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An Assessment of Sea Scallop Abundance and Distribution in Selected Areas: Georges Bank Closed Area II, Southern New England/Long Island, New York Bight and the DelMarVa Closed Area

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Submitted to:
Sea Scallop Plan Development Team

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Summary

During the spring and summer of 2010, VIMS and the sea scallop industry conducted abundance surveys of Georges Bank Closed Area II (GBCAI), Southern New England/ Long Island (SNE/LI), New York Bight (NYB) and the DelMarVa Closed Area (DMV). The primary objective of these surveys was to estimate the exploitable biomass of sea scallops in the access area of CAII and the entire SNE/LI, NYB and DMV. During the cruises, we sampled 99 stations within the boundaries of the GBCAII access area, 103 stations in SNE/LI, 101 stations in the NYB and 104 stations in the DMV. The resulting catch data as well as scallops sampled to estimate the length-weight relationships formed the basis for the analysis. Our results indicate that, depending upon the length weight relationship used, roughly 11,000 to 17,000 metric tons of exploitable sea scallops (meat weight) are contained within the GBCAII, and 12,000 to 17,000 metric tons (meat weight) are contained within the SNE/LI area, 2,000 to 7,000 metric tons of exploitable sea scallops (meat weight) are contained within the NYB area and 1,500 to 2,200 metric tons of exploitable sea scallops (meat weight) are contained within the DMV area.

While the overall levels of biomass in the areas were encouraging in some of the areas surveyed, a couple of cautionary observations were made during the cruises. In the case of the GBCAII, we observed numbers of large scallops. Signs of recruitment were limited spatially to a relatively small area. In the case of the open area surveys, one objective was to delineate the inshore boundary of the scallop population. As a result, sampling was conducted shoreward of where we hypothesized that scallops were present. In the case of SNE/LI, the population of scallops was impressive and we were able to gather abundance and length:weight information in an area that suffers from somewhat limited fishery independent survey information. During the NYB cruise, the resource was quite patchy and exhibited a marked shoreward delineation. The scallops that were observed appeared to be healthy and quite robust. The DMV survey portrayed a rotational area that is nearing the end of its closure cycle. As a result, the abundance of scallop in that area was quite limited and the overall biomass was low.

Methods

Survey Area and Sampling Design

The proposed access area of GBCAII, the inshore areas of SNE/LI and NYB as well as the entire DMV (at depths less than 50 fathoms) were surveyed during the course of the 2011 campaign. The boundary coordinates as well as the station maps of the surveyed areas can be found in Table 1 and Figures 1-4. Sampling stations for this study were selected within the context of a systematic random grid. With the patchy distribution of sea scallops determined by some unknown combination of environmental gradients (i.e. latitude, depth, hydrographic features, etc.), a systematic selection of survey stations results in an even dispersion of samples across the entire sampling domain. The systematic grid design was successfully implemented during industry-based surveys since 1998. This design has also been utilized for the execution of a trawl survey in the Bering Sea (Gunderson, 1993).

Sampling Protocols

While at sea, the vessel simultaneously towed two dredges. A NMFS survey dredge, 8 feet in width equipped with 2-inch rings, 4-inch diamond twine top and a 1.5-inch diamond mesh liner was towed on one side of the vessel. On the other side of the vessel, a 14 or 15 foot commercial scallop dredge equipped with 4-inch rings, a 10-inch diamond mesh twine top and no liner was utilized. The dredge frame used in this study was the recently developed

“Coonamessett Farm Turtle Dredge” design. Position of twine top within the dredge bag was standardized throughout the study and rock chains/and turtle chains were used in configurations as dictated by the area surveyed and current regulations. In this paired design, it is assumed that the dredges cover a similar area of substrate and sample from the same population of scallops. The dredges were switched to opposite sides of the vessel mid-way throughout the trip to help minimize any bias.

For each survey tow, the dredges were fished for 15 minutes with a towing speed of approximately 3.8-4.0 kts. High-resolution navigational logging equipment was used to accurately determine and record vessel position. A Star-Oddi™ DST sensor was used on the dredge to measure and record dredge tilt angle as well as depth. With these measurements, the start and end of each tow was estimated. Synchronous time stamps on both the navigational log and DST sensor were used to estimate the linear distance for each tow.

Sampling of the catch was performed using the protocols established by DuPaul and Kirkley, 1995 and DuPaul *et. al.* 1989. For each survey tow, the entire scallop catch was placed in baskets. Depending on the total volume of the catch, a fraction of these baskets were measured for sea scallop length frequency. The shell height of each scallop in the sampled fraction was measured on NMFS sea scallop measuring boards in 5 mm intervals. This protocol allows for the estimation of the size frequency for the entire catch by expanding the catch at each shell height by the fraction of total number of baskets sampled. Finfish and invertebrate bycatch were quantified, with finfish being sorted by species and measured to the nearest 1 cm.

Samples were taken to determine area specific shell height-meat weight relationships. At roughly 25 randomly selected stations the shell height of a sample of 10 scallops was measured to the nearest 0.1 mm. These scallops were then carefully shucked and the adductor muscle individually packaged and frozen at sea. Upon return, the adductor muscle was weighed to the nearest 0.1 gram. The relationship between shell height and meat weight was estimated using a generalized linear mixed model (gamma distribution, log link) incorporating depth as an explanatory variable in SAS v. 9.2. with the model:

$$\ln MW = \ln\alpha + \beta^{*}\ln SH + \gamma^{*}\ln Depth$$

where MW=meat weight (grams), SH=shell height (millimeters), Depth=depth (meters). α, β and γ are parameters to be estimated.

The standard data sheets used since the 1998 Georges Bank survey were used. The bridge log maintained by the captain/mate recorded location, time, tow-time (break-set/haul-back), tow speed, water depth, catch, bearing, weather and comments relative to the quality of the tow. The deck log maintained by the scientific personnel recorded detailed catch information on scallops, finfish, invertebrates and trash.

Data Analysis

The catch and navigation data were used to estimate swept area biomass within the areas surveyed. The methodology to estimate biomass is similar to that used in previous survey work by VIMS. In essence, we estimate a mean abundance from the point estimates and scale that value up to the entire area of the domain sampled. This calculation is given:

$$TotalBiomass = \sum_{j} \left(\frac{\left(\frac{CatchWtperTowinSubarea_j}{AreaSweptperTow} \right)}{Efficiency} \right) SubArea_j$$

Catch weight per tow of exploitable scallops was calculated from the raw catch data as an expanded size frequency distribution with an area and depth appropriate shell height-meat weight relationship applied (length-weight relationships were obtained from SARC 50 document as well as the actual relationship taken during the cruise) (NEFSC, 2010). Exploitable biomass, defined as that fraction of the population vulnerable to capture by the currently regulated commercial gear, was calculated using two approaches. The observed catch at length data from the NMFS survey dredge (assumed to be non-size selective) was adjusted based upon the size selectivity characteristics of the commercial gear (Yochum and DuPaul, 2008). The observed catch-at-length data from the commercial dredge was not adjusted due to the fact that these data already represent that fraction of the population that is subject to exploitation by the currently regulated commercial gear.

Utilizing the information obtained from the high resolution GPS, an estimate of area swept per tow was calculated. Throughout the cruises the location of the ship was logged every three seconds. By determining the start and end of each tow based on the recorded times as determined by the tilt sensor data of, a survey tow can be represented by a series of consecutive coordinates (latitude, longitude). The linear distance of the tow is calculated by:

$$TowDist = \sum_{i=1}^{n} \sqrt{(lon_2 - lon_1)^2 + (lat_2 - lat_1)^2}$$

The linear distance of the tow is multiplied by the width of the gear to result in an estimate of the area swept by the gear during a given survey tow.

The final two components of the estimation of biomass are constants and not determined from experimental data obtained on these cruises. Estimates of survey dredge gear efficiency have been calculated from a prior experiment using a comparison of optical and dredge catches (NEFSC, 2010). Based on this experiment, an efficiency value of 38% was used for the survey dredge on Georges Bank and a value of 44% was used in the mid-Atlantic. Estimates of commercial sea scallop dredge gear efficiency have been calculated from prior experiments using a variety of approaches (Gedamke *et. al.,* 2005, Gedamke *et. al.,* 2004, D. Hart, pers. comm.). The efficiency of the commercial dredge is generally considered to be higher and based on the prior work as well as the relative efficiency from the data generated from this study; efficiency values of 60%and 65% were used for Georges Bank and the Mid-Atlantic, respectively. To scale the estimated mean scallop catch to the full domain, the total area of the GBCAII, SNE?LI, NYB and DMV was calculated in ArcGIS v.10.0.

Results

Summary statistics including the dates of the cruises as well as the number of tows included in the biomass estimates are shown in Table 2. Mean total and exploitable scallop densities observed during the cruises are shown in Table 3. From the density data, an estimate of the total number of scallops contained in the areas is shown in Table 4. From the catch data, an estimate of the average meat weight per scallop for both total catch as well as exploitable animals is shown in Table 5. Mean catch per tow is shown in Table 6. Total and exploitable biomass estimates are shown for both areas in Tables 7 and 8, respectively. The length weight relationships used in the analyses representing estimates from the actual cruises or SARC 50 are shown in Table 9. Length frequency distributions for both of the cruises are shown in Figures 5 to 8.

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Table 1 Boundary coordinates of the access Area of closed Area II and the DelMarVa Closed Area. The SNE/LI and NYB areas surveyed have irregular boundaries that followed depth contours. As a result, those areas are better represented visually. Please see Figures 1-4 for a spatial representation of all areas sampled.

	Latitude	**Longitude**
GBCAII		
GBCAII -1	41° 00' N	67° 20' W
GBCAII -2	41° 00' N	66° 35.8' W
GBCAII -3	41° 18.6' N	66° 24.8' W
GBCAII -4	41° 30' N	66° 34.8' W
GBCAII -5	41° 30' N	67° 20' W
DMV		
DMV-1	38° 10' N	74° 50' W
DMV-2	38° 10' N	74° 00' W
DMV-3	37° 15' N	74° 00' W
DMV-4	37° 15' N	74° 50' W

Table 2 Summary statistics for the survey cruises.

Area	Cruise dates	Number of stations included in biomass estimate (survey dredge)	Number of stations included in biomass estimate (comm. dredge)
Georges Bank Closed Area II	May 5-15, 2011	99	99
Southern New England/Long Island	June 25-30, 2011	103	103
New York Bight	August 31-Sept. 6, 2011	101	101
DelmarVa Closed Area	Sept. 26 – Oct. 1, 2011	104	104

Table 3 Mean total and mean exploitable scallop densities observed during the 2011 cooperative sea scallop surveys of GBCAII, SNE/LI, NYB and DMV..

Gear	Efficiency	Average Total Density (scallops/m^2)	SE	Average Density of Exploitable Scallops (scallops/m^2)	SE
GBCAII					
Commercial	60%			0.099	0.016
Survey	38%	0.216	0.047	0.127	0.020
SNE/LI					
Commercial	65%			0.041	0.004
Survey	44%	0.061	0.006	0.036	0.004
NYB					
Commercial	65%			0.018	0.002
Survey	44%	0.015	0.003	0.008	0.001
DMV					
Commercial	65%			0.014	0.001
Survey	44%	0.031	0.004	0.013	0.001

Table 4 Estimated number of scallops in the area surveyed. The estimate is based upon the estimated density of scallops at commercial dredge efficiencies of 60% and 65% and survey dredge efficiencies of 38% and 44% for the Georges Bank and mid-Atlantic areas, respectively. The total areas surveyed was estimated at 3,865 km^2 (GBCAII), 11,203 km^2 (SNE/LI), 7,634 km^2 (NYB) and 4,472 km^2 (DMV).

Gear	Efficiency	Estimated Total	Estimated Total Exploitable
GBCAII			
Commercial	60%		384,366,855
Survey	38%	834,391,751	489,598,869
SNE/LI			
Commercial	65%		455,277,587
Survey	44%	680,541,651	400,618,210
NYB			
Commercial	65%		134,887,158
Survey	44%	112,544,513	63,676,272
DMV			
Commercial	65%		61,518,948
Survey	44%	137,616,767	58,090,775

Table 5 Estimated average scallop meat weights for the area surveyed Estimated weights are for the total size distribution of animals as represented by the catch from the NMFS survey dredge as well as the mean weight of exploitable scallops in the area as represented by the catches from both the survey and commercial dredge. Length:weight relationships from both SARC 50 as well as that observed from the cruise are shown.

Gear	SH:MW	Mean Meat Weight (g) Total scallops	Mean Meat Weight (g) Exploitable scallops
GBCAII			
Commercial	SARC 50 (CAII specific)		35.82
Survey	SARC 50 (CAII specific)	26.22	34.64
Commercial	SARC 50 (GB general)		33.89
Survey	SARC 50 (GB general)	24.71	32.82
Commercial	VIMS (depth weighted)		29.42
Survey	VIMS (depth weighted)	21.28	28.53
SNE/LI			
Commercial	SARC 50 (MA general)		31.98
Survey	SARC 50 (MA general)	24.70	31.05
Commercial	VIMS (depth weighted)		38.32
Survey	VIMS (depth weighted)	30.05	37.26
NYB			
Commercial	SARC 50 (MA general)		45.15
Survey	SARC 50 (MA general)	26.19	36.07
Commercial	VIMS (depth weighted)		49.49
Survey	VIMS (depth weighted)	31.13	41.38
DMV			
Commercial	SARC 50 (MA general)		30.94
Survey	SARC 50 (MA general)	16.57	28.73
Commercial	VIMS (depth weighted)		35.36
Survey	VIMS (depth weighted)	19.97	33.04

Table 6 Mean catch of sea scallops observed during the 2011 VIMS-Industry cooperative surveys. Mean catch is depicted as a function of various shell height meat weight relationships, either an area specific relationship derived from samples taken during the survey, or a relationship from SARC 50.

Gear	Samples	SH:MW	Total Scallops (mean grams/tow)	Standard Error	Exploitable Scallops (mean grams/tow)	Standard Error
GBCAII						
Commercial	99	SARC 50 (CAII specific)			17,903.10	2,145.56
Survey	99	SARC 50 (CAII specific)	9,570.24	1,386.29	7,447.98	909.24
Commercial	99	SARC 50 (GB general)			16,942.34	2,008.05
Survey	99	SARC 50 (GB general)	9,020.89	1,284.80	7,057.02	854.60
Commercial	99	VIMS (depth weighted)			14,704.33	1,686.79
Survey	99	VIMS (depth weighted)	7,767.44	1,064.98	6,134.18	721.07
SNE/LI						
Commercial	103	SARC 50 (MA general)			6,864.01	548.81
Survey	103	SARC 50 (MA general)	2,857.30	270.06	2,112.52	192.74
Commercial	103	VIMS (depth weighted)			8,222.86	663.62
Survey	103	VIMS (depth weighted)	3,476.56	333.53	2,534.83	233.10
NYB						
Commercial	101	SARC 50 (MA general)			4,420.95	546.15
Survey	101	SARC 50 (MA general)	764.99	120.01	597.60	87.73
Commercial	101	VIMS (depth weighted)			4,845.92	605.90
Survey	101	VIMS (depth weighted)	909.23	148.69	685.55	103.61
DMV						
Commercial	104	SARC 50 (MA general)			2,112.89	189.93
Survey	104	SARC 50 (MA general)	978.41	95.29	717.83	68.14
Commercial	104	VIMS (depth weighted)			2,414.70	223.22
Survey	104	VIMS (depth weighted)	1,179.16	117.96	825.67	80.22

Table 7 Estimated total biomass of sea scallops observed during the July 2011 VIMS-Industry cooperative surveys. Biomass is presented as a function of different shell height meat weight relationships, either an area specific relationship derived from samples taken during the actual survey or a relationship from SARC 50.

Gear	SH:MW	Efficiency	Total Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
GBCAII						
Survey	SARC 50 (CAII specific)	38%	21,761.06	3,808.54	17,952.52	25,569.60
Survey	SARC 50 (GB general)	38%	20,511.92	3,529.73	16,982.19	24,041.66
Survey	VIMS (depth weighted)	38%	17,661.80	2,925.81	14,735.99	20,587.61
SNE/LI						
Survey	SARC 50 (MA general)	44%	16,676.32	1,462.47	10,867.04	13,791.99
Survey	VIMS (depth weighted)	44%	20,290.58	1,768.78	13,025.51	16,563.07
NYB						
Survey	SARC 50 (MA general)	44%	2,927.79	597.15	2,330.64	3,524.94
Survey	VIMS (depth weighted)	44%	3,479.81	739.86	2,739.95	4,219.68
DMV						
Survey	SARC 50 (MA general)	44%	2,287.03	289.60	1,997.43	2,576.63
Survey	VIMS (depth weighted)	44%	2,756.29	358.50	2,397.80	3,114.79

Table 8 Estimated exploitable biomass of sea scallops observed during the July 2011 VIMS-Industry cooperative surveys. Biomass is presented as a function of different shell height meat weight relationships, either an area specific relationship derived from samples taken during the actual survey or a relationship from SARC 50.

Gear	SH:MW	Efficiency	Exploitable Biomass (mt)	95% CI	Lower Bound 95% CI	Upper Bound 95%CI
GBCAII						
Commercial	SARC 50 (CAII specific)	60%	13,750.43	2,501.85	11,248.58	16,252.28
Survey	SARC 50 (CAII specific)	38%	16,935.41	2,497.96	14,437.45	19,433.37
Commercial	SARC 50 (GB general)	60%	13,012.53	2,341.50	10,671.02	15,354.03
Survey	SARC 50 (GB general)	38%	16,046.44	2,347.83	13,698.60	18,394.27
Commercial	VIMS (depth weighted)	60%	11,293.63	1,966.89	9,326.73	13,260.52
Survey	VIMS (depth weighted)	38%	13,948.05	1,980.99	11,967.06	15,929.04
SNE/LI						
Commercial	SARC 50 (MA general)	65%	14,463.07	1,827.35	12,635.72	16,290.42
Survey	SARC 50 (MA general)	44%	12,329.52	1,462.47	10,867.04	13,791.99
Commercial	VIMS (depth weighted)	65%	17,326.29	2,209.62	15,116.67	19,535.91
Survey	VIMS (depth weighted)	44%	14,794.29	1,768.78	13,025.51	16,563.07
NYB						
Commercial	SARC 50 (MA general)	65%	6,108.53	1,192.47	4,916.06	7,300.99
Survey	SARC 50 (MA general)	44%	2,287.13	436.52	1,850.61	2,723.65
Commercial	VIMS (depth weighted)	65%	6,695.72	1,322.92	5,372.80	8,018.64
Survey	VIMS (depth weighted)	44%	2,623.77	515.57	2,108.20	3,139.33
DMV						
Commercial	SARC 50 (MA general)	65%	1,910.43	271.37	1,639.05	2,181.80
Survey	SARC 50 (MA general)	44%	1,677.93	207.09	1,470.83	1,885.02
Commercial	VIMS (depth weighted)	65%	2,183.31	318.93	1,864.38	2,502.24
Survey	VIMS (depth weighted)	44%	1,930.00	243.80	1,686.21	2,173.80

Table 9 Summary of area specific shell height-meat weight parameters used in the analyses. Parameters were obtained from two sources: (1) samples collected during the course of the surveys, and (2) SARC 50 (NEFSC, 2010).

Area surveyed	**Date**	**α**	**β**	**γ**	**δ**
Survey data					
GBCAII	May, 2011	-6.0044	2.827	-0.9979	
SNE/LI	June, 2011	-8.8079	2.7546	-0.1859	
NYB	Sept., 2011	-7.8163	2.5077	-0.1343	
DMV	Sept., 2011	-6.9325	2.4468	-0.3145	
SARC 50					
GB general		9.6771	2.8387	-0.5084	-4.7629
CAII specific	-	-8.7026	2.8338	-0.3354	
Mid-Atlantic general		-16.88	4.64	1.57	-0.43

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*The length weight relationship for sea scallops from data collected on the cruise and SARC 50 is modeled as:

$$W=\exp(\alpha+ \beta*\ln(L) + \gamma*\ln(D))$$

For SARC 50 (mid-Atlantic) an interaction term is included in the model as follows:

$$W=\exp(\alpha+ \beta*\ln(L) + \gamma*\ln(D) + \delta*\ln(L)*\ln(D))$$

For SARC 50 (GB general) the model is as follows:

$$W=\exp(\alpha+ \beta*\ln(L) + \gamma*\ln(D) + \delta*\ln(\mathrm{Lat}))$$

Where *W* is meat weight in grams, *L* is scallop shell height in millimeters (measured from the umbo to the ventral margin), *D* is depth in meters and Lat is latitude in decimal degrees.

Figure 1 Locations of sampling stations in the access area of Georges Bank Closed Area II survey by the F/V *Celtic* during the cruise conducted in May, 2011.

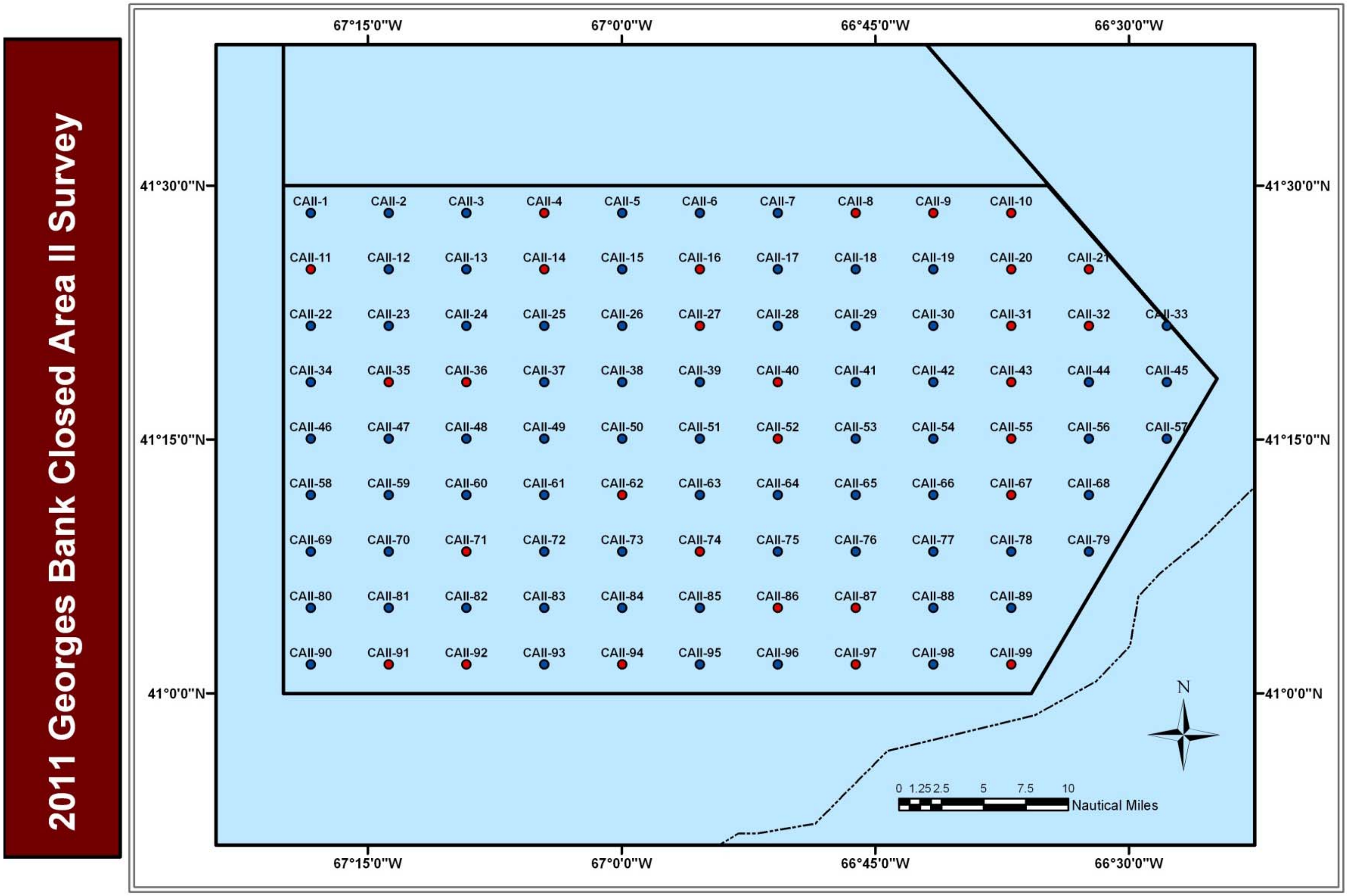


Figure 2 Locations of sampling stations for the Southern New England/Long Island survey conducted by the F/V *Celtic* during June, 2011.

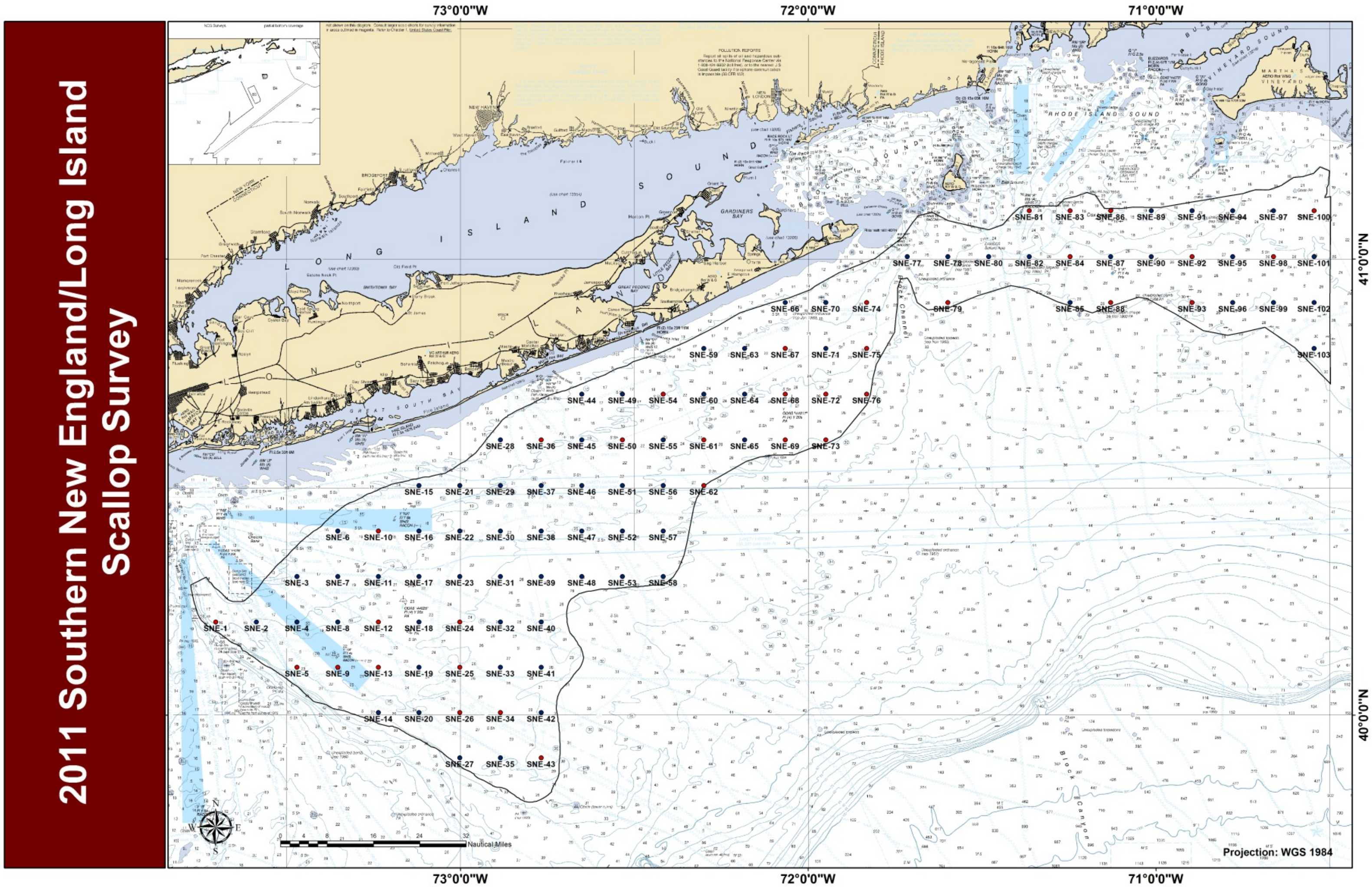


Figure 3 Locations of sampling stations for the New York Bight survey conducted by the F/V *Kathy Ann* during September, 2011.

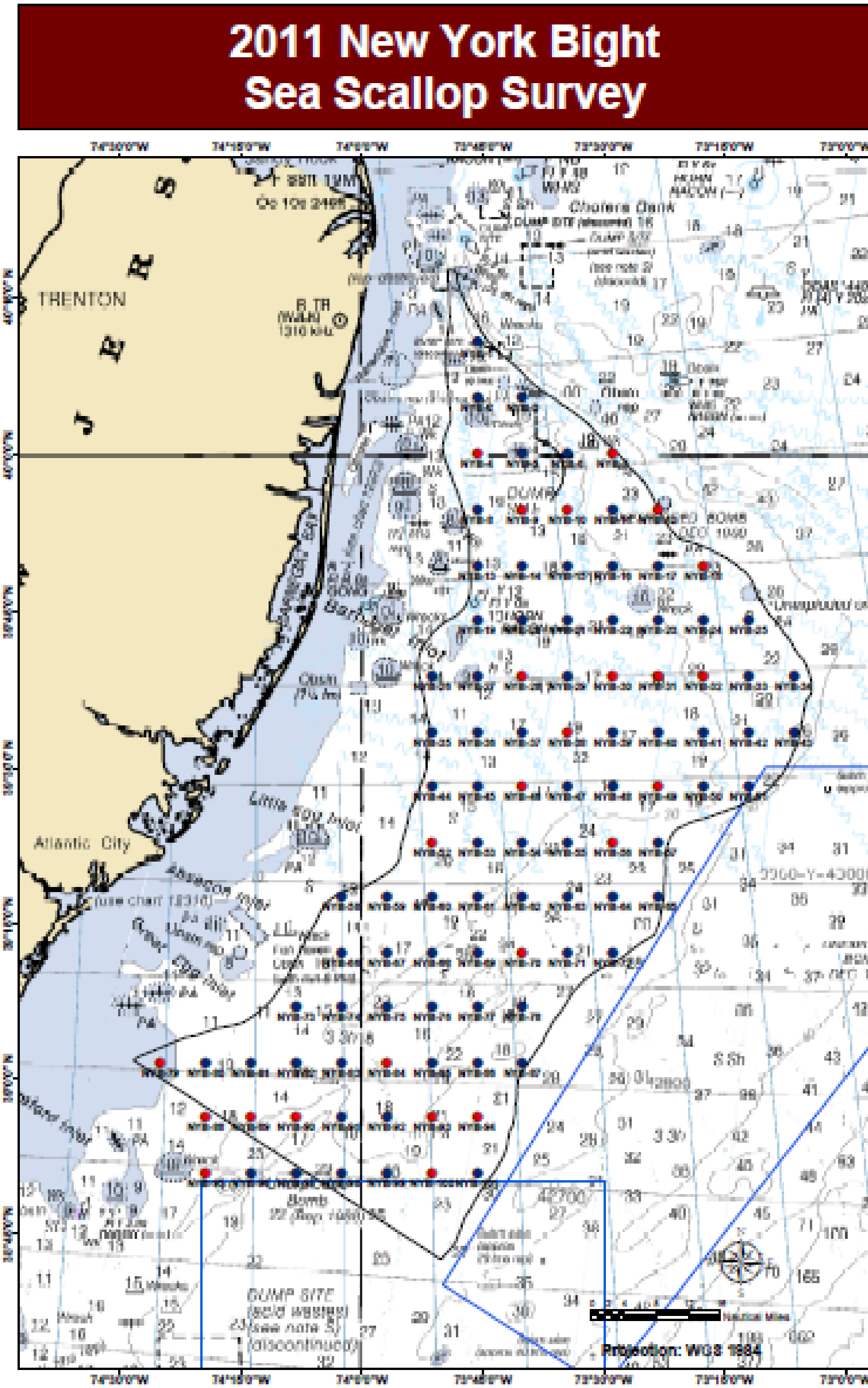
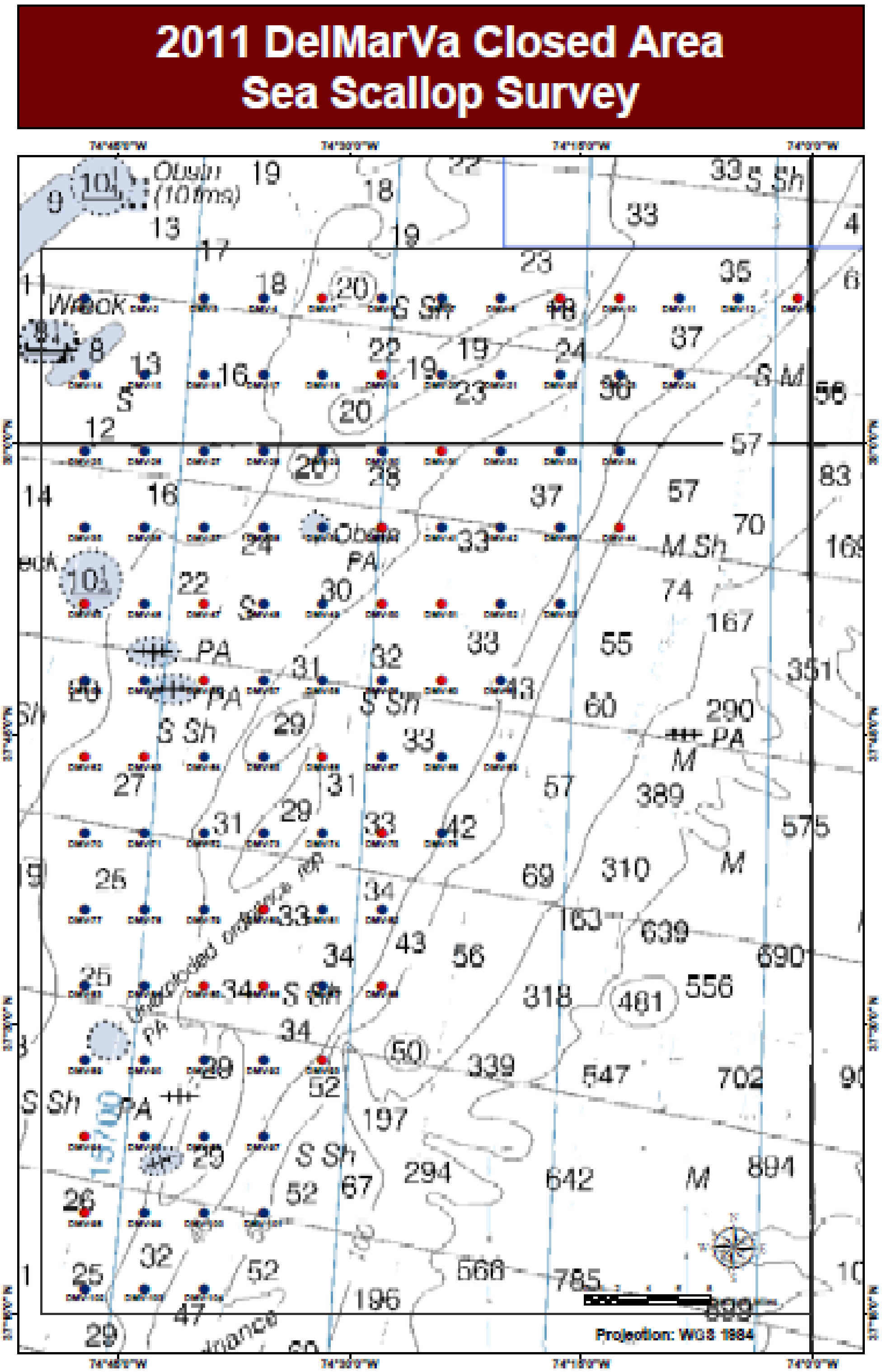


Figure 4 Locations of sampling stations for the DelMarVa closed area survey conducted by the F/V *Pursuit* during September, 2011.



<u>Figure 5</u> Shell height frequencies for the two dredge configurations used to survey the access area of Georges Ban Closed Area II during May, 2011. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

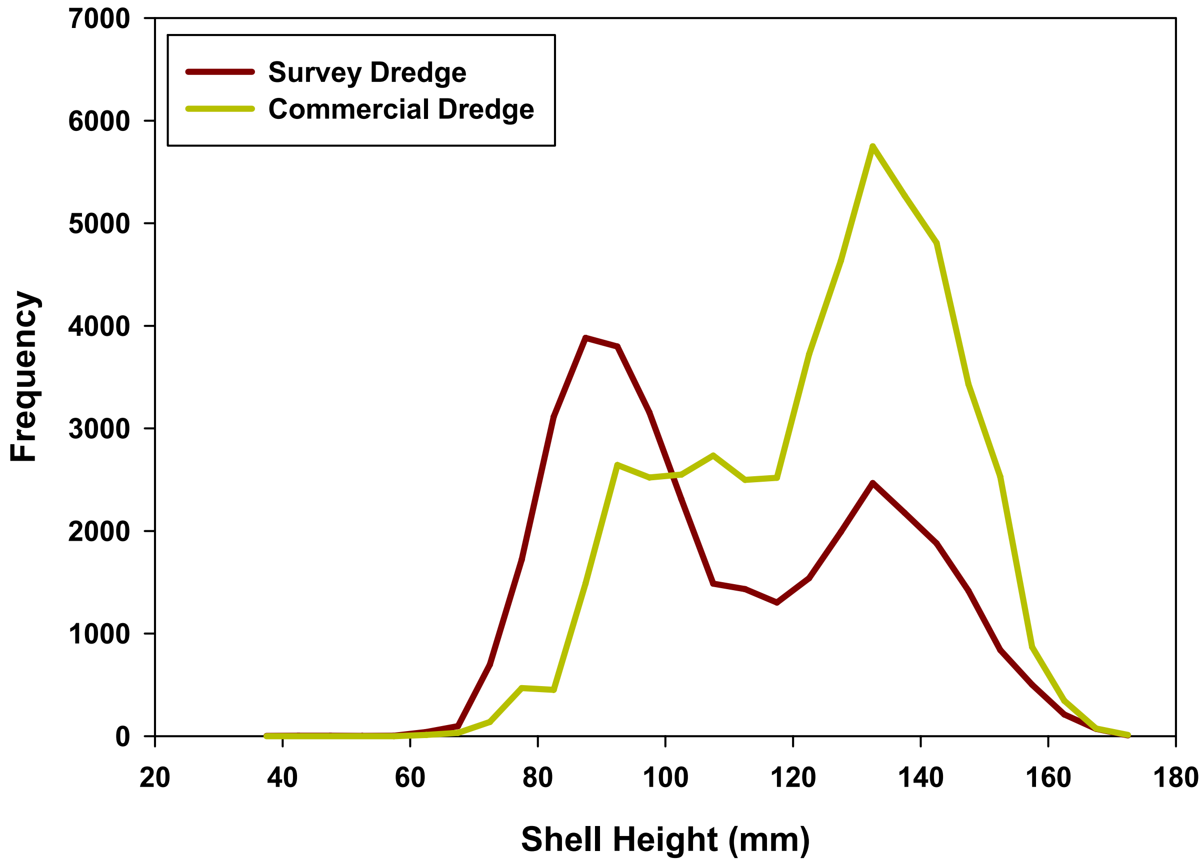


Figure 6 Shell height frequencies for the two dredge configurations used to survey the Southern New England/Long Island area during June of 2011. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

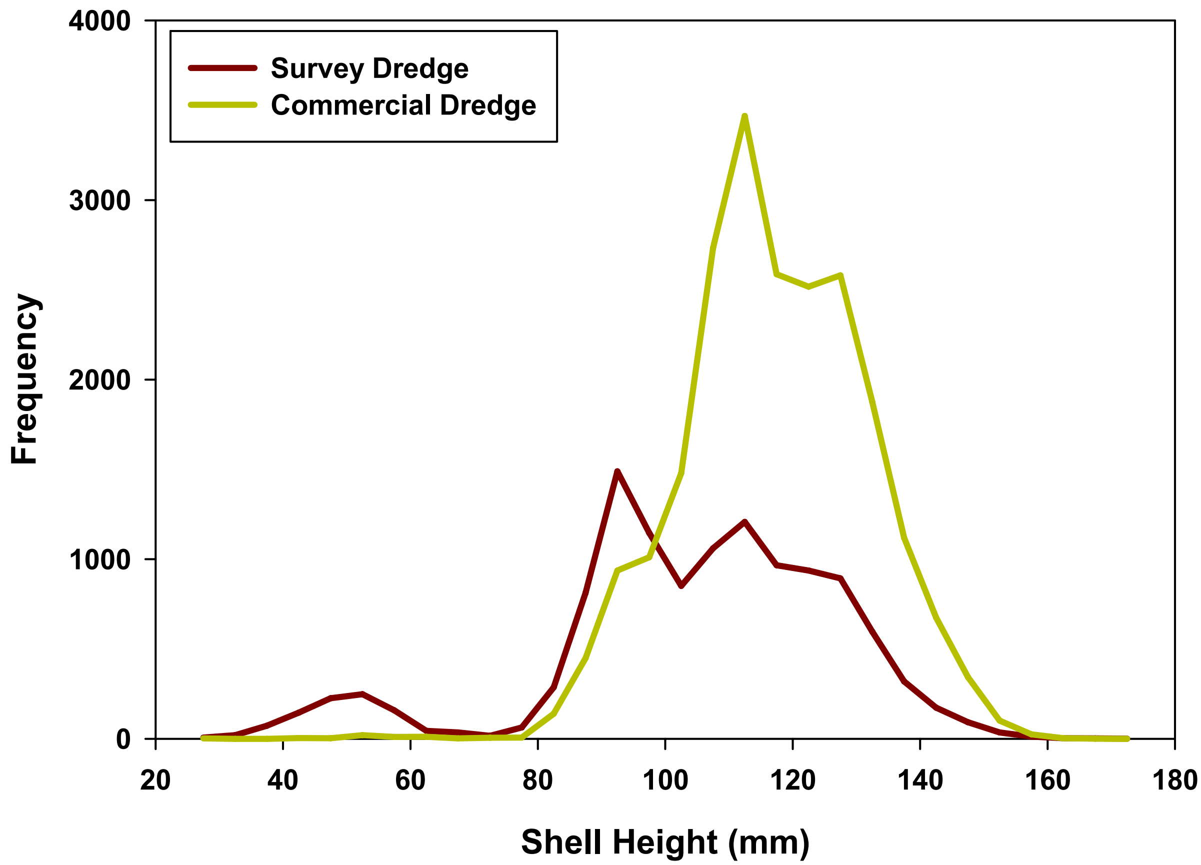


Figure 7 Shell height frequencies for the two dredge configurations used to survey the New York Bight area during early September, 2011. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

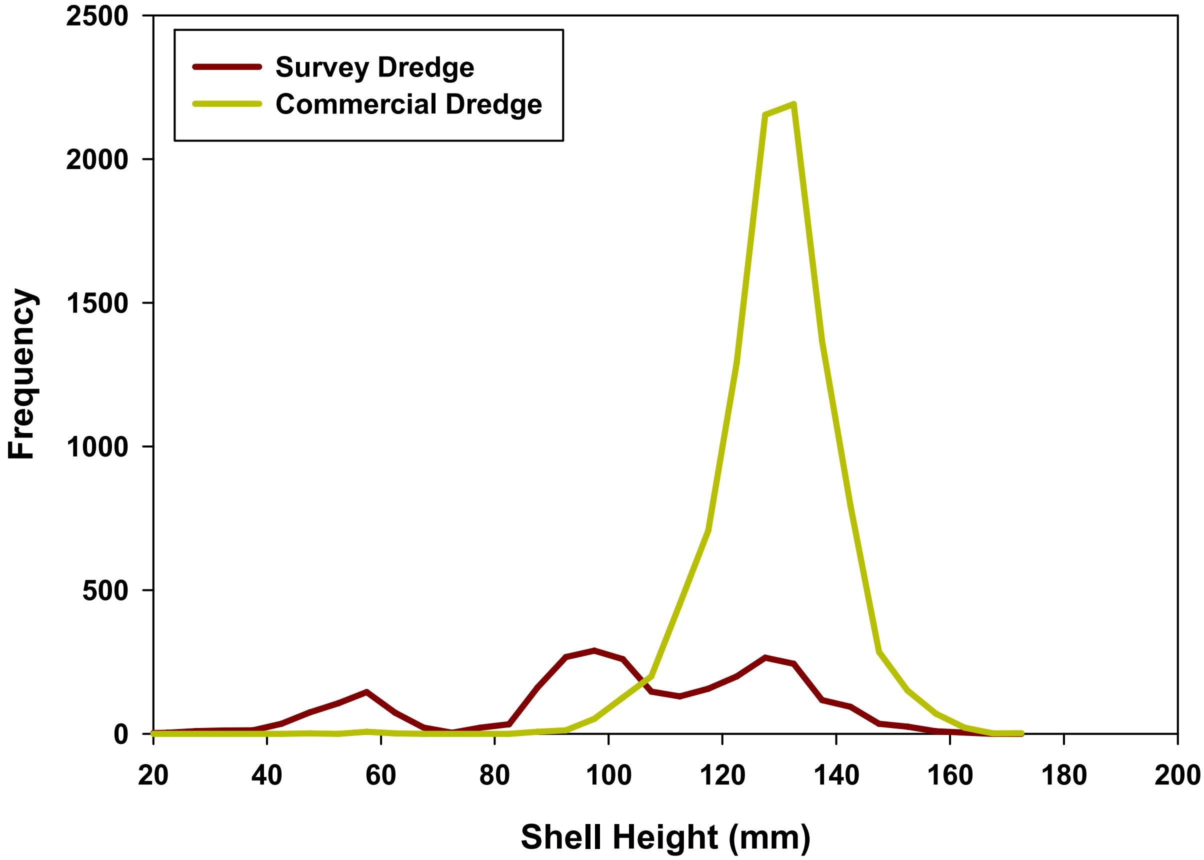


Figure 8 Shell height frequencies for the two dredge configurations used to survey the DelMarVa closed area during late September, 2011. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.