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FINAL REPORT Calibrating Industry Scallop Surveys with NOAA Vessel Platforms

William D. DuPaul
Virginia Institute of Marine Science

David Rudders
Virginia Institute of Marine Science

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Calibrating Industry Scallop Surveys with NOAA Vessel Platforms

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One Blackburn Drive
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Submitted by:

William D. DuPaul
David B. Rudders

Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, Virginia 23062

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Project Summary

The annual synoptic survey of the United States sea scallop resource by the National Marine Fisheries Service represents a vital component of the information used to manage the fishery. Sea scallop abundance indices obtained from this survey, have been generated from research cruises aboard the R/V *Albatross IV* since the 1970's. In addition to the continuity of vessel platform, the survey dredge had also been consistent throughout the time series. Research vessels have a finite life span and improvements to sampling gear are sometimes required. Care, however, must be taken to account for any changes in catchability that might occur due to altering a vessel or sampling gear. Systematic error may be introduced into the time series if the indices are not adjusted to account for these changes the sampling protocol.

The summer of 2007 represented the final year of operations for the R/V *Albatross IV.* In anticipation of the retirement of this vessel, the Virginia Institute of Marine Science (VIMS) in conjunction with the Northeast Fisheries Science Center (NEFSC) and the sea scallop industry conducted vessel calibration experiments during the 2007 NMFS sea scallop survey. These experiments, conducted aboard two commercial sea scallop vessels, were intended to preserve the continuity of the time series by providing fishing power correction factors relative to the R/V *Albatross IV*. This information would facilitate the use of the calibrated commercial vessels to conduct the survey, or at least form a link from the R/V *Albatross IV* to any future survey platform. In addition to calibrating two potential vessel platforms, an updated dredge design (developed by the Sea Scallop Survey Panel (SSSP)) was also used in the experiment. The new dredge design, towed simultaneously with the standard dredge was used to anticipate and account for a potential change in survey gear. In total fishing power correction factors were estimated for four different vessel-gear configurations with respect to the CPUE of sea scallops. Correction factors ranged from 0.975 to 1.863 indicating that the systematic bias associated with different vessel-gear configurations was not large. Results suggest a possible regional effect as a result of the predominant substrate type differentially affecting the relative catchability of the gear configurations tested). Overall, these results indicate that commercial vessels represent a viable option to conduct the annual dredge survey and present the correction factors that would enable the use of these vessels during future survey efforts.

Project Background

Fishery surveys provide information that is vital for the assessment of aquatic resources. Information supplied by annual synoptic surveys of fish and shellfish stocks serves a variety of important roles. Indices of abundance generated by surveys, track relative changes in population abundance over time, and depending on the configuration of the gear used the presence and relative magnitude of recruitment events. Surveys can provide information to detect changes in species assemblage over time, as well as providing samples to assess changes on an organismal level (Hilborn and Walters 1992; Gunderson 1993). Perhaps most important, the information gathered by annual fishery surveys populate stock assessment models. These models, in turn, estimate critical components of the assessed stock such as estimates of present and future abundance, as well as mortality rates. With these estimates, guidance to managers relating to responsible levels of harvest can be supplied in order to achieve management goals. Given the importance of the time series to both stock assessments and ultimately the responsible and effective management of marine resources, the onus lies on maintaining a high level of long term data quality. It is essential to preserve the continuity of the time series and is vital to insure its utility as a source of information in both retrospective as well a forward projecting modeling efforts.

When monitoring relative changes in abundance over time through annual fishery surveys, the implicit assumption in comparing the results between years is that the measured index of abundance is proportional to the actual abundance. The proportionality constant known as the catchability coefficient (q) is assumed in the strictest sense to be constant, or at least stationary (varying without trend) (Kimura and Somerton 2006). To satisfy the assumption of stationarity of q, researchers must standardize all components of the survey methodology. Should changes to the methodology occur it is vital to calibrate the new methodology to the old to ensure comparability to existing time series. This calibration will allow for the utilization of the entire time series to seamlessly be included in stock assessment models.

Many components of fishery surveys can be standardized through time to satisfy the assumption of stationarity of the catchability coefficient. Maintaining a standard survey design, fishing gear and sampling methodology are excellent practices, however a major impetus necessitating calibration studies is either the replacement of a dedicated survey vessel, the utilization of multiple vessels to complete a given survey or changes to the survey gear (Tyson *et. al.,* 2006). Differences in survey vessels can have a profound effect on the magnitude of the CPUE observed during in a given survey. This vessel effect has the potential to introduce bias into the time series if left unaccounted for (Pelletier, 1998). Calibration experiments designed to quantify the relative differences in fishing power can account for any changes to the survey methodology (vessel, gear, design, etc.) and are used to adjust the time series moving forward (von Szalay and Brown, 2001).

The methodology for conducting fishing vessel inter-calibration experiments was reviewed by Pelletier (1998). He observed that these experiments generally fall into two experimental design categories. The first design was an independent haul approach which sampled in a confined area with the assumption of uniform fish abundance and environmental conditions throughout the area. Experiments utilizing this approach generally estimated the fishing power correction factors within a randomized block ANOVA framework with each tow representing a block. In general, this design introduces considerable spatial and temporal variability. The result of this variability is a requirement of a large effective sample size to detect differences in the block-treatment effect. Additionally, these additional sources of unaccounted variability have the potential to affect the precision of estimated fishing power correction factors (FPC) (Pelletier, 1998). The second and much more common experimental approach was the paired design, where two vessels occupied tows either simultaneously separated by a safe, but small distance, or reoccupied the same tow path in close succession. This design has the advantage of reducing the spatial and temporal variability relative to the independent haul method.

Regardless of the survey design used, fishing power correction factors lend themselves to certain classes of analytical approaches. First used by Robson (1966) variations of log–transformed multiplicative models have been a common analytical approach (Sissenwine and Bowman 1978; Wilderbuer *et al.* 1998). Another approach involves a ratio estimator of the mean CPUE of the two gears or vessel/gear combination (Wilderbuer *et al.* 1998; Tyson *et al.* 2006). These two analytical approaches are sensitive to implicit assumptions relating to the availability of fish in the tow path. Violation of these assumptions is possible due to the nature of some habitats sampled as well as the contagious distribution of fish (Lewy *et al.* 2004.

Kappenman (1992) developed an approach to estimate relative fishing power based upon a ratio of scale parameters for two positive random variables (CPUE). The underlying assumption of this method is that the two CPUE distributions for a given species have the same underlying shape, but different scales. With this technique, a fishing power correction factor is estimated from the ratio of the two scale parameters. This approach is attractive relative to more traditional analytical procedures (randomized block ANOVA, ratio of mean CPUE, least squares regression) due to the lack of assumptions required. The Kappenman technique does not require a strict pairing of tows and there is no assumption of equal fish density available for each tow. Utilizing the same data set, Wilderbuer *et al.* (1998) compared 4 approaches (randomized block ANOVA, ratio of mean CPUE, least squares regression, Kappenman) and found similar and superior performance for the randomized block ANOVA and Kappenman. While procedures for calculating 95% confidence intervals exist for randomized block ANOVA, ratio of mean CPUE, least squares regression one does not exist for the Kappenman estimator. von Szalay and Brown (2001) used a bootstrapping approach to resample the CPUE data from the two vessels and estimate the variance of the Kappenman estimator.

More recently, FPCs have been estimated with analytical approaches utilizing generalized linear models (GLM) and generalized linear mixed models (GLMM) (Helser *et al.* 2004; Lewy *et al.* 2004). In addition to estimating FPC, Lewy *et al.* (2004) was able to estimate the disturbance effect that occurs when two vessels consecutively tow along a similar tow paths causing a change in the availability of fish. Both the Kappenman method (1992) as well as the GLMM approach by Helser *et al.* (2004) have been used to examine FPCs in surveys where multiple vessels have been used in a given survey. These studies are interesting in the fact that explicit calibration experiments were not performed, yet survey results were analyzed *a posteriori* and allowed the consolidation of multiple data sets data into calibrated indices of abundance (von Szalay and Brown, 2001; Helser *et al.* 2004). This approach can have benefits in reducing the inherent spatial and temporal variability when large geographic areas are surveyed especially with highly mobile or migratory species.

Regardless of the technique used to estimate a FPC, the critical decision is whether to apply the correction to the existing time series. Traditionally, 95% confidence intervals were use to decide whether to apply the factor. If the interval spanned 1 (implying there was no difference in vessel/gear variant for a given species) a correction was not applied. Conversely, if the interval did not include 1 then the correction was applied. This thinking can be problematic in the sense that FPCs are notoriously imprecise (i.e. wide confidence intervals that include unity) and true differences in relative fishing power may be incorrectly rejected. Munro (1998) developed an objective decision rule for the application of the correction factor based on the conjecture that the application of a FPC was only beneficial if it reduces the error in the estimate of the mean CPUE. His decision rule was based on the concept of minimizing the mean squared error (MSE) and the FPC was applied only if:

$$MSE[CPUE_{corrected}] > MSE[CPUE_{uncorrected}]$$

Where $CPUE_{corrected}$ and $CPUE_{uncorrected}$ are the mean CPUE from the corrected and uncorrected catch data (von Szalay and Brown, 2001). MSE is an appropriate measure to assess the effect of the application of an FPC because MSE is the sum of the variance (between the estimated CPUE and "true" CPUE) and the square of the bias (from the application of a FPC).

In anticipation of the retirement of the R/V *Albatross IV*, the Virginia Institute of Marine Science (VIMS) in conjunction with the Northeast Fisheries Science Center (NEFSC) and the sea scallop industry conducted vessel calibration experiments during the 2007 NMFS sea scallop survey. These experiments, conducted aboard two commercial sea scallop vessels, were intended to preserve the continuity of the time series by providing fishing power correction factors relative to the R/V *Albatross IV*. This information would facilitate the use of the calibrated commercial vessels to conduct the survey, or at least form a link from the R/V *Albatross IV* to any future survey platform.

Project Goals and Objectives

Estimate fishing power correction factors between the R/V *Albatross IV* and two commercial scallop vessels (F/V *Nordic Pride* and F/V *Celtic*), as well as test both the standard NMFS scallop dredges and a newly re-designed survey dredge. This information will facilitate the transition of the NMFS Northeast scallop dredge survey from the R/V *Albatross IV* to the these commercial vessels or another yet-to-be named platform.

Methods

Experimental Design

For this experiment, the two commercial vessels were selected based on vessel characteristics. To be a candidate vessel to conduct offshore survey work, these vessels needed to be able to sample in all portions of the sea scallops range. In the fishery, there is a wide range of vessels and not all vessels can effectively operate in all areas due to different prevailing weather and oceanic characteristics. The vessels also needed to be large enough to accommodate the scientific party as well as the vessel crew with ample space for the completion of sampling. Vessel characteristics are shown in Table 1.

The calibration experiments were conducted within the context of the NMFS annual sea scallop survey (Figure 1). This survey utilizes a stratified random design to sample throughout the entire U.S. range of the sea scallop. (Serchuk and Wigley 1986). Due to regional differences in the composition of the substrate as well as hydrographic conditions, our goal was to sample throughout the geographic regions sampled by the R/V *Albatross IV.* Sampling cruises occurred during two legs of the NMFS survey. The first cruise sampled stations in the mid-Atlantic region, specifically the DelMarVa area (Figure 2). The second cruise was to Georges Bank and stations were occupied along the northern flank of the bank from the Southeast Channel to the Northeast Peak (Figure 2).

The project utilized two sea scallop survey dredges. Commercial sea scallop vessels generally have the capability of towing two dredges simultaneously. The first dredge was the standard NMFS sea scallop survey dredge that has been in service, virtually unmodified since the 1970’s (Figure 3). This dredge is 8 ft in width, with a dredge bag consisting of 2 inch rings. The twine top is comprised of 3.5 inch diamond mesh and there is a 1.5” liner in the dredge bag. There were no turtle excluder chains on this dredge. The second dredge used in this study was a modified version of the standard dredge developed by the Sea Scallop Survey Advisory Panel (Figure 4). In this document, this dredge will be referred to as the "prototype'" dredge. The components of the prototype dredge are almost identical to the standard dredge (i.e. ring size, liner mesh size, twine top mesh size). Differences exist in relation to a slightly modified dredge frame, modifications to the ring bag and slight modifications to the mesh counts of the liner and twine top. A major difference between the two dredges is the addition of turtle/rock chains on the prototype dredge. The rationale behind the inclusion of chains for this dredge was to construct a dredge that was functional in all areas sampled as well as being proactive in taking measures relating to the exclusion of sea turtles from sea scallop dredges.

While at sea, the sampling protocol included the re-occupation of sampling stations occupied by the R/V *Albatross IV.* Start/stop locations for each tow completed by the R/V *Albatross IV* were relayed to the commercial vessel via VHF radio. With the goal of re-occupying the stations as quickly as possible, a subset of stations was selected for re-sampling (the R/V *Albatross IV* conducts 24 hour operations, while the F/V's in this study sampled for roughly 16-18 hrs/day). During the execution of the tow, the captain of the F/V attempted to mirror the start/stop locations as close as possible. While it is safe to assume that there was some crossing of tow paths, it is unlikely that the tow path was duplicated precisely. For each comparative 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 vessel position and speed over ground. Time stamps from the navigational log in conjunction with the tow level information recorded on the bridge were used to determine the location, duration and area fished by the dredges.

Sampling of the catch will be in the same manner established by DuPaul *et. al,.*1989. For each paired tow, the entire scallop catch will be placed in baskets. A fraction of these baskets will be measured to estimate length frequency for the entire catch. The shell height of each scallop in the sampled fraction will be measured in 5 mm intervals. This protocol will allow for the determination of the size frequency of the entire catch by expanding the catch at each shell height by the fraction of total number of baskets sampled. Finfish and invertebrate bycatch will be quantified, with finfish being sorted by species and measured to the nearest 1 cm.

The standard data sheets, used since the 1998 Georges Bank industry-based survey, will be used. The bridge log maintained by the captain/mate will record 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 will record detailed catch information on scallops, finfish, invertebrates and trash.

Data Analysis

Two analytical techniques were used to estimate fishing power correction factors for the commercial vessels relative to the R/V Albatross for sea scallops. In the review by Pelletier (1998), he recommends the maximization of comparative stations that record non-zero catches. Zero catches are uninformative and high numbers of these instances can result in the inability to detect differences in fishing power. While the overall abundance of sea scallops is high, at times zero catches were observed. In the cases where both the R/V *Albatross IV* and the F/V recorded zero catches, the tow was excluded.

The first analytical method used to estimate fishing power correction factors between the R/V *Albatross IV* and the commercial vessels was a ration of the mean catch per unit effort (CPUE) from the R/V *Albatross IV* to the mean CPUE to the two Fishing vessels for each of the dredge configurations tested (standard and prototype). This estimator is calculated by:

$$\hat{R} = \frac{\frac{\sum_{j=1}^{n} Y_j}{n}}{\frac{\sum_{j=1}^{n} X_j}{n}} \qquad (1)$$

Where $\hat{R}$ = the ratio estimate, n = the number of non-zero tow pairs, j = the index of tow pairs, Y_j = the CPUE from the jth tow aboard the R/V *Albatross IV* using the standard NMFS survey dredge, and X_j = the CPUE from the jth tow aboard the commercial vessel using either the standard NMFS survey dredge or the prototype dredge.

The variance of the ratio estimate was calculated after the formulation given in Cochran (1977).

$$Var(\hat{R}) = \frac{1-f}{n\overline{X}^2} \frac{\sum_{j=1}^{n} (Y_j - \hat{R}X_j)^2}{n-1} \quad (2)$$

Where $\overline{X}$ = the mean CPUE for all hauls made by the F/V for scallops with either the standard NMFS survey dredge or the prototype dredge. f = the finite population correction factor (for this analysis, it was assumed to be so small that it was effectively 0 and ignored). $\hat{R}$, n, j, Y_j and X_j are defined as in Equation 1. This variance estimate was used to calculate 95% confidence intervals for the FPC estimate.

Cochran (1977) expressed some concern regarding bias for both the ratio and variance estimators shown above. For the ratio estimator, sampling method and sample size have the potential to bias the estimate of $\hat{R}$. In general, however, the sample sizes in this study for both vessels and gear types are in excess of the minimum number of samples. For the variance estimator, Cochran (1977) stated that the formulation was an approximation and valid for large samples sizes only. He goes on to state that the large sample requirement is valid if the number of tow pairs is greater than 30. Another requirement to meet the large sample size assumption stipulates that the coefficients of variation for the CPUEs for both the F/V and the R/V must not exceed 10%. In our study, the sample size requirement was satisfied for both experiments, however the CV's for all of the treatments were greater than 10%.

The second approach used to estimate FPCs was a randomized block analysis of variance. Between haul variability is a common problem encountered in calibration studies. By treating each tow pair as a block, this approach in effect partitions out the inter-tow variability and the vessel-gear effect can be estimated. The CPUE data was transformed (ln(CPUE+1)) to account for any single zero catch in a tow pair. The estimated ln(CPUE+1) of vessel/gear combination *i*=(F/V, R/V) for tow pair *j* was the grand mean (μ), plus the estimated vessel/gear effect ($\pm v_i$) and the estimated haul effect (h_i). The haul effect was treated as the randomized block in the model. We used PROC MIXED in SAS v.9 to estimate the parameters μ, $v_{i,}$, and h_i. The full model is shown below.

$$\ln(CPUE_{ij} + 1) = \mu + v_i + h_j + \varepsilon_{ij} \tag{3}$$

Where the parameters μ, $v_{i,}$, and h_i are referenced as above and ε_{ij} represent the random error term.

The fishing power correction factor FPC was estimated as shown below.

$$F\hat{P}C = \frac{C\hat{P}UE_{Albatross}}{C\hat{P}UE_{F/V}} = e^{2v(1+0.5s^2)} \tag{4}$$

To estimate the FPC, the estimated anti-logged CPUEs were first calculated disregarding the haul effect. The estimated CPUEs were calculated as shown below.

$$C\hat{P}UE = e^{\mu \pm v} \tag{5}$$

Where $v_{Albatross}$ = +v, $v_{F/V}$ = -*v* and s^2 = the variance of the parameter estimate of *v*. This can be calculated by substitution or as an output from the ANOVA model. 95% confidence intervals for the estimated FPC can be calculated by the following.

$$\exp\left[2v \pm (1.96)2\sqrt{\mathrm{var}(v)}\right] \tag{6}$$

Results

We conducted two comparative fishing experiments during the annual NMFS sea scallop dredge survey aboard the R/V *Albatross IV*. The two trips coincided with the mid- Atlantic and Georges Bank legs of the survey. The first trip during the mid-Atlantic leg of the survey was aboard the F/V *Nordic Pride* hailing from New Bedford, MA (see Table 1 for vessel characteristics and Figure 2 for a map of the occupied stations). This cruise occurred from July 10, 2008 to July 17, 2008. During that time 101 comparative tows were completed , with the eventual number of valid hauls being slightly lower due to a couple of fouled hauls In general, the comparative stations were completed in the DelMarVa region of the mid-Atlantic Bight. Sampled during this cruise, were stations in the high density areas within the Elephant Trunk Closed Area as well as the newly closed DelMarVa Closed Area. Occupying stations within these areas resulted in samples that included high densities of scallops.

The second cruise was conducted during the Georges Bank portion of the NMFS survey. This trip was conducted aboard the F/V *Celtic* hailing from New Bedford, MA (See Table 1 for vessel characteristics and Figure 2 for a map of the occupied stations). This cruise occurred from August 9, 2008 to August 14, 2008. During that time 99 comparative tows were completed, with the number of eventual valid comparisons being lower due to fouled hauls, gear damage, and other factors. In general, the comparative stations were completed along the northern flank of Georges Bank from the Great South Channel to the Northeast Peak. Stations on this cruise varied greatly in relation to substrate composition, hydrographic conditions, and scallop abundance.

Scallop abundance encountered during the experiments varied, however, with resource abundance levels being at historically high levels, scallops were encountered at the majority of stations. In total, approximately 270,053 and 138,705, scallops were captured by the two vessels on the mid-Atlantic and Georges Bank cruises, respectively. Shell height frequency distributions for the two gears and both cruises are shown in Figures 5 &6. Catch on a tow-by-tow basis for both cruises and gear types are shown in Figures 7-14. These two visualizations of the catch data represent both the actual catch observed during each of the comparative tows as well as the proportion of scallops captured by the R/V *Albatross IV* relative to the total number caught by both gears at each station.

Fishing power correction factors were developed for sea scallops for all of the vessel/ gear combinations tested relative to the R/V *Albatross IV* (Table 2). Fishing power correction factors that are above one indicate that the R/V *Albatross IV* operated more efficiently relative to the commercial vessels, while a FPC less than one indicates that the commercial vessel/gear combination was more efficient. Overall, the estimated

FPCs ranged from 0.975 to 1.863. With one exception, the R/V *Albatross IV* was more efficient at capturing scallops than the commercial vessels.

The two estimators used in this study gave somewhat different results. The randomized block ANOVA consistently gave higher estimates of the FPC relative to the ratio estimator of mean CPUEs. In addition, the confidence intervals generated from the ANOVA were wider than those from the ratio estimate. By following the guidance of implementing a FPC only when the 95% confidence intervals do not include unity, corrections would be applied to the catches from the F/V *Nordic Pride*/prototype dredge combination (as evidenced from both analytical methods) and the F/V *Celtic* for both dredge configurations (from the randomized block ANOVA). Based upon the examination of 95% confidence intervals, there was no evidence to support correcting the other vessel/gear combinations.

Discussion

Monitoring the changes in fish abundance over time is a critical component of the assessment and management of aquatic resources (Gunderson 1993). Much of the information to accomplish these assessments comes from fishery independent surveys conducted by governmental agencies. As these time series grow older, it becomes more difficult to maintain a standardized survey operation. Vessels age and need to be replaced, and technology improves, necessitating the updating of older gear configurations. While these changes presumably allow the fishery biologist to collect more precise data, care must be taken during times of transition not to introduce a systematic bias into the time series (Pelletier 1998).

In an effort to facilitate the transition of the NMFS NEFSC's sea scallop survey from the retiring F/V *Albatross IV* to a future vessel platform and potentially a change in the design of the survey dredge a series of calibration experiments were conducted. Commercial sea scallop vessels were selected based on their availability, and ability to conduct survey operations for sea scallops. A paired design was deemed to be the most expedient approach to calibrate the vessels, and with the standard protocol specifying short tow times (15 min), relatively short steaming times between stations, many tows pairs could be accomplished. Wilderbuer *et. al.,* 1998 warns against implementing any correction factor when less than 50 valid tow pairs (non-zero) were used to estimate the correction factor. Based on the operational characteristics of the survey, and the healthy status of the scallop resource, obtaining an adequate sample of valid tow pairs was attained.

With a paired design and the traditional analytical approaches that have been used to analyze the resulting data, the assumption was made of equal scallop availability in front of each vessel. The vessels in this experiment consecutively occupied the same tow (within the abilities of the vessel operator and constraints of the environmental conditions), thereby satisfying the assumption of equal scallop availability for both vessels. By satisfying this assumption, the difference in the CPUE is a function of a vessel/gear effect. The FPCs generated from this experiment appeared to reflect a general robustness of the dredge survey to the effect of vessel. One interesting result from this study came from the potential regional effect that dredge design had on relative CPUE. The "prototype" dredge was designed with the addition of a chain mat for both a potential mitigation of sea turtle bycatch and an ability to operate consistently in rocky habitat without incurring damage. Results suggest that relative to the standard dredge (no chains) in the smoother, less rocky habitat of the Mid-Atlantic Bight the prototype dredge was less efficient relative to the R/V *Albatross IV*. This conclusion was supported by higher FPCs of the prototype dredge relative to the standard dredge during the F/V *Nordic Pride* cruise. This pattern was reversed on the F/V *Celtic* cruise to Georges Bank that is characterized, in general, by rockier substrate.

Traditionally, the inclusion of unity in the 95% confidence interval determined whether or not a FPC was implemented. Due to the variable nature of the populations sampled, these confidence intervals are notoriously imprecise, are generally quite wide and can result in the non-implementation of a correction even when one vessel/gear combination is clearly more efficient. In our study, based on this criteria, half (4 of 8) corrections would have been implemented (1 from the ratio estimator, 3 from the ANOVA). Care must be taken in the decision to implement a FPC, and guidance from Munro (1998) could be beneficial in the deciding whether to apply a correction factor. His argument was based on the conjecture that the application of a FPC was only beneficial if it reduces the error in the estimate of the mean CPUE.

In this experiment we attempted to facilitate the transition of the NMFS sea scallop survey to potentially both a new vessel platform and new survey dredge. The estimation of FPCs for sea scallops utilizing two commercial vessels with two different survey gears, allows for some latitude going forward. Potentially one or both of the commercial vessels could perform the survey with either the standard or prototype dredge. This flexibility with multiple vessels and multiple gears will allow for a smoother transition to a new platform while maintaining the temporal continuity of the time series that has characterized sea scallop abundance since the 1970's.

Problems encountered

In our original proposal, we specified that the Kappenman method would be the primary analytical method. Problems encountered implementing this approach precluded its inclusion in the final report. It is our goal to continue to work on this technique in conjunction with scientists at NEFSC and report on these results at a later time. In addition, the decision rule as specified by Munro (1998) will also be examined and utilized as a means to objectively decide on the application of an FPC.

Acknowledgements

We wish to thank the owners, captains and crews of the two commercial sea scallop vessels involved in this work. Without their assistance, expertise and patience, this work would never have been completed. Victor Nordahl from the NEFSC worked tirelessly to ensure that the logistics of all components of this project from the preparation of the survey gear to at-sea vessel coordination were in place. Dr. Dvora Hart was invaluable in the planning and analytical aspects of the project. We would also like to thank the captain and crew of the R/V *Albatross IV* for allowing us to conduct operations in their shadow. Finally, thanks go to the sea going scientists that we convinced to participate.

Table 1 Characteristics of vessels used in the comparative fishing experiments.

	F/V *Nordic Pride*	**F/V *Celtic***
Hailing Port	New Bedford, MA	New Bedford, MA
Owner	Nordic Fisheries, Inc.	Celtic Fisheries, LLC
Year Built	1987	1978
LOA (ft.)	92.7	88.1
Hull Depth (ft.)	13.2	13.6
Hull Breadth (ft.)	26	24
Gross Tonnage	192	199

Table 2. Fishing Power Correction Factors for sea scallops as determined for the four vessel/gear configurations tested. The FPC represents the correction factor of the commercial vessel (using the standard or prototype dredges) relative to the R/V *Albatross IV*. Two analytical techniques were tested, the ratio of the mean CPUEs and a randomized block ANOVA. 95% Confidence intervals around each FPC are shown in parentheses beneath each estimate. Sample size represents the number of valid paired tows used in the analyses. A ** represents a statistically significant difference between the vessel/gear combinations tested.

Vessel/Gear Combination	**Sample Size**	**Ratio of mean CPUE**	**Randomized Block ANOVA**
Mid-Atlantic Region			
F/V *Nordic Pride*	100	0.975	1.035
Standard Dredge		(0.83-1.12)	(0.84-1.22)
F/V *Nordic Pride*	98	1.250**	1.863**
Prototype Dredge		(1.07-1.43)	(1.65-2.06)
Georges Bank			
F/V *Celtic*	67	1.175	1.814**
Standard Dredge		(0.99-1.37)	(1.42-2.20)
F/V *Celtic*	84	1.063	1.587**
Prototype Dredge		(0.92-1.21)	(1.21-1.96)

Figure 1 Station locations for the 2007 NEFSC sea scallop survey

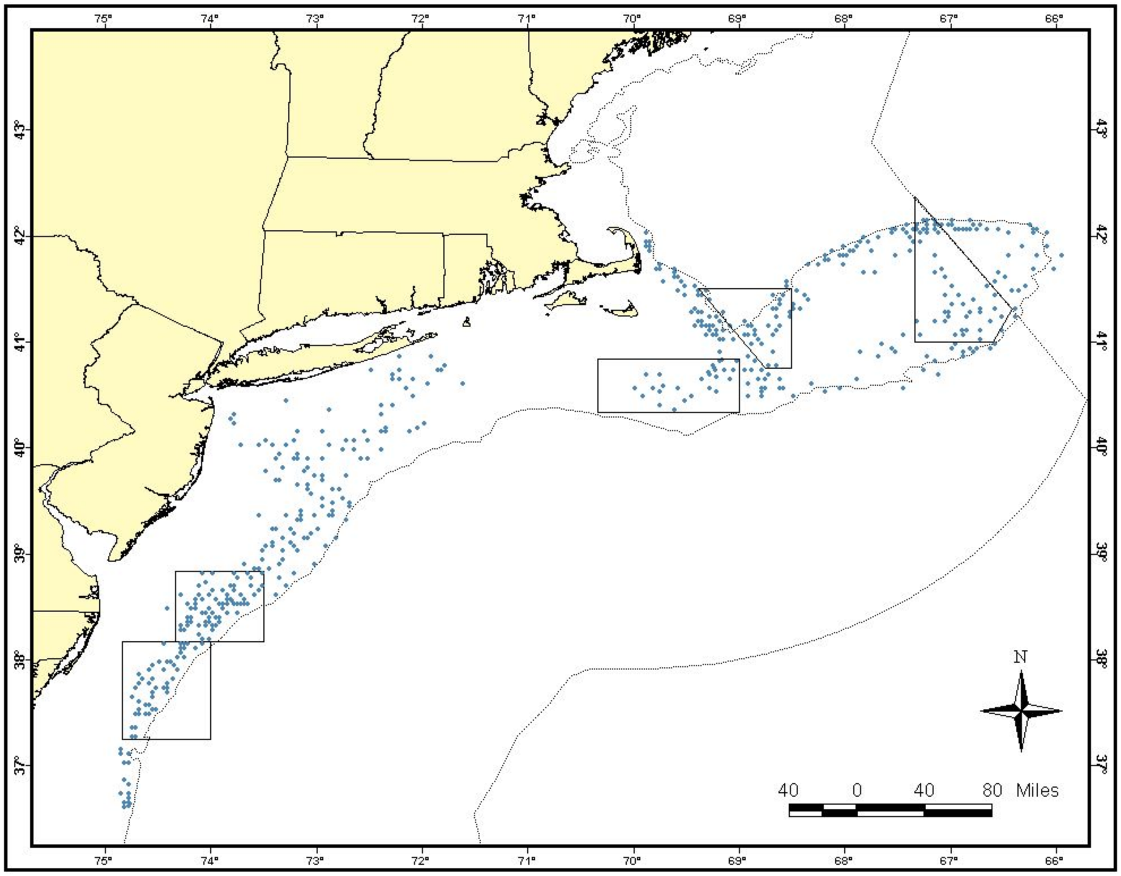


Figure 2 Station locations of the paired hauls completed during the 2007 calibration experiments.

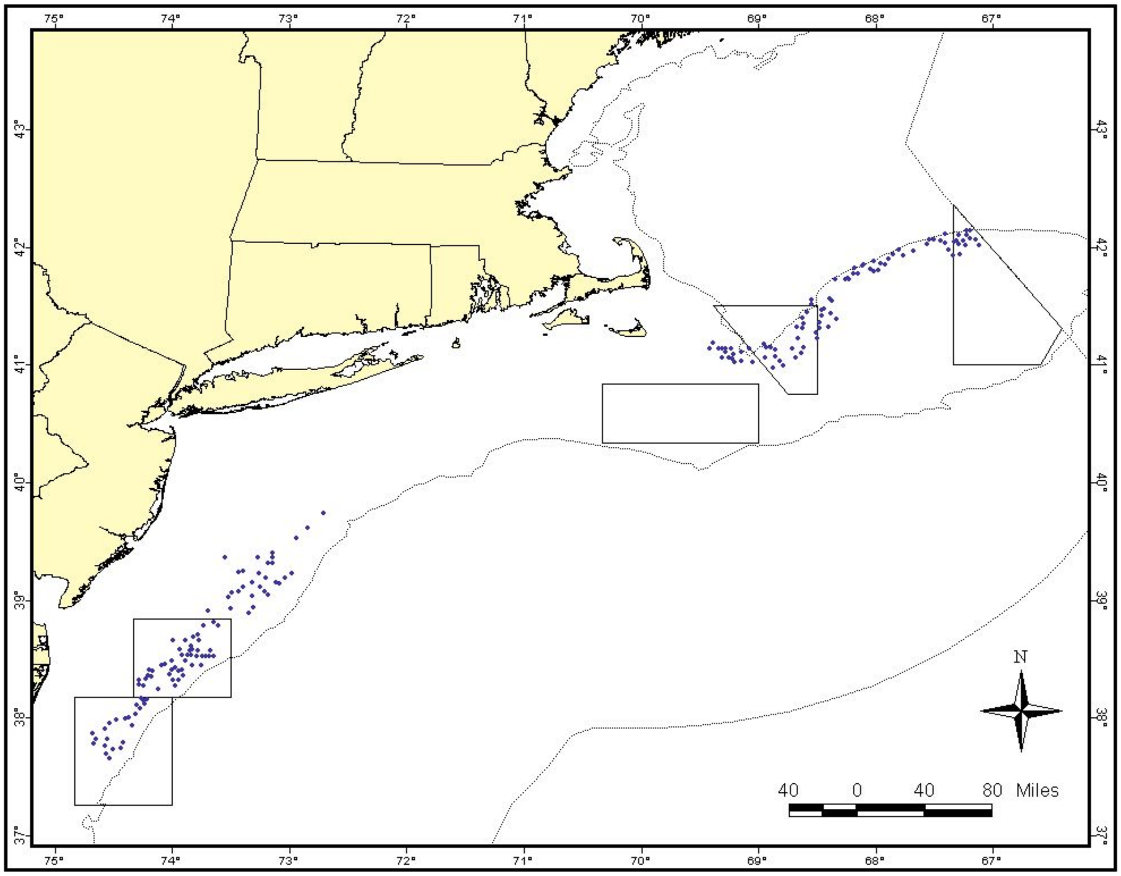
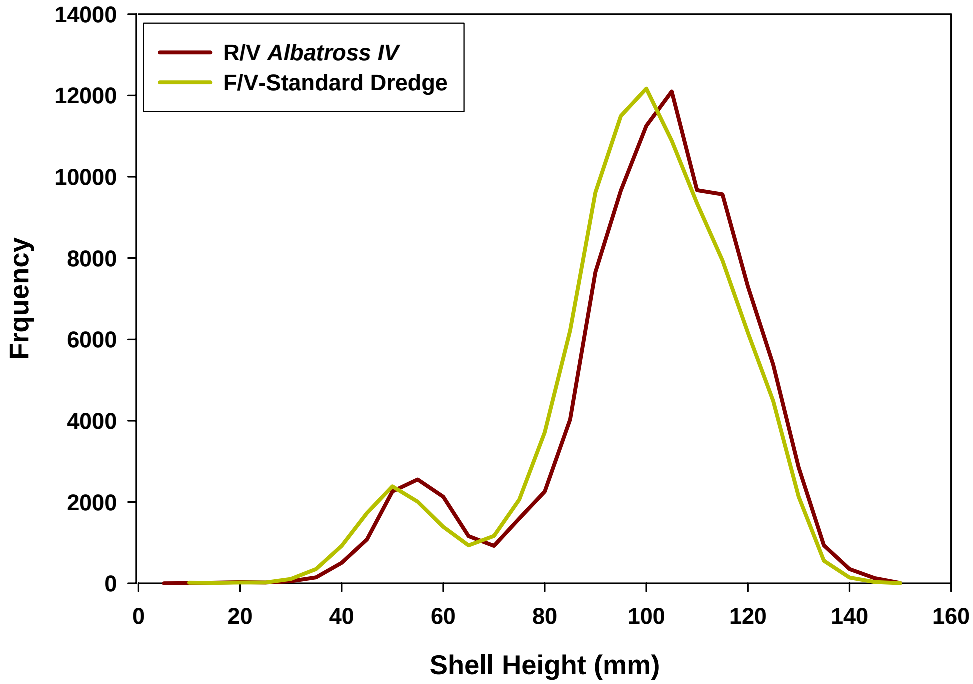
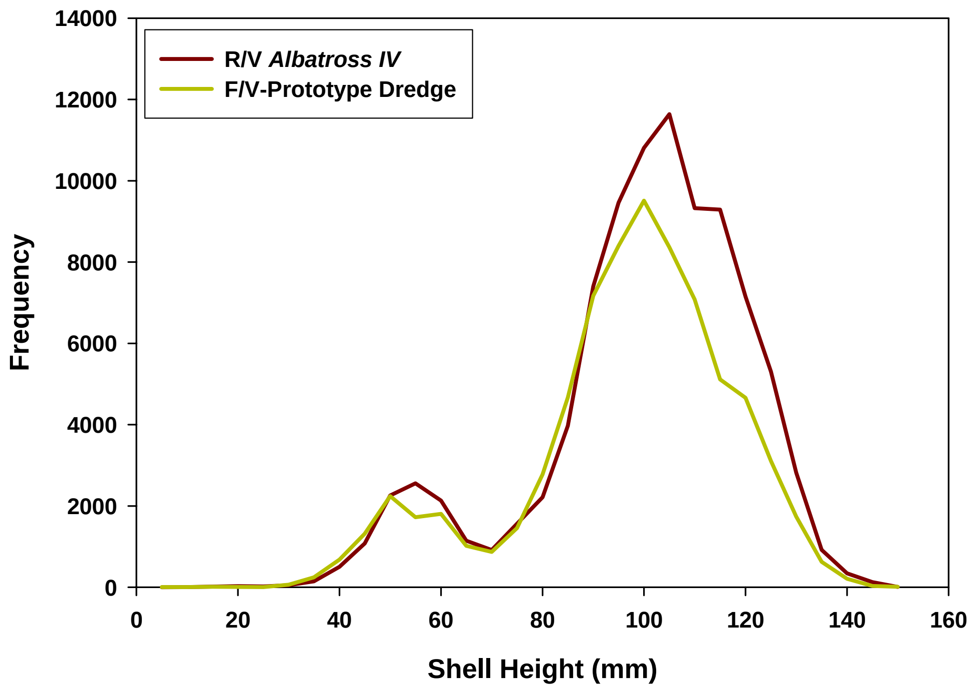


Figure 3 NMFS standard survey dredge

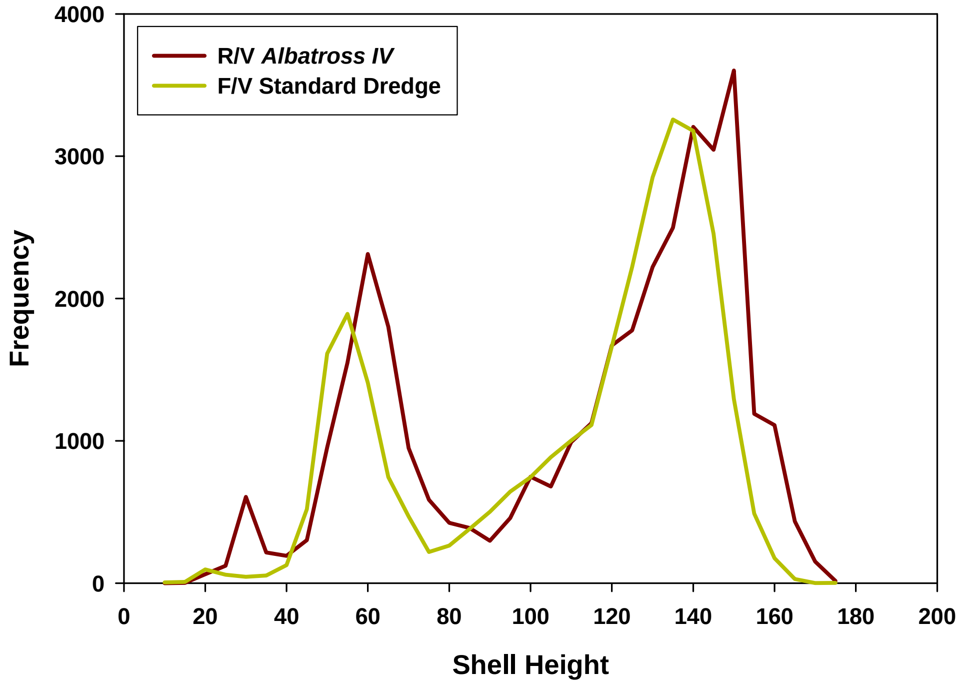
Figure 4 "Prototype" sea scallop survey dredge as developed by the Scallop Survey Advisory Panel (SSAP).

<u>Figure 5</u> Shell height frequencies for the catches aboard the R/V *Albatross IV* and the F/V *Nordic Pride*.





<u>Figure 6</u> Shell height frequencies for the catches aboard the R/V *Albatross IV* and the F/V *Celtic*.



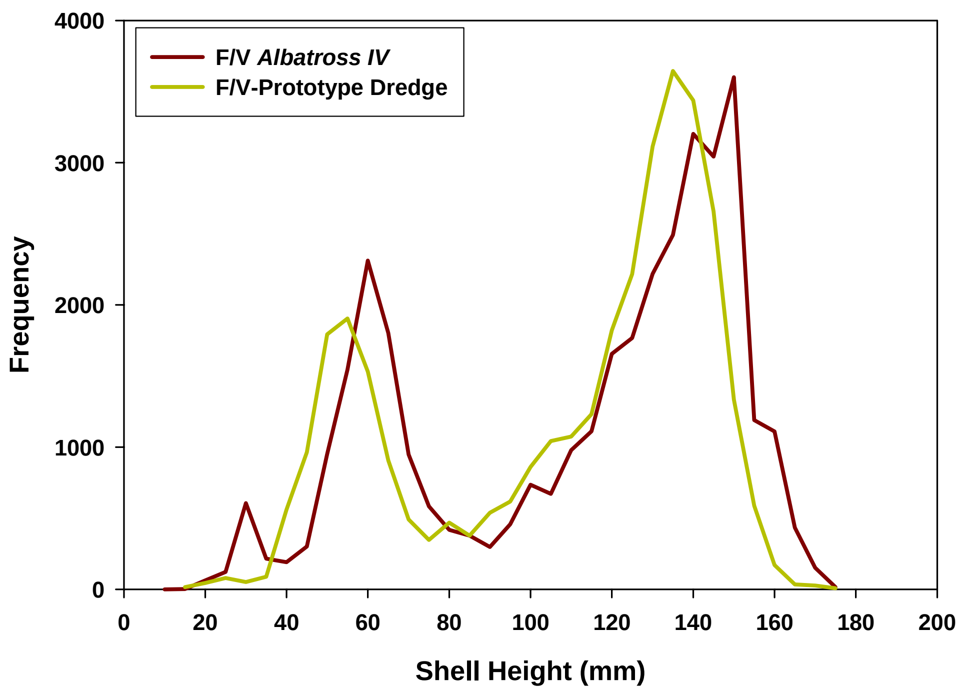


Figure 7 Proportion caught by the R/V *Albatross IV* relative to the F/V *Nordic Pride* using the NMFS standard dredge. For each paired tow, the proportion caught is defined as the $Catch_{Albatross}/(Catch_{Albatross} + Catch_{F/V})$. The horizontal line (.5) represents the level of catch where the two vessel/gear combinations fished equally.

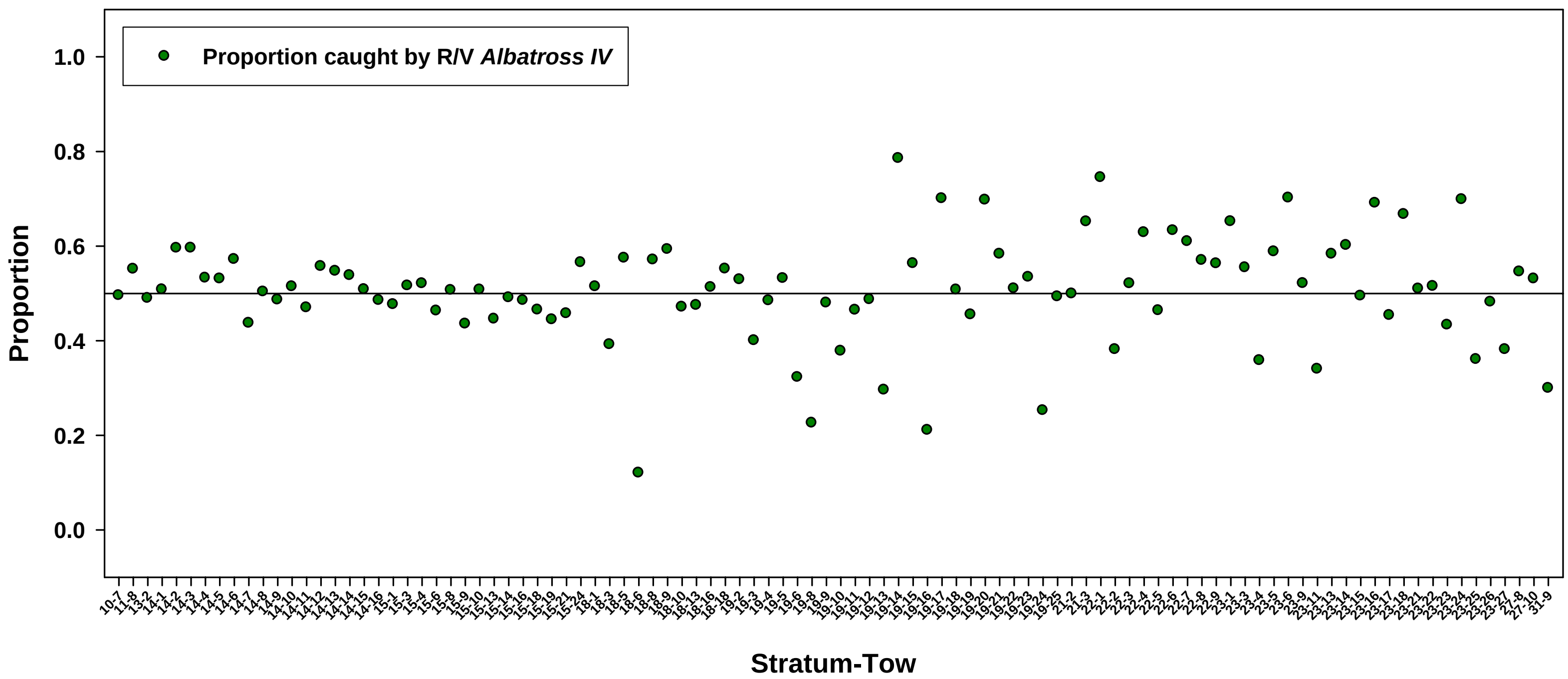


Figure 8 Sea scallop catch by comparative station by the R/V *Albatross IV* and the F/V *Nordic Pride* using the NMFS standard dredge.

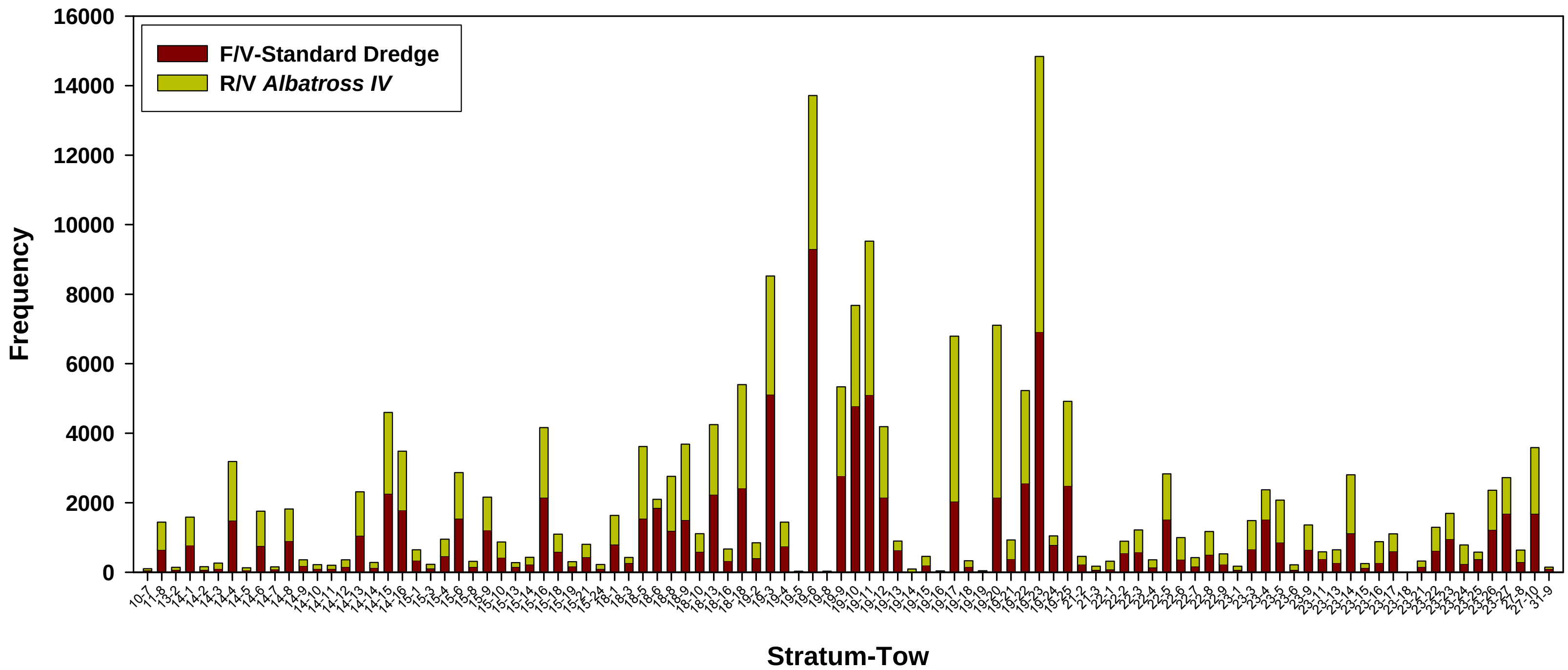


Figure 9 Proportion caught by the R/V *Albatross IV* relative to the F/V *Nordic Pride* using the prototype dredge. For each paired tow, the proportion caught is defined as the $Catch_{Albatross}/(Catch_{Albatross} + Catch_{F/V})$. The horizontal line (.5) represents the level of catch where the two vessel/gear combinations fished equally.

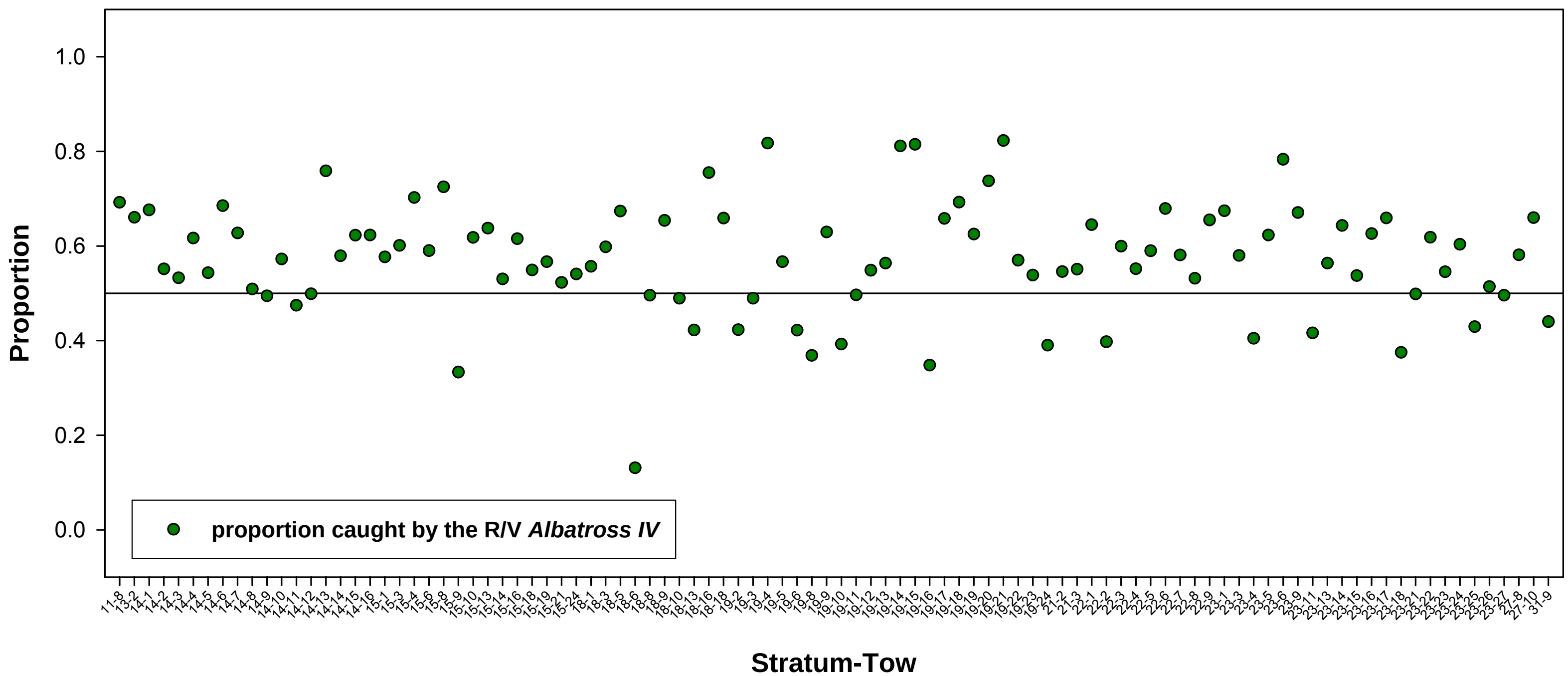


Figure 10 Sea scallop catch by comparative station by the R/V *Albatross IV* and the F/V *Nordic Pride* using the prototype dredge.

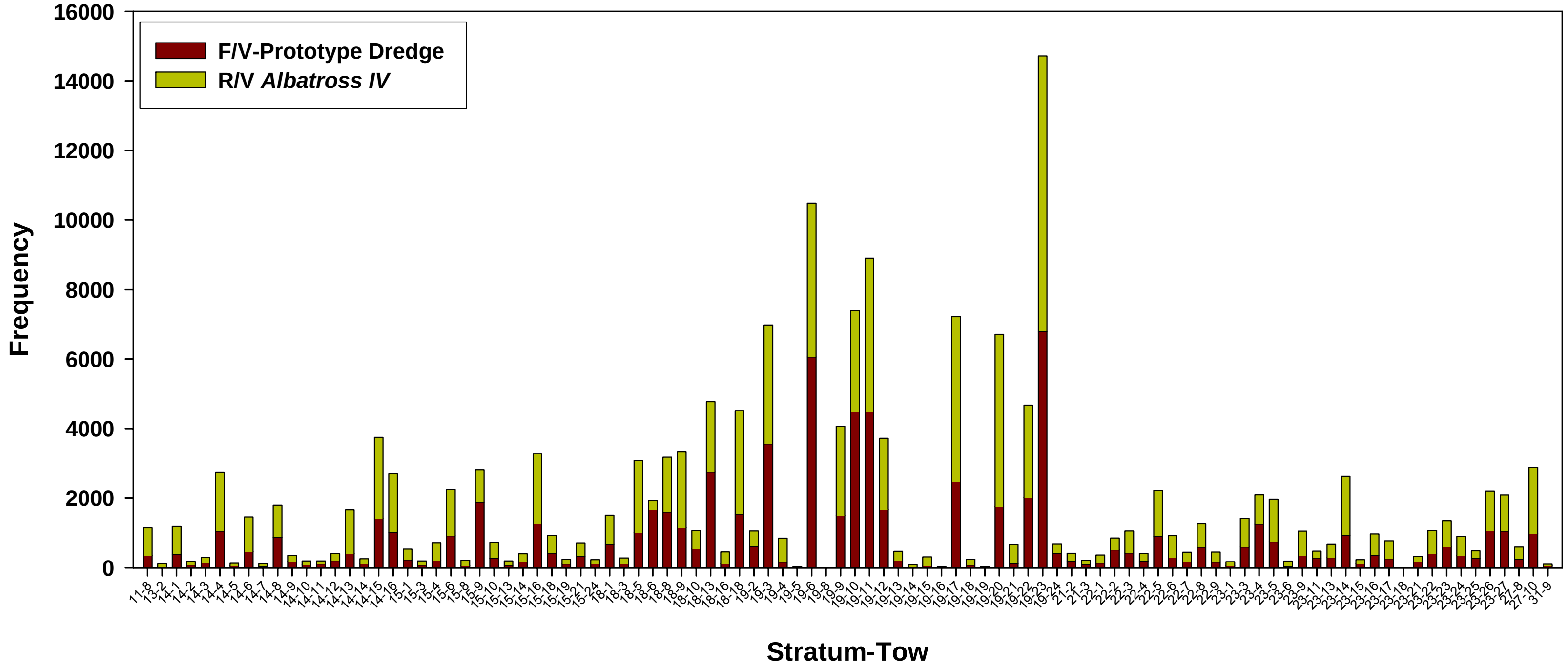
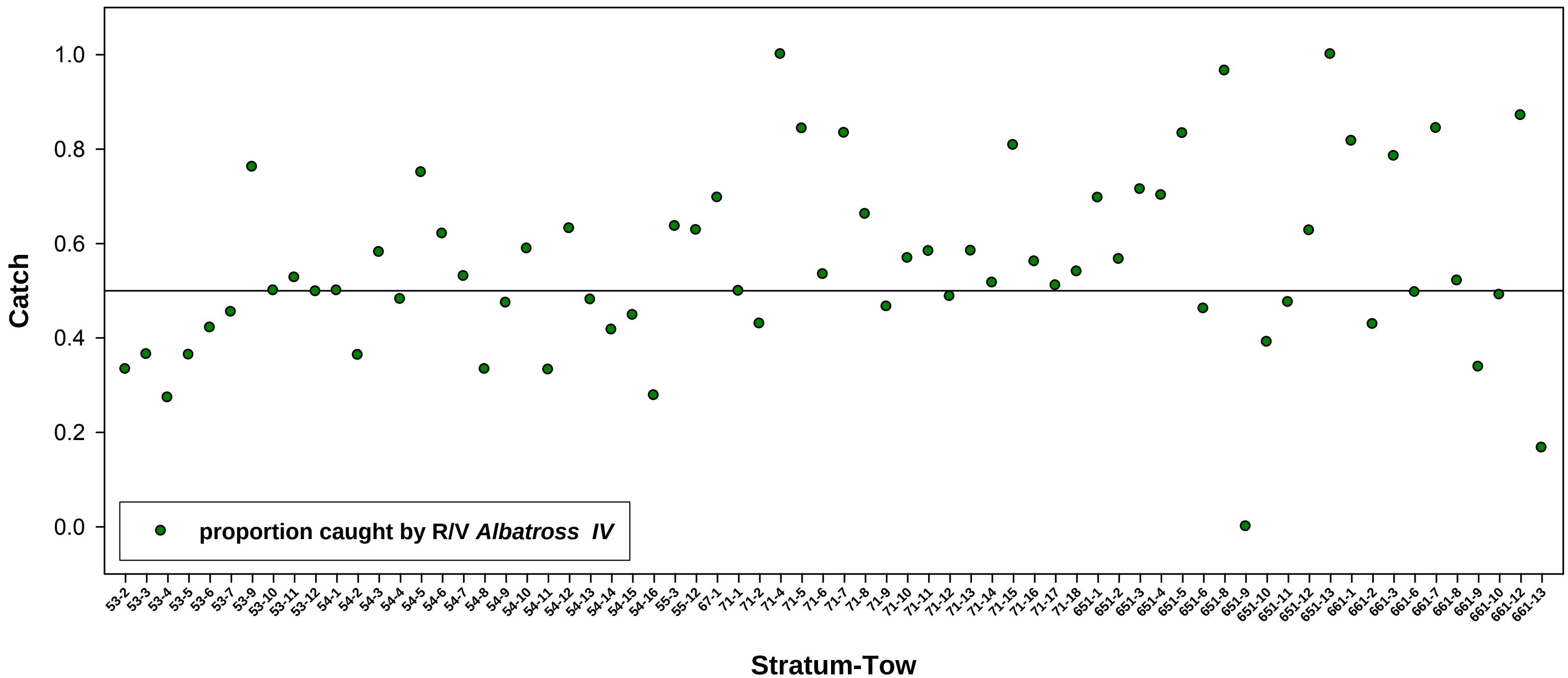
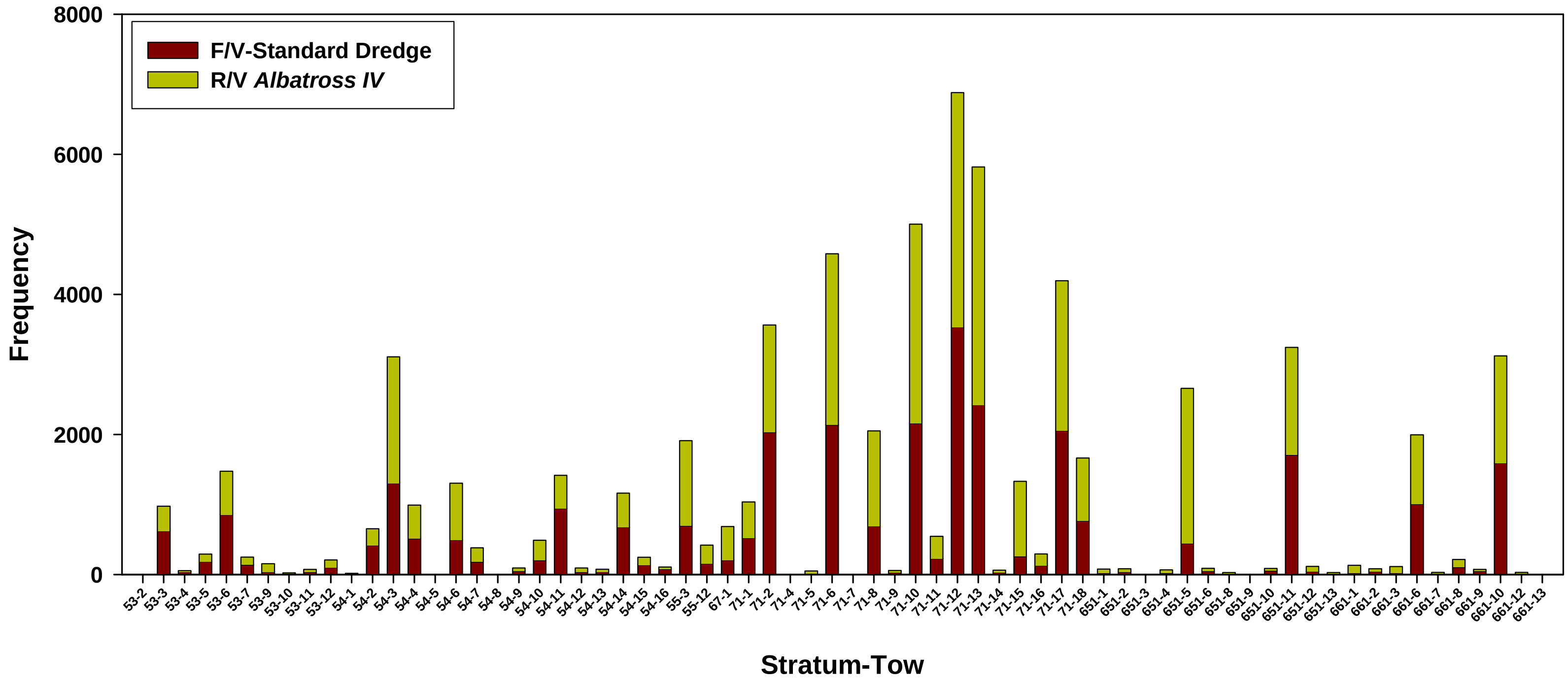


Figure 11 Proportion caught by the R/V *Albatross IV* relative to the F/V *Celtic* using the NMFS standard dredge. For each paired tow, the proportion caught is defined as the $Catch_{Albatross}/(Catch_{Albatross} + Catch_{F/V})$. The horizontal line (.5) represents the level of catch where the two vessel/gear combinations fished equally.



<u>Figure 12</u> Sea scallop catch by comparative station by the R/V *Albatross IV* and the F/V *Celtic* using the NMFS standard dredge.



<u>Figure 13</u> Proportion caught by the R/V *Albatross IV* relative to the F/V *Celtic* using the prototype dredge. For each paired tow, the proportion caught is defined as the $Catch_{Albatross}/(Catch_{Albatross} + Catch_{F/V})$. The horizontal line (.5) represents the level of catch where the two vessel/gear combinations fished equally.

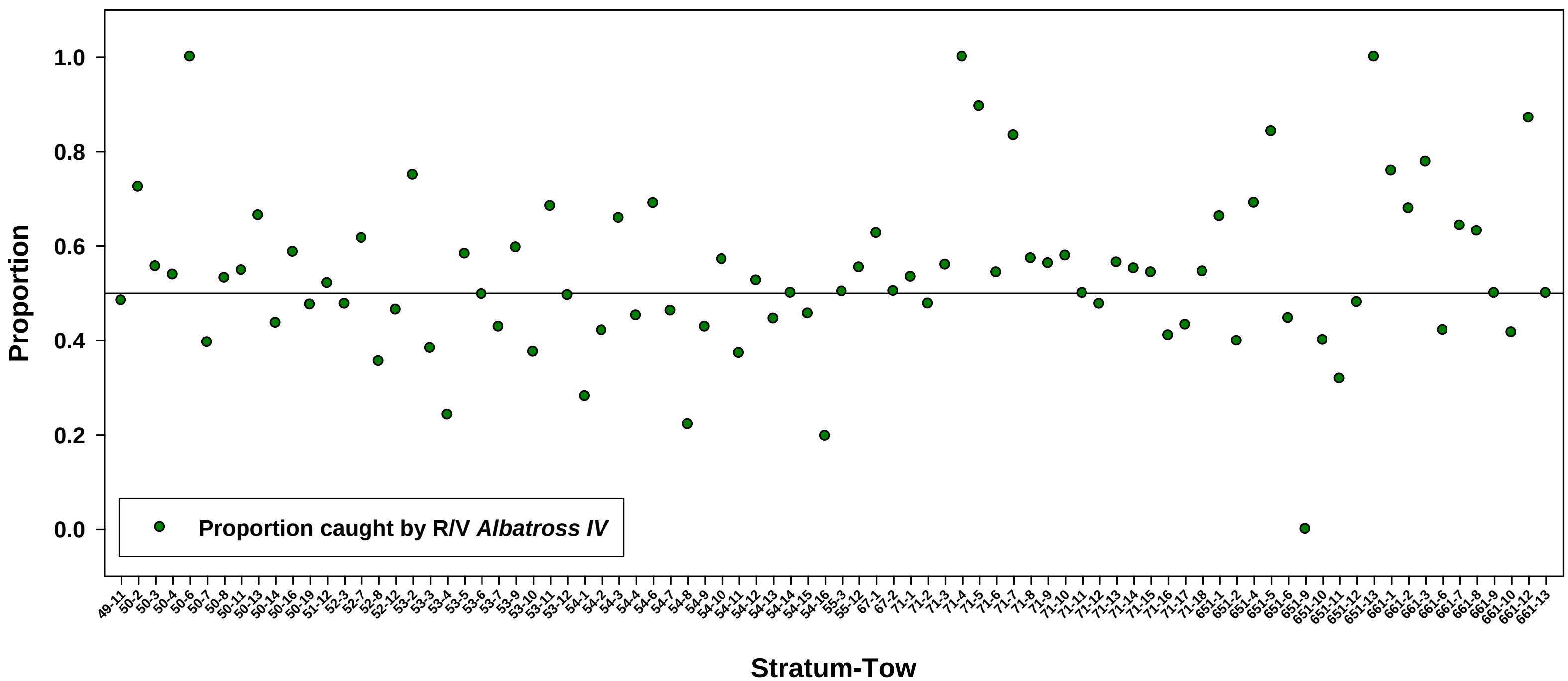
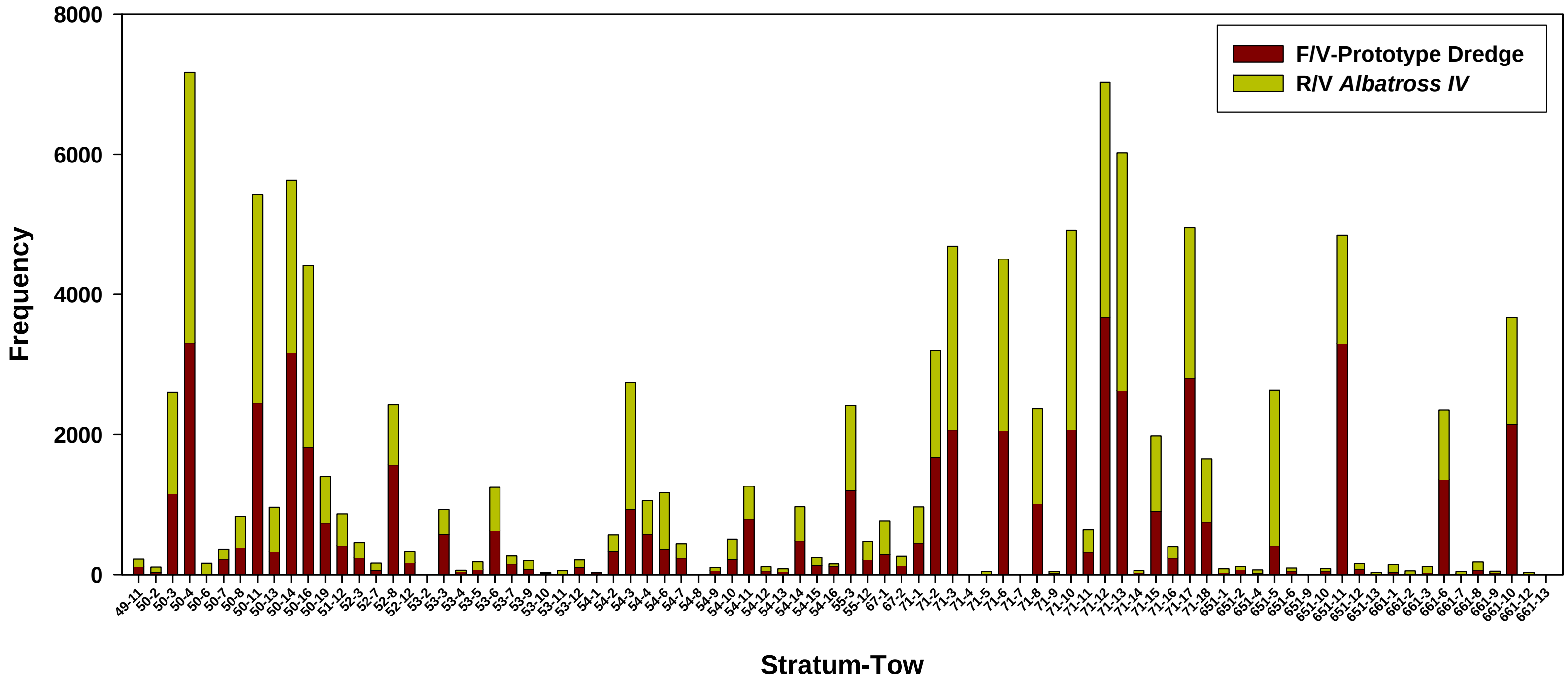


Figure 14 Sea scallop catch by comparative station by the R/V *Albatross IV* and the F/V *Celtic* using the prototype dredge.



Literature Cited

Cochran, W.G. 1977. Sampling techniques. Wiley, New York.

DuPaul, W.D., E.J. Heist, and J.E. Kirkley, 1989. Comparative analysis of sea scallop escapement/retention and resulting economic impacts. College of William & Mary, Virginia Institute of Marine Science, Gloucester Point, VA. VIMS Marine Resource Report 88-10. 70 pp.

Gunderson, D.R. 1993. Surveys of Fisheries Resources. John Wiley & Sons, Inc. New York, New York.

Helser, T.E., A. Punt and R. Methot. 2004. A generalized mixed model analysis of a multi-vessel fishery resource survey. Fisheries Research. **70**:251-264.

Hilborn, R., C.J Walters. 1992. Quantitative Fisheries Stock Assessment: Choice Dynamics and Unceratinty. Chapman & Hall, London.

Kappenman, R. F. 1992. Robust estimation of the ratio of scale parameters for positive random variables. Communications in Statistics. Part A: Theory and Methods. **21**:2983–2996.

Kimura, D.K. and D.A. Somerton. 2006. reviews of statistical aspects of survey sampling for marine fisheries. Reviews in Fishery Science. **14**:245-283.

Lewy, P., J.R. Nielsen and H. Hovgard. 2004. Survey gear calibration independent of spatial fish distribution. Canadian Journal of Fisheries and Aquatic Sciences, **61**: 636-647.

Munro, P.T. 1998. A decision rule based on the mean squared error for correcting relative fishing power differences in trawl survey data. Fishery Bulletin. **96**:538-546.

Pelletier, D. 1998. Intercalibration of research survey vessels in fisheries: A review and an application. Canadian Journal of Fisheries and Aquatic Sciences. **55**: 2672–2690.

Robson, D. S. 1966. Estimation of the relative fishing power of individual ships. International Commission for the Northwest Atlantic Fisheries, Research Bulletin. **3**:5–15.

Serchuk, F.M. and S.E. Wigley. 1986. Evaluation of USA and Canadian research vessel survey for sea scallops (*Placopecten magellanicus*) on Georges Bank. Journal of Northwest Atlantic Fisheries Science. **7**:1-13.

Sissenwine, M. P., and E.W. Bowman. 1978. An analysis of some factors affecting the catchability of fish by bottom trawls. International Commission for the Northwest Atlantic Fisheries, Research Bulletin. **13**: 81–87.

Tyson, J.T., T.B. Johnson, C.T. Knight, and M.T. Bur. 2006 Intercalibration of research survey vessels on Lake Erie. North American Journal of Fisheries Management. **26:**559-570.

von Szalay, P.G., and E. Brown. 2001. Trawl comparisons of fishing power differences and the applicability to National Marine Fisheries Service and Alaska Department of Fish and Game trawl survey gear. Alaska Fishery Research Bulletin. **8(2)**:85–95.

Wilderbuer, T. K., R. F. Kappenman, and D. R. Gunderson. 1998. Analysis of fishing power correction factor estimates from a trawl comparison experiment. North American Journal of Fisheries Management, **18**: 11–18.