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# An Assessment of Sea Scallop Abundance and Distribution in Selected Areas of Georges Bank and the Mid-Atlantic Part II: Selectivity of a New Bedford Style Sea Scallop Dredge

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# An Assessment of Sea Scallop Abundance and Distribution in Selected Areas of Georges Bank and the Mid-Atlantic

Part II: Selectivity of a New Bedford Style Sea Scallop Dredge

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## Project Summary

A size-selectivity curve was constructed to characterize the performance of the New Bedford style Atlantic sea scallop (*Placopecten magellanicus)* dredge, configured to meet the requirements of Amendment #10 to the Sea Scallop Fishery Management Plan. The curve was generated using the SELECT model on catch-at-length data obtained by simultaneously towing the New Bedford style dredge and the non-selective National Marine Fisheries Service sea scallop survey dredge from commercial sea scallop vessels. Data was collected during three cruises in the Northwest Atlantic between 2005 and 2006. One cruise was completed in Georges Bank (Groundfish Closed Area II) and two cruises were completed in the Mid-Atlantic Bight (both in the Elephant Trunk Closed Area) [Results from data collected in an additional cruise in the Nantucket Lightship Closed Area will be presented separately.] The resulting selectivity curve for all cruises combined yielded a 50% retention length ($l_{50}$) of 97. 6 mm, a selection range of 23.6 mm and a relative efficiency value of 0.77. A $l_{50}$ value of 97.6 mm corresponds to an age of approximately 4 ½ years in Georges Bank and 5 ½ years in the Mid-Atlantic. This implies that sea scallops are being recruited into the fishery after they have taken advantage of their substantial growth potential in their early years of life and after they have increased their spawning potential. The selectivity curve can serve to assist fisheries managers with stock assessments, mortality calculations and with the interpretation of catch data from government and industry-based surveys. Additionally, the selection curve can be used as a foundation for evaluating the effect of future changes to sea scallop dredge design.

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## Project Background

The Atlantic sea scallop (*Placopecten magellanicus*) population supports the most lucrative fishery along the east coast of the United States (Van Voorhees 2005). In order to ensure the longevity of this industry, management strategies such as effort controls, closed area rotation and gear configuration requirements are used to promote a healthy sea scallop resource. By modifying the gear used to harvest sea scallops, fishing pressure can be reduced on young animals and the age at entry into the fishery can be increased. This results in a potential increase in both the yield-per-recruit and the total reproductive output of the population.

Under Amendment #10 to the Sea Scallop Fishery Management Plan, New Bedford style dredges (the principal offshore commercial fishing gear, "commercial") are required to have twine tops with a minimum mesh size of 10-inches (25.4 cm), restrict chafing gear to the bottom of the dredge, have rings with a minimum internal diameter of 4-inches (102 mm) and use no more than double links between rings, except on the dredge bottom where a maximum of triple links may be used (NEFMC 2003). With the passing of this amendment in 2003, it becomes necessary to determine whether or not a dredge configured with these specifications will attain the goal of selecting against smaller scallops. Additionally, it becomes imperative to evaluate this gear configuration so that comparisons can be made when future alterations are attempted.

Size-selectivity curves have the potential to address both of these concerns by modeling the probability that a sea scallop of length *l*, if contacting the gear, will be retained (Millar 1992). A curve of this nature can also assist fisheries managers translate survey abundance into expected yield and can provide insight into how the gear is interacting with scallops of a given length. Additionally, because gear selectivity measurements are used in connection with fishing mortality calculations, this information can assist fisheries managers in making stock assessments (Wileman 1996). Furthermore, a selection curve can provide insight into incidental morality and assist with yield-per-recruit analysis and the estimation of population length frequency (Millar and Fryer 1999).

In order to construct an absolute size-selectivity curve, the commercial (experimental) gear must be compared to a non-selective (control) gear. The National Marine Fisheries Service (NMFS) survey dredge ("survey") served as the control gear in this study. The survey dredge is assumed to be non-selective because there is a liner sewn into the dredge bag which prohibits scallops from escaping. With the catch-at-length data from the two dredges, the Share Each LEngth's Catch Total (SELECT) model developed by Millar (1992) was used to generate the curve. This is preferential to other methods because the SELECT model is biologically meaningful, does not require knowledge of the actual population length distribution, and, because the model conditions on the total catch, it avoids the problem of dividing by zero and it allows the data to be modeled as binary data. Additionally, the SELECT model incorporates a parameter that denotes relative fishing intensity between the two gears (experimental and control). This is the split parameter, $p_j$, which factors in how catch between gears ($j$=1,…, n) will vary due to differential fishing effort, fish avoidance behavior and localized fish concentrations (Millar 1992). It is the probability that a fish entered gear $j$, given that it entered the combined gear. In addition to estimating $p_j$, the SELECT model calculates two other factors often used to characterize selection. These are: 1. the 50% retention length ($l_{50}$), the length at which a scallop has a 50% probability of escaping and of being retained (above this length most of the scallops will be retained) and 2. the selection range (SR), the difference between the 75 and 25% retention lengths ($l_{75}$- $l_{25}$), which is a measure of how quickly the 100% retention length is approached, i.e., the steepness of the curve.

## Methods

### ***Data Collection***

In August, September and October of 2005 and in June of 2006, four cruises were completed aboard commercial sea scallop vessels. During these cruises, three closed areas were sampled, two in Georges Bank (Nantucket Lightship Closed Area, NLCA, and Groundfish Closed Area II, CA2) and one in the Mid-Atlantic Bight (Elephant Trunk Closed Area, ETCA) (Figure 1, Table 1) [Because the gears used in the NLCA were not configured in the same way as in the other areas, the results from this cruise will be presented separately.] Within each area, pre-determined stations (Figure 2), selected within a systematic random grid, were sampled. At each station, a standard NMFS survey dredge was towed simultaneously with a New Bedford style commercial sea scallop dredge. The survey dredge was 8-feet (2.4 m) in width, was configured with 2-inch (51 mm) rings, a 3.5-inch (89 mm) diamond twine top, and a 1.5-inch (3.8 cm) diamond mesh liner and the commercial dredges were 15-feet (4.6 m) in width, had 4-inch (102mm) rings, a 10-inch twine top and no liner. Certain aspects of the commercial gear configuration varied on the different vessels used for this study, but this is advantageous since this variation exists within the actual commercial fleet. Rock chains and chafing gear were used on both dredges as dictated by the area surveyed and current regulations. Simultaneously towing the two dredges from the same vessel allowed for similar area of substrate and population of scallops to be sampled. The duration of each tow was approximately 15 minutes and towing speed was 3.8 knots. Depth range varied in each area; however a 3:1 wire scope (scope being the ratio of the amount of wire out to the vertical distance from the boat to the seafloor) was attempted for all tows (Table 2). During each cruise the survey dredge was towed from the port side of the vessel for the first half of the stations and from the starboard side for the remainder in order to counteract any random effect associated with fishing from a particular side. In order to determine bottom contact time and to ensure that the gear was fishing correctly, an inclinometer was attached to the survey dredge. Also, high-resolution navigational logging equipment was used to document tow time, vessel position, speed over ground and bearing.

Upon completion of each tow, the entire catch from both gears was emptied on deck. Scallops (live and clappers) were then sorted out of the catch and placed into baskets. The number of baskets from each side was counted and a fraction of these was measured. Measurements of the scallops were made in 5 mm increments (shell height measured as the longest distance between the umbo and the outer margin of the shell) on counting boards. Additionally, all bycatch was quantified, trash from both gears was counted in baskets and, at 15 randomly selected stations for each cruise, 15 individual scallops were measured to the nearest millimeter and the meat was frozen and taken back to the lab where it was weighed to the nearest kilogram in order to generate shell height-meat weight curves.

### ***Data Analysis***

Data for all valid tows was entered into both Excel and Access data bases and the number of scallops caught per length class, from each gear, was multiplied by an expansion factor equivalent to the number of baskets caught during the tow divided by the number of baskets measured. The tows were then combined by cruise, closed area, year and all tows together. Following this, for each tow and combination of tows, a plot was made of the ratio of the number of scallops at each length in the commercial dredge to the total in both dredges (Commercial/Total) in order to determine if the commercial gear was behaving selectively. This assessment validated proceeding with analysis.

The catch-at-length data from all valid tows was multiplied by an expansion factor equivalent to the number of baskets of scallops caught during the tow divided by the number measured. The tows were then combined by cruise, closed area, year and all tows together and the resulting data was analyzed with the SELECT model. Historically, selectivity, r(*l*), (the probability that a fish of length *l* will be retained given that it enters the gear), for a dredge has taken a logistic form because of the fact that as fish increase in length the probability of retention asymptotically approaches 100% due to the fact that at larger sizes there is no opportunity for escape. If selection of the commercial gear is logistic, the SELECT model equates the proportion ($\Phi(l)$) of scallops (of length *l* ) that are caught in the commercial gear out of the total catch from both gears to:

$$\Phi(l) = \frac{p_c \exp(a+bl)}{(1-p_c)+\exp(a+bl)}$$

Where *a* and *b* are the logistic parameters and $p_c$ is the split-parameter, which describes the relative fishing intensity or efficiency of the commercial dredge (the relative efficiency of the survey dredge is $1- p_c$) (Millar 1992). These three parameters (*a, b* and $p_c$ ) are estimated by maximizing the likelihood:

$$L(a,b,p_c|data) = \prod_{l=5}^{175} \left(\frac{pc\exp(a+bl)}{(1-pc)+\exp(a+bl)}\right)^{C_C}\left(1-\frac{pc\exp(a+bl)}{(1-pc)+\exp(a+bl)}\right)^{C_S}$$

In this equation, the length classes are taken from 5 to 175 mm (a *l* of "5 mm" equates to the length class "5-10 mm"), $C_C$ is the number of length *l* scallops in the commercial gear and $C_S$ is the number of length *l* scallops in the survey gear. To generate the selectivity curve, values for *a* and *b* are reinserted into the logistic equation. The resultant curve is symmetric about $l_{50}$ and the shape is determined by the selection range. The data was evaluated using the R-Statistical Program for Windows (R). Code to facilitate this analysis was written by Dr. Russell Millar and can be found on his website (http://www.stat.auckland.ac.nz/~millar/). For verification, the analysis was also completed in Excel using the Solver function.

Due to variation in wind speed, water depth, sea state, scallop density and other factors that cannot be controlled by the experiment, there is variation in the selectivity from one tow to the next. This variation must be considered. The replication estimate of between-haul variation (REP) is able to evaluate this as well as account for the effect of inflated sample sizes due to scaling up the data. The combined hauls approach discussed in Millar et al. 2004 was used in this analysis to account for these effects. In order to avoid over-inflating the degrees of freedom for this analysis, only length classes where, when all tows are combined, one dredge has caught at least 20 scallops were used.

## **Results**

The catch-at-length data obtained during this study was evaluated with the SELECT model using the Logistic as well as Richards, Log-Log and C-Log-Log curves. The resulting residuals from the Logistic curve showed no considerable trends and the curve sufficiently fit the data. The other three curves did not significantly improve the fit of the curve and, therefore, the results will be presented for the Logistic SELECT model. Additionally, in order to avoid over-inflating the sample size, only length classes where there were at least 20 scallops in one of the two dredges were used in the analysis. In order to determine if this affected the estimated parameters, the model was run under this criterion as well as under the criteria that, for each length class: 1) at least one dredge had more than zero scallops, 2) at least one dredge had more than 60 scallops and 3) at least one dredge had more than 1,000 scallops. In general, with fewer length classes used in the analysis, the 50% retention length, selection range, split parameter and likelihood values all increased. However, as seen in Table 3, these changes were not substantial.

An assessment of the potential overdispersion from combining the tows indicated that there was extra Poisson variation and, therefore, the standard errors for the estimated parameters from the SELECT analysis were multiplied by the square root of REP. These parameters are given in Table 4 and the fitted curves and deviance residuals are in Figure 3. A common feature for all tow combinations is that at the largest sizes the proportion caught in the commercial dredge decreases. This causes a pattern in the residuals, namely that residuals at the larger lengths are negative. This is not of great concern since the data points for these sizes are influenced by only a handful of tows which makes them susceptible to outlying information. For example, the 150 mm data point for the ETCA 2005 SELECT fitted curve is influenced primarily by two tows where there were a few scallops at 150 mm in the survey dredge and none in the commercial. When this data was multiplied by the expansion factor the discrepancy between the two dredges was exaggerated. Additionally, patterns in the residuals attributed to this are not significant since, when these outlying length classes were removed, as seen in Table 3, there is not a significant change in the estimated parameter values.

The *a* and *b* parameters estimated for each combination of tows were inserted into the logistic selectivity curve equation (Figure 4). The range of $l_{50}$ values from the different combinations of data was 95.6 -102.7 mm, a small difference of 7.1 mm. Also, there is variation in the selection range for the different tow combinations; however the resultant curves are relatively similar.

The final results are those that were estimated for tows combined for the CA2 2005, ETCA 2005 and ETCA 2006 cruises since an evaluation of the resulting parameters and confidence intervals from all other combinations of data (by cruise, area and year) revealed little significant difference (Figure 5). Additionally, by including tows from multiple cruises the selectivity curve becomes more representative of the commercial fleet. The resulting SR for this analysis was 23.6 mm and the $l_{50}$ was 97.6 mm, which indicates that sea scallops larger than this are likely to be retained by the commercial dredge. The split parameter ($p_c$) indicates that the commercial dredge is fishing more efficiently than the survey dredge. If the two gears were equally efficient, then the difference in the number of scallops entering the dredges would merely be a function of the width of the gears and the split parameter value for the commercial dredge would be equal to $\frac{15}{(15+8)}$ or 0.65. However, the resulting value, 0.77, indicates that other factors are affecting efficiency. An additional analysis was done to evaluate how increasing number of baskets of scallops and trash caught in the commercial gear might affect these values. The results indicated that the estimated parameters sufficiently represent the selective properties of the commercial gear regardless of these two variables.

## Discussion

Using the Von Bertalanffy growth model and the parameters from Serchuk et al. 1979, the resultant $l_{50}$ value of 97.6 mm indicates that sea scallops that have a 50% probability of retention are 4.5 years old in Georges Bank and are 5.6 years old in the Mid-Atlantic. Also, using the resulting curves from the shell height-meat weight analysis on the data obtained during this study, a shell height of 97.6 mm would yield a meat weight (on average) of 12.04 g. [Using the NEFSC 2001 shell height-meat weight parameters this shell height would yield a meat weight of 14.86 g in Georges Bank and 14.94 g in the Mid-Atlantic. It must also be noted that shell height-meat weight relationships vary seasonally and by location (Smolowitz and Serchuk 1987).]

These results imply that scallops are being able to take advantage of their substantial growth potential in their early years of life before being recruited into the fishery and that the current commercial gear being used in sea scallop harvest is promoting higher yield-per-recruit. Additionally, scallops being recruited into the fishery have been able to maximize their spawning potential, based on the findings of Langton et al. that somatic production steadily increases to and levels off at age 5 (1987).

## Nantucket Lightship Closed Area 2005 Cruise

In order to combine the tows from two or more different cruises for the analysis it is imperative that the gears remain the same throughout. Gear configuration was consistent for the Closed Area II (CA2) cruise in 2005 and for the cruises in the Elephant Trunk Closed Area (ETCA) in 2005 and 2006. The dredges used during the cruise in the

Nantucket Lightship Closed Area (NLCA), however, were not equivalent. To begin with, the hanging ratio and the size of the twine top on the survey dredge used in the NLCA were different from those used on the other cruises. The hanging ratio changed since, while the number of rings along the frame of the dredge remained the same for all cruises, the size of the twine top was 25 x 17 meshes for the NLCA cruise and was 40 x 15 meshes for the others. Additionally, there was a reduced surface area, and hence a tighter fit, in the NLCA survey dredge twine top because the dimensions 25x17 equates to a total of 425 meshes where a twine top with 40x15 has 600. Furthermore, the commercial dredge in the NLCA differed in that it had a shorter twine top and a longer sweep chain. Because of these differences, analysis for the data from the NLCA cruise is presented separately and is not included in the final results.

The catch-at-length data from the NLCA cruise was analyzed in the same manner as the other cruises. The estimated parameters for the NLCA cruise yielded a 50% retention length of 99.14 mm, a selection range of 17.63 mm and a split parameter value of 0.76. Standard errors for the estimated parameters were multiplied by the square root of REP because the data were overdispersed. Results from the NLCA are comparable to the results from the other cruises (Figures 6 and 7, Table 5). The split parameter values are similar and there is less than a two millimeter difference between the 50% retention lengths for the NLCA cruise and the other cruises combined. However, the selection ranges differ in that the curve for the NLCA cruise is steeper, indicating that fewer small and more large scallops will be retained. Additionally, the ratio of number of baskets of scallops in the survey dredge to the commercial dredge (Survey/Commercial) for the NLCA cruise was smaller than for all other cruises. The ratios for the NLCA cruise, CA2 cruise, ETCA cruise in 2005 and ETCA cruise in 2006 were 0.34, 0.44, 0.54 (0.45 if one outlying point is excluded), and 0.47 respectively. This potentially implies that the difference in the survey gear configuration affected the number of baskets of scallops caught in the survey dredge, but further investigation is needed to confirm this hypothesis.

**Figure 1. Closed areas surveyed in this study.**

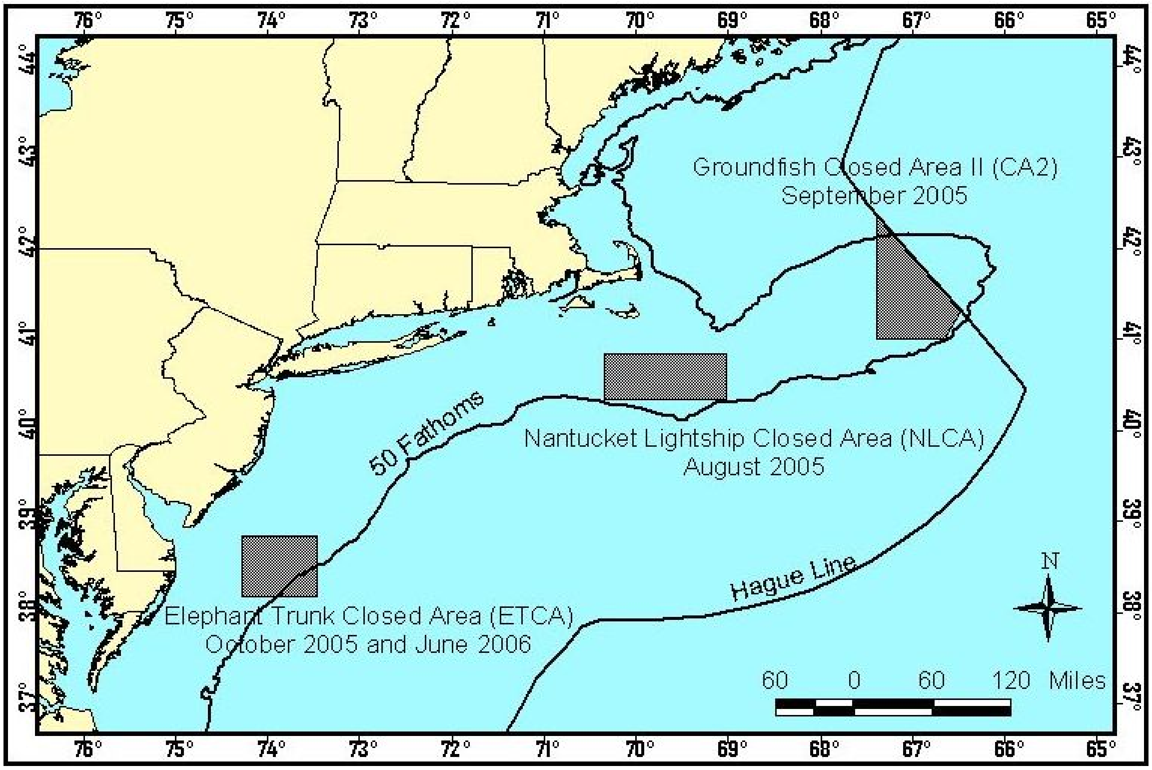
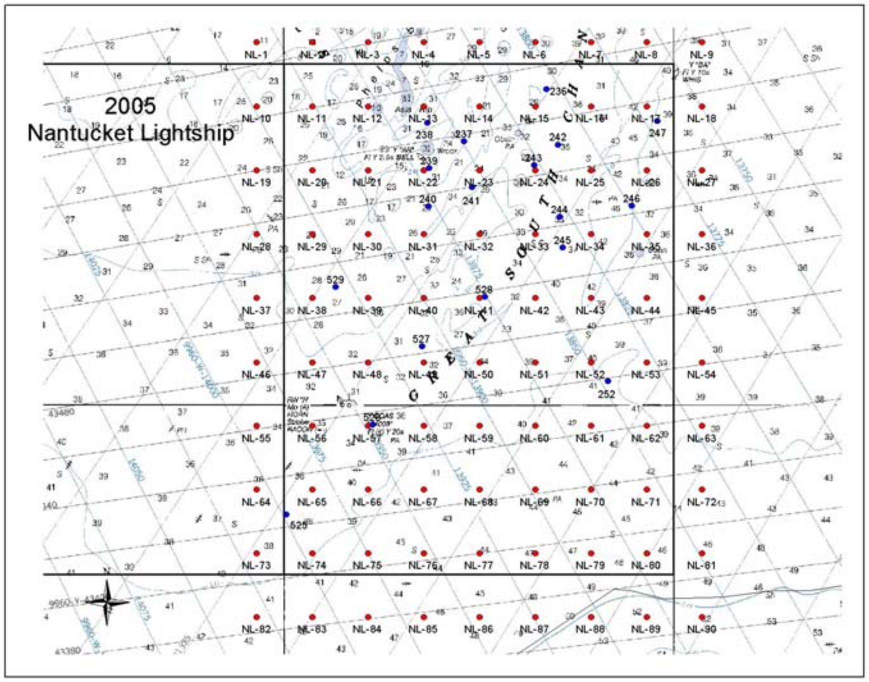
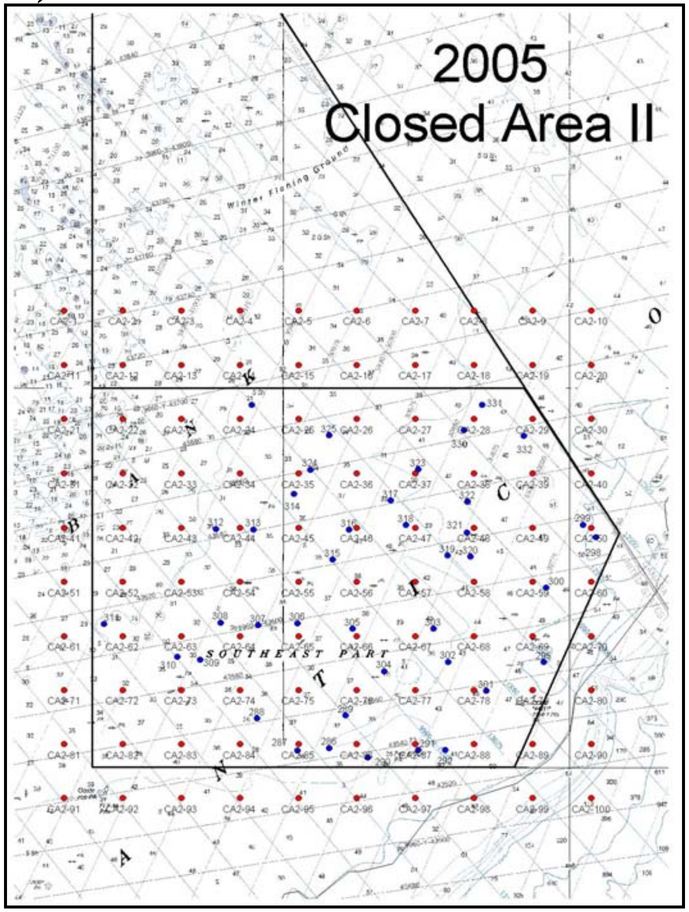


**Figure 2. Systematic random stations generated for this study. All stations within the closed area boundary were surveyed for cruises: a) Nantucket Lightship Closed Area 2005, b) Groundfish Closed Area II 2005, c) Elephant Trunk Closed Area 2005, and d) Elephant Trunk Closed Area 2006.**

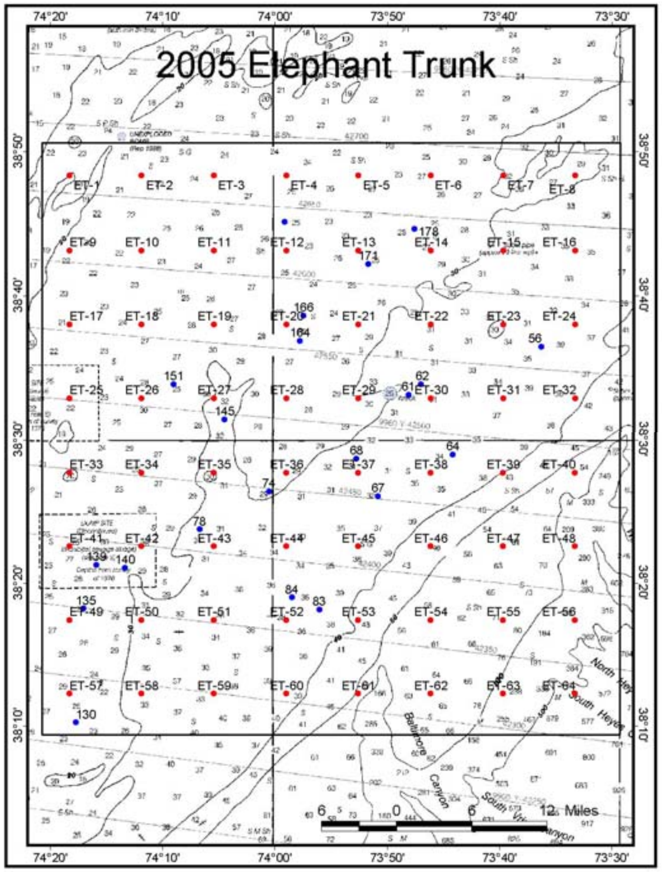
**A)**




**B)**



C)




D)

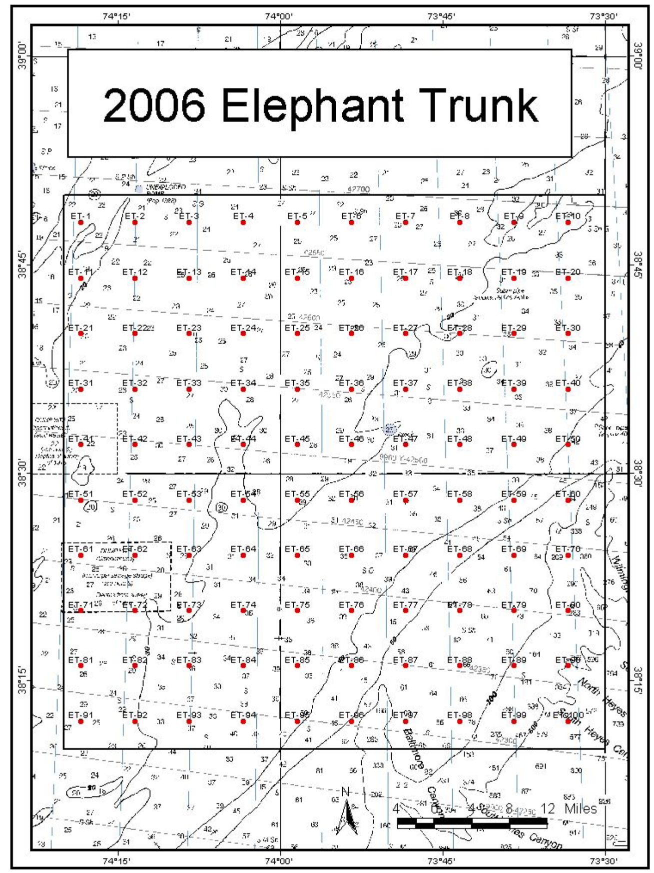
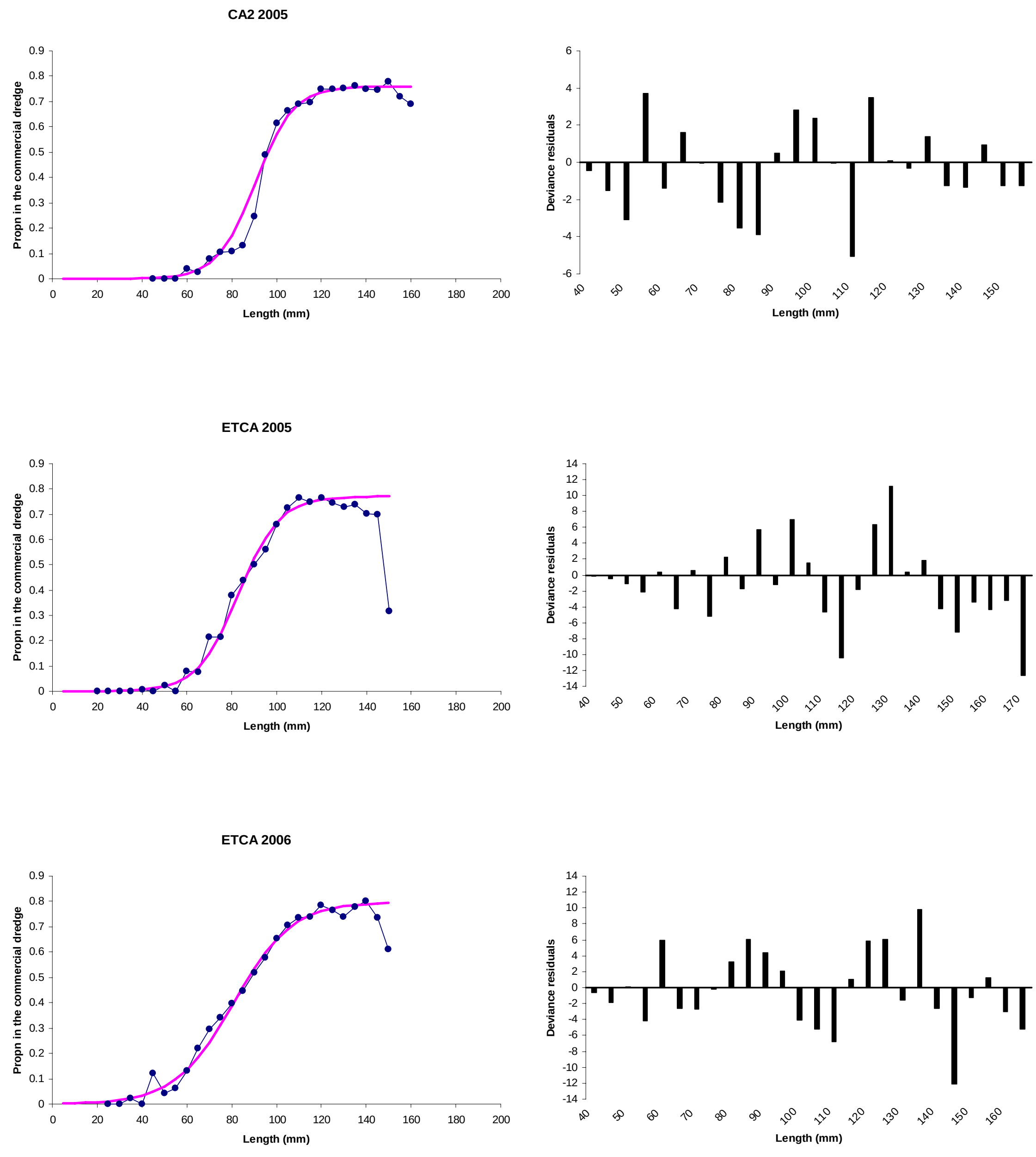
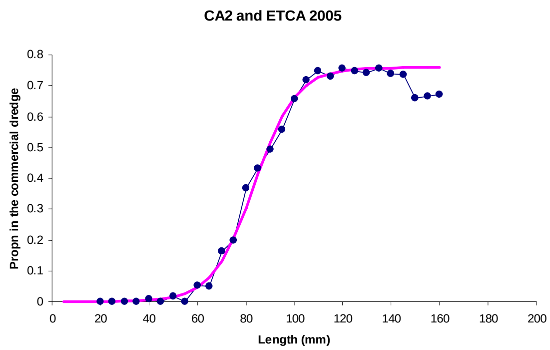
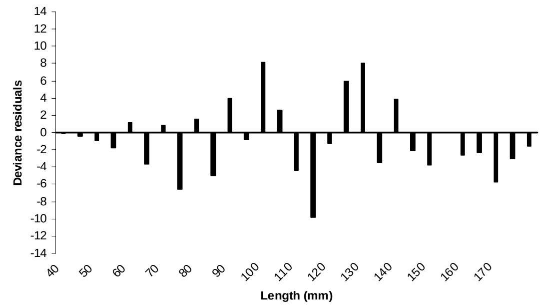
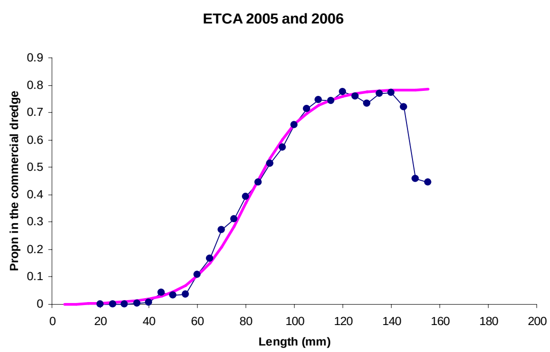


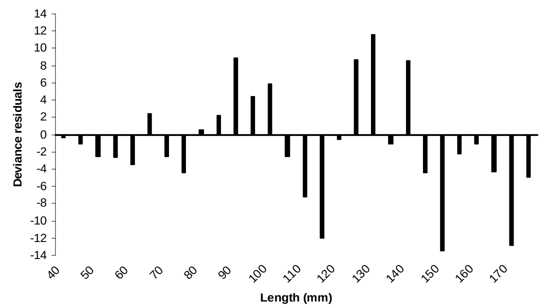
**Figure 3. Logistic SELECT curves fit to the proportion of the total catch in the commercial gear and deviance residuals for a) Groundfish Closed Area II 2005 (CA2 2005), b) Elephant Trunk Closed Area 2005 (ETCA 2005), c) Elephant Trunk Closed Area 2006 (ETCA 2006), d) CA2 2005 and ETCA 2005 combined, e) ETCA 2005 and ETCA 2006 combined, and f) CA2 2005, ETCA 2005 and ETCA 2006 combined.**

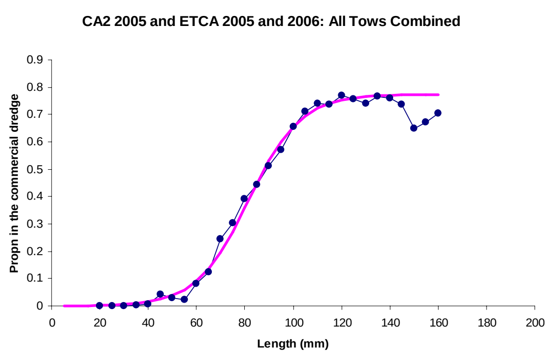



CA2 and ETCA 2005
Propn in the commercial dredge
Length (mm)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8
0 20 40 60 80 100 120 140 160 180 200


Deviance residuals
Length (mm)
14 12 10 8 6 4 2 0 -2 -4 -6 -8 -10 -12 -14
40 50 60 70 80 90 100 110 120 130 140 150 160 170


ETCA 2005 and 2006
Propn in the commercial dredge
Length (mm)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
0 20 40 60 80 100 120 140 160 180 200


Deviance residuals
Length (mm)
14 12 10 8 6 4 2 0 -2 -4 -6 -8 -10 -12 -14
40 50 60 70 80 90 100 110 120 130 140 150 160 170


CA2 2005 and ETCA 2005 and 2006: All Tows Combined
Propn in the commercial dredge
Length (mm)
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
0 20 40 60 80 100 120 140 160 180 200

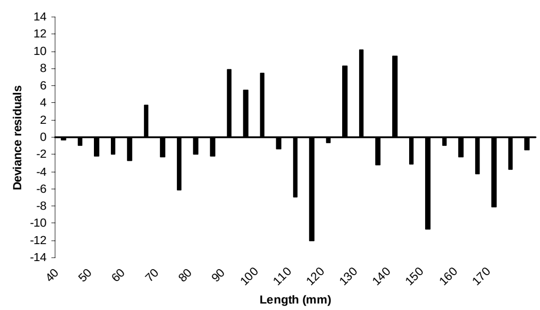

Deviance residuals
Length (mm)
14 12 10 8 6 4 2 0 -2 -4 -6 -8 -10 -12 -14
40 50 60 70 80 90 100 110 120 130 140 150 160 170

**Figure 4. Size-selection curves from the estimated logistic parameters for Groundfish Closed Area II 2005 (CA2 2005), Elephant Trunk Closed Area 2005 (ETCA 2005), Elephant Trunk Closed Area 2006 (ETCA 2006), CA2 2005 and ETCA 2005 combined, ETCA 2005 and ETCA 2006 combined, and CA2 2005, ETCA 2005 and ETCA 2006 combined.**

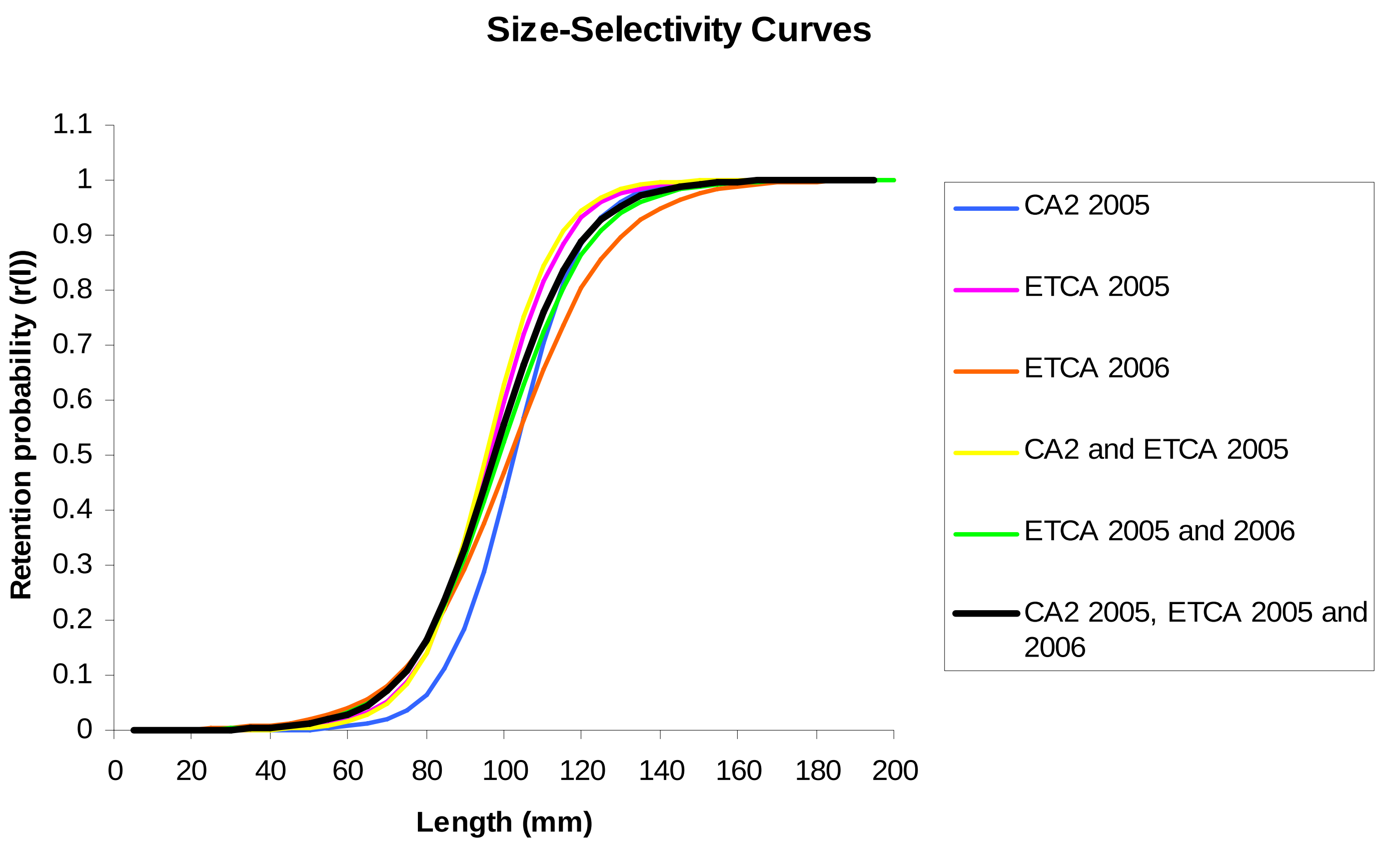
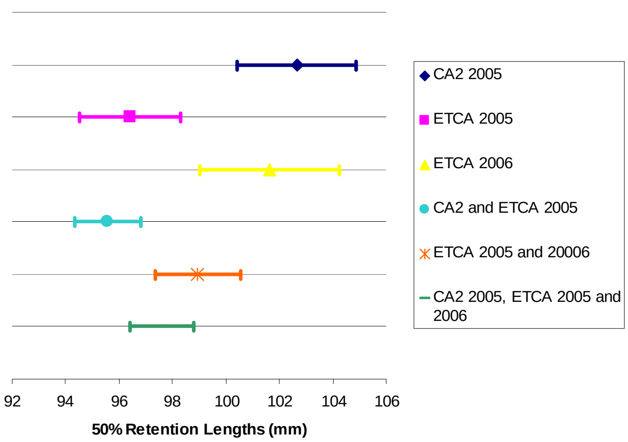
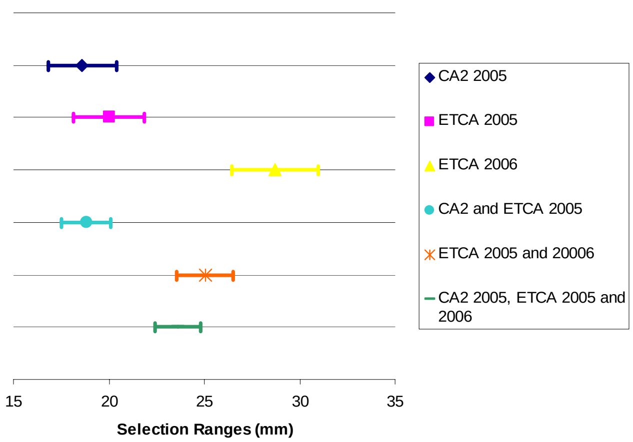


**Figure 5. Estimated parameters for the different combinations of data with their confidence intervals.**

**A)**




**B)**




**C)**

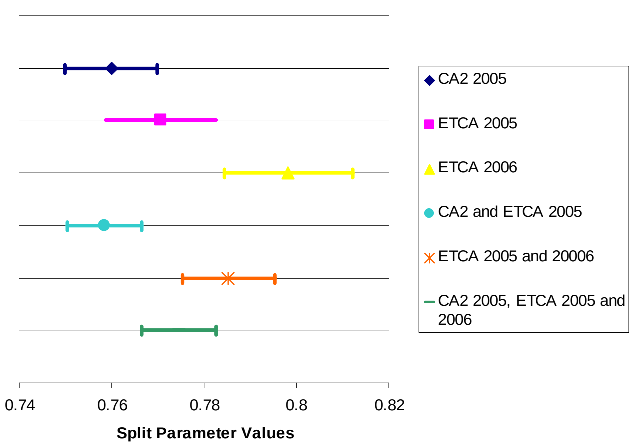


**Figure 6. Logistic selection curve for the NLCA 2005 cruise and the curve for the CA2 2005, ETCA 2005 and ETCA 2006 cruises combined (final curve).**

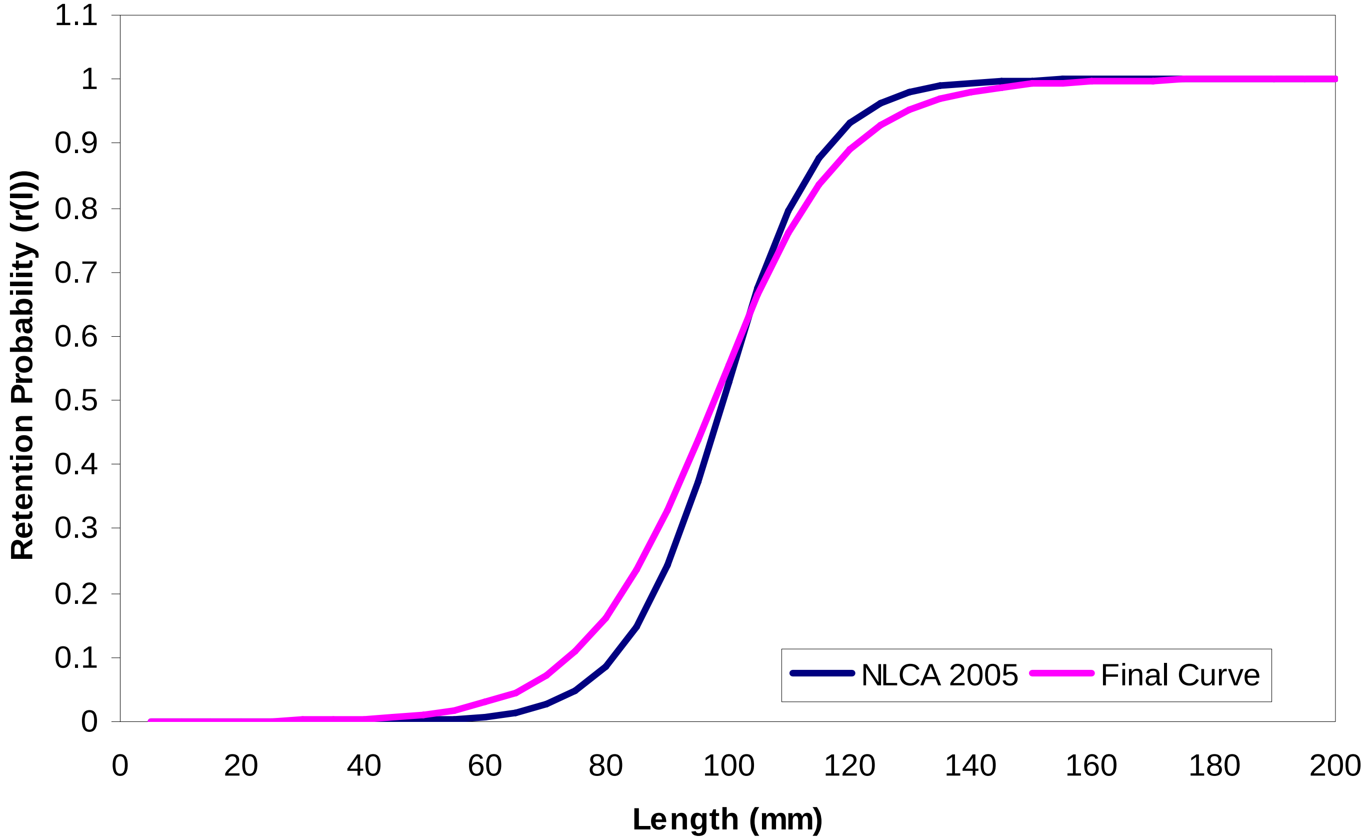
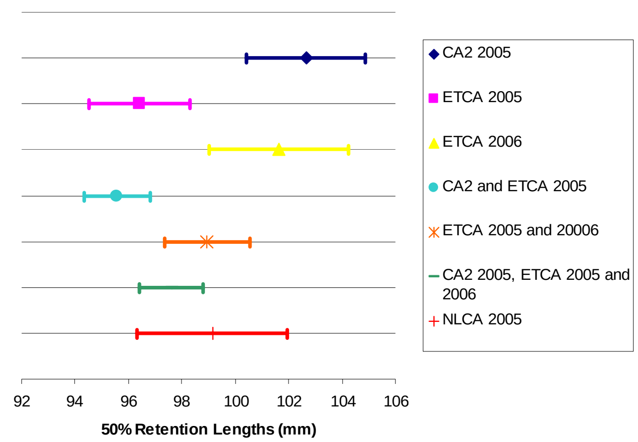
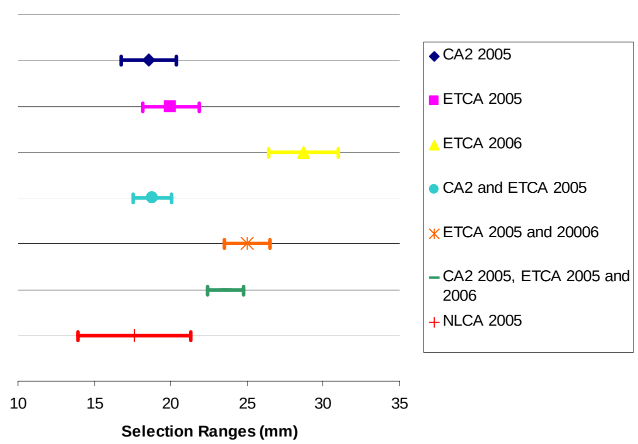


**Figure 7. Estimated parameters for the different combinations of data (including the Nantucket Lightship Closed Area 2005 cruise) with their confidence intervals.**

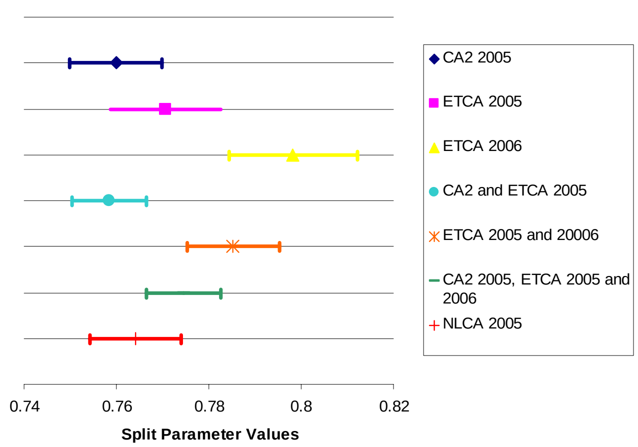
**A)**




**B)**




**C)**



## Table 1. Cruise and vessel information.

| Cruise Number | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| **Location** | Nantucket Lightship Closed Area | Groundfish Closed Area II | Elephant Trunk Closed Area | Elephant Trunk Closed Area |
| **Reference** | NLCA 2005 | CA2 2005 | ETCA 2005 | ETCA 2006 |
| **Dates of Survey** | August 19-24 | September 17-23 | October 10-12, 18-23 | June 5-12 |
| **Year** | 2005 | 2005 | 2005 | 2006 |
| **Vessel** | F/V *Westport* | F/V *Celtic* | F/V *Carolina Boy* | F/V *Carolina Boy* |
| **Length (ft)** | 88.1 | 88.1 | 85.3 | 85.3 |
| **Gross Tonnage** | 196 | 199 | 195 | 195 |
| **Captain** | Edie Welch | Charlie Quinn | Rodney Watson | Rodney Watson |
| **No. Tows Used in Analysis** | 35 | 54 | 50 | 69 |

**Table 2. Survey station and tow information (only the stations used in the data analysis are included in these figures).**

| Cruise | NLCA 2005 | CA2 2005 | ETCA 2005 | ETCA 2006 |
|---|---|---|---|---|
| Average Station Depth (fathoms) | 35.80 | 40.04 | 28.16 | 28.06 |
| Station Depth Range (fathoms) | 28-43 | 32-51 | 18-39 | 20-38 |
| Average Minimum/Maximum Wind Speed | 6.88/11.46 | 9.34/14.91 | 11.00/17.50 | 10.96/16.67 |
| Average Minimum/Maximum Sea State | 2/4.13 | 1.74/3.78 | 2.24/4.46 | 2.46/4.91 |
| Average Tow Duration (hr:min) | 14:37 | 15:47 | 14:42 | 15:39 |
| Average Vessel Speed (knots) | 3.8 | 3.8 | 3.8 | 3.8 |
| Average Scope | 3.11 | 3.06 | 3.01 | 2.97 |

**Table 3. An assessment of how the number of length classes used in the analysis will affect the resulting parameters (the 50% retention length ($l_{50}$), the selection range (SR= $l_{75}$ - $l_{25}$) and the relative efficiency split parameter ($p_c$)). The data was analyzed under the criteria that, for each length class, 1) at least one dredge had more than zero scallops, 2) at least one dredge had more than 20 scallops, 3) at least one dredge had more than 60 scallops and 4) at least one dredge had more than 1,000 scallops. The second criterion represents that which is used for this study. The length classes used under each situation and the log likelihoods (L) are also given.**

| Cruise(s) | | >0 | >20 | >60 | >1000 |
|---|---|---|---|---|---|
| CA2 2005 | Lengths | 25-165 | **45-160** | 50-155 | 60-145 |
| | $l_{50}$ (mm) | 102.65447 | **102.66044** | 102.68471 | 102.76290 |
| | SR (mm) | 18.59938 | **18.60577** | 18.62312 | 18.90600 |
| | $p_c$ | 0.75989 | **0.75992** | 0.76008 | 0.76070 |
| | L | -44823.84 | **-44814.15** | -44773.37 | -44383.55 |
| ETCA 2005 | Lengths | 5-170 | **20-150** | 25-150 | 75-135 |
| | $l_{50}$ (mm) | 96.37136 | **96.41731** | 96.41799 | 96.87916 |
| | SR (mm) | 19.99227 | **20.02289** | 20.02307 | 20.12396 |
| | $p_c$ | 0.77034 | **0.77070** | 0.77071 | 0.77406 |
| | L | -92431.86 | **-92396.01** | -92395.99 | -90342.28 |
| ETCA 2006 | Lengths | 25-160 | **25-150** | 30-150 | 65-140 |
| | $l_{50}$ (mm) | 101.64999 | **101.64497** | 101.65734 | 102.04229 |
| | SR (mm) | 28.70759 | **28.70136** | 28.71451 | 29.04931 |
| | $p_c$ | 0.79827 | **0.79825** | 0.79831 | 0.80035 |
| | L | -173214.64 | **-173197.30** | -173197.05 | -172008.06 |
| CA2 & ETCA 2005 | Lengths | 5-170 | **20-160** | 25-155 | 60-145 |
| | $l_{50}$ (mm) | 95.54761 | **95.57826** | 95.58805 | 95.84932 |
| | SR (mm) | 18.80613 | **18.80661** | 18.81477 | 19.21789 |
| | $p_c$ | 0.75833 | **0.75835** | 0.75842 | 0.76021 |
| | L | -137465.80 | **-137451.90** | -137406.22 | -136672.66 |
| ETCA 2005 & 2006 | Lengths | 5-170 | **20-155** | 25-150 | 45-140 |
| | $l_{50}$ (mm) | 98.94422 | **98.94415** | 98.97836 | 99.45376 |
| | SR (mm) | 25.03686 | **25.03441** | 25.06050 | 25.49206 |
| | $p_c$ | 0.78522 | **0.78522** | 0.78544 | 0.78828 |
| | L | -265847.43 | **-265835.70** | -265792.77 | -264889.72 |
| CA2 2005, ETCA 2005 & ETCA 2006 | Lengths | 5-170 | **20-160** | 25-155 | 45-145 |
| | $l_{50}$ (mm) | 97.60958 | **97.60939** | 97.62017 | 97.85313 |
| | SR (mm) | 23.60812 | **23.60612** | 23.61602 | 23.84986 |
| | $p_c$ | 0.77445 | **0.77445** | 0.77452 | 0.77596 |
| | L | -311049.03 | **-311034.80** | -310986.57 | -310200.04 |

**Table 4.** **Estimated parameters from the Logistic SELECT analysis on catch-at-length data for all length classes with at least 20 scallops in one of the dredges. Listed are the length classes used in the analysis' and the starting values to estimate the parameters. In addition, the estimated values (left column) for logistic parameters *a* and *b*, as well as the 50% retention length ($l_{50}$), the selection range (SR= $l_{75}$- $l_{25}$) and the relative efficiency split parameter ($p_c$) are given. The log likelihood (L) and the replication estimate of between-haul variation (REP) are specified as well as the standard errors (right column), which have been multiplied by the square root of REP.**

| | **CA2 2005** | | **ETCA 2005** | | **ETCA 2006** | | **CA2 & ETCA 2005** | | **ETCA 2005 & 2006** | | **CA2 2005, ETCA 2005 & 2006** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Lengths** | 45-160 | | 20-150 | | 25-150 | | 20-160 | | 20-155 | | 20-160 | |
| **Start values** | (-13, 0.13, 0.8) | | (-10, 0.1, 0.75) | | (-12, 0.12, 0.8) | | (-11, 0.11, 0.8) | | (-12, 0.12, 0.8) | | (-12, 0.12, 0.8) | |
| ***a*** | -12.1235 | | -10.5804 | | -7.7814 | | -11.1667 | | -8.6841 | | -9.0853 | |
| ***b*** | 0.1181 | | 0.1097 | | 0.0766 | | 0.1168 | | 0.0878 | | 0.0931 | |
| $p_c$ | 0.7599 | 0.005 | 0.7707 | 0.006 | 0.7983 | 0.007 | 0.7584 | 0.004 | 0.7852 | 0.005 | 0.7745 | 0.004 |
| $l_{50}$ **(mm)** | 102.6604 | 1.112 | 96.4173 | 0.941 | 101.6450 | 1.303 | 95.5783 | 0.625 | 98.9442 | 0.799 | 97.6094 | 0.602 |
| **SR (mm)** | 18.6058 | 0.905 | 20.0229 | 0.924 | 28.7014 | 1.129 | 18.8066 | 0.638 | 25.0344 | 0.738 | 23.6061 | 0.594 |
| **L** | -44814.15 | | -92396.01 | | -173197.30 | | -137451.90 | | -265835.70 | | -311034.80 | |
| **REP** | 4.5372 | | 8.7343 | | 8.5071 | | 7.0850 | | 8.7949 | | 7.9839 | |

**Table 5.** **Estimated parameters from the Logistic SELECT analysis' on catch-at-length data for all length classes with at least 20 scallops in one of the dredges given for the NLCA 2005 cruise and for the CA2 2005, ETCA 2005 and 2006 cruises combined. Listed are the length classes used in the analysis' and the starting values to estimate the parameters. In addition, the estimated values (left column) for logistic parameters *a* and *b*, as well as the 50% retention probability length ($l_{50}$), the selection range (SR= $l_{75}$- $l_{25}$) and the relative efficiency split parameter ($p_c$) are given. The log likelihood (L) and the replication estimate of between-haul variation (REP) are specified as well as the standard errors (right column), which have been multiplied by the square root of REP.**

| | NLCA 2005 | | CA2 2005, ETCA 2005 & 2006 | |
|---|---|---|---|---|
| **Lengths** | 40-170 | | 20-160 | |
| **Start values** | (-12, 0.12, 0.8) | | (-12, 0.12, 0.8) | |
| ***a*** | -12.3559 | | -9.0853 | |
| ***b*** | 0.1246 | | 0.0931 | |
| $p_c$ | 0.7642 | 0.0049 | 0.7745 | 0.0035 |
| $l_{50}$ **(mm)** | 99.1353 | 1.4168 | 97.6094 | 0.6020 |
| **SR (mm)** | 17.6290 | 1.8481 | 23.6061 | 0.5941 |
| **L** | -50672.09 | | -311034.80 | |
| **REP** | 2.8297 | | 7.9839 | |

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