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An Assessment of Sea Scallop Abundance and Distribution in Selected Areas: Nantucket Lightship Closed Area, Hudson Canyon Closed Area, and the DelMarVa Closed Area

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Submitted to:
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Summary

During April and May of 2012, VIMS, in conjunction with the the sea scallop industry conducted abundance surveys of the Nantucket Lightship Closed Area (NLCA), Hudson Canyon Closed Area (HCCA),and the DelMarVa Closed Area (DMV). The primary objective of these surveys was to estimate the exploitable biomass of sea scallops these areas for inclusion in the decision making process for Framework 24 to the Sea Scallop Fishery Management Plan. During the cruises, we sampled 108 stations within the boundaries of the NLCA, 105 stations in the HCCA, and 113 stations in the DMV. The resulting catch data as well as estimates of the actual length-weight relationships observed on the cruise formed the basis for the results contained in this report. Our results indicate that, depending upon the length weight relationship used, roughly 7,000 to10,000 metric tons of exploitable sea scallops (meat weight) are contained within the NLCA, 4,000 to 6,000 metric tons (meat weight) are contained within the HCCA, and 900 to 1,400 metric tons of exploitable sea scallops (meat weight) are contained within the DMV area.

While the overall level of biomass in the NLCA was encouraging, biomass in the HCCA was cause for some concern and biomass in the DMV was observed to be very low. In the case of the NLCA, we observed numbers of large scallop with signs of recruitment limited spatially to a relatively small area. For the mid-Atlantic areas, adult biomass was low (HCCA) to extremely low (DMV). This is a cause of great concern in this resource area. With the Elephant Trunk, at low biomass levels and reverted back to an open area designation, these two rotational areas represent the entire spatial extent of rotational areas in the mid-Atlantic. Based on our observations, it will be difficult to envision the allocation of a significant number of access area trips to these areas in the next framework action.

While the adult biomass for the HCCA and DMV, was cause for great concern, observations of a large recruitment event served as hope for the future of the mid-Atlantic resource area. Sampling in both areas demonstrated the widespread occurrence of multiple cohorts of juvenile scallops. A number of tows in the HCCA recorded pre-recruit (<70mm) abundance in excess of 5000 scallops/ tow with a couple of tows in excess of 10,000. The observation of a large recruitment event in these two area and possibly outside of our survey area should be viewed as an important event guiding the future thinking of area closures in the mid-Atlantic region.

Methods

Survey Area and Sampling Design

The access area of NLCA, and the entire HCCA and DMV (at depths less than 50 fathoms) areas were surveyed during the course of the 2012 campaign. The boundary coordinates as well as the station maps of the surveyed areas can be found in Table 1 and Figures 1-3. 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 Coonamessett Farm Turtle Deflector Dredge (CFTDD) equipped with 4-inch rings, a 10-inch diamond mesh twine top and no liner was utilized. 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 three 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 NLCA and 44% was used for the mid-Atlantic areas. 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 these study; efficiency values of 60% and 65% was used for the NLCA and Mid-Atlantic areas, respectively. To scale the estimated mean scallop catch to the full domain, the total area of the NLCA, HCCA 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 4 to 6.

Literature Cited

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Table 1 Boundary coordinates of the Nantucket Lightship Closed Area, the Hudson Canyon Closed Area, and the DelMarVa Closed Area.

	Latitude	**Longitude**
NLCA		
NLCA-1	40° 50’ N	69° 00’ W
NLCA -2	40° 30’ N	69° 00’ W
NLCA -3	40° 30 N	69° 14.5’ W
NLCA -4	40° 50’ N	69° 29.5’ W
HCCA		
HCCA-1	39°30’	73°10’
HCCA-2	39°30’	72°30’
HCCA-3	38°30’	73°30’
HCCA-4	39°50’	73°30’
HCCA-5	39°50’	73°42’
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)
Nantucket Lightship Closed Area	May 24 – May 29, 2012	108	108
Hudson Canyon Closed Area	May 4 - May 10, 2012	105	105
DelmarVa Closed Area	April 18-April 25, 2012	113	113

Table 3 Mean total and mean exploitable scallop densities observed during the 2012 cooperative sea scallop surveys of NLCA, HCCA, and DMV.

Gear	Efficiency	Average Total Density (scallops/m^2)	SE	Average Density of Exploitable Scallops (scallops/m^2)	SE
NLCA					
Commercial	60%			0.167	0.021
Survey	38%	0.243	0.030	0.166	0.021
HCCA					
Commercial	65%			0.051	0.005
Survey	44%	0.265	0.083	0.044	0.004
DMV					
Commercial	65%			0.009	0.001
Survey	44%	0.092	0.018	0.009	0.001

Table 4 Estimated number of scallops in the area surveyed. The estimate is based upon the estimated density of scallops at a commercial dredge efficiency of 65% and a survey dredge efficiency of 44% for the Nantucket Lightship Closed Area, the Hudson Canyon Closed Area, and the DelMarVa Closed Area. The total areas surveyed was estimated at 1,153 km^2 (NLCA), 3,865 km^2 (HCCA), and 4,462 km^2 (DMV).

Gear	Efficiency	Estimated Total	Estimated Total Exploitable
NLCA			
Commercial	60%		192,316,171
Survey	38%	279,905,507	191,400,092
HCCA			
Commercial	65%		198,687,772
Survey	44%	1,023,726,520	170,199,208
DMV			
Commercial	65%		38,264,886
Survey	44%	410,219,280	40,933,365

<u>Table 5</u> 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**
NLCA			
Commercial	SARC 50 NLCA		38.99
Survey	SARC 50 NLCA	34.41	42.74
Commercial	SARC50 W/ LAT		37.81
Survey	SARC50 W/ LAT	33.26	41.63
Commercial	VIMS (depth weighted)		45.43
Survey	VIMS (depth weighted)	40.37	49.39
HCCA			
Commercial	SARC 50 HCCA		28.03
Survey	SARC 50 HCCA	6.96	25.86
Commercial	SARC 50 W/ INT		26.87
Survey	SARC 50 W/ INT	6.70	24.78
Commercial	VIMS (depth weighted)		31.53
Survey	VIMS (depth weighted)	10.06	29.65
DMV			
Commercial	SARC 50 DMV		32.99
Survey	SARC 50 DMV	6.05	24.63
Commercial	SARC50 DEP & INT		32.31
Survey	SARC50 DEP & INT	5.69	24.02
Commercial	VIMS (depth weighted)		30.24
Survey	VIMS (depth weighted)	8.31	23.79

Table 6 Mean catch of sea scallops observed during the 2012 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
NLCA						
Commercial	108	SARC 50 NLCA			33,389.74	3,991.91
Survey	108	SARC 50 NLCA	14,487.57	1,762.31	12,283.64	1,503.43
Commercial	108	SARC50 W/ LAT			32,380.87	3,844.35
Survey	108	SARC50 W/ LAT	14,004.61	1,689.57	11,966.22	1,450.18
Commercial	108	VIMS (depth weighted)			38,905.40	4,672.20
Survey	108	VIMS (depth weighted)	16,994.23	2,074.27	14,195.42	1,743.44
HCCA						
Commercial	105	SARC 50 HCCA			8,004.49	784.10
Survey	105	SARC 50 HCCA	3,649.45	425.17	2,274.76	220.10
Commercial	105	SARC 50 W/ INT			7,673.25	761.18
Survey	105	SARC 50 W/ INT	3,513.51	413.38	2,179.77	213.36
Commercial	105	VIMS (depth weighted)			9,006.70	895.15
Survey	105	VIMS (depth weighted)	5,271.61	836.25	2,607.98	254.41
DMV						
Commercial	113	SARC 50 DMV			1,557.64	154.54
Survey	113	SARC 50 DMV	1,098.11	158.41	446.52	50.68
Commercial	113	SARC50 DEP & INT			1,525.65	151.17
Survey	113	SARC50 DEP & INT	1,033.13	148.82	435.40	49.28
Commercial	113	VIMS (depth weighted)			1,427.79	142.27
Survey	113	VIMS (depth weighted)	1,507.18	237.22	431.20	50.04

Table 7 Estimated total biomass of sea scallops observed during the 2012 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
NLCA						
Survey	SARC 50 NLCA	44%	9,722.29	1,428.91	8,293.38	11,151.19
Survey	SARC50 W/ LAT	44%	9,398.18	1,369.92	8,028.26	10,768.11
Survey	VIMS (depth weighted)	44%	11,404.45	1,681.85	9,722.60	13,086.30
HCCA						
Survey	SARC 50 HCCA	44%	7,053.40	1,068.37	5,985.03	8,121.77
Survey	SARC 50 W/ INT	44%	6,790.67	1,038.73	5,751.94	7,829.40
Survey	VIMS (depth weighted)	44%	10,188.61	2,101.31	8,087.30	12,289.92
DMV						
Survey	SARC 50 DMV	44%	2,443.19	458.23	1,984.96	2,901.42
Survey	SARC50 DEP & INT	44%	2,298.62	430.49	1,868.13	2,729.12
Survey	VIMS (depth weighted)	44%	3,353.34	686.20	2,667.14	4,039.54

Table 8 Estimated exploitable biomass of sea scallops observed during the 2012 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
NLCA						
Commercial	SARC 50 NLCA	60%	7,568.63	1,373.78	6,194.85	8,942.40
Survey	SARC 50 NLCA	38%	8,243.28	1,219.00	7,024.28	9,462.28
Commercial	SARC50 W/ LAT	60%	7,339.94	1,323.00	6,016.94	8,662.93
Survey	SARC50 W/ LAT	38%	8,030.27	1,175.82	6,854.44	9,206.09
Commercial	VIMS (depth weighted)	60%	8,818.89	1,607.89	7,211.00	10,426.78
Survey	VIMS (depth weighted)	38%	9,526.23	1,413.61	8,112.62	10,939.84
HCCA						
Commercial	SARC 50 HCCA	65%	5,585.26	864.55	4,720.70	6,449.81
Survey	SARC 50 HCCA	44%	4,396.50	553.06	3,843.45	4,949.56
Commercial	SARC 50 W/ INT	65%	5,354.13	839.28	4,514.84	6,193.41
Survey	SARC 50 W/ INT	44%	4,212.91	536.14	3,676.77	4,749.04
Commercial	VIMS (depth weighted)	65%	6,284.56	987.01	5,297.56	7,271.57
Survey	VIMS (depth weighted)	44%	5,040.53	639.28	4,401.25	5,679.81
DMV						
Commercial	SARC 50 DMV	65%	1,340.54	210.17	1,130.37	1,550.71
Survey	SARC 50 DMV	44%	993.48	146.61	846.86	1,140.09
Commercial	SARC50 DEP & INT	65%	1,313.01	205.58	1,107.43	1,518.59
Survey	SARC50 DEP & INT	44%	968.72	142.55	826.17	1,111.27
Commercial	VIMS (depth weighted)	65%	1,228.79	193.48	1,035.31	1,422.27
Survey	VIMS (depth weighted)	44%	959.37	144.76	814.61	1,104.13

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					
NLCA		-6.8474	2.3440	-0.1590	
HCCA		-3.3804	2.0036	-0.6603	
DMV		-2.9552	1.960	-0.7692	
SARC 50					
GB general		9.6771	2.8387	-0.5084	-4.7629
NLCA specific		-8.1709	2.6554	-0.2298	
HCCA specific		-7.305	2.9066	-0.7863	
DMV Specific		-8.0407	2.8249	-0.5194	
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:

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

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 Nantucket Lightship closed area surveyed by the F/V *Celtic* during the cruise conducted in May, 2012.

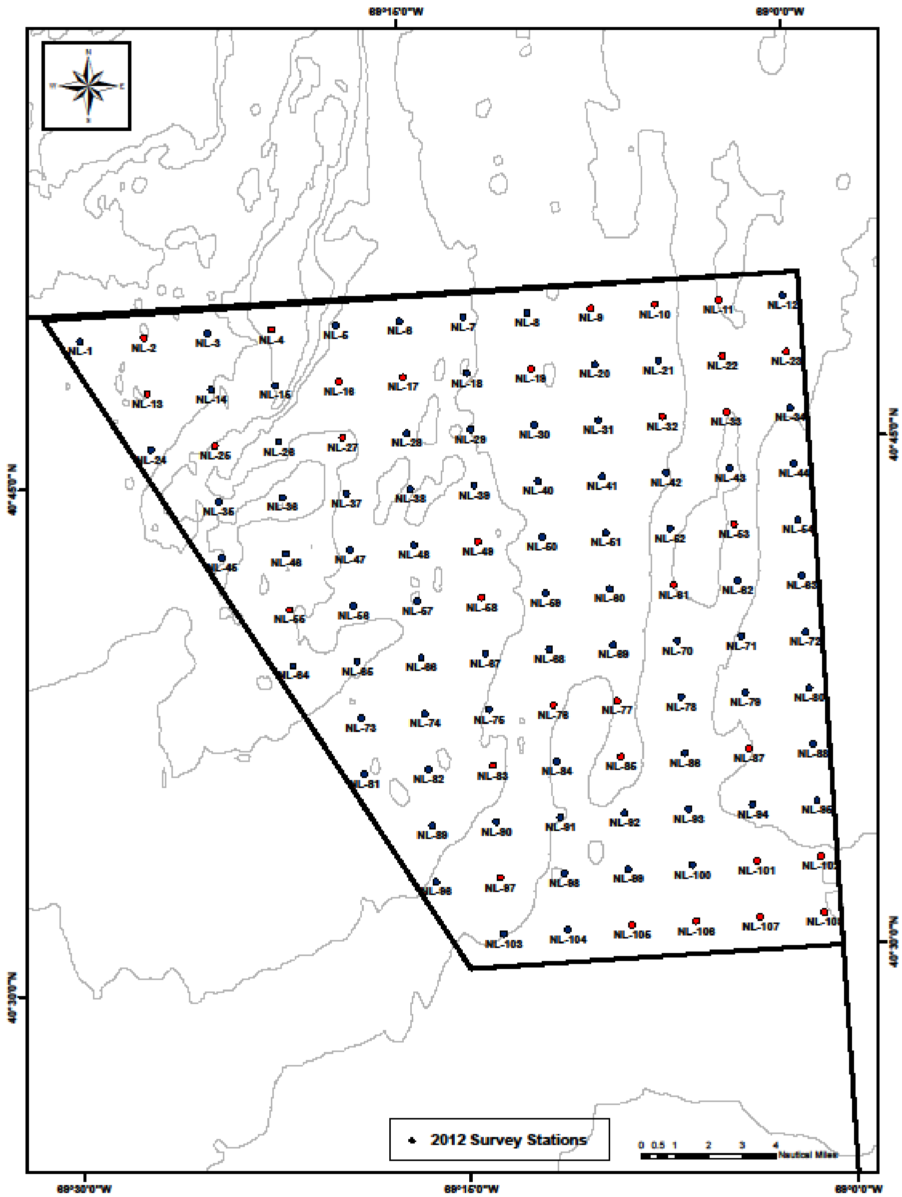
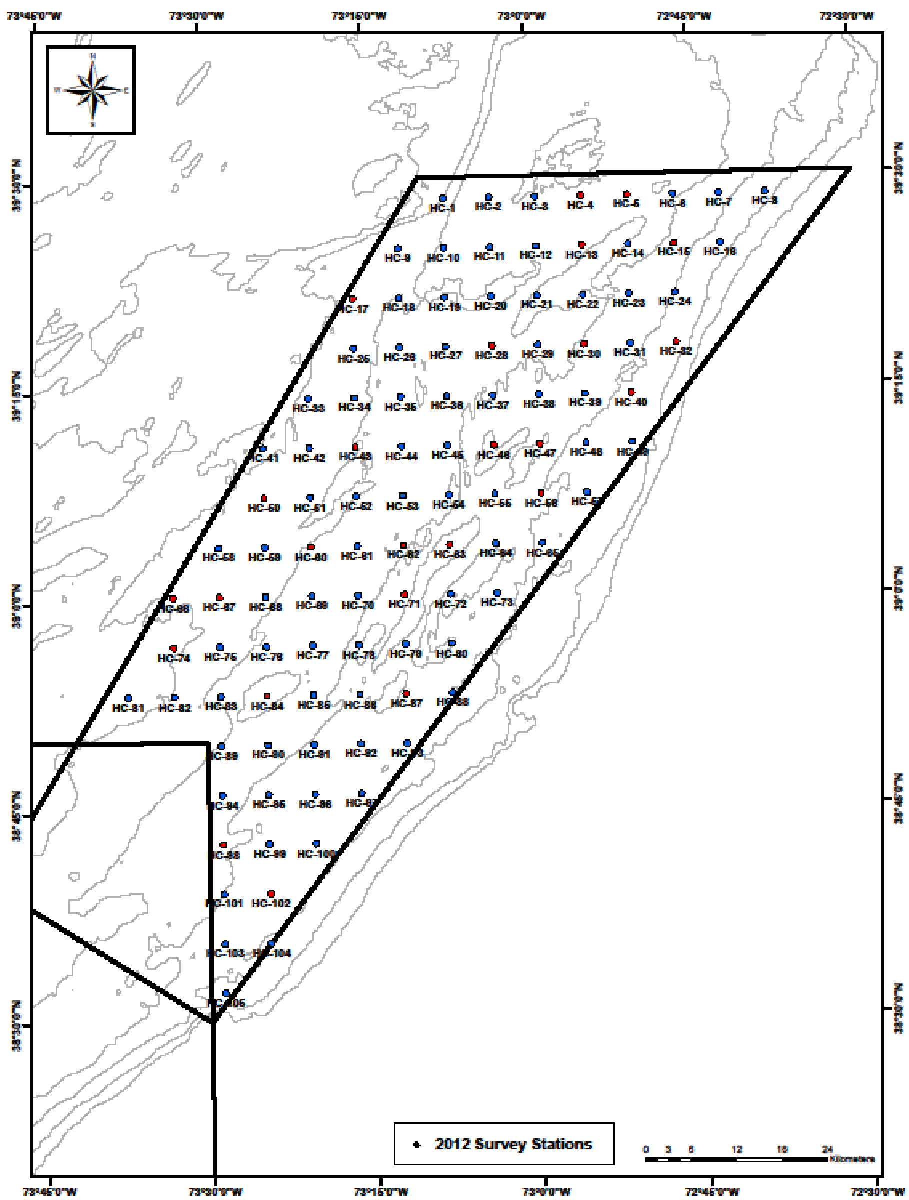


Figure 2 Locations of sampling stations for the Hudson Canyon Closed Area survey conducted by the F/V *Kathy Ann* during May, 2012.



<u>Figure 3</u> Locations of sampling stations for the DelMarVa Close Area survey conducted by the F/V *Stephanie B* during April, 2011.

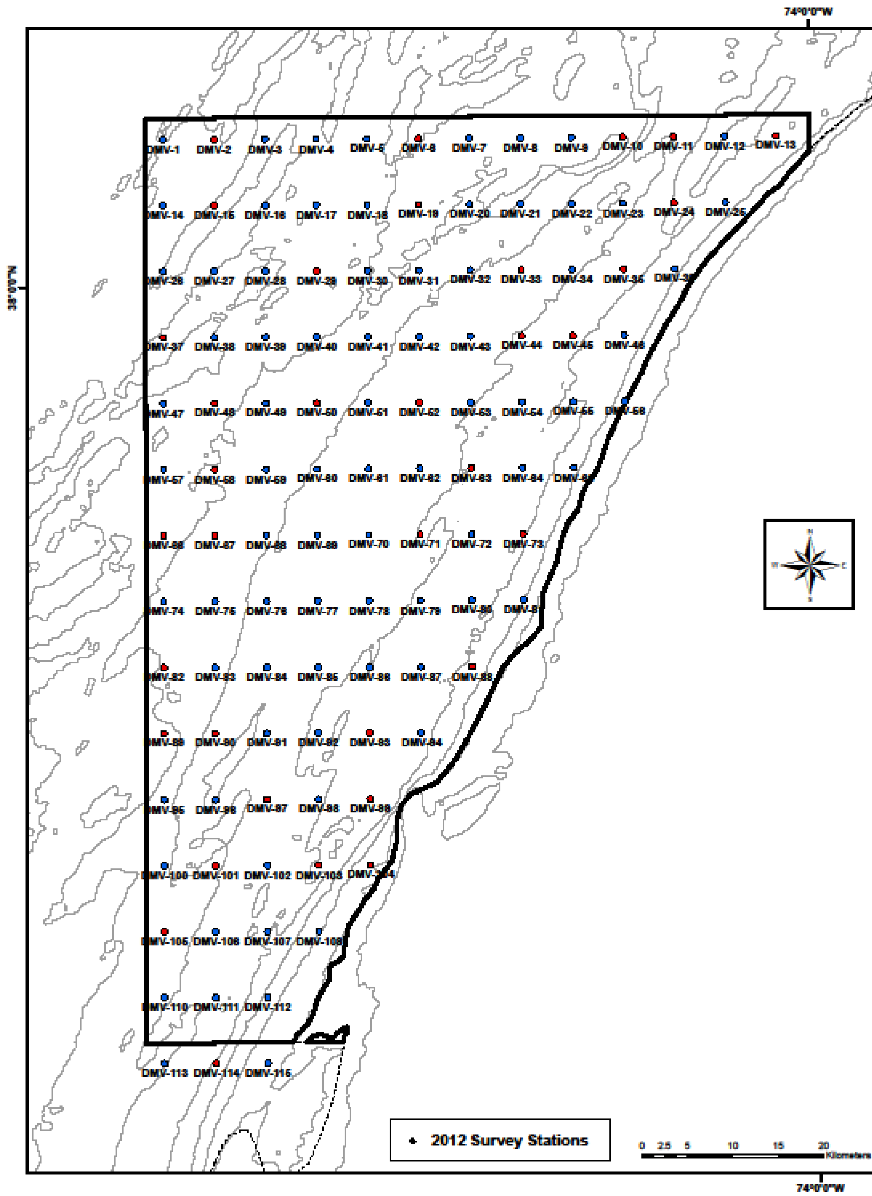


Figure 4 Shell height frequencies for the two dredge configurations used to survey the access area of the Nantucket Lightship Closed Area during May, 2012. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

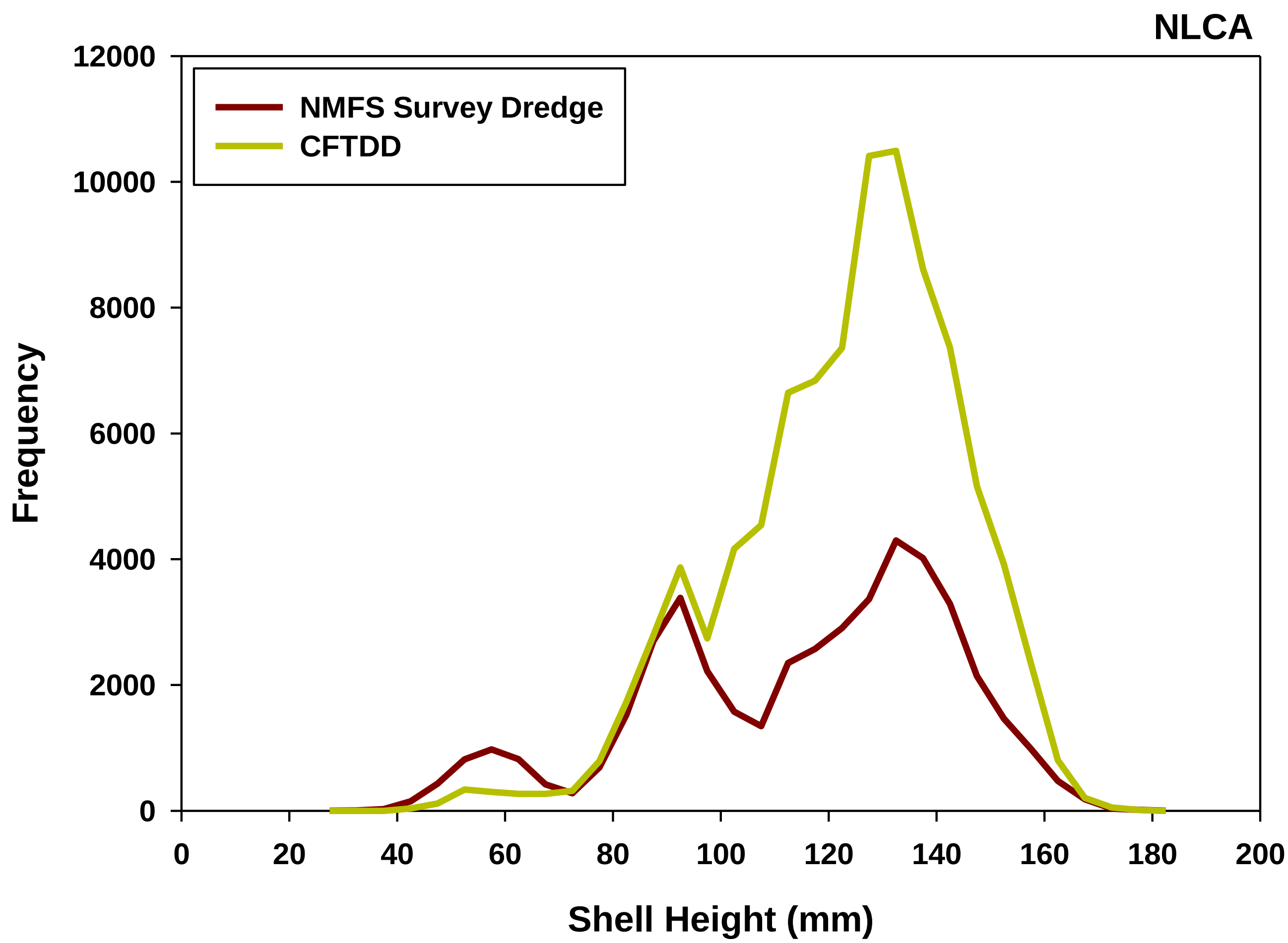


Figure 5 Shell height frequencies for the two dredge configurations used to survey the Hudson canyon Closed Area during May of 2012. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.

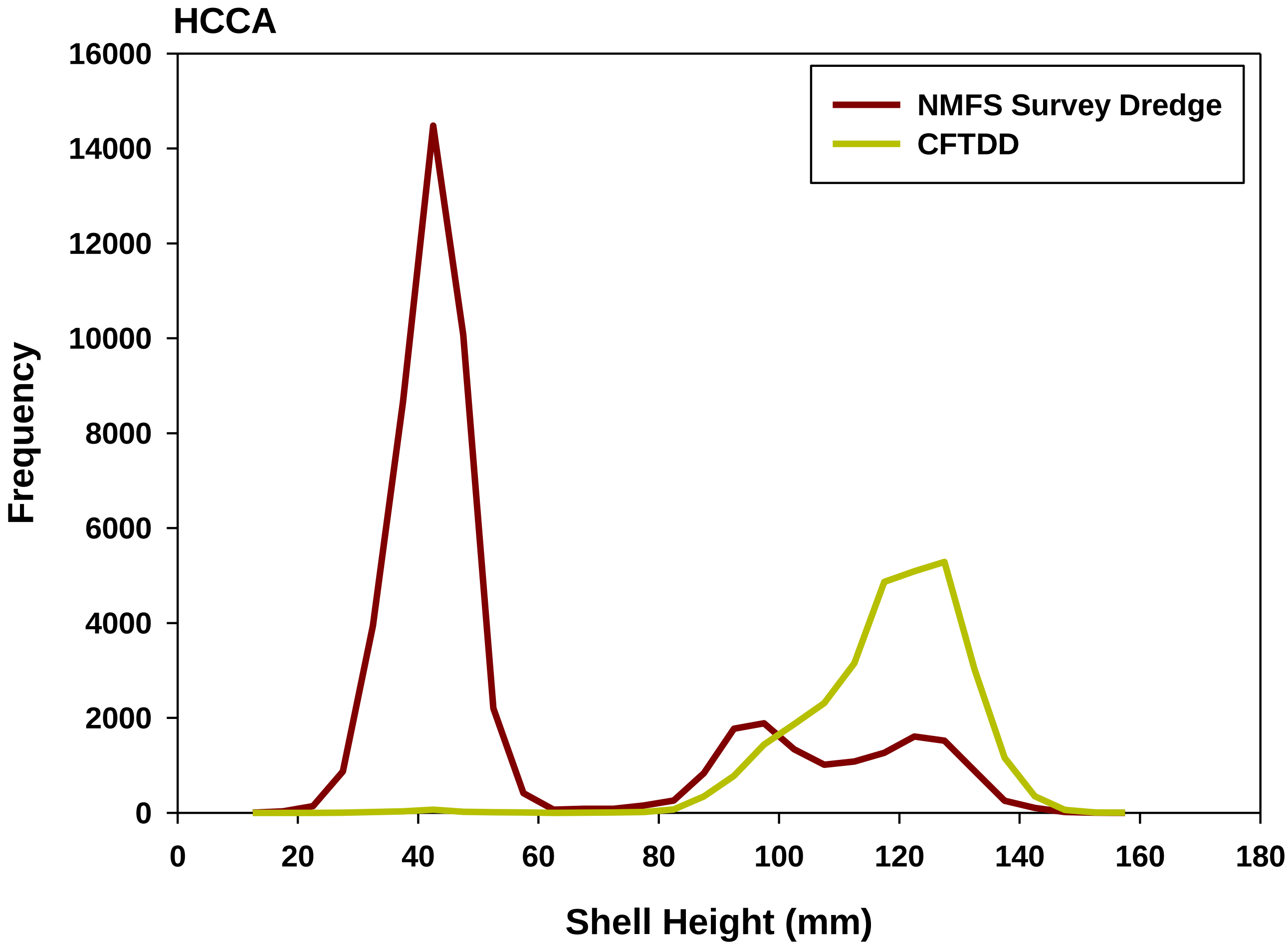


Figure 6 Shell height frequencies for the two dredge configurations used to survey the DelMarVa Closed Area during April of 2012. The frequencies represent the expanded but unadjusted catches of the two gears for all sampled tows.