a. Water quality measurements for Raritan Bay, 2014.

Raritan		Temperature (°C)	Dissolved Oxygen (mg/L)	Salinity (‰)	pH
Surface	Minimum	17.4	5.2	24.4	7.4
	Maximum	25.2	9.5	27.5	8.0
	Mean	21.5	7.0	25.9	7.6
	SD	2.3	1.5	1.0	0.2
Bottom	Minimum	17.3	3.8	24.4	7.3
	Maximum	25.2	10.1	28.0	7.9
	Mean	21.4	6.4	26.5	7.6
	SD	2.2	1.7	1.1	0.2

Table 1b. Water quality measurements for Sandy Hook Bay, 2014.

Sandy Hook		Temperature (°C)	Dissolved Oxygen (mg/L)	Salinity (‰)	pH
Surface	Minimum	16.7	6.3	26.1	7.5
	Maximum	20.8	10.1	27.1	7.8
	Mean	18.9	7.5	26.5	7.6
	SD	1.5	1.2	0.4	0.1
Bottom	Minimum	15.9	5.9	26.1	7.4
	Maximum	20.0	7.7	28.1	7.7
	Mean	18.7	6.6	26.9	7.6
	SD	1.5	0.6	0.7	0.1

Hard Clam Abundance and Distribution

The total hard clam resource in Raritan Bay and Sandy Hook Bays was estimated at 839.1 and 355.1 million clams, respectively (Table 2). When the dredge efficiency factor was not applied to the raw data (in order to produce a conservative estimate), the stock was estimated at 738 million clams for Raritan Bay and 312 million clams for Sandy Hook Bay. An estimate of the stock based upon commercial size classes is presented in Table 3 and Figure 4. Table 4 summarizes the estimated stock for each depuration zone, breakdown of the stock by commercial size class, as well as the mean length of clams in that zone.

There was a significant difference in the mean abundance of clams (clams/foot^2) on a station-by-station basis in Raritan Bay, but no significant difference in abundance in Sandy Hook Bay. Details of the analysis are provided in Table 5.

A grand summary of station location, hard clam abundance, mean length, percent mortality, and commercial size classes percentages, are provided in Table 6.

Figure 5 provides the abundance and relative distribution of hard clams sized 30mm and greater for 2014. Figures 6 and 7 are copies of the abundance charts from the 2000 and 1983 surveys, respectively, and are provided for comparison purposes. Figure 8 depicts the 2014 hard clam distribution relative to the depuration zones.

Figure 9 depicts the stations where clams less than 30mm were collected. The dredge is not designed to retain clams less than 30mm, so a failure to collect these small clams should not be interpreted as an absence of smaller clams.

Table 2. Summary of hard clam stock estimates for Raritan and Sandy Hook Bays.

Year	Raritan Bay	Sandy Hook Bay
1983	221,714,632	171,686,715
2000	601,650,715	342,746,995
2014	839,057,163	355,070,980

Table 3. Stock estimate based upon commercial size classes.

	Sublegals	Littlenecks	Cherrystones	Chowders
Raritan	59,662,318	140,253,155	407,562,208	231,553,592
Sandy Hook	48,511,623	116,465,729	117,570,429	72,523,199
Depuration Harvest Zones	94,816,875	183,454,281	378,395,504	274,156,948

Table 4. Summary of hard clam stock estimates by depuration zone.

Depuration Harvest Zone	Mean Length (mm)	Percent Sublegals	Percent Littlenecks	Percent Cherrystones	Percent Chowders	Stock Estimate
1A	74.9	1.83	12.74	38.41	47.02	10,095,715
1B	68.9	7.59	23.02	41.93	27.46	2,473,959
1C	83.3	1.45	6.33	27.15	65.06	1,354,038
2A	67.8	3.54	13.40	49.93	33.13	7,870,395
2B	68.3	3.35	9.32	50.20	37.13	10,776,679
2C	73.7	1.61	14.87	33.46	50.07	1,502,765
10A	81.7	17.78	21.87	20.98	39.37	20,201,951
10B	53.7	18.95	39.25	26.82	14.98	88,021,681
10C	57.7	14.80	42.53	32.56	10.12	20,275,434
10D	59.9	8.73	45.24	39.43	6.61	51,104,686
10E	67.8	2.73	17.56	47.91	31.81	9,602,168
10F	68.2	11.19	21.97	32.79	33.91	39,967,825
11A	61.0	15.87	22.37	26.00	31.97	5,434,018
11B	77.8	3.44	6.28	26.42	63.43	9,115,817
11C	73.4	9.13	7.55	38.89	44.43	160,014,945
11D	54.8	19.98	25.49	28.11	26.41	56,889,473
11E	69.6	10.64	16.84	30.15	42.21	11,046,016
12A	70.3	13.72	14.03	40.72	31.52	123,830,033
12B	68.0	7.68	18.71	52.63	20.98	134,961,238
13A	74.2	1.21	3.53	52.29	42.97	57,900,212
13B	82.5	1.66	0.55	39.92	57.86	3,293,164
13C	76.4	0.17	6.68	37.16	55.98	8,680,464
13D	65.5	4.88	18.27	45.80	31.05	27,502,295
14	69.2	5.04	25.34	53.05	16.57	69,229,871

Table 5. Summary of abundance analysis.

Raritan	**Abund14**	**Abund00**
Mean	0.8467014	0.62029564
Variance	0.5307577	0.53678813
Observations	108	108
df	107	
t Stat	3.0126013	
P(T<=t) two-tail	0.0032331	

Sandy Hook	**Abund14**	**Abund00**
Mean	0.941028941	0.92259276
Variance	0.652346344	0.6270362
Observations	98	98
df	97	
t Stat	0.211906421	
P(T<=t) two-tail	0.832624665	

Population Age/Size Structure

A composite (sum of all clams measured) percent-length-frequency and length-frequency distribution graph were produced for each waterbody (Figures 10a and 10b), where lengths were combined into three-millimeter groupings (starting at, but not including clams obtained at 29mm). Percent-length-frequency graphs were also produced for each depuration zone (Figure 11). A summary of the total number of clams collected and measured in each survey year, along with mean lengths, standard deviation, and other measures of central tendency are presented in Table 7. A t-Test for means of paired samples indicated significantly greater mean lengths for Raritan Bay clams in 2014 compared with 2000, while the opposite was true of clams in Sandy Hook Bay (clams were significantly smaller in 2014) (Table 8).

Table 7. Summary statistics for hard clam lengths.

Raritan	**2014**	**2000**
n	7851	5653
Mean	66.3551	61.9172
SD	15.9004	17.4988
Median	69	64
Mode	78	68

Sandy Hook	**2014**	**2000**
n	7998	8891
Mean	60.5999	64.8736
SD	17.7461	18.799
Median	60	66
Mode	60	82

Table 8. Summary of hard clam lengths analysis.

Raritan	**2014**	**2000**
Mean	69.60154235	65.69622929
Observations	94	94
df	93	
t Stat	3.533228603	
P(T<=t) two-tail	0.000641386	

Sandy Hook	**2014**	**2000**
Mean	64.8711828	68.35483871
Observations	93	93
df	92	
t Stat	-3.09853914	
P(T<=t) two-tail	0.002579647	

Recruitment

Summary analysis for recruitment was conducted for stations with abundances of ≥ 0.20 clams/ft^2. Statistical comparison between the 2000 and 2014 surveys in Raritan Bay indicated that there was a small, but statistically significant decrease in the percentage of recruitment in 2014. However, 62% of all stations sampled had evidence of recruitment in 2014, compared with 59% of all stations sampled in 2000.

For Sandy Hook Bay, there was no significant difference in recruitment between 2000 and 2014 and both years had high percentages of stations with recruitment (73% in 2014, 74% in 2014). Table 9 summarizes the analysis. Figure 12a provides the percentage of recruitment (the percentage of sublegal clams found) at each station throughout the bays. Data from 2000 (Figure 12b) and 1983 (Figure 12c) are also provided for comparison purposes.

Table 9. Summary of recruitment analyses.

Raritan Bay	**2014**	**2000**
Mean	9.13391	14.5714
Observations	37	37
df	36	
t Stat	-2.0427	
P(T<=t) two-tail	0.04846	

Sandy Hook	**2014**	**2000**
Mean	11.8588	11.1157
Observations	51	51
df	50	
t Stat	0.46065	
P(T<=t) two-tail	0.64705	

Mortality

Statistical analysis using a paired t-Test showed no significant difference in mortality in Raritan Bay between 2000 and 2014. However, the proportion of stations exhibiting mortality increased, where 89% of stations in 2014 had mortality and only 66% of stations had mortality in 2000. In Sandy Hook Bay, mortality was significantly higher in 2014 than in 2000, and all stations (99%) but one exhibited mortality. In 2000, 93% of stations showed mortality. Table 10 summarizes the mortality analysis. Figure 13a plots the binned mortality percentages throughout the bays in 2014. Figures 13b and 13c depict the mortality percentages in 2000 and 1983, respectively, for comparison purposes.

Table 10. Summary of mortality analysis.

Raritan	**2014**	**2000**
Mean	11.941	9.45544
Observations	103	103
df	102	
t Stat	1.28686	
P(T<=t) two-tail	0.20106	

Sandy Hook	**2014**	**2000**
Mean	15.478	8.60589
Observations	95	95
df	94	
t Stat	3.59873	
P(T<=t) two-tail	0.00051	

Associated Species

At each sampling location, the presence of associated species of interest was noted, but not enumerated, except for blue crabs (*Callinectes sapidus*) and horseshoe crabs (*Limulus polyphemus*), where length and sex were recorded. The data are not presented in this report but are available upon request.

Distribution charts were produced for blue mussels (*Mytilus edulis*) (Figure 14a), surf clams (*Spisula solidissima*) and soft clams (*Mya arenaria*) (Figure 15a). For comparison purposes, Figures 14b and 14c are copies of the blue mussel distribution charts from the 2000 and 1983 surveys, respectively, while Figures 15b and 15c are copies of the surf clam and soft clam distribution charts from the 2000 and 1983 surveys. Note that although Eastern oysters

(*Crassostrea virginica*) were found in the 1983 survey, oysters were not found in either the 2000 or 2014 surveys.

Discussion and Conclusions

The standing stock of hard clams for Raritan and Sandy Hook Bays in 2014 was estimated at a combined total of approximately 1.2 billion clams. This number represents the highest estimated stock of the bays when compared with the two prior surveys conducted in 1983 and 2000.

There was a dramatic increase in the standing stock of hard clams in Raritan Bay between the two survey years of 2000 and 2014 (39% increase; 839.1 million clams). Most notably, the western part of the bay (west of Union Beach) that was previously designated as low density in 2000, and low density or "none" in 1983, was occupied by high and moderate densities of clams in 2014, resulting in a westward expansion effect of the population. East of Union Beach and leading to the pier at U.S. Naval Weapons Station Earle remained mostly similar between 2000 and 2014 in terms of clam distribution, with only minor changes. Additionally, the statistical difference in abundance over time on a station by station basis, and review of the data, indicated not only that more stations contained higher abundances of clams than in the past, but also that many of the stations with previously moderate and high densities had even higher densities of clams than in 2000.

In addition to the increase in numbers of individuals, the average size of clams increased by about 3.9mm since 2000. As shown in Figure 4, the population in Raritan Bay was dominated by larger cherrystone and chowder sized clams, which is unsurprising given that the year 2000 population was dominated by all sizes of cherrystone clams and also had a strong sublegal year class (Figure 10a). It is likely that these smaller clams grew into the larger clams that dominated the population in 2014, as overlaying the 2000 recruitment data with the 2014 distribution chart shows remarkable overlap.

The sublegal year class represented just over 7% of all clams collected, but this year class was not as strong as the one in 2000 (13.6%). As shown in Figure 9 and 12a, it is reassuring that sublegal clams and clams smaller than 29mm were distributed throughout most of the bay, although statistically there was a significant decrease in the percentage of recruitment on a station-by-station basis in 2014. However, it is important to note that more stations showed evidence of recruitment in 2014 than in 2000. Additionally, since the data are reported as percentage of the total catch, the reader should use caution when interpreting the results, as most of the stations in 2014 with recruitment contained very large numbers of clams overall, which affects the percentage of sublegal clams relative to the total catch.

For all clam sizes, although there was no statistical difference in mortality between 2000 and 2014, natural mortality was more frequently observed in 2014, with evidence of mortality at 89% of the stations in 2014 and only 66% of all stations in 2000. Anecdotal evidence of predation on smaller clams showed a strong presence of moon snail predation in 2014.

Sandy Hook Bay experienced an increase in stock from 2000 as well, but less notably so with only a 4% increase over time (355.1 million clams). Statistically, there was no difference in abundance on a station-by-station basis over time, so the increase is attributed to the few stations that transitioned to higher densities since 2000. Comparison of the 2000 and 2014 distribution charts indicated that the distribution of clams also remained similar over time, with only minor changes. In particular, the northern part of the Bay transitioned from moderate densities of clams to high densities of clams, while the very southeastern part of the bay, near the Highlands, experienced a decrease from high densities of clams to moderate densities.

The population in Sandy Hook was dominated by littleneck and cherrystone clams, which was generally consistent with the size frequency distribution in 2000. However, the average length of clams was significantly smaller in 2014, by about 3.5mm. The percentage of sublegal clams collected in 2014 was greater by 2% than in 2000, but no statistical increase in percent recruitment on a station-by-station basis was found. More notably, a geographical shift occurred between the two survey years where the higher percentages of recruitment at stations were found in the northern part of Sandy Hook Bay, instead of the southcentral area where recruitment was higher in 2000.

Natural mortality in 2014 was significantly higher than in 2000, jumping from an average of 9% in 2000 to 15% in 2014. Local shellfishermen remarked that the numbers of dead clams appeared to be high at that time as well. As with Raritan Bay, there appeared to be noticeable predation from moon snails, especially on smaller clams, but specific data are not available to compare over time. The most intense mortality in 2014 occurred along the southwestern bank, adjacent to the Earle Pier, and along the western bank running south to north, along Sandy Hook.

The stock estimate for only the depuration zones also increased over time by 27% to reflect a stock of approximately 931.1 million clams. This is encouraging for the commercial depuration harvest of hard clams in the bay.

Distribution charts were produced for surf clam (Spisula solidissma), blue mussels (Mytilus edulis) and soft clams (Mya arenaria). The distribution of surf clams appears relatively similar between 2000 and 2014, with the population primarily found on Flynn's Knoll and the southeastern shoreline of Sandy Hook Bay. Two small pockets of surf clams were also found in central Raritan Bay. Soft clams were found only in a small pocket near the Atlantic Highlands, which contrasts with the large area in the western Raritan Bay where they were found in 2000, and even more with the comprehensive distribution throughout Raritan Bay in 1983. However, blue mussels were widely found throughout both Raritan and Sandy Hook Bays, appearing more similar in distribution to the 1983 chart than the 2000 chart.

In conclusion, the overall Raritan/Sandy Hook Bay system in New Jersey waters is estimated to have 1.2 billion hard clams. This increase in population since 1983 and 2000 is encouraging for the status of the resource and continuation of the commercial fishery.

Acknowledgements

Sincere appreciation is extended to Jeff Normant for vessel operation, instruction and guidance in completing the survey work and analysis. Special thanks are extended to the vessel operator, Bill Maxwell, and to Garrison Grant, Ian O'Neil, Julie McCarthy, Jamie Taylor, and Jenny Tomko for field, office, and laboratory assistance. NJDEP staff at the Leonardo State Marina are also sincerely thanked for providing mooring for the research vessel. This report benefited from the review and comments of Jeff Normant, Michael Celestino, and Lloyd Lomelino. Finally, special thanks are extended to the United States Navy for allowed special access to the restricted area surrounding the Earle Navy Pier.

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Figure 1. Location of Raritan and Sandy Hook Bays, Monmouth County, New Jersey

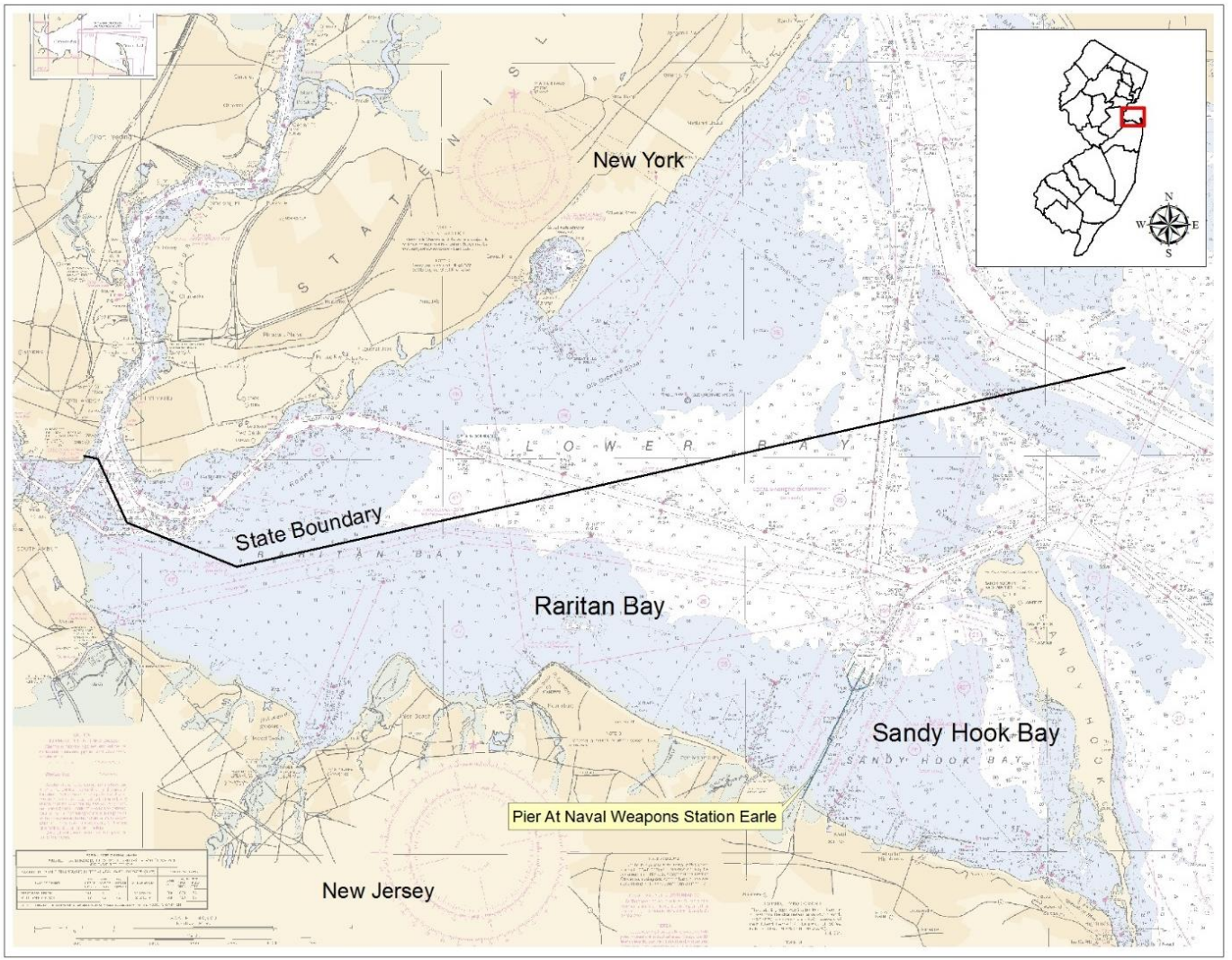


Figure 2. Raritan and Sandy Hook Bays estuarine inventory station locations.

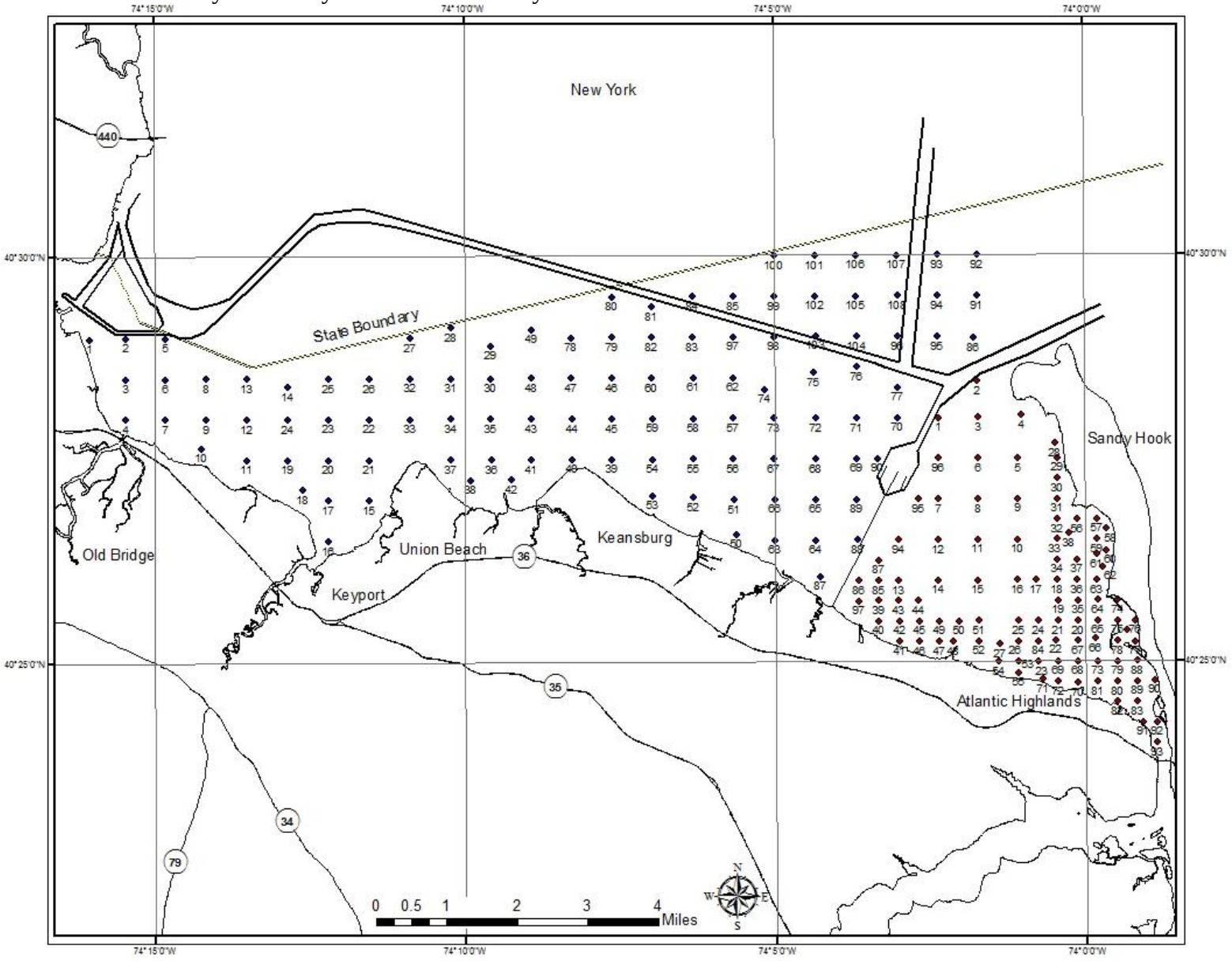


Figure 3. Depuration zones in Raritan and Sandy Hook Bays.

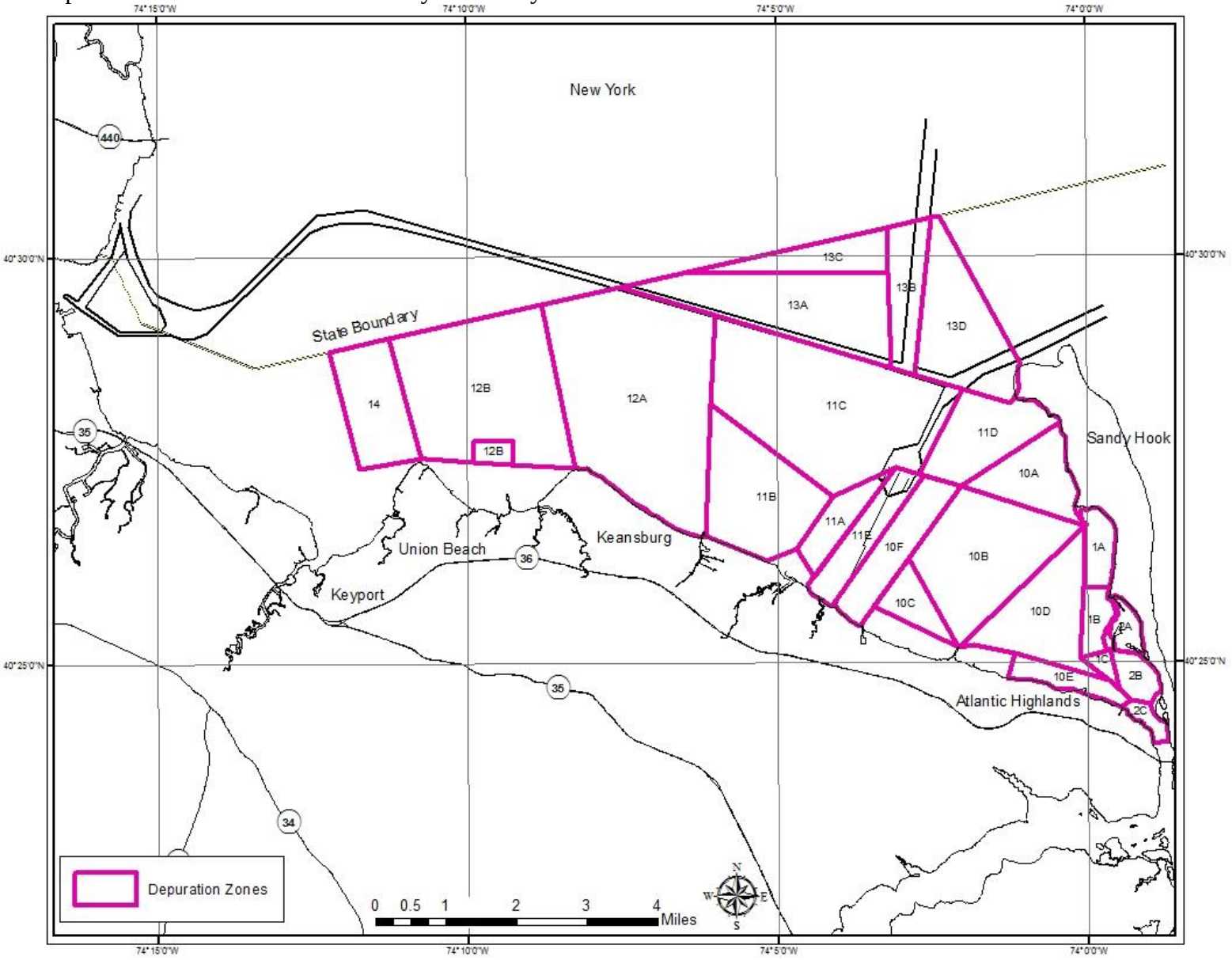


Figure 4. Stock estimate for Raritan Bay, Sandy Hook Bay, and depuration zones, by commercial size class, 2014.

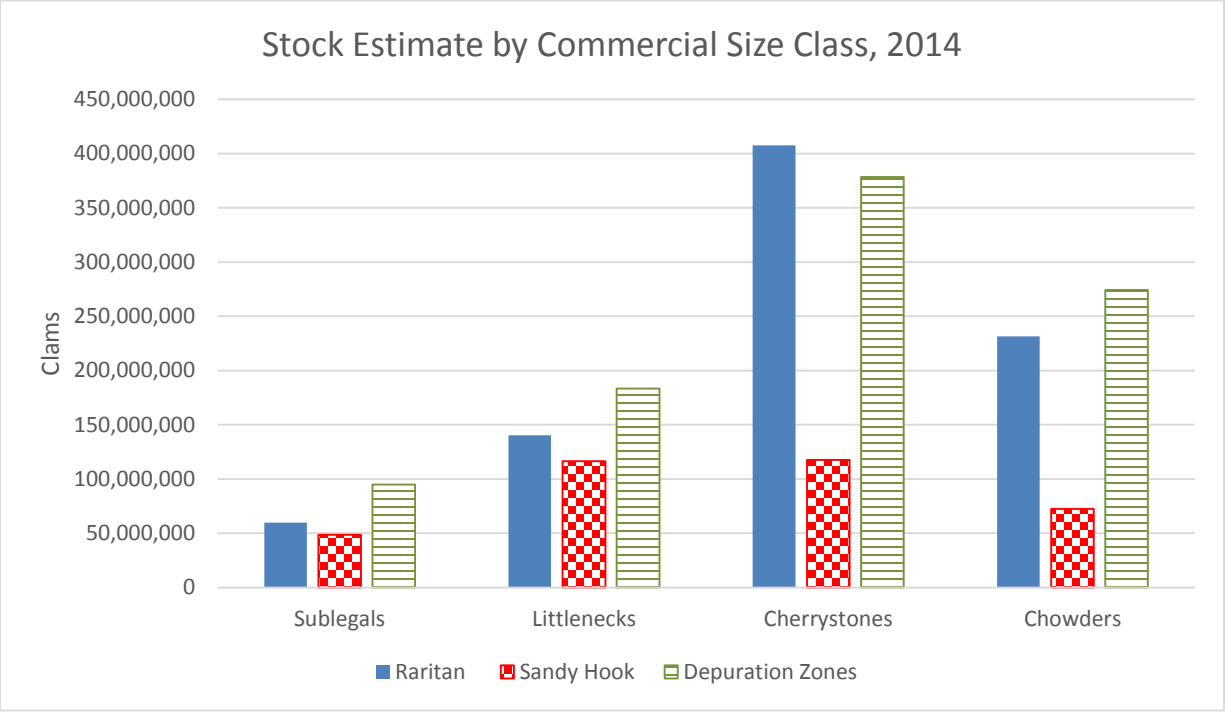


Table 6. Data summary for Raritan and Sandy Hook Bays, 2014.

Station	Date	Latitude	Longitude	Abundance$_{adj}$ (clams foot^{-2})	Mean Length (mm)	Percent Mortality	Percent Sublegals	Percent Littlenecks	Percent Cherrystones	Percent Chowders
RB-14-001	9/26/2014	40 28.990	74 16.053	0.19	69.1	5.56	0.00	17.65	47.06	35.29
RB-14-002	9/26/2014	40 29.000	74 15.470	1.52	59.8	6.31	2.88	25.00	68.27	3.85
RB-14-003	9/26/2014	40 28.499	74 15.470	0.47	62.4	0.01	4.88	24.39	57.32	13.41
RB-14-004	9/26/2014	40 28.000	74 15.470	1.00	71.4	2.22	4.71	7.06	47.06	41.18
RB-14-005	9/23/2014	40 28.999	74 14.820	3.31	62.6	7.62	2.75	15.46	76.98	4.81
RB-14-006	9/23/2014	40 28.500	74 14.820	0.89	61.2	4.88	5.13	24.36	58.97	11.54
RB-14-007	9/23/2014	40 28.000	74 14.819	1.18	58.8	5.45	2.88	33.65	59.62	3.85
RB-14-008	9/23/2014	40 28.500	74 14.170	0.76	59.2	2.90	4.48	32.84	58.21	4.48
RB-14-009	9/23/2014	40 28.000	74 14.170	0.52	61.0	2.63	2.70	35.14	54.05	8.11
RB-14-010	9/26/2014	40 27.650	74 14.250	1.61	67.3	2.74	2.86	12.14	65.00	20.00
RB-14-011	9/26/2014	40 27.499	74 13.509	0.91	61.2	4.84	6.78	26.27	50.85	16.10
RB-14-012	9/23/2014	40 27.999	74 13.510	0.83	61.9	8.75	4.11	21.92	65.75	8.22
RB-14-013	9/23/2014	40 28.500	74 13.510	0.55	65.8	5.88	2.08	22.92	52.08	22.92
RB-14-014	9/23/2014	40 28.399	74 12.850	1.94	63.2	7.57	5.26	19.88	60.23	14.62
RB-14-015	9/26/2014	40 27.000	74 11.540	0.68	59.5	3.23	12.07	27.59	48.28	12.07
RB-14-016	9/26/2014	40 26.499	74 12.200	0.49	61.8	2.27	2.33	37.21	34.88	25.58
RB-14-017	9/26/2014	40 27.000	74 12.200	0.28	67.5	7.41	0.00	20.00	56.00	24.00
RB-14-018	9/26/2014	40 27.130	74 12.620	0.46	67.5	10.00	6.67	13.33	46.67	33.33
RB-14-019	9/23/2014	40 27.500	74 12.850	0.19	55.5	15.00	6.25	62.50	12.50	18.75
RB-14-020	9/23/2014	40 27.500	74 12.200	1.37	62.0	4.50	3.77	24.53	62.26	9.43
RB-14-021	9/23/2014	40 27.500	74 11.540	1.99	62.1	15.52	8.16	18.37	59.18	14.29
RB-14-022	9/23/2014	40 28.000	74 11.539	1.08	63.3	6.86	8.42	23.16	45.26	23.16
RB-14-023	9/23/2014	40 28.000	74 12.200	1.60	62.7	1.40	3.55	21.28	65.25	9.93
RB-14-024	9/23/2014	40 28.000	74 12.850	1.13	59.1	10.00	8.08	30.30	53.54	8.08
RB-14-025	9/23/2014	40 28.500	74 12.200	3.67	58.5	6.10	3.72	36.53	52.63	7.12
RB-14-026	9/23/2014	40 28.500	74 11.540	2.14	63.4	3.59	3.72	25.53	51.60	19.15
RB-14-027	9/23/2014	40 29.000	74 10.880	1.26	73.1	6.72	0.00	3.64	66.36	30.00

Station	Date	Latitude	Longitude	Abundance$_{adj}$ (clams foot^{-2})	Mean Length (mm)	Percent Mortality	Percent Sublegals	Percent Littlenecks	Percent Cherrystones	Percent Chowders
RB-14-028	9/23/2014	40 29.125	74 10.220	1.81	58.2	13.11	15.09	31.45	31.45	22.01
RB-14-029	9/23/2014	40 28.899	74 09.570	1.51	68.6	2.92	1.50	11.28	63.91	23.31
RB-14-030	9/11/2014	40 28.500	74 09.570	0.84	61.5	8.64	12.33	23.29	41.10	23.29
RB-14-031	9/11/2014	40 28.500	74 10.220	0.06	70.2	37.50	0.00	0.00	80.00	20.00
RB-14-032	9/11/2014	40 28.500	74 10.880	0.05	83.0	0.00	0.00	0.00	0.00	100.00
RB-14-033	9/11/2014	40 28.000	74 10.879	0.24	74.4	22.22	0.00	0.00	63.16	36.84
RB-14-034	9/11/2014	40 27.999	74 10.220	0.36	72.9	20.00	3.85	3.85	57.69	34.62
RB-14-035	9/11/2014	40 28.000	74 09.570	1.96	62.7	8.51	6.43	19.30	61.99	12.28
RB-14-036	9/26/2014	40 27.500	74 09.570	0.72	70.5	14.86	0.00	12.90	59.68	27.42
RB-14-037	9/26/2014	40 27.500	74 10.220	0.11	69.1	0.00	0.00	12.50	62.50	25.00
RB-14-038	9/26/2014	40 27.250	74 09.895	0.15	69.4	18.75	9.09	9.09	36.36	45.45
RB-14-039	9/26/2014	40 27.500	74 07.620	0.20	73.4	30.77	0.00	11.76	41.18	47.06
RB-14-040	9/26/2014	40 27.499	74 08.270	0.26	76.0	11.54	0.00	5.00	50.00	45.00
RB-14-041	9/26/2014	40 27.500	74 08.920	1.39	68.7	3.92	0.00	16.33	53.06	30.61
RB-14-042	9/26/2014	40 27.250	74 09.245	0.16	72.8	0.00	0.00	15.38	38.46	46.15
RB-14-043	9/11/2014	40 28.000	74 08.920	2.23	57.5	5.31	11.70	32.45	43.62	12.23
RB-14-044	9/11/2014	40 28.000	74 08.269	0.03	63.7	0.00	33.33	0.00	33.33	33.33
RB-14-045	10/14/2014	40 27.999	74 07.620	0.00	n/a	100.00	n/a	n/a	n/a	n/a
RB-14-046	9/11/2014	40 28.499	74 07.620	0.01	79.0	0.00	0.00	0.00	0.00	100.00
RB-14-047	9/11/2014	40 28.500	74 08.270	1.02	67.5	20.35	1.11	10.00	68.89	20.00
RB-14-048	9/11/2014	40 28.500	74 08.920	2.33	59.8	6.39	16.08	20.60	46.73	16.58
RB-14-049	9/17/2014	40 29.099	74 08.920	1.19	70.3	8.70	0.00	7.14	64.29	28.57
RB-14-050	9/4/2014	40 26.574	74 05.615	0.11	83.5	44.44	0.00	0.00	33.33	66.67
RB-14-051	9/4/2014	40 27.000	74 05.660	0.01	42.0	50.00	0.00	100.00	0.00	0.00
RB-14-052	9/4/2014	40 27.030	74 06.310	0.26	81.0	28.13	0.00	0.00	33.33	66.67
RB-14-053	9/4/2014	40 27.050	74 06.969	0.13	79.8	0.00	0.00	0.00	45.45	54.55
RB-14-054	9/11/2014	40 27.500	74 06.970	0.32	72.9	17.65	0.00	13.64	36.36	50.00

Station	Date	Latitude	Longitude	Abundance$_{adj}$ (clams foot^{-2})	Mean Length (mm)	Percent Mortality	Percent Sublegals	Percent Littlenecks	Percent Cherrystones	Percent Chowders
RB-14-055	9/4/2014	40 27.500	74 06.310	0.44	82.5	9.30	3.13	3.13	15.63	78.13
RB-14-056	9/4/2014	40 27.500	74 05.660	0.00	n/a	100.00	n/a	n/a	n/a	n/a
RB-14-057	9/17/2014	40 28.000	74 05.659	0.65	77.2	6.56	0.00	7.02	29.82	63.16
RB-14-058	9/17/2014	40 28.000	74 06.310	1.10	61.9	13.39	23.71	16.49	27.84	31.96
RB-14-059	9/11/2014	40 28.000	74 06.970	1.83	54.1	4.73	20.13	38.99	27.67	13.21
RB-14-060	9/11/2014	40 28.500	74 06.969	1.23	64.0	14.29	14.81	8.33	51.85	25.00
RB-14-061	9/17/2014	40 28.499	74 06.310	1.98	54.0	26.89	34.48	21.84	23.56	20.11
RB-14-062	9/17/2014	40 28.500	74 05.660	2.08	56.3	14.49	28.96	21.86	22.40	26.78
RB-14-063	9/4/2014	40 26.500	74 05.000	0.27	84.3	14.29	0.00	4.35	21.74	73.91
RB-14-064	9/18/2014	40 26.500	74 04.330	0.03	n/a	0.00	n/a	n/a	n/a	n/a
RB-14-065	9/4/2014	40 27.000	74 04.330	0.06	89.5	0.00	0	0.00	0.00	100.00
RB-14-066	9/4/2014	40 27.000	74 05.000	0.01	90.0	0.00	0.00	0.00	0.00	100.00
RB-14-067	9/4/2014	40 27.500	74 05.000	0.05	77.5	20.00	0.00	0.00	50.00	50.00
RB-14-068	9/4/2014	40 27.500	74 04.330	0.72	74.9	7.35	5	1.59	41.27	52.38
RB-14-069	9/18/2014	40 27.499	74 03.670	1.38	71.5	23.90	7.50	3.33	50.83	38.33
RB-14-070	9/17/2014	40 28.000	74 03.010	0.58	81.8	1.92	0.00	1.96	27.45	70.59
RB-14-071	9/17/2014	40 28.000	74 03.670	1.72	76.0	11.18	0.66	3.97	47.02	48.34
RB-14-072	9/4/2014	40 28.000	74 04.329	0.97	75.0	9.30	2.34	1.17	48.54	47.95
RB-14-073	9/4/2014	40 28.000	74 05.000	1.41	70.3	2.68	8.26	3.67	52.29	35.78
RB-14-074	9/4/2014	40 28.352	74 05.152	1.58	65.9	12.03	18.71	8.63	33.81	38.85
RB-14-075	9/4/2014	40 28.556	74 04.356	1.21	75.6	12.50	4.76	0.00	41.27	53.97
RB-14-076	9/17/2014	40 28.625	74 03.669	1.58	73.1	3.47	3.60	5.04	45.32	46.04
RB-14-077	9/17/2014	40 28.375	74 03.010	0.40	79.4	0.00	0.00	5.71	25.71	68.57
RB-14-078	9/17/2014	40 29.000	74 08.270	1.25	68.9	13.39	10.00	7.27	45.45	37.27
RB-14-079	9/17/2014	40 29.000	74 07.619	0.06	74.8	16.67	20.00	0.00	40.00	40.00
RB-14-080	9/17/2014	40 29.500	74 07.620	0.98	75.0	15.69	0.00	2.33	51.16	46.51
RB-14-081	9/17/2014	40 29.375	74 06.969	1.14	73.8	20.63	3.00	2.00	52.00	43.00

Station	Date	Latitude	Longitude	Abundance$_{adj}$ (clams foot^{-2})	Mean Length (mm)	Percent Mortality	Percent Sublegals	Percent Littlenecks	Percent Cherrystones	Percent Chowders
RB-14-082	9/17/2014	40 29.000	74 06.969	0.65	73.7	3.39	5.26	1.75	43.86	49.12
RB-14-083	9/17/2014	40 29.000	74 06.309	0.93	60.6	9.89	20.73	15.85	41.46	21.95
RB-14-084	9/17/2014	40 29.500	74 06.310	1.00	70.9	5.38	2.27	6.82	54.55	36.36
RB-14-085	9/17/2014	40 29.500	74 05.659	0.44	74.6	30.36	0.00	5.13	56.41	38.46
RB-14-086	9/16/2014	40 28.979	74 01.785	0.06	64.2	0.00	0.00	20.00	80.00	0.00
RB-14-087	9/18/2014	40 26.048	74 04.275	0.09	86.3	20.00	0.00	0.00	12.50	87.50
RB-14-088	9/18/2014	40 26.500	74 03.670	0.40	61.3	2.74	12.68	22.54	42.25	22.54
RB-14-089	9/18/2014	40 27.000	74 03.670	0.75	61.0	9.59	18.18	25.76	27.27	28.79
RB-14-090	9/18/2014	40 27.500	74 03.340	0.83	75.2	17.98	9.59	6.85	20.55	63.01
RB-14-091	9/16/2014	40 29.500	74 01.719	0.41	51.2	44.62	22.22	55.56	5.56	16.67
RB-14-092	9/16/2014	40 29.999	74 01.720	0.00	n/a	n/a	n/a	n/a	n/a	n/a
RB-14-093	9/16/2014	40 30.000	74 02.360	0.00	n/a	n/a	n/a	n/a	n/a	n/a
RB-14-094	9/16/2014	40 29.500	74 02.359	0.72	81.6	16.00	0.00	0.00	31.75	68.25
RB-14-095	9/16/2014	40 29.000	74 02.360	1.51	65.2	24.86	4.51	19.55	54.14	21.80
RB-14-096	9/16/2014	40 29.000	74 03.009	0.38	77.6	4.35	4.55	1.52	34.85	59.09
RB-14-097	9/17/2014	40 28.999	74 05.660	1.05	72.3	24.59	5.43	5.43	43.48	45.65
RB-14-098	9/17/2014	40 29.000	74 05.000	1.88	74.4	13.16	3.64	4.24	42.42	49.70
RB-14-099	9/16/2014	40 29.500	74 04.999	0.84	71.9	18.68	2.70	4.05	59.46	33.78
RB-14-100	9/16/2014	40 30.000	74 05.000	0.51	77.6	8.16	0.00	2.50	40.00	57.50
RB-14-101	9/16/2014	40 29.999	74 04.330	0.11	71.9	9.09	0.00	11.11	44.44	44.44
RB-14-102	9/16/2014	40 29.500	74 04.330	0.53	74.2	21.67	0.00	4.26	48.94	46.81
RB-14-103	9/16/2014	40 29.015	74 04.317	1.05	76.4	10.68	1.09	2.17	39.13	57.61
RB-14-104	9/16/2014	40 29.000	74 03.670	1.03	76.5	10.78	0.00	1.10	54.95	43.96
RB-14-105	9/16/2014	40 29.499	74 03.670	1.22	74.6	13.01	0.00	2.80	57.01	40.19
RB-14-106	9/16/2014	40 30.000	74 03.670	0.38	79.7	8.33	0.00	9.68	25.81	64.52
RB-14-107	9/16/2014	40 30.000	74 03.010	0.02	97.0	0.00	0.00	0.00	0.00	100.00
RB-14-108	9/16/2014	40 29.500	74 03.009	0.45	77.9	13.04	0.00	0.00	46.15	53.85

Sandy Hook Bay

Station	Date	Latitude	Longitude	Abundance$_{adj}$ (clams foot^{-2})	Mean Length (mm)	Percent Mortality	Percent Sublegals	Percent Littlenecks	Percent Cherrystones	Percent Chowders
SHB-14-001	10/3/2014	40 28.000	74 02.360	0.41	51.5	7.69	22.86	42.86	20.00	14.29
SHB-14-002	10/3/2014	40 28.445	74 01.728	0.00	na	na	na	na	na	na
SHB-14-003	10/3/2014	40 28.000	74 01.720	0.90	59.1	20.20	30.38	20.25	11.39	37.97
SHB-14-004	10/3/2014	40 28.026	74 01.020	1.76	64.9	6.63	8.39	16.13	50.97	24.52
SHB-14-005	10/3/2014	40 27.499	74 01.080	1.18	60.8	11.11	21.15	22.12	24.04	32.69
SHB-14-006	10/3/2014	40 27.500	74 01.720	2.10	53.8	7.50	33.51	29.19	12.43	24.86
SHB-14-007	10/3/2014	40 27.000	74 02.360	1.41	63.6	10.14	18.55	16.13	28.23	37.10
SHB-14-008	10/3/2014	40 27.000	74 01.719	0.99	69.0	6.45	5.75	25.29	26.44	42.53
SHB-14-009	10/3/2014	40 27.000	74 01.080	0.51	64.5	11.76	15.56	20.00	28.89	35.56
SHB-14-010	10/3/2014	40 26.500	74 01.080	1.49	53.6	5.07	23.66	31.30	29.01	16.03
SHB-14-011	10/14/2014	40 26.500	74 01.720	1.46	54.6	9.22	27.34	32.03	18.75	21.88
SHB-14-012	10/14/2014	40 26.500	74 02.360	0.63	66.0	14.06	7.27	29.09	25.45	38.18
SHB-14-013	10/10/2014	40 26.000	74 03.000	1.26	50.2	7.50	18.02	48.65	33.33	0.00
SHB-14-014	10/14/2014	40 25.999	74 02.359	0.82	51.9	8.86	16.67	41.67	40.28	1.39
SHB-14-015	10/14/2014	40 26.000	74 01.720	0.98	47.4	10.42	20.93	59.30	17.44	2.33
SHB-14-016	10/14/2014	40 26.000	74 01.080	0.94	50.3	8.79	19.28	50.60	26.51	3.61
SHB-14-017	10/3/2014	40 26.004	74 00.791	1.32	49.9	12.12	17.24	50.86	29.31	2.59
SHB-14-018	10/3/2014	40 26.000	74 00.440	0.80	51.7	20.45	11.43	57.14	28.57	2.86
SHB-14-019	10/10/2014	40 25.750	74 00.439	1.11	57.0	11.65	7.69	32.97	54.95	4.40
SHB-14-020	10/3/2014	40 25.500	74 00.119	0.92	56.3	4.71	3.70	41.98	53.09	1.23
SHB-14-021	10/10/2014	40 25.500	74 00.440	1.16	51.6	8.11	12.75	50.00	36.27	0.98
SHB-14-022	10/10/2014	40 25.258	74 00.468	0.92	63.9	6.90	2.47	18.52	63.58	15.43
SHB-14-023	10/10/2014	40 25.000	74 00.760	0.76	59.3	4.96	2.99	32.09	61.19	3.73
SHB-14-024	10/10/2014	40 25.500	74 00.760	1.34	51.0	7.09	8.47	64.41	25.42	1.69
SHB-14-025	10/10/2014	40 25.499	74 01.080	1.15	52.0	4.72	3.96	64.36	27.72	3.96
SHB-14-026	10/10/2014	40 25.250	74 01.079	0.96	56.0	4.55	7.14	34.52	52.38	5.95

Station	Date	Latitude	Longitude	Abundance$_{adj}$ (clams foot^{-2})	Mean Length (mm)	Percent Mortality	Percent Sublegals	Percent Littlenecks	Percent Cherrystones	Percent Chowders
SHB-14-027	10/10/2014	40 25.215	74 01.366	1.07	53.7	1.05	6.38	56.38	29.79	7.45
SHB-14-028	9/30/2014	40 27.684	74 00.469	0.10	90.4	18.18	0.00	0.00	0.00	100.00
SHB-14-029	9/30/2014	40 27.500	74 00.440	0.39	90.8	5.56	0.00	0.00	6.25	93.75
SHB-14-030	9/30/2014	40 27.250	74 00.440	0.10	89.0	18.18	0.00	0.00	0.00	100.00
SHB-14-031	9/30/2014	40 27.000	74 00.440	0.16	91.0	0.00	0.00	0.00	0.00	100.00
SHB-14-032	10/3/2014	40 26.750	74 00.440	1.38	50.5	31.64	23.14	42.98	31.40	2.48
SHB-14-033	10/3/2014	40 26.499	74 00.440	2.06	44.6	15.81	27.62	58.56	13.26	0.55
SHB-14-034	10/3/2014	40 26.250	74 00.440	1.50	51.9	18.01	15.91	50.00	28.79	5.30
SHB-14-035	10/3/2014	40 25.750	74 00.120	0.80	63.9	23.91	1.43	24.29	57.14	17.14
SHB-14-036	10/3/2014	40 26.000	74 00.120	0.34	83.5	21.05	0.00	3.85	23.08	73.08
SHB-14-037	10/3/2014	40 26.250	74 00.119	0.36	75.9	11.11	0.00	3.45	44.83	51.72
SHB-14-038	10/3/2014	40 26.574	74 00.263	1.88	50.5	27.63	16.97	52.73	28.48	1.82
SHB-14-039	9/18/2014	40 25.749	74 03.320	3.17	57.2	5.42	15.13	33.95	35.79	15.13
SHB-14-040	9/18/2014	40 25.500	74 03.320	1.41	66.1	9.49	0.00	28.93	46.28	24.79
SHB-14-041	9/18/2014	40 25.250	74 03.000	0.13	76.1	8.33	0.00	0.00	54.55	45.45
SHB-14-042	9/18/2014	40 25.500	74 03.000	0.78	70.4	21.15	7.32	17.07	29.27	46.34
SHB-14-043	10/10/2014	40 25.750	74 03.000	1.16	55.7	3.28	6.78	45.76	33.90	13.56
SHB-14-044	10/10/2014	40 25.750	74 02.680	1.66	49.1	4.58	21.23	47.95	28.08	2.74
SHB-14-045	9/18/2014	40 25.499	74 02.680	0.28	81.0	35.90	0.00	4.35	17.39	78.26
SHB-14-046	9/18/2014	40 25.249	74 02.679	0.64	71.5	17.65	0.00	14.55	45.45	40.00
SHB-14-047	10/10/2014	40 25.250	74 02.359	0.20	67.2	18.18	0.00	25.00	50.00	25.00
SHB-14-048	10/10/2014	40 25.247	74 02.128	0.23	67.6	39.39	10.00	15.00	40.00	35.00
SHB-14-049	10/10/2014	40 25.500	74 02.360	1.51	53.0	2.21	11.28	52.63	33.08	3.01
SHB-14-050	10/14/2014	40 25.500	74 02.039	0.82	52.3	15.29	15.28	43.06	36.11	5.56
SHB-14-051	10/14/2014	40 25.499	74 01.720	1.19	53.5	17.32	10.48	42.86	43.81	2.86
SHB-14-052	10/10/2014	40 25.250	74 01.719	2.26	55.4	8.29	5.53	44.22	47.24	3.02

Station	Date	Latitude	Longitude	Abundance$_{adj}$ (clams foot^{-2})	Mean Length (mm)	Percent Mortality	Percent Sublegals	Percent Littlenecks	Percent Cherrystones	Percent Chowders
SHB-14-053	10/10/2014	40 25.000	74 01.079	0.86	53.4	6.17	7.89	52.63	36.84	2.63
SHB-14-054	10/10/2014	40 25.000	74 01.400	2.71	60.6	2.46	2.52	28.99	61.76	6.72
SHB-14-055	10/10/2014	40 24.861	74 01.080	0.47	83.0	18.00	0.00	2.70	29.73	67.57
SHB-14-056	9/29/2014	40 26.750	74 00.119	0.42	85.5	17.78	0.00	5.88	17.65	76.47
SHB-14-057	9/29/2014	40 26.749	73 59.800	2.62	69.0	5.74	0.90	17.57	49.10	32.43
SHB-14-058	9/29/2014	40 26.629	73 59.650	1.86	75.2	14.14	2.53	6.33	35.44	55.70
SHB-14-059	9/30/2014	40 26.500	73 59.800	0.51	75.3	13.46	6.82	9.09	27.27	56.82
SHB-14-060	9/30/2014	40 26.361	73 59.653	0.28	78.6	19.35	0.00	8.33	33.33	58.33
SHB-14-061	9/30/2014	40 26.316	73 59.804	0.61	80.1	16.92	0.00	13.73	21.57	64.71
SHB-14-062	9/30/2014	40 26.160	73 59.720	0.00	na	na	na	na	na	na
SHB-14-063	9/30/2014	40 26.000	73 59.799	0.18	71.1	11.11	6.67	20.00	6.67	66.67
SHB-14-064	9/29/2014	40 25.750	73 59.800	0.14	76.1	14.29	8.33	8.33	16.67	66.67
SHB-14-065	9/29/2014	40 25.500	73 59.800	0.11	58.8	41.18	44.44	0.00	11.11	44.44
SHB-14-066	9/29/2014	40 25.283	73 59.830	0.10	71.9	40.00	0.00	11.11	55.56	33.33
SHB-14-067	9/29/2014	40 25.249	74 00.120	0.01	67.0	0.00	0.00	0.00	100.00	0.00
SHB-14-068	9/29/2014	40 25.000	74 00.120	0.07	62.0	14.29	16.67	16.67	33.33	33.33
SHB-14-069	10/10/2014	40 24.999	74 00.440	0.28	69.9	30.56	5.88	0.00	64.71	29.41
SHB-14-070	10/10/2014	40 24.731	74 00.111	0.40	70.8	20.00	0.00	35.71	21.43	42.86
SHB-14-071	10/10/2014	40 24.781	74 00.692	3.00	71.0	17.81	1.03	7.22	63.92	27.84
SHB-14-072	10/10/2014	40 24.749	74 00.440	0.39	72.8	5.56	8.82	11.76	35.29	44.12
SHB-14-073	9/29/2014	40 25.000	73 59.800	0.48	83.3	12.50	0.00	2.38	23.81	73.81
SHB-14-074	9/30/2014	40 25.749	73 59.479	0.00	na	100.00	na	na	na	na
SHB-14-075	9/30/2014	40 25.500	73 59.480	0.31	48.1	10.00	18.52	55.56	25.93	0.00
SHB-14-076	9/30/2014	40 25.501	73 59.193	0.15	64.0	51.85	7.69	38.46	15.38	38.46
SHB-14-76.5	9/30/2014	40 25.386	73 59.333	0.59	59.8	7.14	5.77	36.54	46.15	11.54
SHB-14-077	9/30/2014	40 25.242	73 59.192	0.01	96.0	75.00	0.00	0.00	0.00	100.00

Station	Date	Latitude	Longitude	Abundance$_{adj}$ (clams foot^{-2})	Mean Length (mm)	Percent Mortality	Percent Sublegals	Percent Littlenecks	Percent Cherrystones	Percent Chowders
SHB-14-078	9/30/2014	40 25.249	73 59.480	4.18	71.1	12.38	2.25	7.87	52.81	37.08
SHB-14-079	9/29/2014	40 24.999	73 59.480	0.35	61.9	11.43	12.07	29.31	34.48	24.14
SHB-14-080	9/29/2014	40 24.750	73 59.479	0.23	71.1	16.67	0.00	15.00	50.00	35.00
SHB-14-081	9/29/2014	40 24.750	73 59.800	0.44	82.4	13.33	0.00	2.63	23.68	73.68
SHB-14-082	9/29/2014	40 24.500	73 59.480	0.17	57.9	40.00	14.29	28.57	42.86	14.29
SHB-14-083	9/29/2014	40 24.500	73 59.159	0.17	67.7	40.00	6.67	6.67	66.67	20.00
SHB-14-084	10/10/2014	40 25.250	74 00.760	1.67	61.1	6.37	1.36	25.85	64.63	8.16
SHB-14-085	9/18/2014	40 26.000	74 03.320	1.82	53.7	11.60	16.25	37.50	43.13	3.13
SHB-14-086	9/18/2014	40 25.999	74 03.640	0.89	82.6	22.77	2.63	1.32	19.74	76.32
SHB-14-087	9/18/2014	40 26.250	74 03.320	2.18	57.1	8.13	13.02	37.50	34.90	14.58
SHB-14-088	9/29/2014	40 25.000	73 59.159	2.08	71.2	5.18	2.21	9.94	48.62	39.23
SHB-14-089	9/29/2014	40 24.750	73 59.160	1.15	74.0	9.01	5.05	7.07	36.36	51.52
SHB-14-090	9/29/2014	40 24.766	73 58.884	2.07	69.6	4.21	1.71	5.71	65.14	27.43
SHB-14-091	9/29/2014	40 24.249	73 59.070	0.08	79.1	12.50	0.00	0.00	42.86	57.14
SHB-14-092	9/29/2014	40 24.250	73 58.840	0.77	74.3	8.11	0.00	19.12	25.00	55.88
SHB-14-093	9/29/2014	40 23.999	73 58.839	0.28	78.0	8.70	0.00	10.00	25.00	65.00
SHB-14-094	9/18/2014	40 26.500	74 03.000	1.43	70.8	4.55	6.35	9.52	38.89	45.24
SHB-14-095	9/18/2014	40 26.999	74 02.680	0.88	70.6	8.82	9.03	17.42	23.23	50.32
SHB-14-096	9/18/2014	40 27.500	74 02.359	1.77	48.0	8.24	31.09	50.00	7.05	11.86
SHB-14-097	9/18/2014	40 25.750	74 03.640	0.18	76.8	23.81	0.00	12.50	31.25	56.25

Figure 5. Distribution and relative abundance of hard clams (Mercenaria mercenaria) in Raritan and Sandy Hook Bays, 2014.

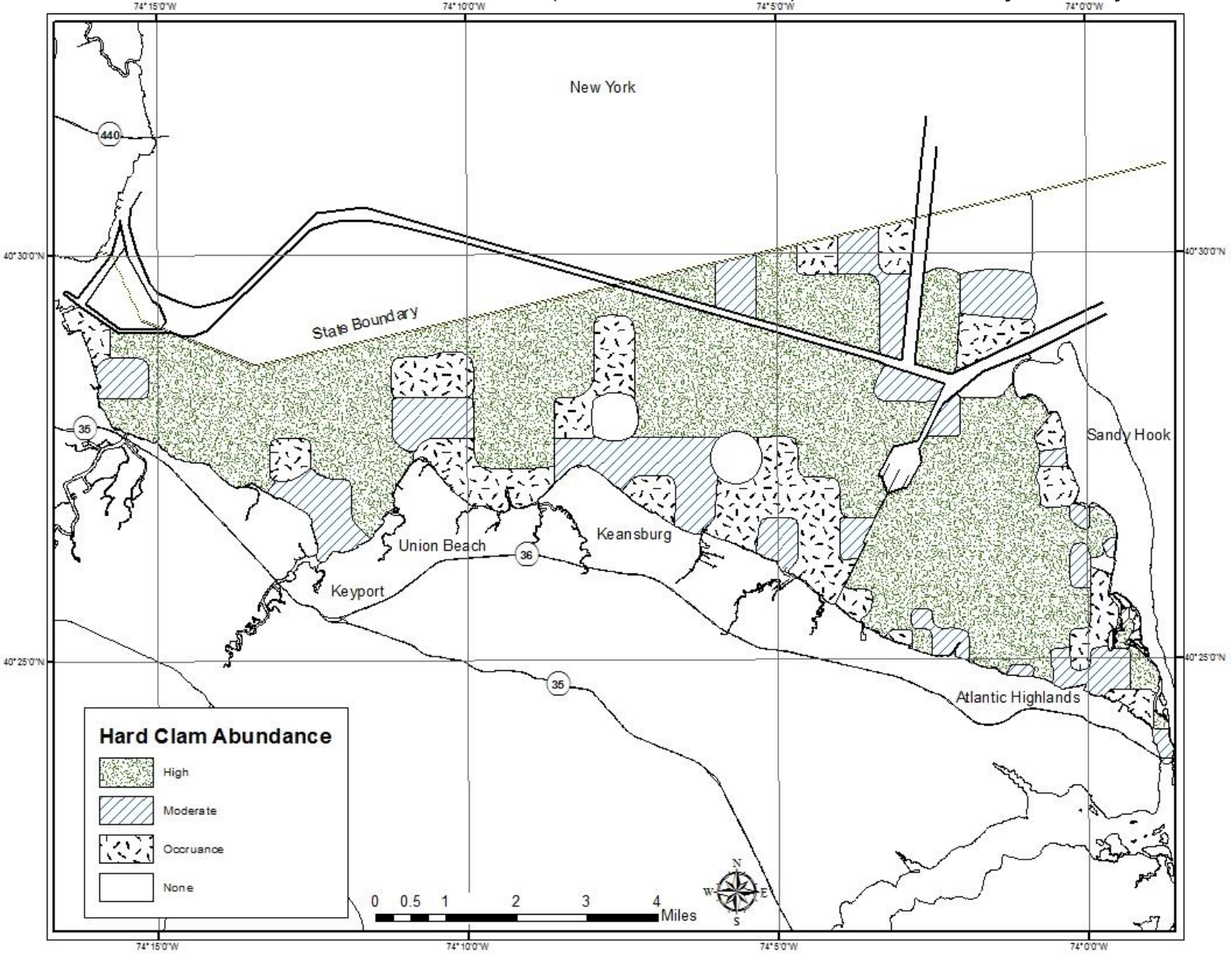


Figure 6. Copy of 2000 hard clam distribution chart (Celestino 2003b).

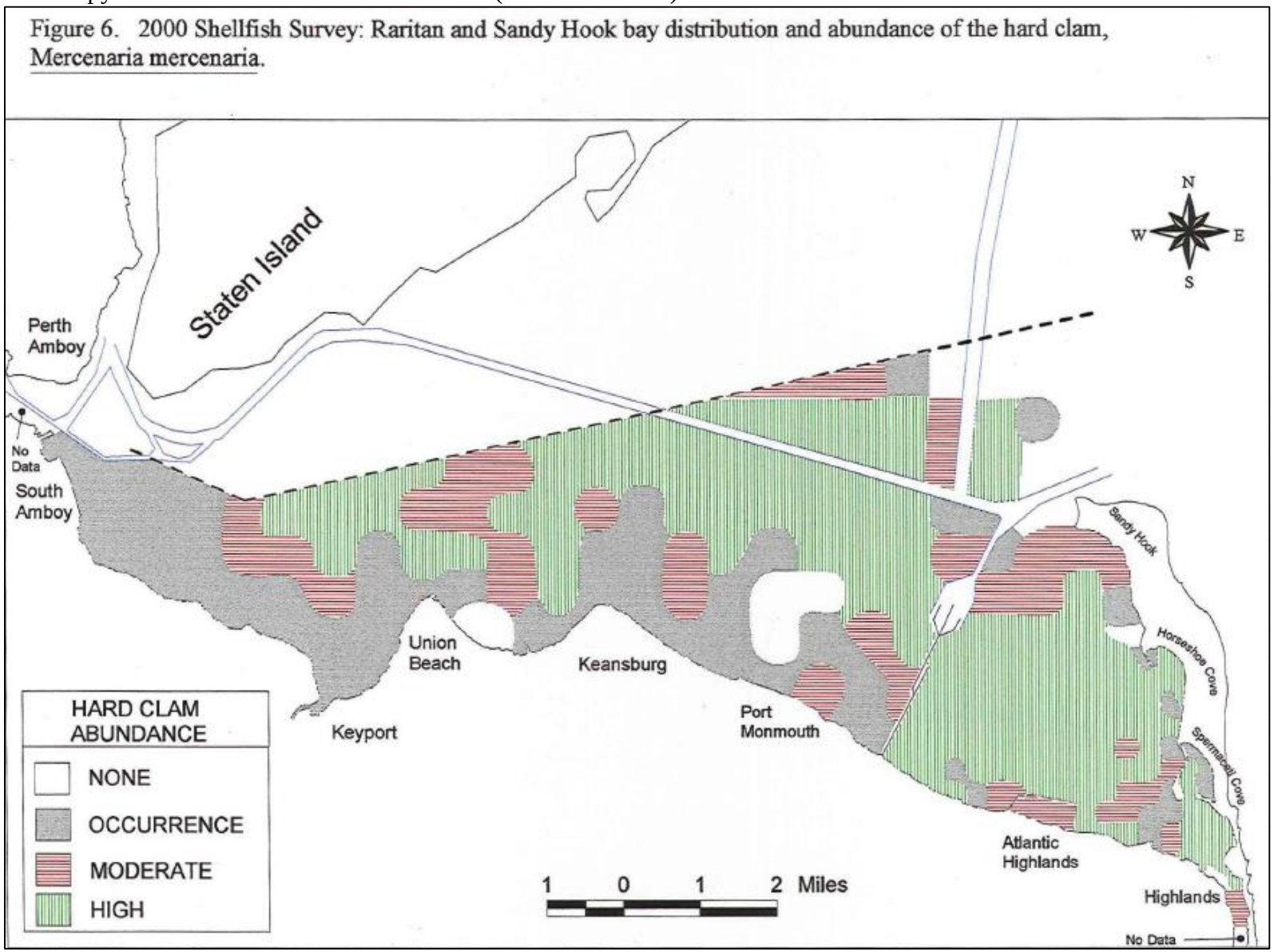


Figure 7. Copy of 1983 hard clam distribution chart (McCloy and Joseph 1984).

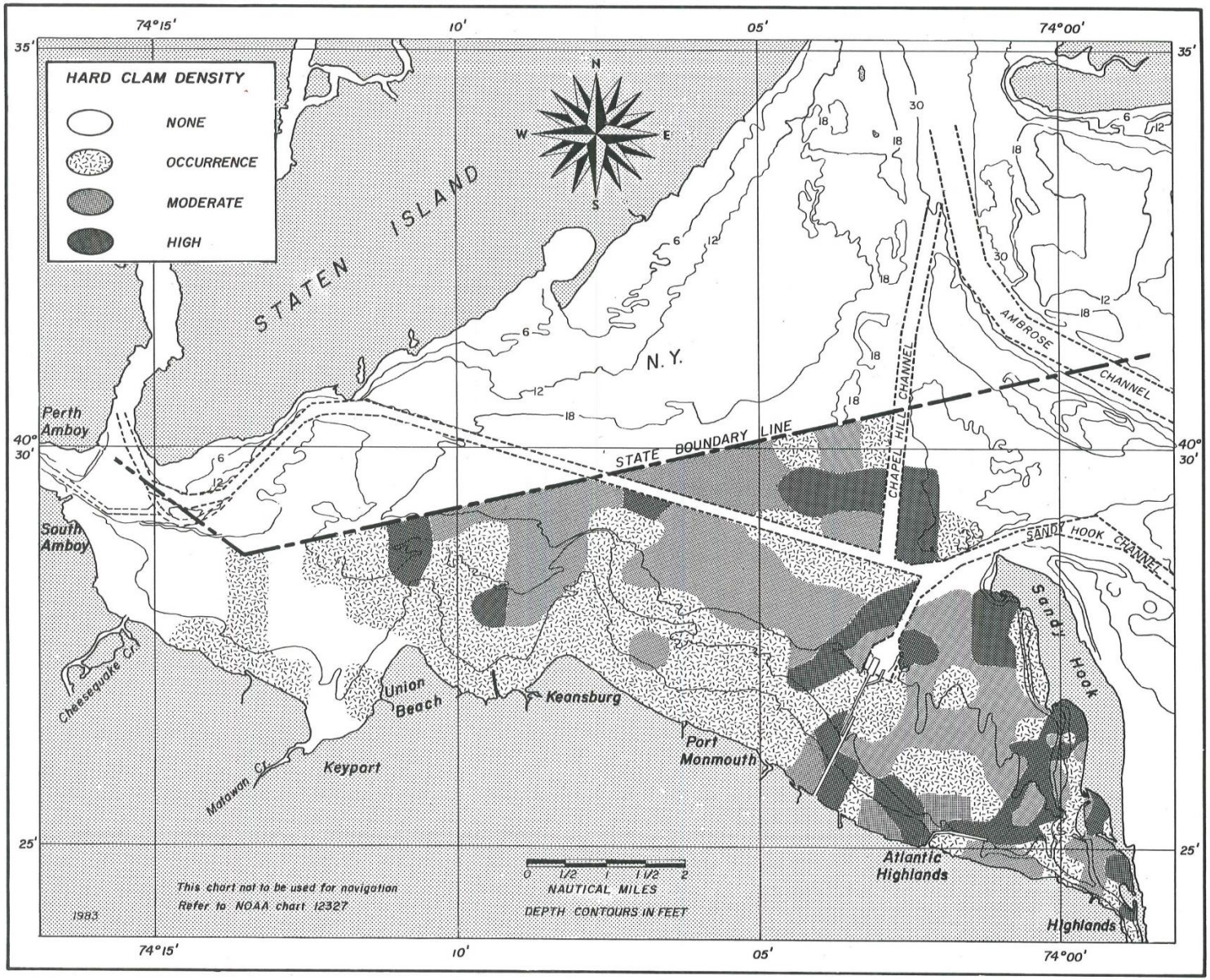


Figure 8. Hard clam abundance and distribution relative to the depuration zones, 2014.

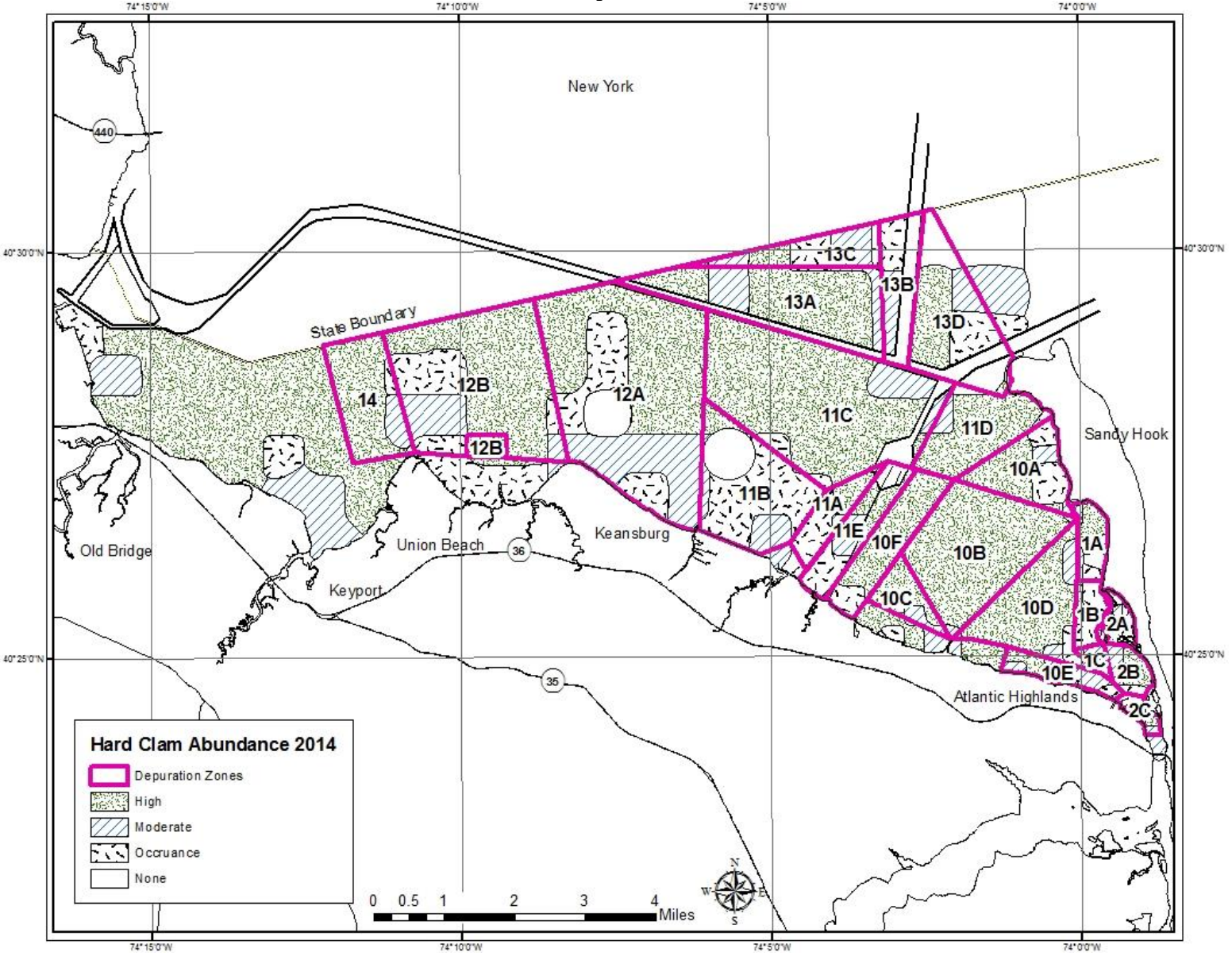


Figure 9. Stations where clams sized 29mm and smaller were retained in the dredge sample. As a reminder, the dredge is not designed to retain clams sized 29mm and smaller.

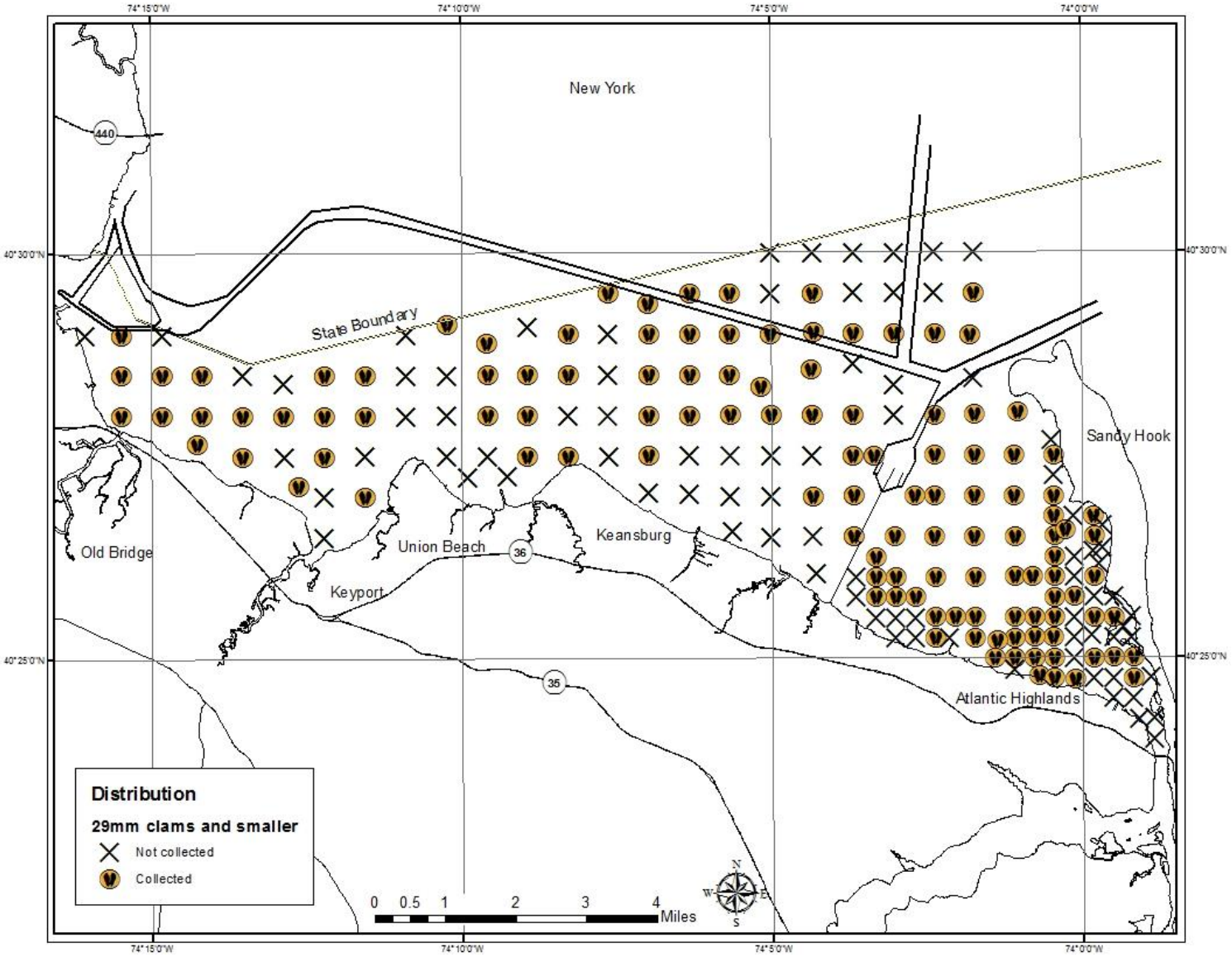
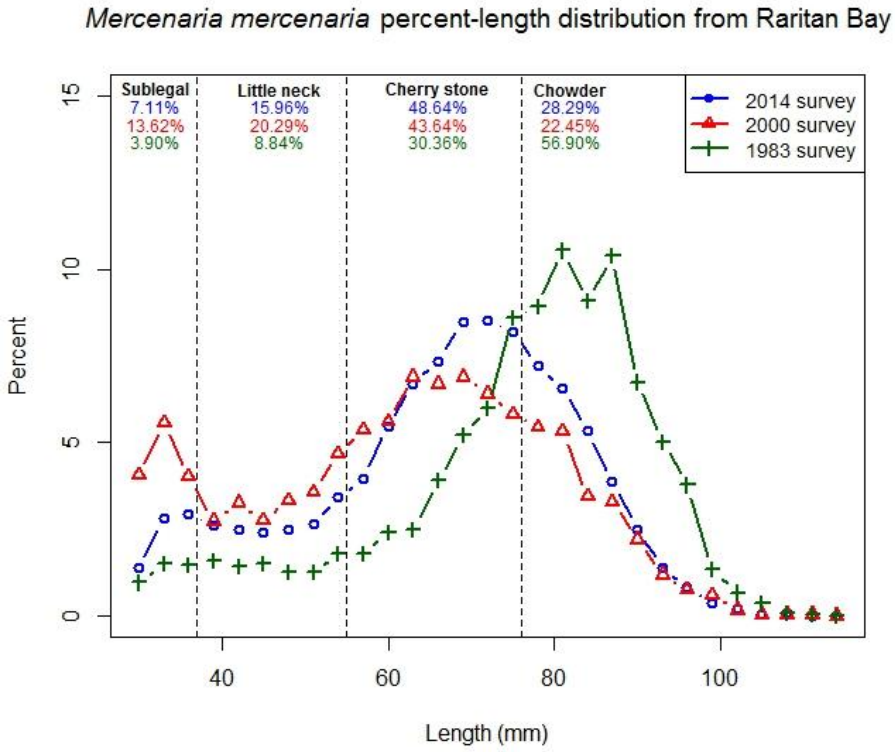


Figure 10a. Hard clam percent-length-frequency and length-frequency in Raritan Bay, 2014.



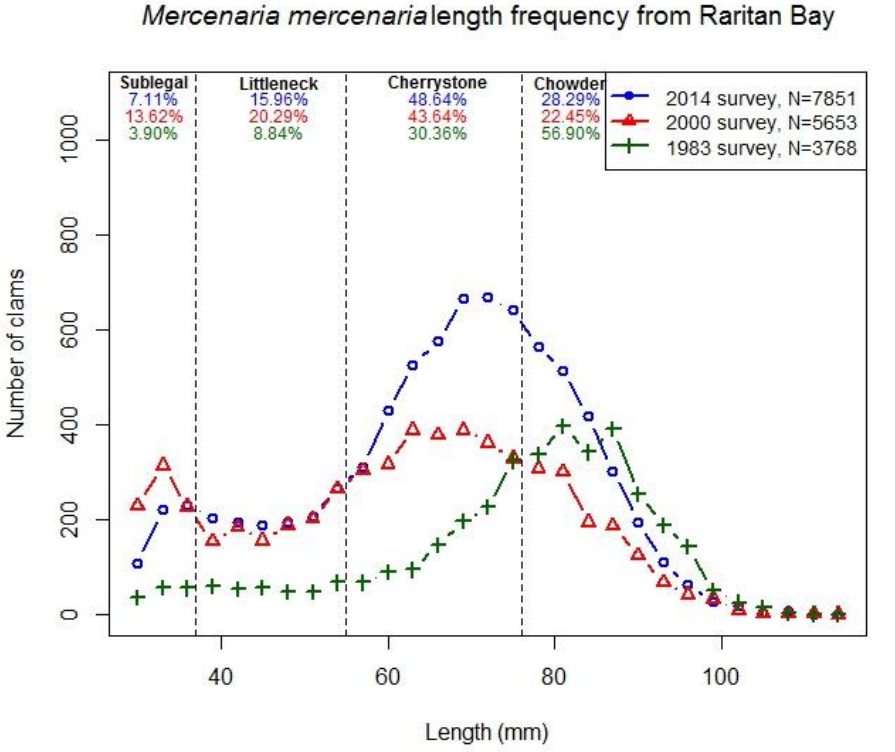


Figure 10b. Hard clam percent-length-frequency and length-frequency in Sandy Hook, 2014.

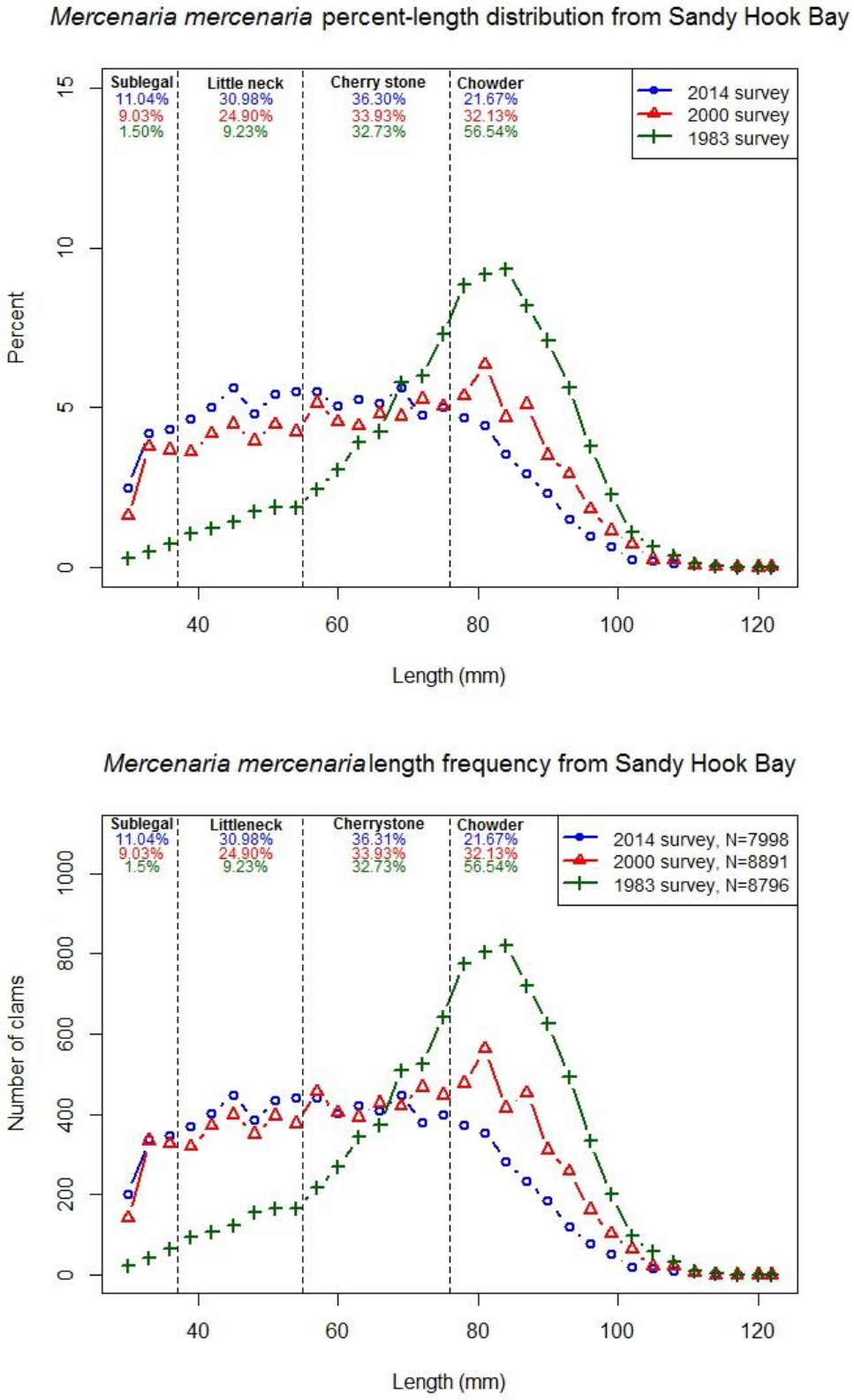
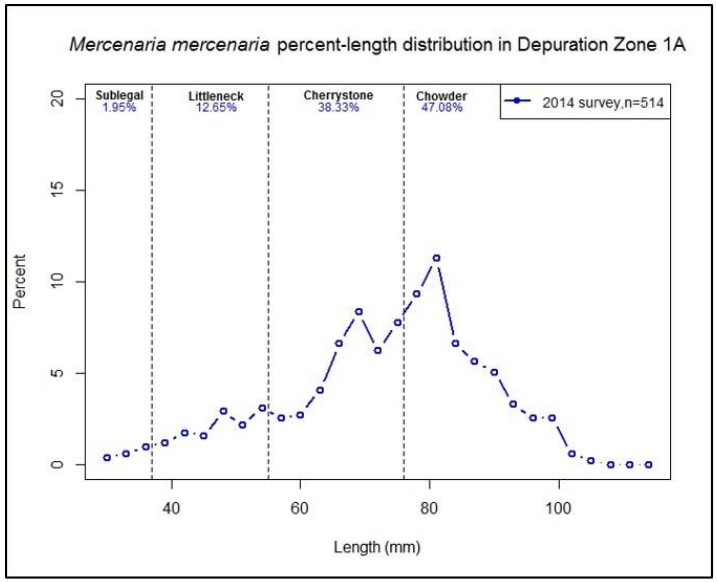
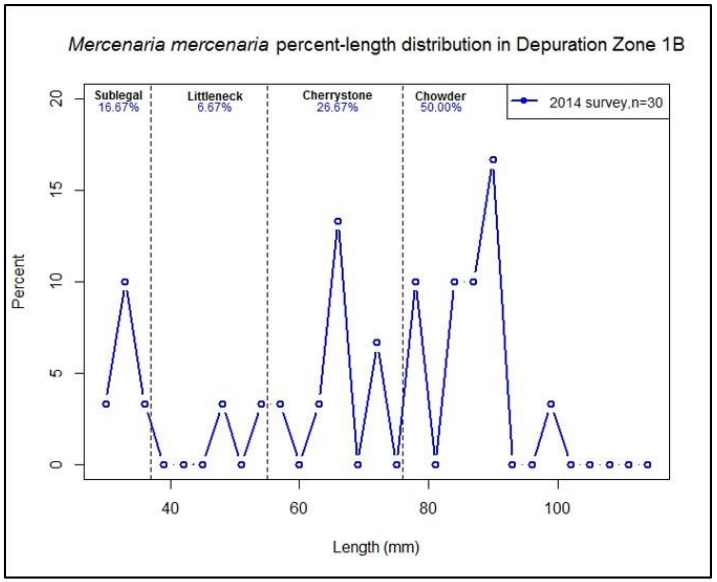
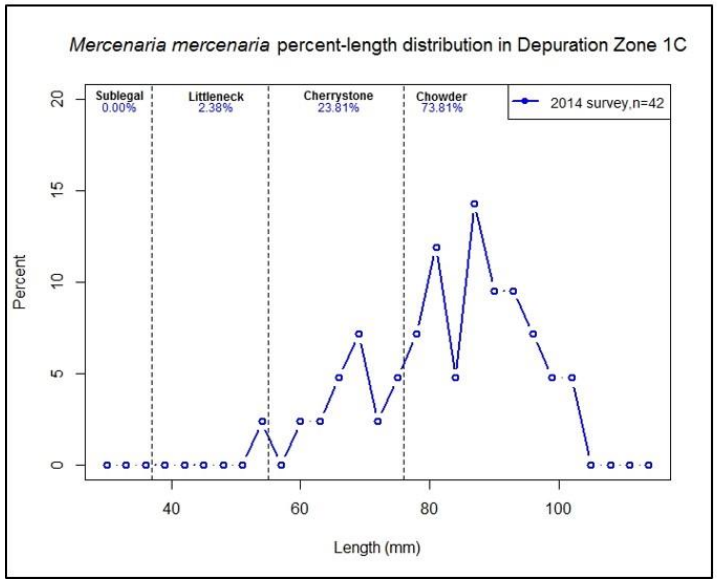


Figure 11. Hard clam percent-length-frequency for each depuration zone; 2014.







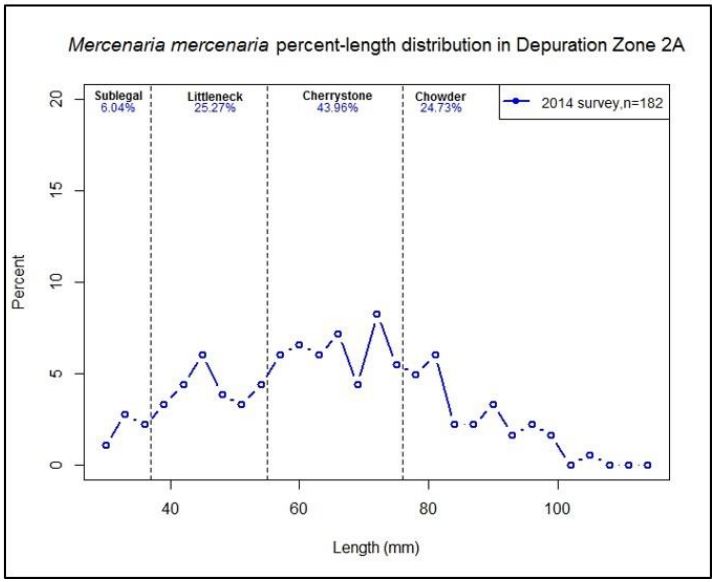
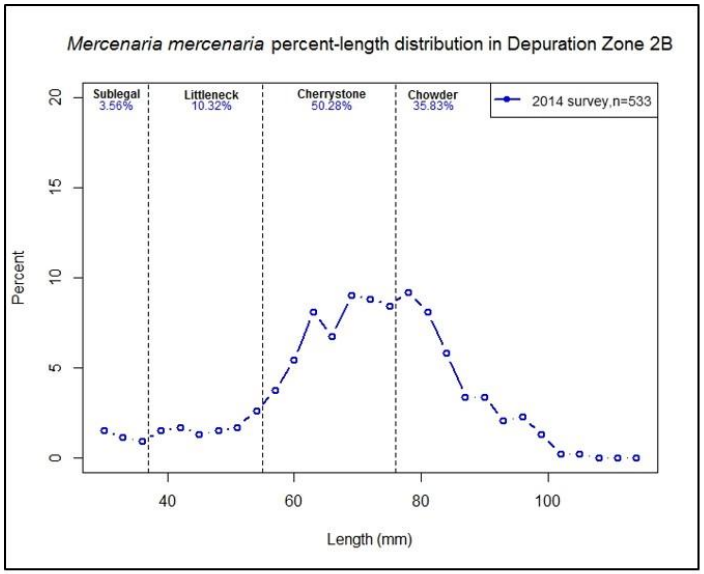
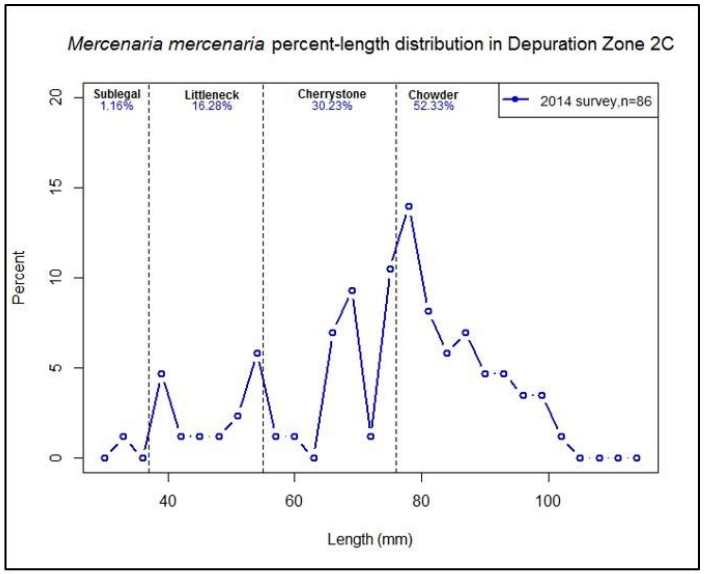
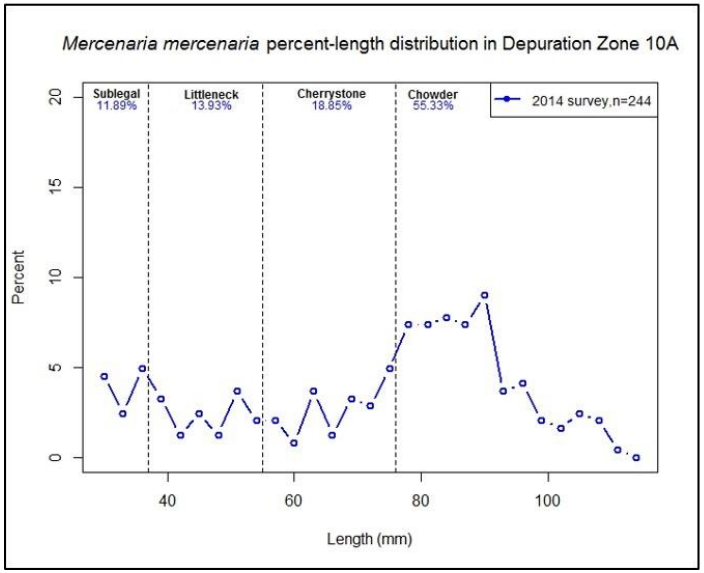


Figure 11 cont.







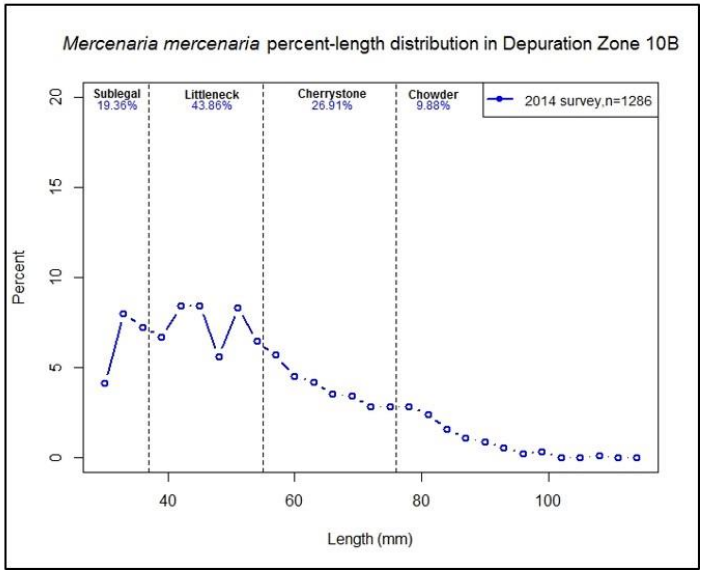
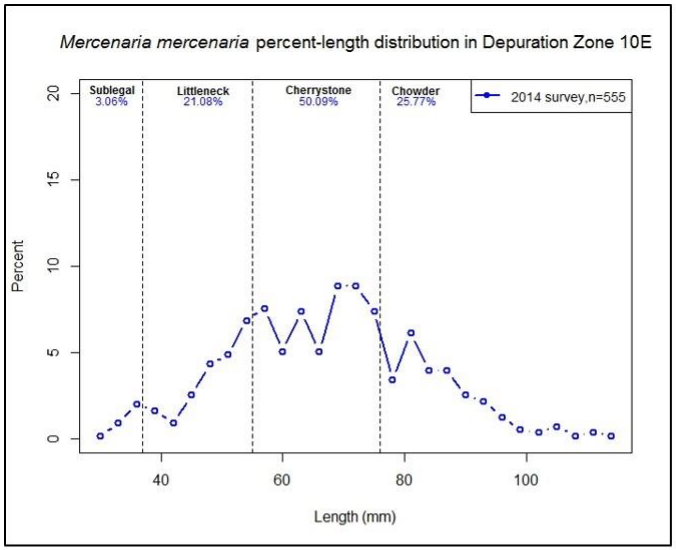
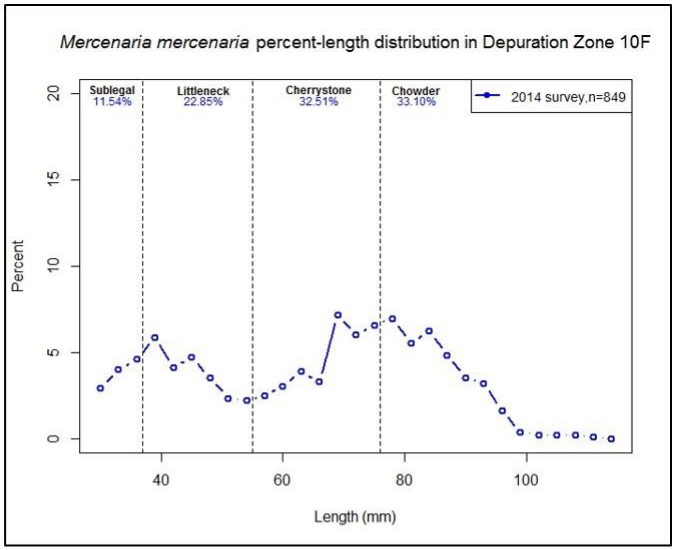
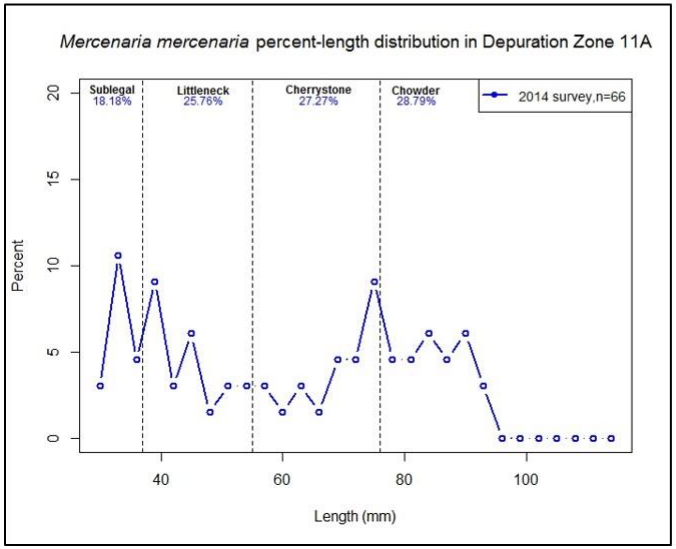
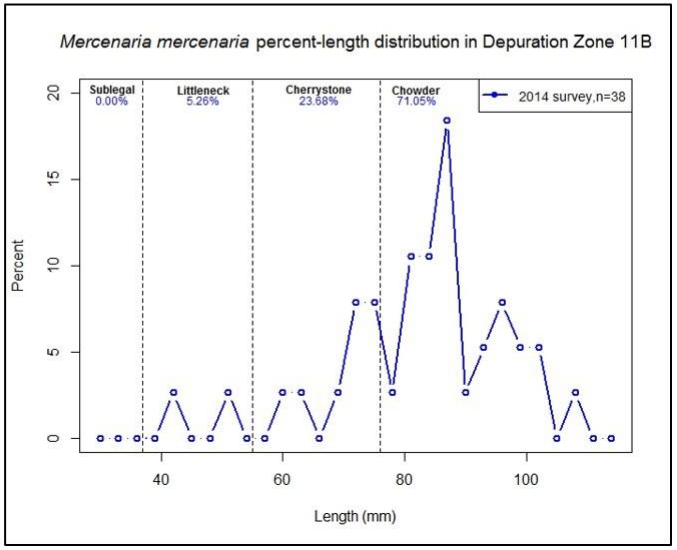


Figure 11 cont.









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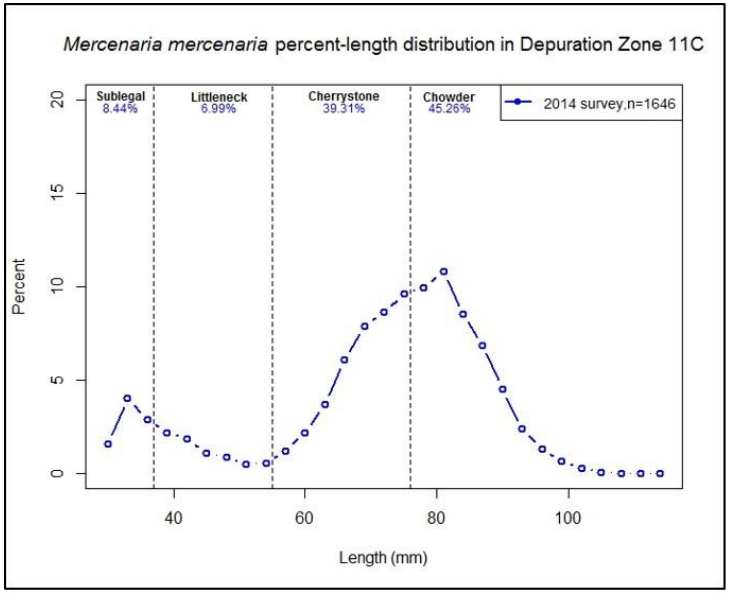

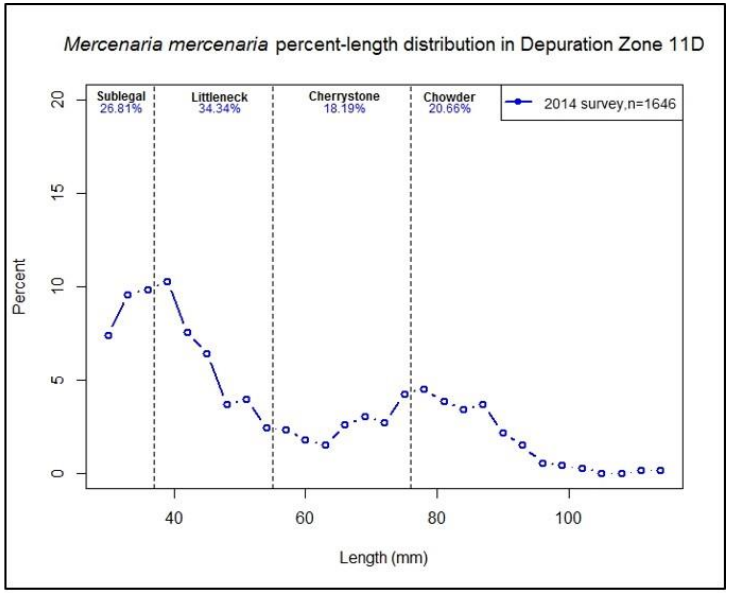

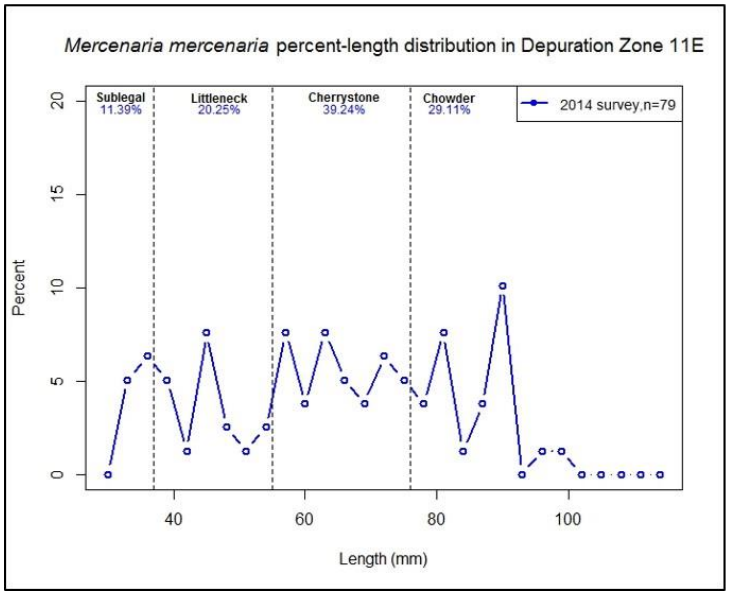

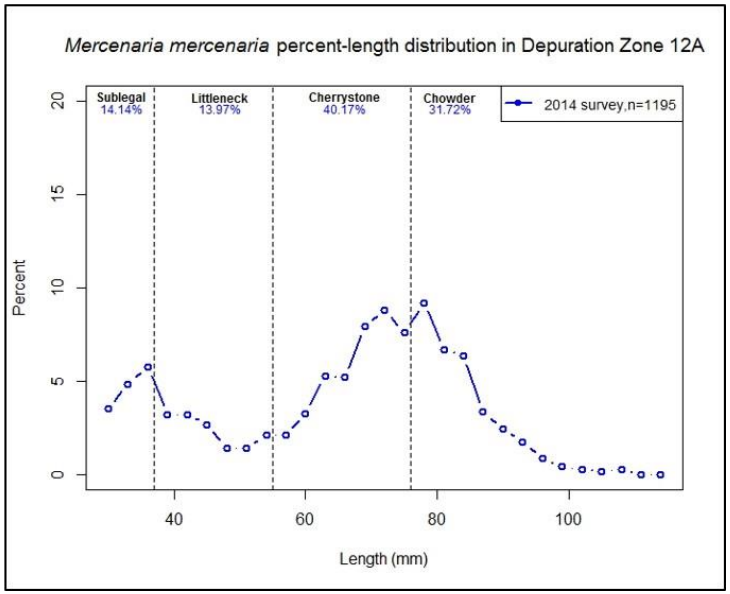

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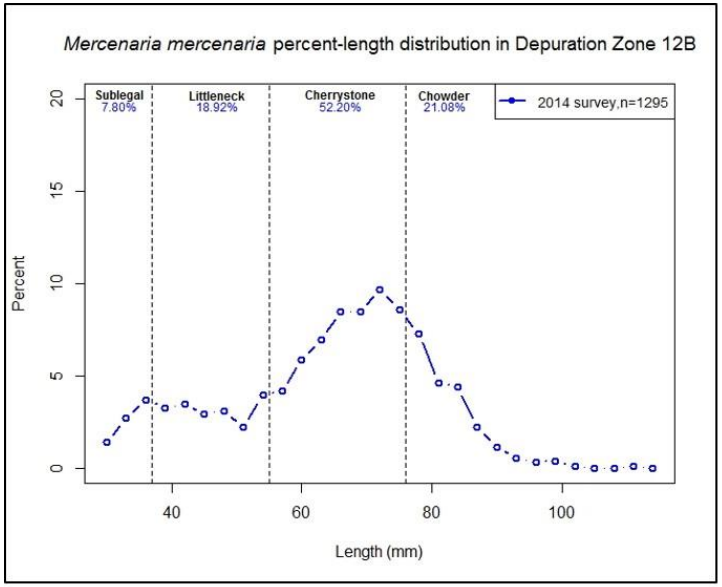
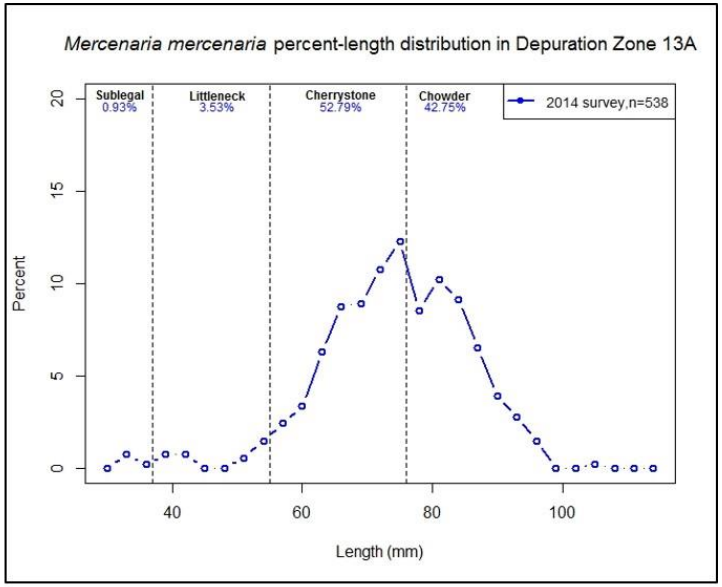
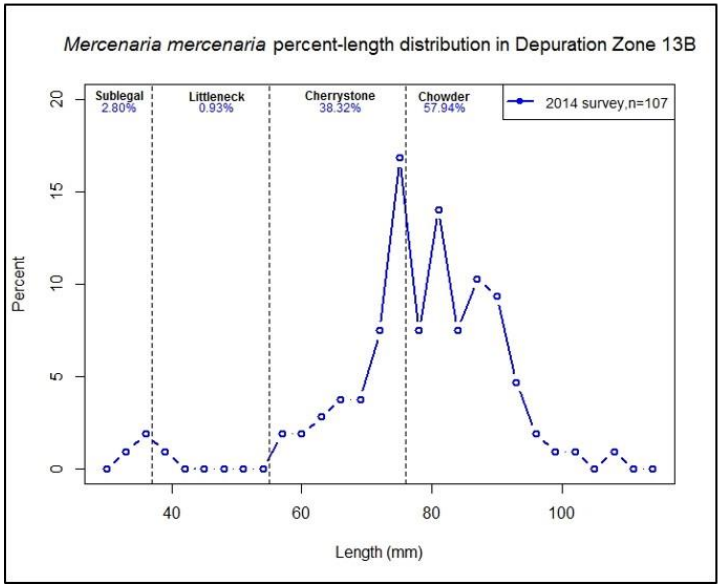






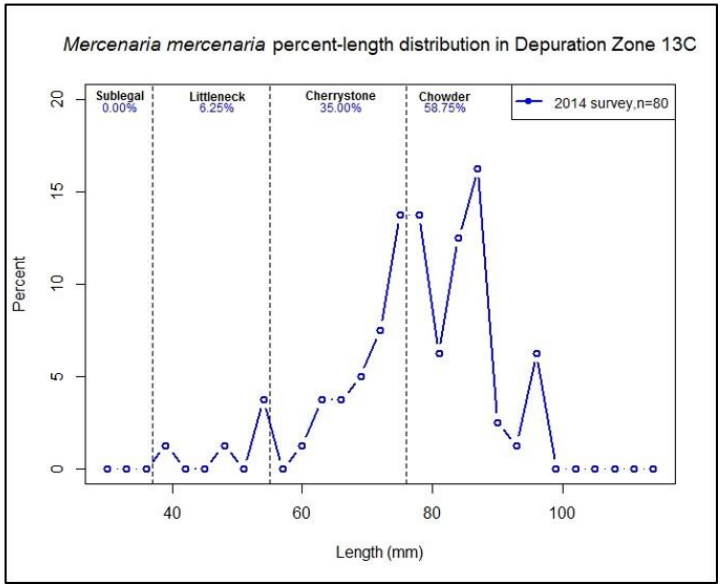
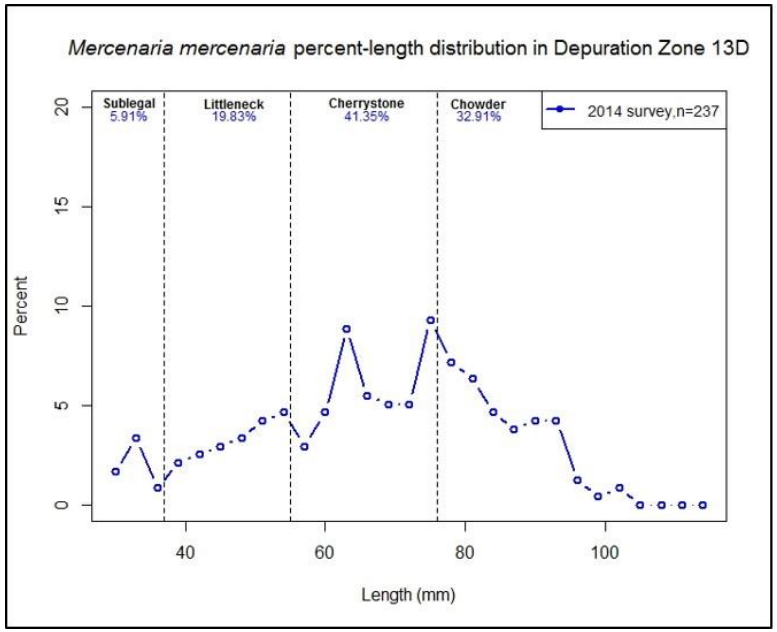


Figure 11 cont.



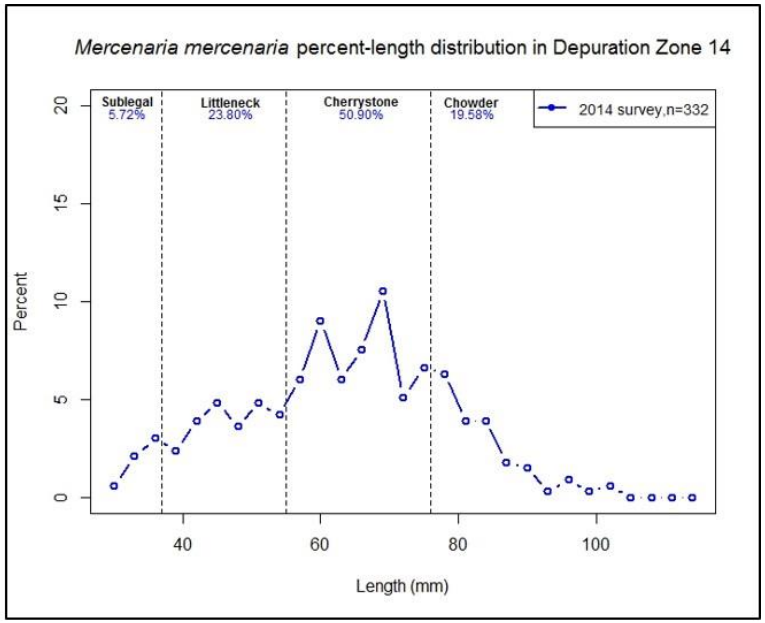


Figure 12a. Percent hard clam recruitment (percentage of sublegal clams) at each station in 2014.

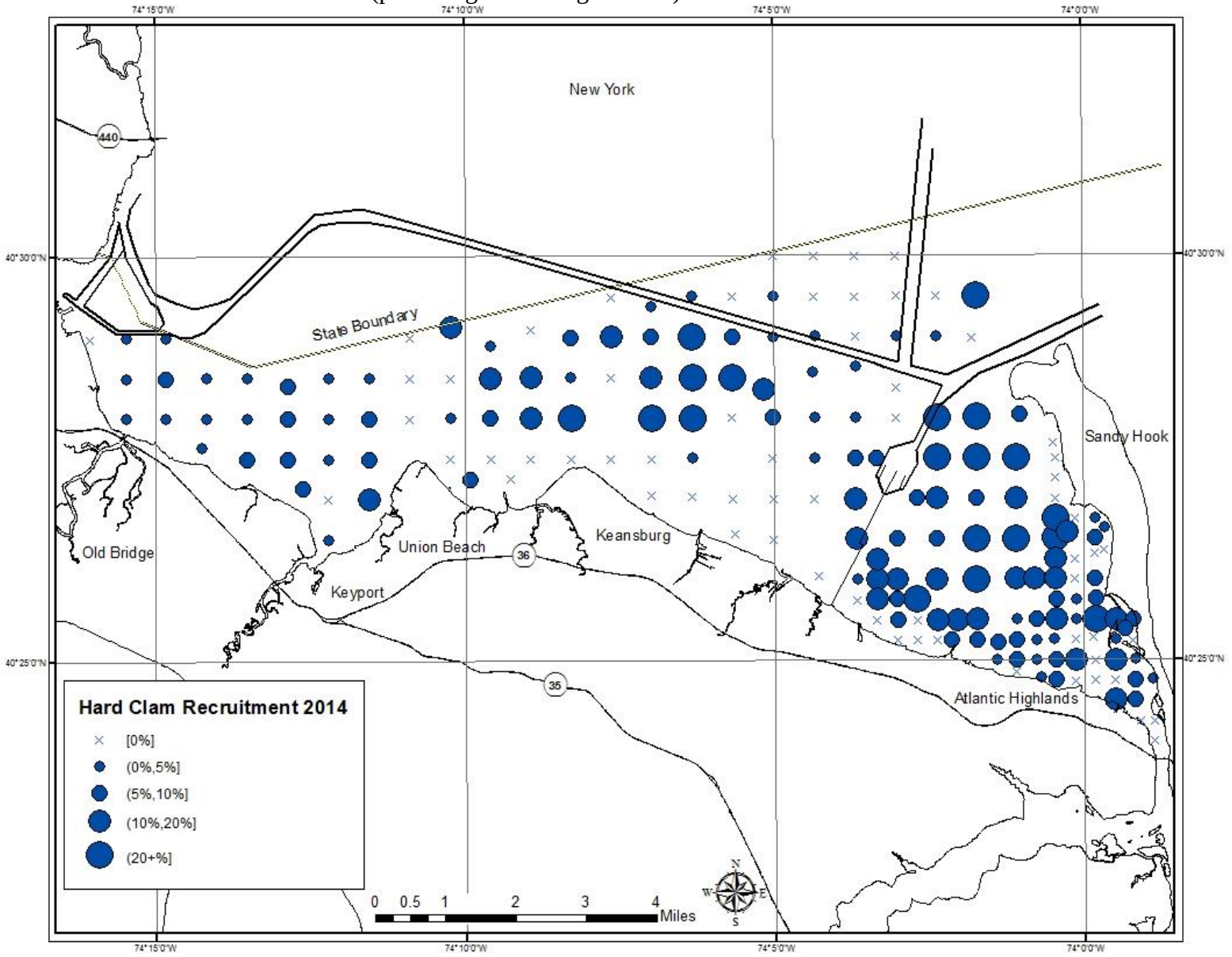


Figure 12b. Percent hard clam recruitment (percentage of sublegal clams) at each station in 2000.

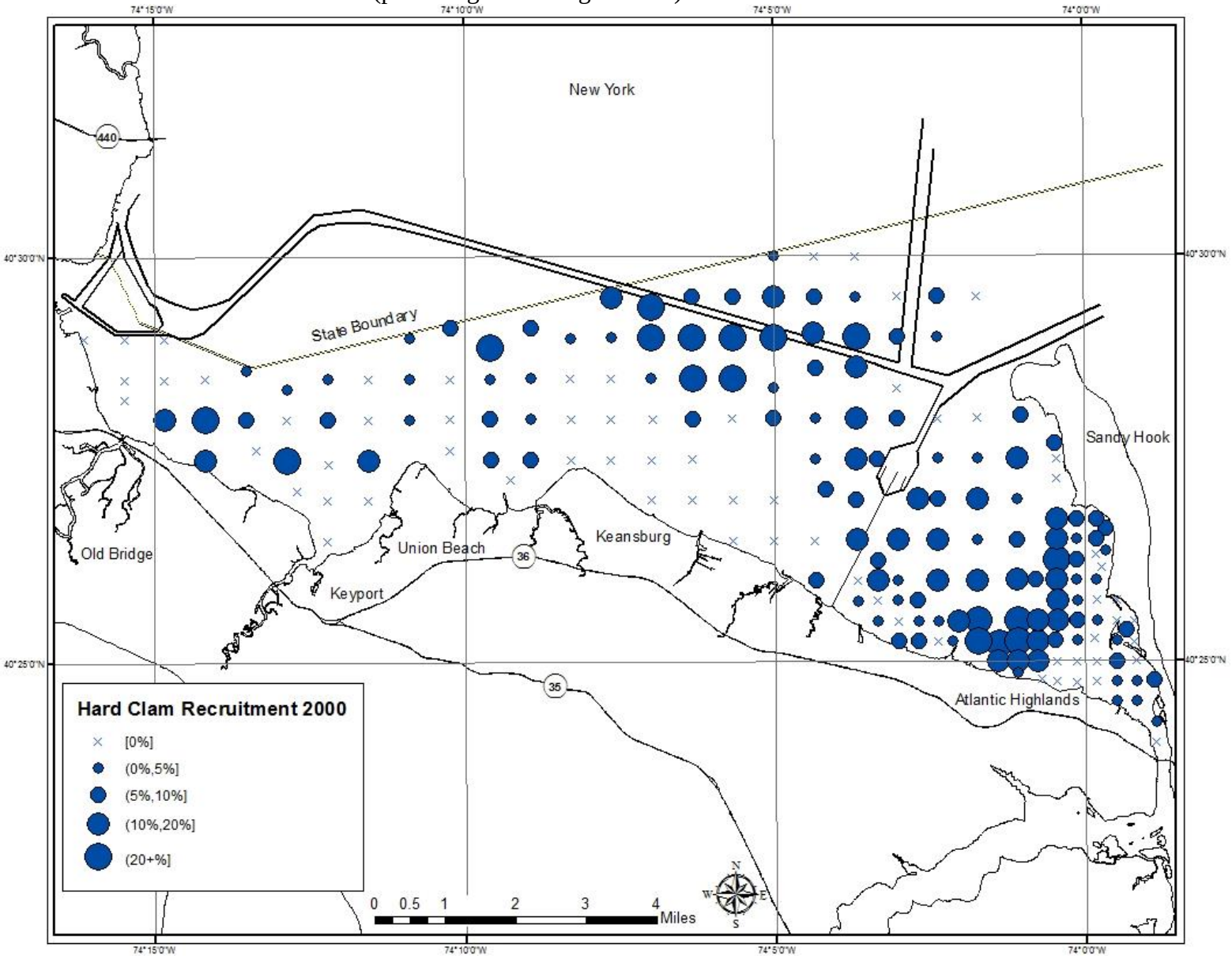


Figure 12c. Percentage of hard clam recruitment (percent of sublegal clams) at each station in 1983.

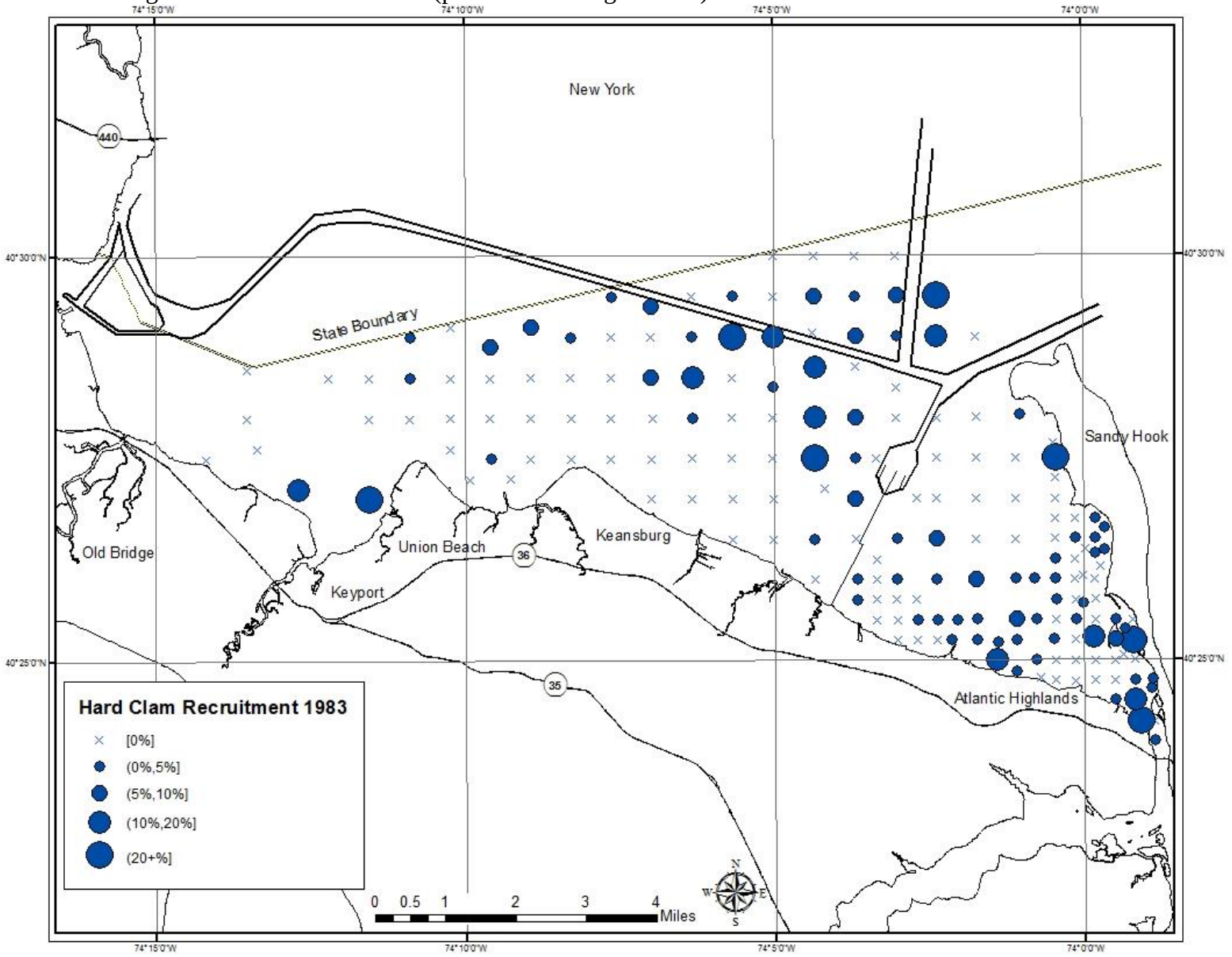


Figure 13a. Percentage of natural mortality at each station in 2014.

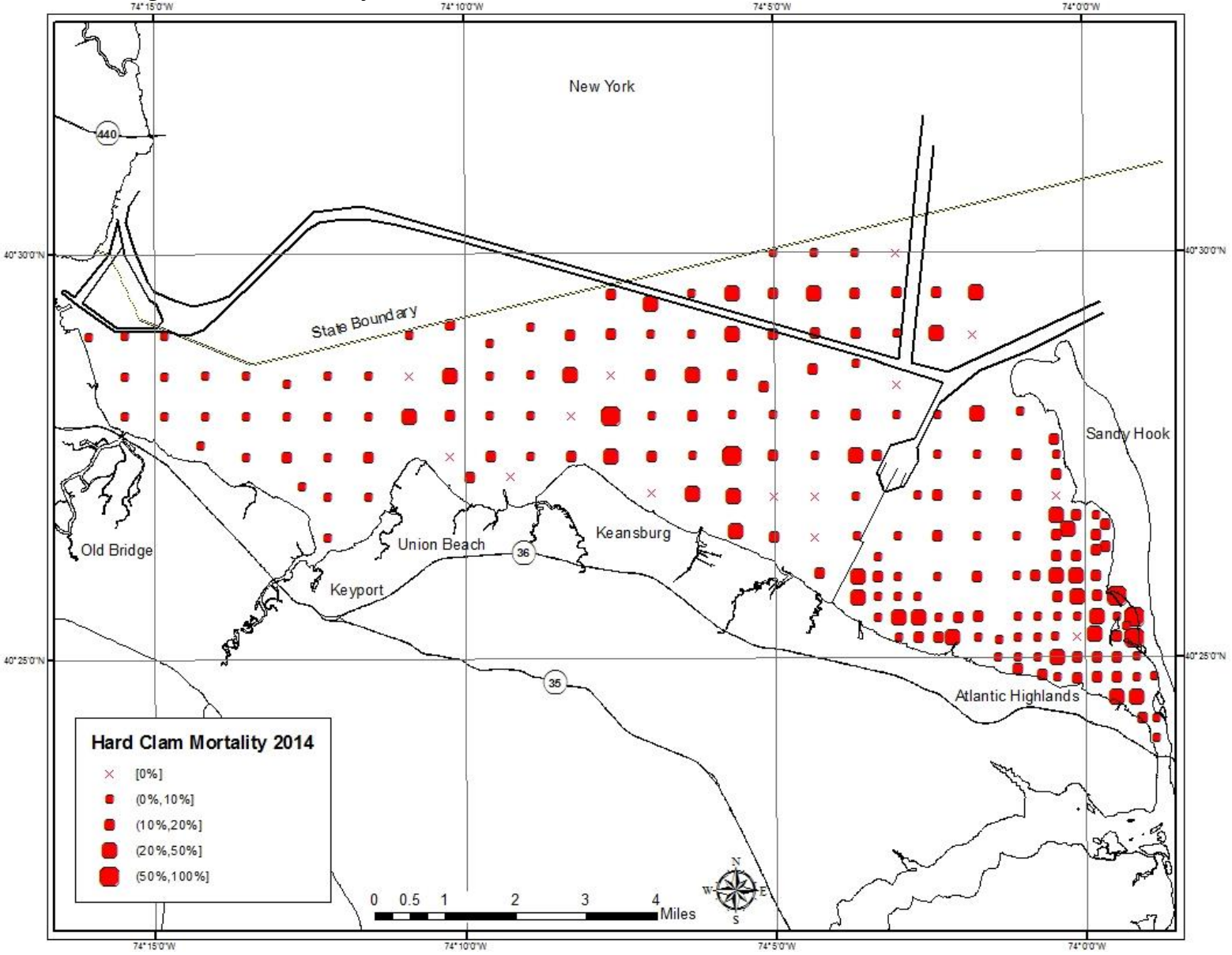


Figure 13b. Percentage of natural mortality at each station in 2000.

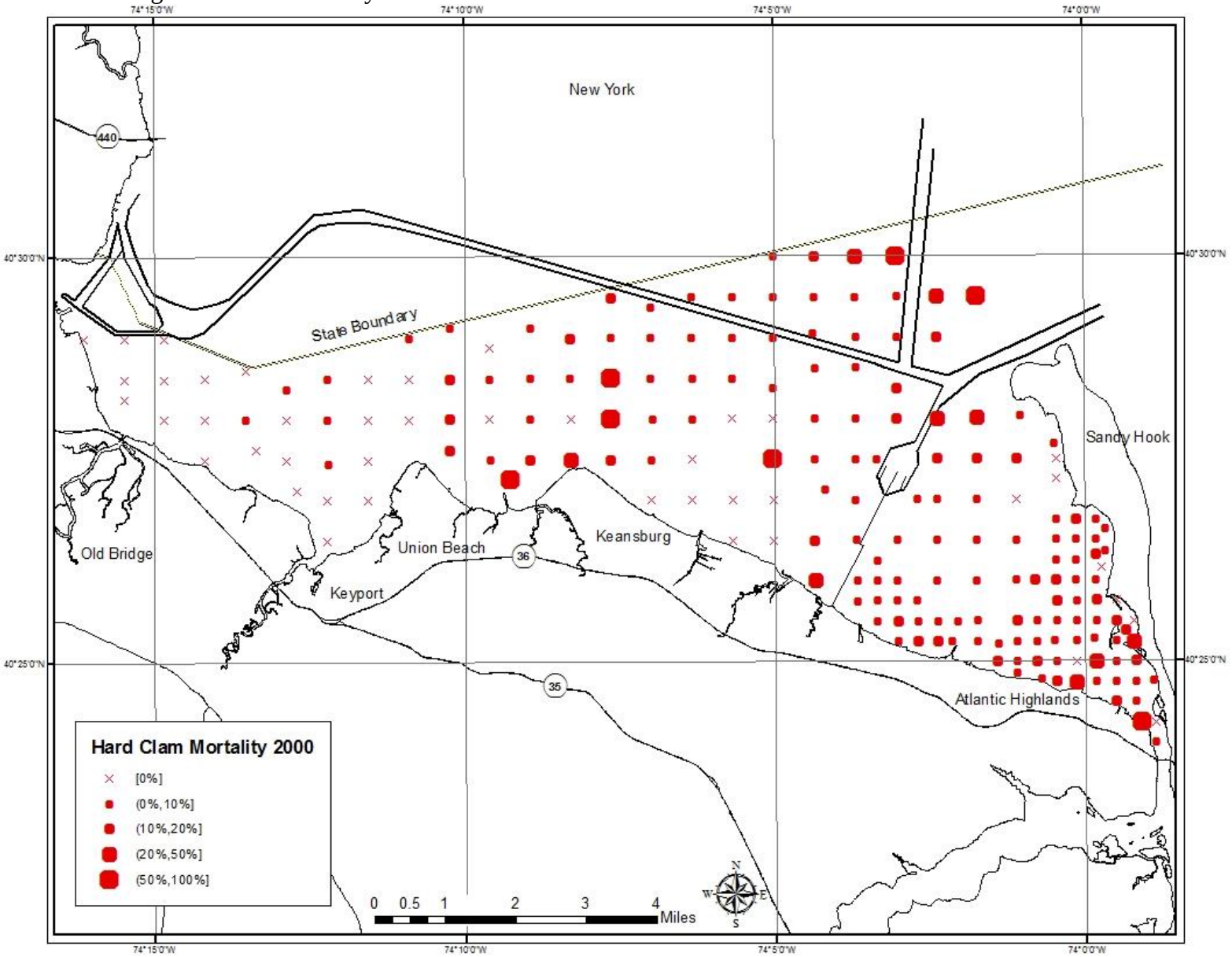


Figure 13c. Percentage of natural mortality at each station in 1983.

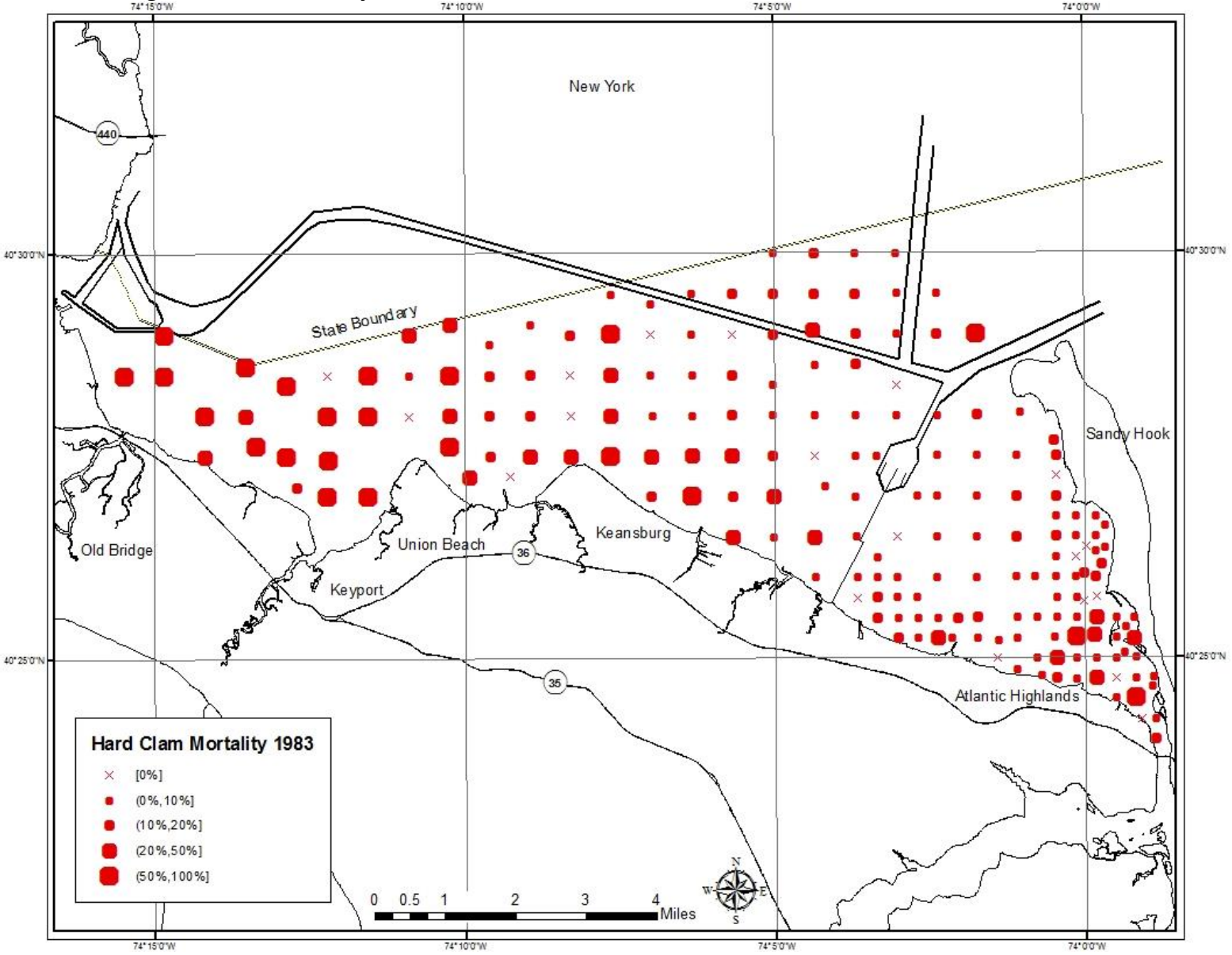


Figure 14a. Distribution of blue mussels (*Mytilus edulis*) in 2014.

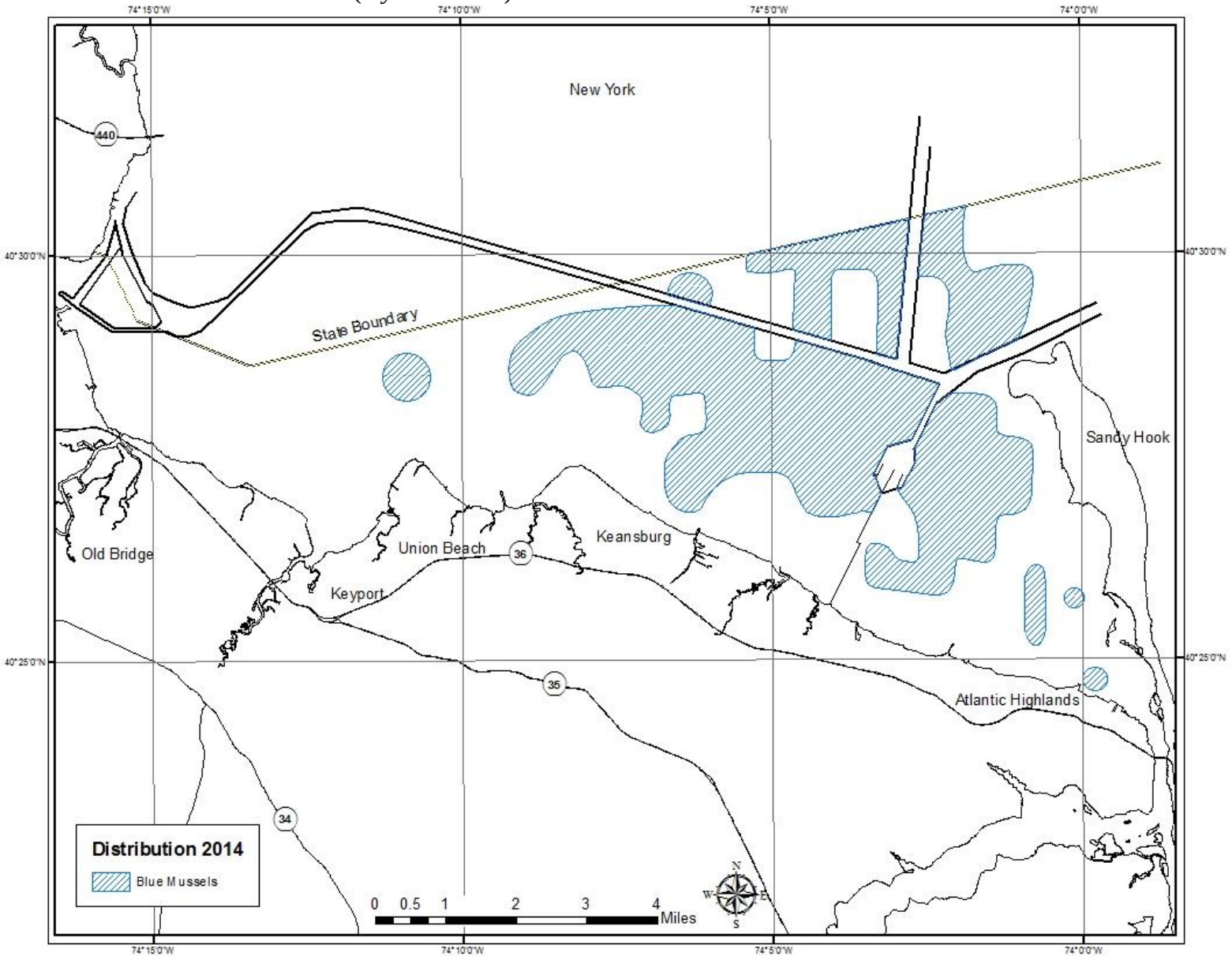


Figure 14b. Copy of distribution chart for blue mussels in 2000 (Celestino 2003b).

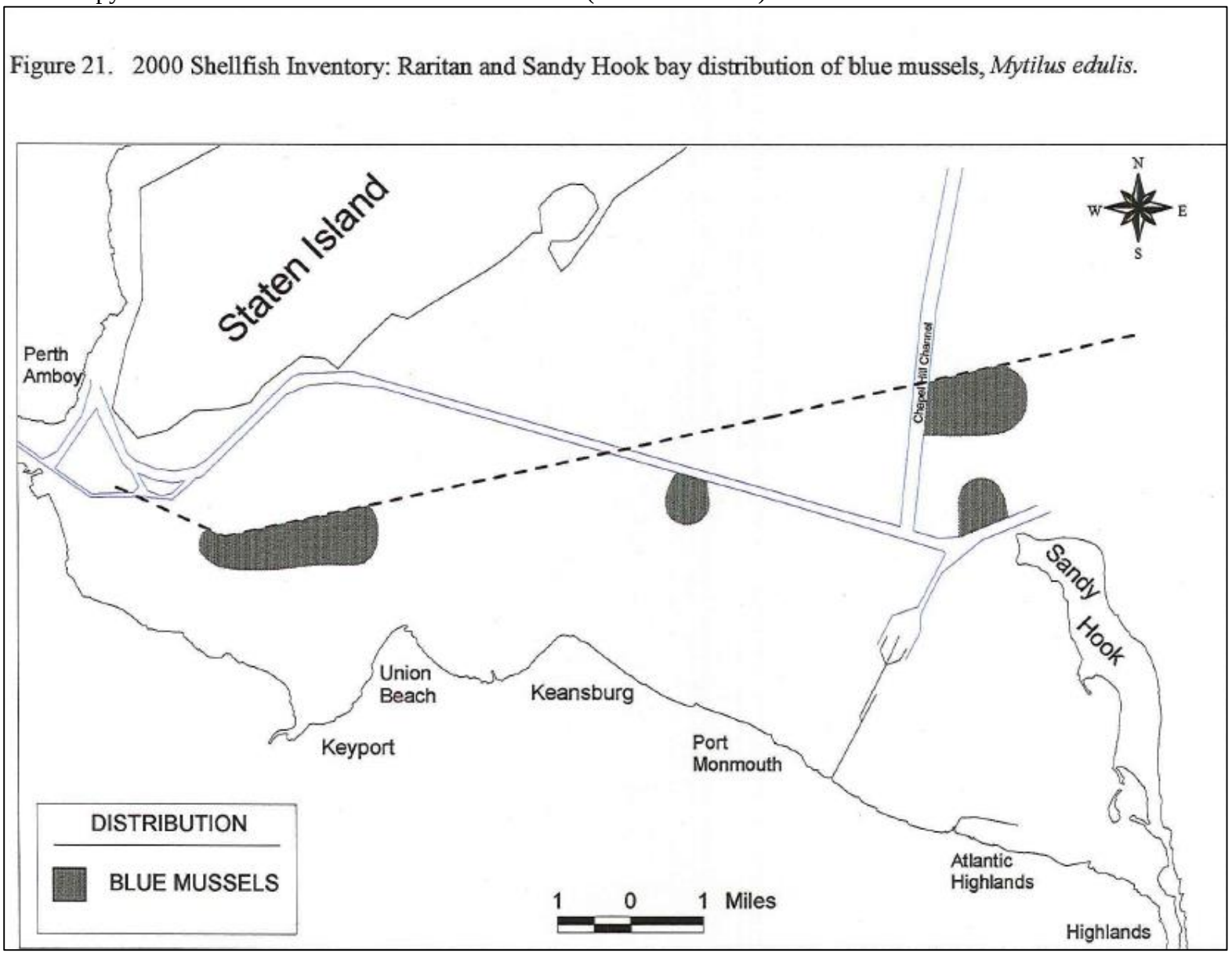


Figure 14c. Copy of distribution chart for blue mussels and eastern oysters in 1983 (McCloy and Joseph 1984).

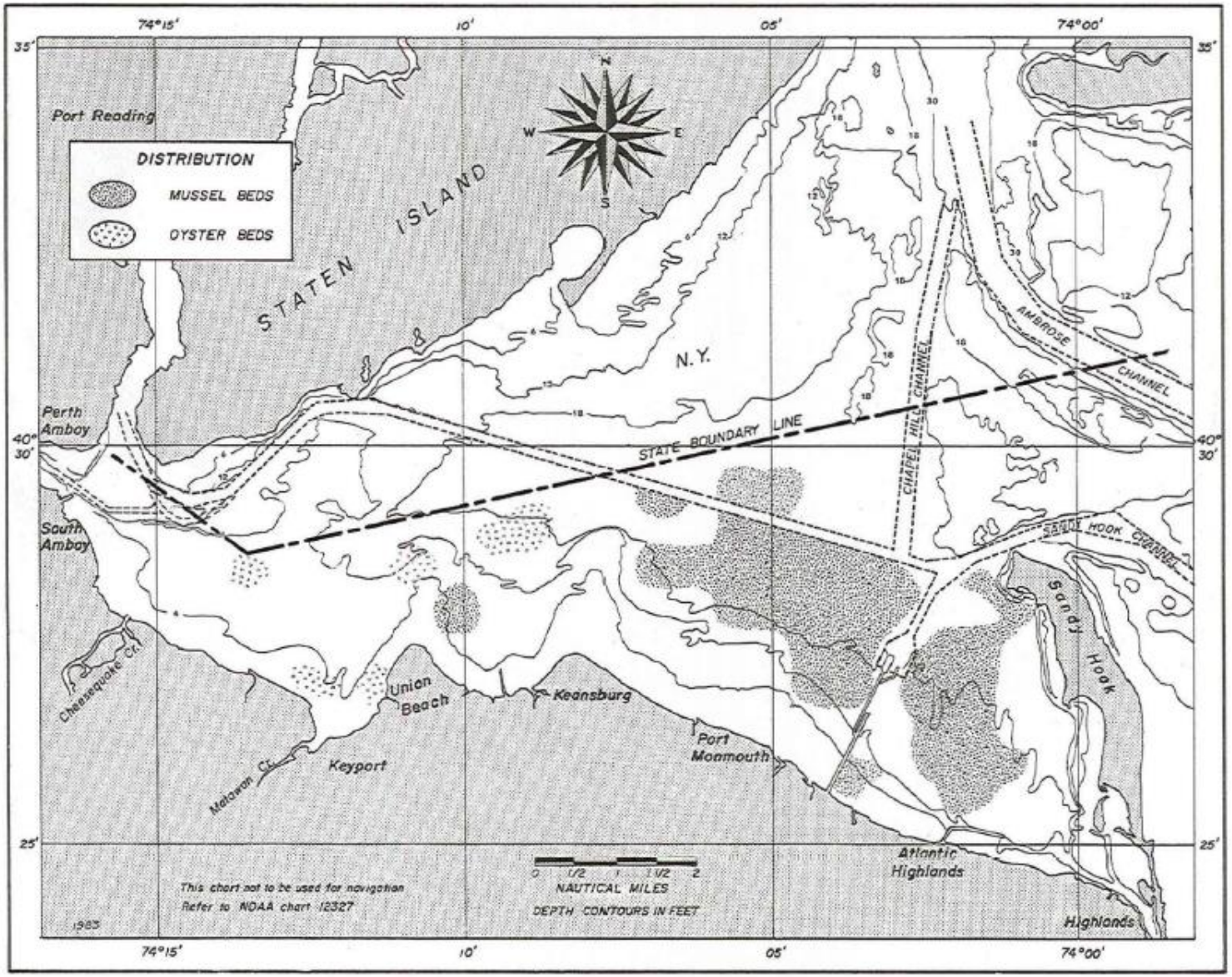


Figure 15a. Distribution of surf clams (*Spisula solidissima*) and soft clams (*Mya arenaria*) in 2014.

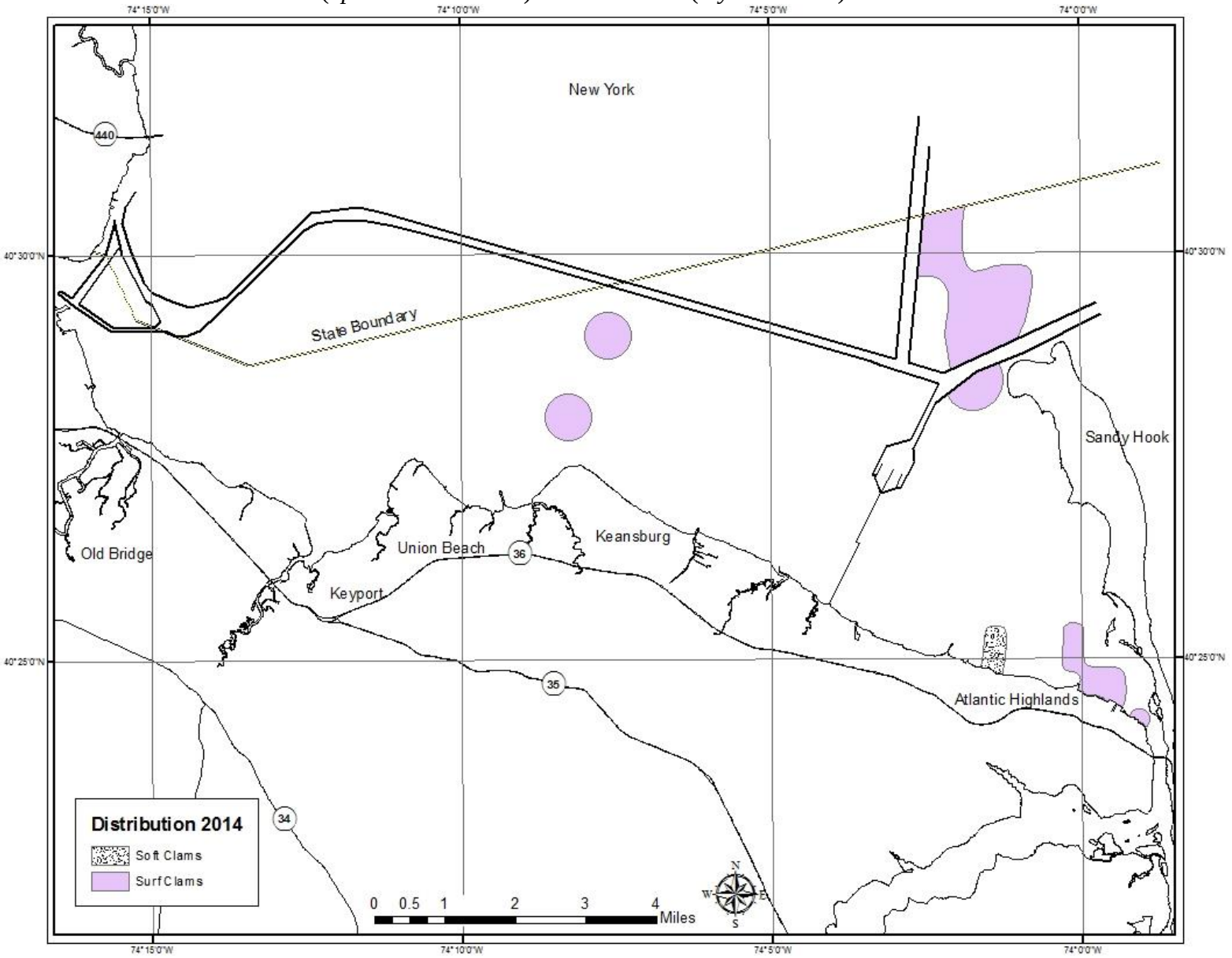


Figure 15b. Copy of distribution chart for surf clams and soft clams in 2000 (Celestino 2003b).

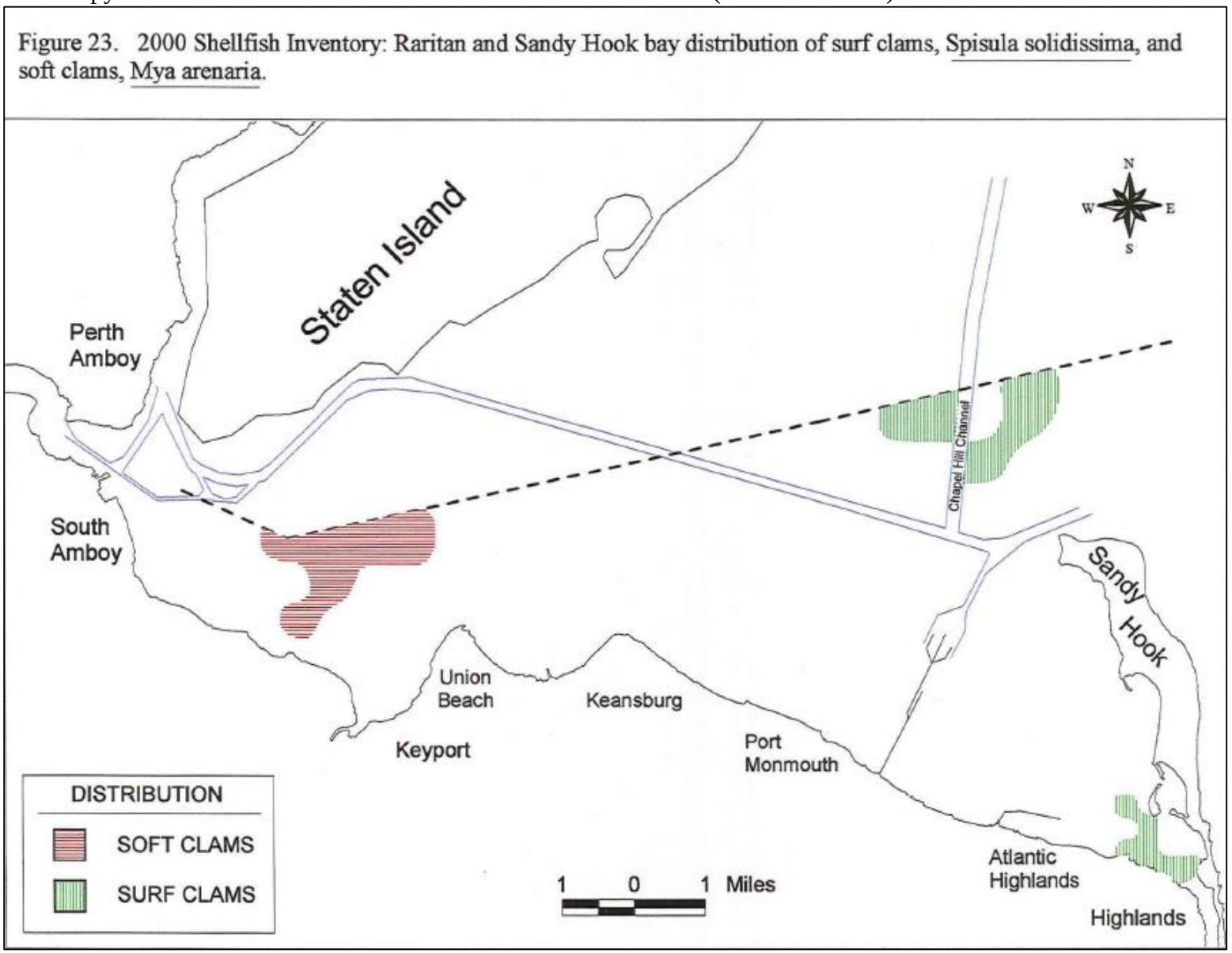


Figure 15c. Copy of distribution chart for surf clams and soft clams in 1983 (McCloy and Joseph 1984).