APPENDIX A8. Stock Assessment for Ocean Quahog in Maine Waters

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Executive Summary

The Maine ocean quahog resource is a unique segment of the quahog stock in Federal waters. As of 1999 under Amendment 10 to the Fishery Management Plan (FMP) for Atlantic Surfclam and Ocean Quahog, Maine was given a separate annual quota of 100,000 "Maine" bushels (bushels used to record landings in Maine are 66% as large as bushels used to report landings in the rest of the EEZ). Fishing is carried out using a "dry" dredge (with no water jets to loosen sediments).

Maine quahogs, often referred to as "mahogany" clams are a substitute for *Mercinaria mercinaria* in the half shell market. Maine quahogs are harvested at a much smaller size (38-64 mm shell length) than MidAtlantic quahogs (89-140 mm shell length).

Landings peaked in Maine in 2002 at 147,191 bushels and have fallen since to a level of 98,153 bushels in 2005. During this time period paralytic shellfish poisoning (PSP) kept many productive beds closed.

The State of Maine conducted a pilot survey for ocean quahogs in 2002 which provided useful information on abundance and distribution along with estimates of key biological parameters. Results from the pilot study were used to plan and narrow the focus of the 2005 survey.

Lacking from the pilot study was an estimate of dredge efficiency which is required to estimate biomass and mortality rates from landings and survey data. Based on data from boxcore samples and "follow on" survey tows during 2005-2006, the efficiency of the commercial dredge used during the 2005 survey was 16.1%. In other words, 16.1% of relatively large (fully recruited) ocean quahogs in the path of the dredge are captured in each pass.

Based on survey density data and estimated dredge efficiency, the biomass of harvestable ocean quahogs during 2005 in the commercial fishing grounds (54 nm^2) surveyed off Maine is 22,493 mt meat weight. Based on the ratio of landings and biomass, the fishing mortality rate in the commercial fishing grounds surveyed off Maine is F=0.022 y^{-1}.

Biological reference points have not been established for the Maine segment of the ocean quahog stock. However, a per recruit model analysis with parameters for the Maine segment of the stock was used to estimate reference points that are often used in fishery management. Based on per recruit modeling, F_{max}=0.0561, $F_{0.1}$=0.0247 and $F_{50\%}$=0.013 y^{-1}.

$F_{0.1}$=0.0247 y^{-1} (corresponding to a harvest rate of 2.5% per year) might be a reasonable reference point for managers if the goal is to maximize yield per recruit while preserving some spawning stock. Simulation analysis (Clark 2002) indicates that $F_{50\%}$=0.013 (1.3% per year) might be a reasonable reference point for managers if the goal was to preserve enough spawning potential to maintain the resource in the long term. The estimated fishing mortality rate during 2005 F=0.022 y^{-1} is nearly equal to $F_{0.1}$=0.0247 y^{-1} and the assumed natural mortality rate M=0.02 y^{-1} but higher than $F_{50\%}$=0.013.

Survey size frequency distributions indicate differences in the size of quahogs between the "western" and "eastern" beds inside the commercial fishing grounds. Larger quahogs were found in eastern beds that had been closed to fishing for three year due to PSP.

Size frequency distributions from boxcores showed signs of recent settlement in the eastern bed (quahogs less than 5 mm SL). However size classes between 5 and 35 mm SL were entirely missing throughout the survey indicating that recruitment is sporadic. Although growth is relatively rapid in Maine waters, it may be 3 decades or longer before these recruits become large enough to enter the fishery.

Stock assessment advice concerning ocean quahog in Maine waters would be easier to provide if management goals were formulated and if biological reference points for biomass and fishing mortality were defined.

Introduction

The Maine fishery for Ocean quahogs, although harvesting the same species (*Artica islandica*), is persecuted in a different way and fills a different sector of the shellfish market than the rest of the EEZ fishery. The Maine "mahogany" quahog is harvested at a smaller size (38-64 mm or 1.5-2.5 in shell length, SL) than elsewhere in the EEZ fishery where ocean quahogs are harvested at 89-140 mm (3.5-5.5 in) SL.

Ocean quahog from Maine waters are marketed as a less expensive alternative for *Mercenaria mercinaria* (Maine DMR 2003). Harvesting takes place year round with the highest market demand during the summer holidays (Memorial Day through Labor Day). During this peak harvest period 30-40 out of a total of 57 license holders may land some volume of product.

The majority of the vessels in the Maine fleet are between 10.7-13.7 m (35-45 ft) and classified as "undertonnage" or "small" in issuing permits. All of the vessels use a "dry" dredge (with no hydraulic jets to loosen the sediments) with a cutter bar set by regulation at no more than 0.91 m (36 in). There are no restrictions on any other dimension of the dredge.

Quahog Fishing in Maine takes place in relatively few locations along the coast north of 43 degree 50 minute latitude (Figure 1). Historically the bulk of fishing activity has taken place between Mt. Desert Rock and Cross Island with two significant quahog beds south of Addison and Great Wass Island covering an area of approximately 60 square nautical miles.

The Maine fishery began to expand into Federal waters in the 1980's due in part to PSP closures within state waters. In 1990 it was determined that this fishing activity conflicted with the Magnuson-Stevens Fishery Management Conservation Act which calls for a stock to be managed as a unit throughout its range. The Maine fishery was granted "experimental" status from 1990-1997. In 1998, the Maine fishery was fully incorporated under Amendment 10 of the FMP and given an initial annual quota of 100,000 bushels based on historical landings data. There was no independent assessment of the resource available at that time. The State of Maine is responsible under Amendent 10 to certify harvest areas free of PSP and to conduct stock assessments.

In 2002 the State of Maine conducted a pilot survey to assess the distribution and abundance of quahogs along the Maine coast (MEDMR 2003[27]). This survey was a critical first step in establishing distribution, size composition and relative abundance information for the Maine fishery and for directing the design of the current survey work. While this initial survey provided valuable

[27] Available with assessment for reviewer's convenience.

information it did not have the resources to estimate dredge efficiency and therefore was not able to estimate total biomass or biological reference points. The survey during 2005 focused effort on two issues: determining dredge efficiency, and mapping quahog densities in the region of highest commercial activity.

Estimates of biomass and mortality presented in this report are only for the commercial beds south of Addison and Jonesport/GreatWass Maine. This approach was chosen due to available resources and because it was conservative. Other quahog beds are known to exist along many parts of the Maine coast. If mortality targets could be met using the estimates from the primary fishing grounds then biomass outside the survey area can act as a *defacto* preserve.

Fishery Data

Data throughout this report is presented in metric units. In some cases there are specialized terms and conversion factors which are listed below.

"MidAtlantic" bushels of Ocean Quahogs x 10	=	lbs meat.
"MidAtlantic" bushels of ocean quahogs x 4.5359	=	kg meat
1 "MidAtlantic" (= "industry") bushel	=	1.88cubic feet
1 "Maine" (= "US Standard") bushel	=	1.2448 cubic feet
"Undertonnage" vessel	=	1-4.9 GRT
"Small" vessel	=	5-49.9 GRT
1 "Maine" bushel	=	0.0049 mt meat weight

In 2005 there were 57 ocean quahog licenses in the State of Maine. Of these 57 licenses 30 reported landings. The number of active licenses has decreased each year since 2002 when 38 licenses had reported fishing activity.

Landings have also decreased steadily since 2002 when they were at a recorded high of 147,191 Maine bushels (TableZ 1). Landings for 2005 were 98,153 Maine bushels. LPUE in recent years tracked downward with landings until the 2005 season when it showed a slight increase from 5.37 to 5.85 Maine bushels per hour towing (Figure 2). This increase may be an artifact of the open and closed status of parts of the main commercial beds due to PSP because the most productive quahog bed was reopened at the end of 2005 after a 3 year closure.

Incidental mortality in ocean quahog off Maine is an important topic for future research. Maine has a very high level of fishing activity relative to the size of the fleet. Approximately 16,766 hours of fishing took place during 2005 representing over 67,000 tows at 8 min per tow. Using standard industry dredge dimensions and tow speeds this level of fishing activity represents 28.68 nautical miles^2 of bottom swept by commercial dredges.

All catches are tagged and vessel logbooks are submitted to track quota status. Marine Patrol has not had enough resources to check the validity of logbook entry or to confirm the vessels on purchased quota are reporting accurately.

Research Surveys

With the limited funds dedicated for survey work on quahogs, it was decided to focus all of the 2005 survey effort on the primary commercial fishing grounds south of Addison and Great Wass. This decision is important in the interpretation of all following data as results because estimates pertain only to these two beds and not to the coast of Maine as a whole. Vessel logbooks and the 2002 independent survey abundance indices show that the majority of fishing activity and a sizable portion of the resource was in this region (Figure 3).

The first step in designing the survey was to establish a 1 km^2 grid overlay using Arcveiw 3.2 over the known commercial beds. Based on number of days at sea, 260 sites (tows) could be completed. The centers of the 260 1 km^2 grids covering the commercial beds were selected as start points for survey tows (Figure 4). These points were transferred to The Cap'n Voyager Software for use on board the survey vessel.

The Quahog bed south of Addison, (referred to as "western") had been the only open fishing grounds for 3 years due to PSP issues in other beds. The quahog bed south of Great Wass Island, (referred to as "eastern") had been unfished for 3 years but had previously been one of the most productive fishing grounds.

Survey gear and procedures

The commercial vessel F/V Promise Land is a 12.8 m (42 ft) Novi Style dragger piloted by Capt. Michael Danforth that was contracted to perform all the survey drag operations. All survey tows were conducted using the same dredge with dimensions: cutter bar 0.91 m (36 in), 2.44 m (8 ft) long x 1.83 m (6 ft) wide x 1.22 m (4 ft) high, overall weight 1,361 kg (3,000 lbs), bar spacing all grills 19.05 mm (¾ in) (Figure 5). The survey dredge was the same dredge used by the F/V Promise Land during normal fishing activity.

As the vessel approached the start of a tow, bottom type and the feasibility of conducting a tow were assessed. If suitable bottom was not immediately present at the predetermined start point, the vessel would start crossing runs within the grid. If after 5 to 6 crosses no towable bottom or a tow path free of fixed lobster gear could not be found, then the grid location was deemed untowable, a note was made, and the captain continued on to the next site. When a suitable tow path was found within a grid the dredge was lowered to the bottom by free-spooling until the ratio of cable length to depth was 3:1. Once the desired cable length was reached the drum was locked, a two minute timer was started and a GPS point was taken.

Tows were made into the current at approximately 6.48 km/hr (3.5 knots) speed over ground (average tow 214 m). After two minutes elapsed, a second GPS point was taken and the dredge was brought to the surface.

Tow distances calculated using the start and stop GPS points are good estimates of the distance actually traveled by the dredge. The manner in which the dredge is set and retrieved does not create a situation in which the dredge continues to fish as it is retrieved or before the drum is locked. In particular, the weight of the dredge keeps it in place on the bottom when the drum is unlocked at the end of the tow. In addition, the practice of backing the vessel toward the stopping point at the end of each tow means that the dredge was unlikely to travel very far at the end of the tow as it is lifted into the water column.

After the dredge was retrieved and before it was brought on board the vessel, excess mud was cleaned from the dredge by steaming in tight circles with the dredge in the vessel's prop wash (Figure 6). Once on board, the dredge was emptied and photographed with a digital camera (Figure 7). The contents were placed on a shaker table (Figure 8), bycatch was noted and then all live quahogs were sorted out from the catch. From each tow a 5 L subsample of quahogs was taken at random (the entire catch was taken if catch was less than 5 L). The subsample was used to estimate tow counts, volume, and size frequency of the catch. The remainder of the catch was placed in calibrated buckets to determine total catch volume.

All data collected on board during operations were entered into a Juniper Systems handheld Allegro field computer running Data Plus Professional Software. All GPS data were collected using a pair of Garmin Etrex handheld units and transmitted in real time to the Allegro and a laptop running Cap'n Voyager Software. Data entry screens on the Allegro for the abundance survey consisted of: 1) trip information (date, time out, weather, sea state, time in, and comments); 2) site information (depth, bottom type, start tow GPS position, speed, end tow GPS position, and comments); 3) catch information (sample portion 5 L or all, volume, weight, count, photo id, size frequency 5 L or all, and comments); and 4) bycatch information (species, abundance).

The lengths (longest dimension) of all subsampled quahogs were measured to the nearest 0.01 mm and entered into the Allegro handheld using a Fowler Ultra-Cal IV digital caliper with an RS232 port. Estimated counts of quahogs were made by counting the number of clams in the 5 L sample and then expanding that value using the total volume of the catch. All data were analyzed using Excel with variances calculated using a bootstrap program (10,000 iterations) written by Dr. Yong Chen at the University of Maine, Orono.

Tow distances were determined by The Cap'n Software and were checked using ESRI ArcInfo software. All data from the tows were standardized to a 200 m tow prior to further analysis.

Dredge efficiency

The Maine dry dredge is much less efficient (2-17%, ME DMR 2003) than hydraulic dredges used in the rest of the EEZ which can be up to 95% efficient (Medcolf and Caddy, 1971). A reliable estimate of dredge efficiency is needed to convert survey densities to a biomass estimate (NEFSC 2004).

One method of estimating dredge efficiency is through depletion experiments which are used to measure survey dredge efficiency for NEFSC clam surveys in Federal waters. Depletion studies for ocean quahog involve sensor and data processing equipment that were not readily available. The dry dredge used in the Maine survey is relatively small compared to the depth of fishing. We hypothesized that it would be difficult to control the dredge precisely given the depth, size of dredge and strong currents in the region off Maine.

For the conditions off Maine is was determined that the best approach to estimating dredge efficiency would be through the use of a boxcore samples (to directly estimate quahog density) followed by survey tows in the same area. Considering only ocean quahog available to the fishery, the ratio of density measured by "follow on" dredge tows divided by boxcore density is an estimate of survey dredge efficiency (Thorarinsdottir and Jacobson 2005).

The *F/V Promise Land* with its large A frame and winches was able to deploy the 544 kg (1,200 lb) Ocean Instruments 610 boxcore with a core capacity of 0.062 m^2 and maximum penetration up to 60 cm (Figure 9). Follow on tows were conducted using the same gear used during all previous portions of the survey.

Boxcore work was conducted at three locations during three separate trips, one in August of 2005, one in January of 2006 and the last in April 2006. In all three experiments, follow on survey tows were made the day after the cores had been taken. The locations sampled were in the eastern quahog bed in an area of relatively high abundance (Figure 10). This area was also selected because it was a closed fishing ground during the August 2005 trip which would eliminate the possibility of the boxcore sites being commercially towed before follow on tows could be made. In January and April 2006 the region had been reopened to commercial fishing. However, VHF radio announcements describing the type of work underway were broadcast to local fisherman who were very cooperative and stayed well away from the experimental areas until all follow on tows could be completed the next day. Data entered into the Juniper Systems Allegro field computer included information about: 1) the trip (date, start tow, end tow), core (core #, core length, count, volume, weight, count of newly settled).

Each experiment began by establishing a single long towpath. To do this, the vessel was slowed to the standard tow speed of 3.5 kts and a GPS point was taken and plotted. After 2 min steaming along a fixed heading, a second GPS point was taken and plotted. These waypoints determined the endpoints for the follow on commercial tows and the path for boxcore sampling. Cores were then taken haphazardly along the tow path (60 for the August 2005 trip, 34 on the January 2006 trip and 30 on the April 2006 trip).

Once a core was brought on board it was measured for overall length and sieved through a large screen (1cm^2 mesh size). All quahogs were counted and their total volume and weight were measured.

During coring operations, it was noted that the upper 1-2 cm of very soft sediment contained recently settled quahogs (< 5mm length). The number of quahogs in this size range were recorded separately for all further cores and newly settled quahogs were retained to be preserved. During the January and April 2006 trips the top 5 cm of each core was removed and washed separately through a 300 µ sieve and all quahogs <5mm SL were preserved.

It was noted during boxcore sampling during the August 2005 boxcore trip that there was a change in sediment type beginning around 12-15 cm from the surface of each core. At this transition the sediment turned to a matrix of solid clay and old quahog shell. None of the live quahogs found in the cores in 2005 were below this transition. To assess this, the maximum depth within the core of live quahogs was measured during the 2006 trips.

After the maximum number of cores had been completed for a given trip the commercial dredge was deployed at one of the endpoints of the established tow path. Standard commercial towing was conducted for 2 min along the same path as the cores had been taken allowing the dredge to tow from one endpoint to the next. After each round of coring, 6 tows were made along the same path, three in one direction and 3 opposing to help mitigate any effect from tide.

Dredge survey results

A total of 259 1km 2 survey grids were selected for sampling (TableZ2). Out of the 259 there were 183 (121 in the western bed and 62 in the eastern bed) or 70.7% that were towable. Only two stations were untowable due to fixed lobster gear or other known obstructions. The remainder of the untowable sites were due to inappropriate substrate.

Calculations of fishable area were reduced by the area of the sites that were untowable. Total biomass calculations are based only on the towable area (183 km^2). The site that had a known obstruction was not included as it is not fished by area harvesters because of the risk to their gear and the site with lobster gear was not included based on personal comments from Capt. Mike Danforth that it was an area of hard untowable substrate. Tow distance, catch volume and counts were all standardized to a 200m tow. Actual tow distances averaged 214 m.

The density plot for the survey (Figure 11) shows the highest concentration of biomass in the eastern bed. The eastern section had been closed to quahog fishing for almost three years. Substrate data (Figure 12) from Kelly et al. (1998) show the complexity of the substrate in the eastern section with highest quahog densities found near the boundary of hard rocky substrate with gravels, sands or mud. Substrate data collected independently using sidescan imaging showed that Kelly et al.'s (1998) substrate information was relatively accurate. However, in some cases substrate labeled as "sand" or "gravel-sand mix" near our most productive tows may have been shell hash from old quahog beds that was seen in boxcores from the same area.

Size frequencies for all subsampled quahogs (n=20,737) taken during the survey are shown in Figure 13. Size frequencies were also plotted separately for quahogs sampled from the western and eastern beds (Figure 14). The western bed had a mean SL of 47.6 mm ± 4.6 mm and the eastern bed had a mean SL of 52.4 mm ± 5.1 mm. Cumulative size frequency distributions and a Kolmogorov-Smirnov test were used to test the null hypothesis that the size frequency distributions in the eastern and western areas were the same (Zar 1999). The null hypothesis was rejected ($p=0.001$)

Because the two beds have differing size compositions and abundance levels, it was decided to calculate abundance for the two beds separately before estimating combined abundance for the entire survey area. Abundance estimates (see below) assume a dredge efficiency of 0.161 (Table Z3 shows effects of different dredge efficiencies on abundance and bushel estimates).

To estimate the total biomass for the commercial fishing grounds the size frequency distributions were converted to proportion of the population in each 1 mm size bin. Shell length (*L*) was converted to meat wet weight (*W*) using $W=4.97\text{x}10\text{-}6 \text{ x } L^{3.5696}$ (Maine DMR 2003). Meat weights were converted to total biomass (meats and shells) by applying the average meat yield from the pilot survey of 17.5% and combining the values for the separate beds.

Variable	**Bed**	**Estimate**	**CV**
Abundance	Western	1.7108×10^9	8%
	Eastern	2.4058×10^9	11%
	Total	4.1163×10^9	8%
Bushels	Western	1.715×10^6	9%
	Eastern	2.787×10^6	11%
	Total	4.502×10^6	9%
Total Biomass (mt)	Western	47,704	8%
	Eastern	94,977	13%
	Total	128,529	7%
Meat Weight (mt)	Western	8,348	8%
	Eastern	16,621	11%
	Total	22,493	8%

Box core results

Efficiency estimates from box core experiments are presented based on sizes taken in the commercial fishery (35mm SL and greater). The estimated dredge efficiency was 16.1% with a 95% bootstrap confidence interval of 11.4%-21.6%.

Another important result from the boxcore work was that the average depth of live quahogs in the region sampled was no deeper than 9.55 cm (CV 20%)._The standard commercial dry dredge has cutting teeth that are set to a depth of 7.62cm. We did not see evidence of anaerobic quahogs located deep in the sediments as has been reported elsewhere (Chenowith and Dennison,1993; Taylor 1976). Based on these results, it would seem that the majority of quahogs in this region would be impacted after one pass of a dredge.

Per recruit modeling

Biological and fishery parameters from a variety of sources were used to carry out a per recruit analysis for ocean quahog in Maine waters. Age at length and growth information was taken from Kraus et al. (1992). Von Bertalanffy growth parameters estimated from a sample of 663 quahogs from Machias Bay were: $L_{inf} = 59.470 \pm 2.089$, $K = 0.055 \pm 0.006$, and $t_o = -0.235 \pm 0.483$. The growth curves from Maine indicate relatively fast growth the first few years of life in comparison to curves for other areas (Figure 19). Length-weight parameters were from the 2002 Maine Quahog survey: $W = 4.97 \times 10^{-6} * L^{3.5696}$. Length-weight curves for the Maine ocean quahogs and the rest of the EEZ stock were similar (Figure 20). Size at maturity data estimates were based on Rowell et al. (1990) who found that females became fully mature at an average size of 49.2mm for a quahog stock in Nova Scotia, Canada.

Fishery selectivity was modeled as a linear ramp function that was zero at 37 mm SL and one at 47mm. Following surveys, quahog of various sizes were pushed through the grates on the commercial dredge (19.05 mm, 3/4 in. bar spacing) to see what sizes might be retained. Clams from 34mm to 38mm generally passed through the grate with some getting caught. After 41mm almost all clams were thick enough to be retained. The regression model for shell depth and shell length in Feindel (2003) shows that a 19.05 mm (¾ in) bar spacing is the thickness of an ocean quahog with 38.7 mm SL.

The per recruit model used in this analysis was a length based approach which can be downloaded from the Northeast Fisheries Science Center as part of the NMFS Stock Assessment Toolbox.[28] The length based per recruit model was also used by Thorarinsdottir and Jacobson (2005). The biological reference points estimated in per recruit modeling for ocean quahog were F_{max} =0.0561, $F_{0.1}$=0.0247 and $F_{50\%}$ =0.013 y^{-1} (Figure 18).

Sensitivity analysis (Figure 21) shows biological reference points from the per recruit model for ocean quahog are most sensitive to fishery selectivity parameters and, in particular, the length at which ocean quahogs in Maine waters become fully recruited to the fishery.

Fishing mortality rate

For this report fishing mortality is estimated as the catch in biomass/average biomass^{-1}. The survey during 2005 took place over a period of two months and mortality rates are relatively low so that survey biomass is a good proxy for average biomass. Following NEFSC (2004), the catch for 2005 used in fishing mortality estimation was landings plus a 5% allowance for incidental mortality to account for clams that are killed during fishing activity but not harvested. Catch including the 5% incidental mortality allowance for 2005 was 505 mt and the biomass estimate was 22,493 mt giving F=505÷22,493 = 0.022 y^{-1}. Thus, the estimated fishing mortality rate is roughly equal to $F_{0.1}$ but higher than $F_{50\%}$.

Stock Status

Ocean quahog biomass in Maine waters was 22,493 mt meat weight and 2.7 million mt meat weight for the EEZ stock as a whole during 2005. It is not necessary to evaluate stock status of ocean quahog in Maine waters relative overfishing definitions because the stock component off Maine is a relatively small part of the EEZ stock as a whole. Overfishing definitions apply to the EEZ stock as a whole.

It was not possible to evaluate current biomass levels relative to a biological reference points associated with maximum productivity, depleted stock or historical levels because no appropriate biological reference points or historical biomass estimates are available.

The fishing mortality rate during 2005 F=0.022 $y^{-1}$was almost equal to $F_{0.1}$=0.0247 and the assumed natural mortality rate M=0.02 y^{-1} but almost double $F_{50\%}$ =0.013 y^{-1}. $F_{0.1}$ might be a

[28] Contact Alan.Seaver@noaa.gov for information about the NMFS Stock Assessment Toolbox.

reasonable reference point for managers if the goal is to maximize yield per recruit while preserving some spawning stock. Simulation analysis (Clark 2002) indicates that $F_{50\%}$ (1.3% per year) might be a reasonable reference point for managers if the goal was to preserve enough spawning potential to maintain the resource in the long term. However, preservation of spawning potential may not be necessary if recruitment originates mostly outside of Maine waters.

There is evidence of recent recruitment (newly settled ocean quahog < 5 mm SL) in one of the beds that were surveyed. However, although growth is relatively rapid in Maine waters, it may be 3 decades or longer before these recruits become large enough to enter the fishery.

Stock assessment advice concerning ocean quahog in Maine waters would be easier to provide if management goals were formulated and if biological reference points for biomass and fishing mortality were defined.

Research Recommendations

1. Impact on habitat and substrate should be investigated for the Maine Dredge along with good estimates of area swept by fishing activity,
2. More work needs to be done to determine age, growth rates and size/age at maturity for Maine ocean quahogs. New digitized methods may help in this process.
3. Need better estimates of gear selectivity.

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**Maine Ocean Quahog Report -- Appendix - **Paired Tows Experiment

Survey design

The current (2005) survey for ocean quahogs was conducted using a substantially larger vessel (F/V Promise Land 12.8m) and drag than the 2002 survey vessel the F/V Whitney and Ashley (11m). In order to link the data from the 2002 pilot survey with the 2005 survey we needed a correction factor between the two vessels and drags. One concern with the pilot survey from industry members had been that the drag on the Ashley and Whitney was to light to get a good sample of the quahogs on bottom and would tend to underestimate abundance. The State of Maine contracted the original vessel, captain and drag to conduct side by side tows with the current survey vessel on April 16, 2005. It was determined that the two vessels would steam to an area in the closed fishing grounds that had a relatively high abundance of quahogs and conduct 8 coordinated close side by side tows in three replicate areas, 24 tows in all.

Survey gear

Each vessel was equipped with the same survey gear as had been used during their respective trips. Once a suitable tow path had been established both vessels in unison deployed there dredges and let out equal lengths of cable (Figure 22). The captain of the F/V Promise Land was responsible for setting the pace and path of towing and for radioing the precise start and stop times for a tow. Tow positions were recorded onboard the F/V Promise Land. Once both dredges had been recovered and washed in the vessel wake all live quahogs were removed and placed in graduated containers to determine total volume. Either a 5L subsample or the entire catch, which ever was greater, was taken for count estimates and size frequency measurements.

Data collection

Both vessels were equipped with a Allegro handheld field computer and data was entered under the categories: trip information (date, vessel, weather, sea state), tow information (tow number, depth, bottom type, start tow gps, speed, end tow gps, weight 5L, count 5L, estimated total count), size information (length). All tow locations were also entered into the Cap'n Voyager software. All data was analyzed in Excel and bootstrapped using Dr. Chen's program.

Paired tows results

Results from the side by side tows indicate a 2.5:1 ratio between the F/V Promise Land and the F/V Whitney and Ashley. The data collected from the tows was bootstrapped 10,000 times to estimate the standard error and 95% CI (Figure 23) Mean number per tow from the F/V Promise land was 1452 (CV 14%). Mean number per tow from F/V Whitney and Ashley was 583 (CV 13%).

The size frequency distribution from quahogs collected from subsamples during the tows (Figure 24) indicates a difference in selectivity between the two drags. A K/S test run on cumulative fractions shows a difference in the two distributions at the 0.02 level (Figure 25). The square mesh liner in the dredge on the F/V Whitney and Ashley was 19.05mm on a side while the bar spacing on the F/V Promise Land is 19.05mm. The smallest quahog present in both dredges subsamples is only 1 mm different at 35mm and 36mm SL respectively. Bar spacing may play a role in the selectivity difference since a square grid would have many more intersections to trap smaller animals or increase the likelihood of clogging the dredge with mud.

The size frequencies not only show that the lighter drag on the F/V Whitney and Ashley retained smaller quahogs it did not sample larger quahogs present in the area. This effect would not be caused by smaller openings but is an indication that the dredge may under sample larger quahogs. If smaller quahogs need to be closer to the surface because of siphon length or substrate availability than the lighter drag on the F/V Whitney and Ashley would have a bias to select a smaller quahog than a heavier dredge that can cut deeper into the substrate. Also the tow speeds set by the F/V Promise Land were faster than those regularly used by the F/V Whitney and Ashley. The lighter drag may not have been as effective at the slightly higher speeds used in the paired towing. The 2002 survey had two types of tows. Those conducted randomly through out the State and those done systematically based on distance from reported commercial catches. The systematic survey may be biased towards heavy catch areas so only the random sites that overlap the 2005 survey area were used for this rough comparison. Area biomass estimates from the 2002 pilot study are based on 25 completed tows.

The current estimate for the region which overlaps many of the same stations is based on 183 completed tows at a much finer scale. This may partly explain the differences between the two estimates. Also three years of fishing has taken place since the initial survey in which nearly 467,000 Maine bushels have been landed from the same region.

The updated 2002 estimate for the current survey area is 5.99 x 10^6 bushels with a 95%CI within 47% of the mean. The estimate from the 2005 survey is 4.502 x 10^6 bushels with a 95%CI within 25.4% of the mean.

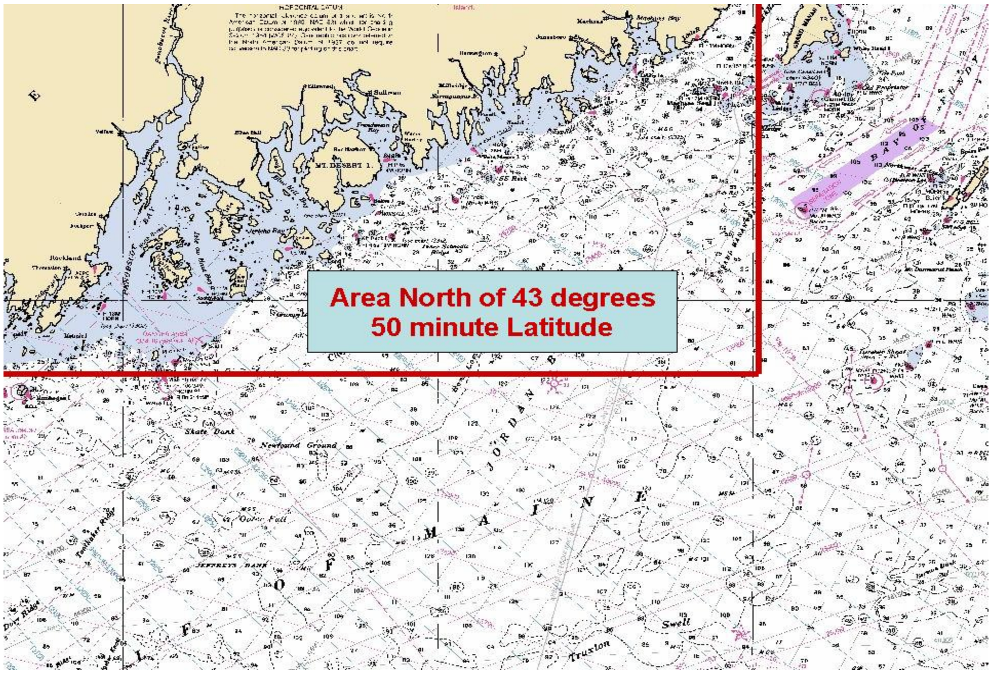
Year	Landings(Maine bushels) all vessel classes combined	Landings (only records with both effort and catch>0)	Effort (hrs fished)	Nominal LPUE (ME bushel/hr)
1990	1018	1018	286	3.56
1991	36679	34360	17163	2.00
1992	24839	24519	13469	1.82
1993	17144	17144	5748	2.98
1994	21672	21672	5106	4.24
1995	37912	37912	5747	6.60
1996	47025	47025	8483	5.54
1997	72706	72706	11829	6.15
1998	72466	72152	11745	6.14
1999	93015	92285	11151	8.28
2000	121274	119103	12739	9.35
2001	110272	110272	13511	8.16
2002	147191	147191	19681	7.48
2003	119675	119675	17853	6.70
2004	102187	102187	19022	5.37
2005	98153	98153	16766	5.85

Appendix A8. Table 1. Landings data for 1990-2005 from vessel logbooks. LPUE is reported for those records with both catch and effort data.

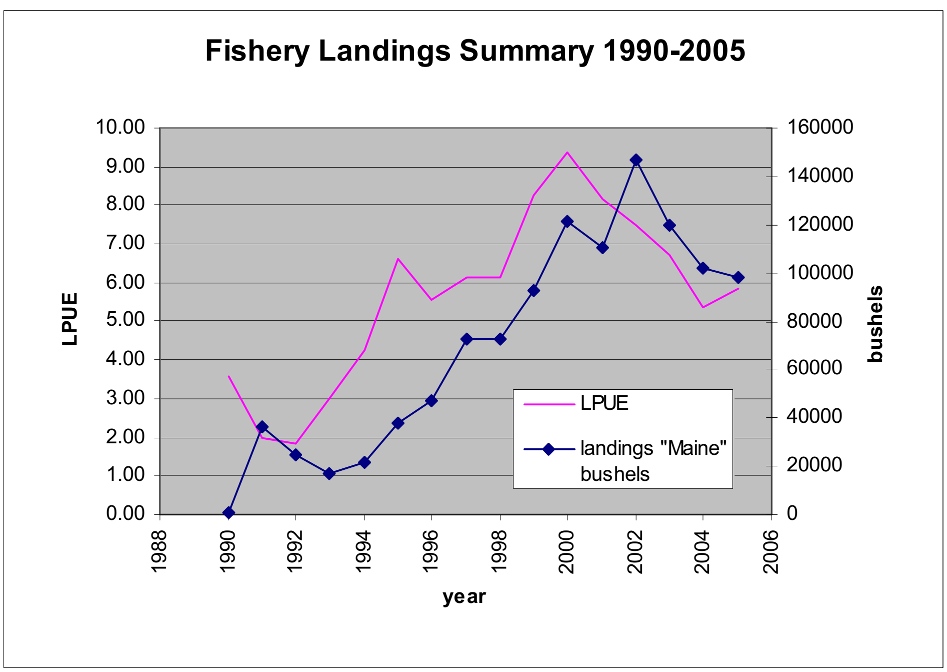
		sizes selected by dredge(>34mm SL)				all sizes		
		lower 95%	**average**	upper 95%		lower95%	**average**	upper 95%
Efficiency %		11.4	16.1	21.6		3.9	5.4	7.1
east	mean	3.3977E+09	2.4058E+09	1.7932E+09		9.9317E+09	7.1729E+09	5.4554E+09
	se	3.6358E+08	2.5744E+08	1.9189E+08		1.0628E+09	7.6757E+08	5.8378E+08
west	mean	2.4161E+09	1.7108E+09	1.2752E+09		7.0625E+09	5.1007E+09	3.8794E+09
	se	1.9464E+08	1.3782E+08	1.0272E+08		5.6894E+08	4.1090E+08	3.1251E+08
all	mean	5.8134E+09	4.1163E+09	3.0682E+09		1.6993E+10	1.2273E+10	9.3341E+09
	se	4.6013E+08	3.2580E+08	2.4284E+08		1.3450E+09	9.7138E+08	7.3880E+08

Bushel Estimates based on 10,000 bootstrap runs				
Efficiency (%)		11.4	16.1	21.6
east	mean	3.936E+06	2.787E+06	2.078E+06
	se	4.156E+05	2.943E+05	2.193E+05
west	mean	2.422E+06	1.715E+06	1.278E+06
	se	2.209E+05	1.564E+05	1.166E+05
all	mean	2.160E+01	4.502E+06	3.356E+06
	se	1.793E+09	3.872E+05	2.886E+05

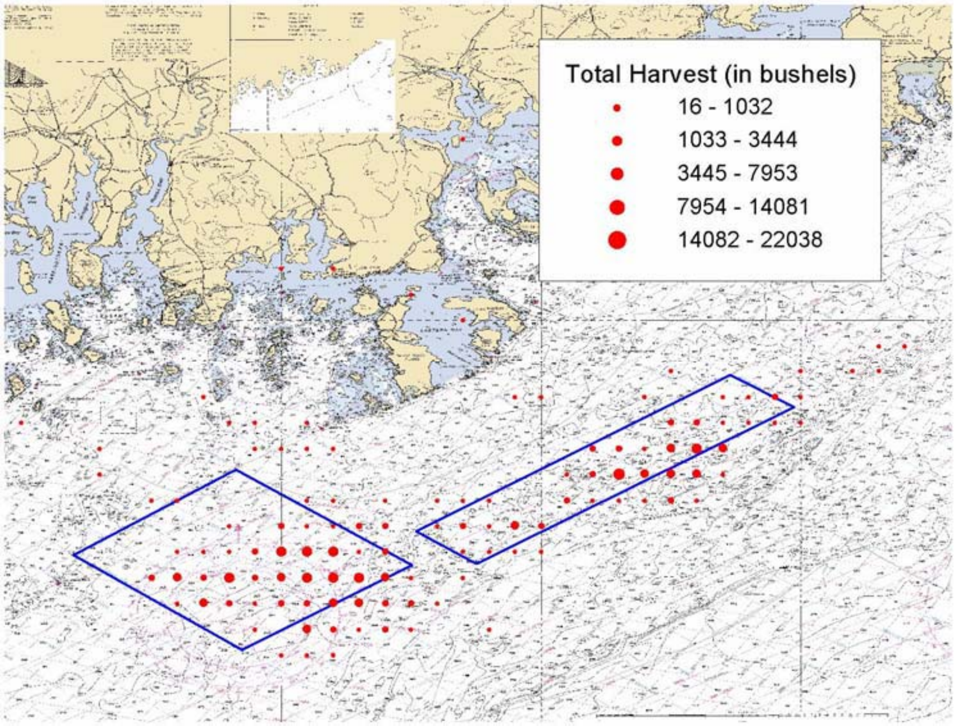
Appendix A8. Table 2. Effects of efficiency estimates on count and bushel estimates.



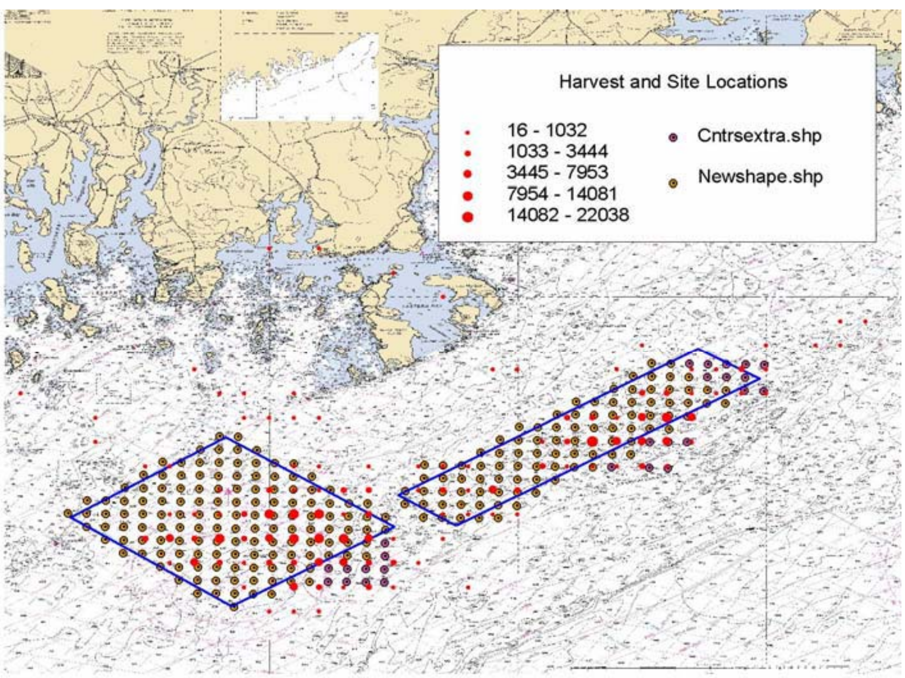
Appendix A8. Figure 1. Under the current Surfclam/Ocean Quahog FMP, the Maine fishing area is defined as north of the 43° 50' N. This line roughly splits the Maine coast in two.



Appendix A8. Figure 2. Catch and effort trends in the Maine quahog fishery. In 2002 one of the primary quahog beds was closed due to PSP. It was reopened in the last quarter of 2005.



Appendix A8. Figure 3. Commercial harvest locations during 2003-2005. Point size represents total bushels reported to that location by all vessels.

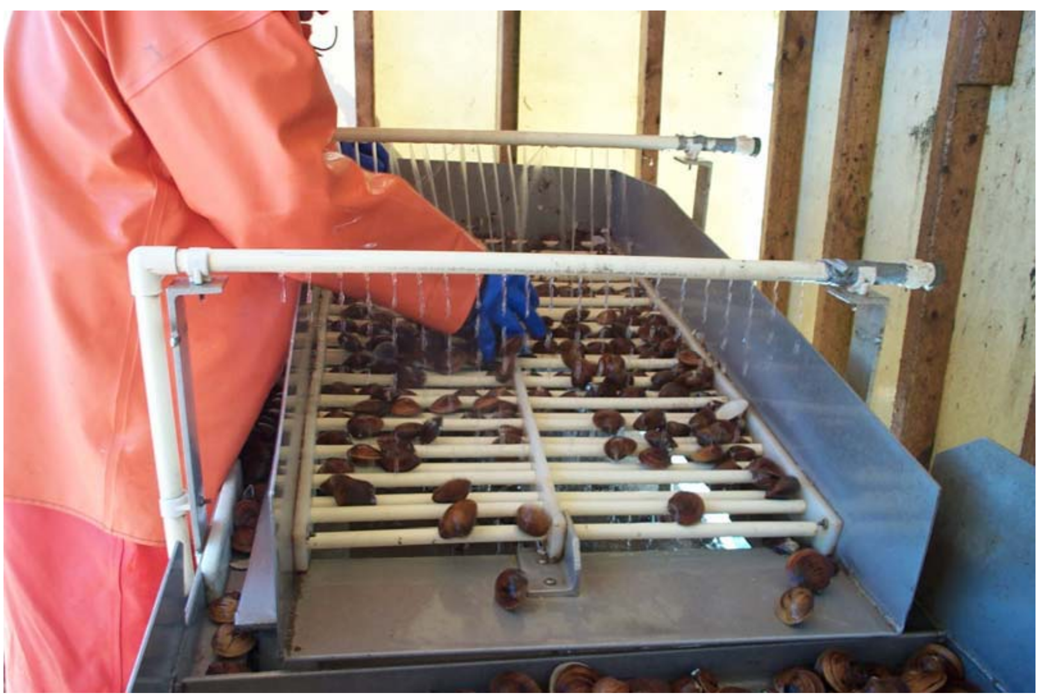


Appendix A8. Figure 4. Spatial grids for abundance survey in relation to commercial activity.

Appendix A8. Figure 5. Commercial drag used in all surveys in 2005.

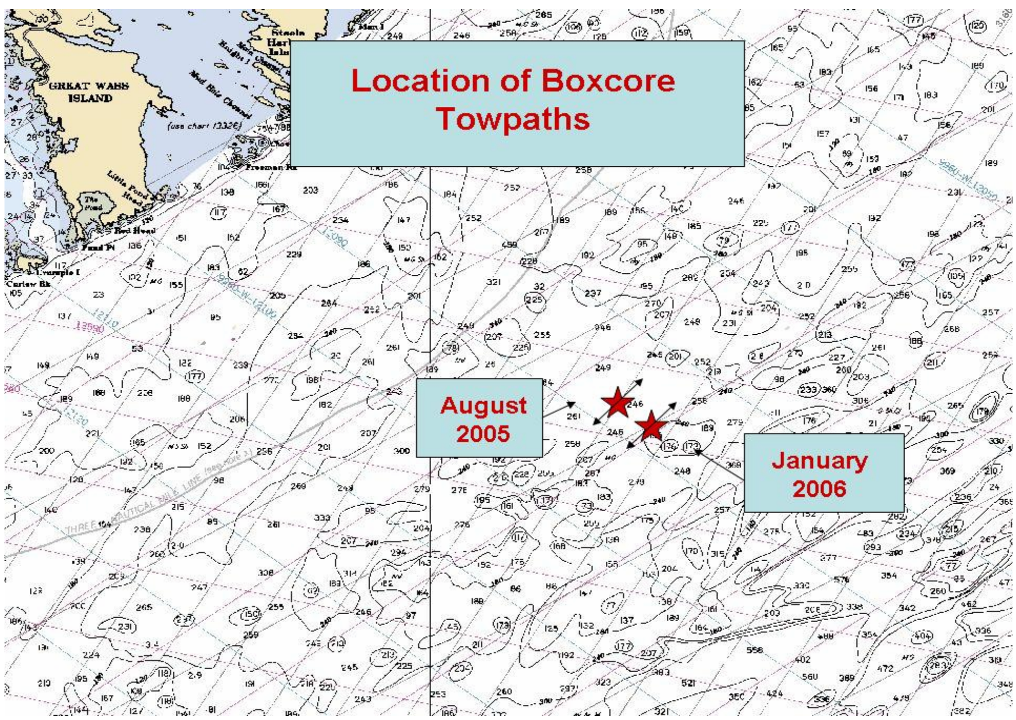
Appendix A8. Figure 6. Cleaning the catch before it is brought on board. This practice is used in commercial operations as well.

Appendix A8. Figure 7. Typical catch as it comes on board. Tow duration 2 minutes.

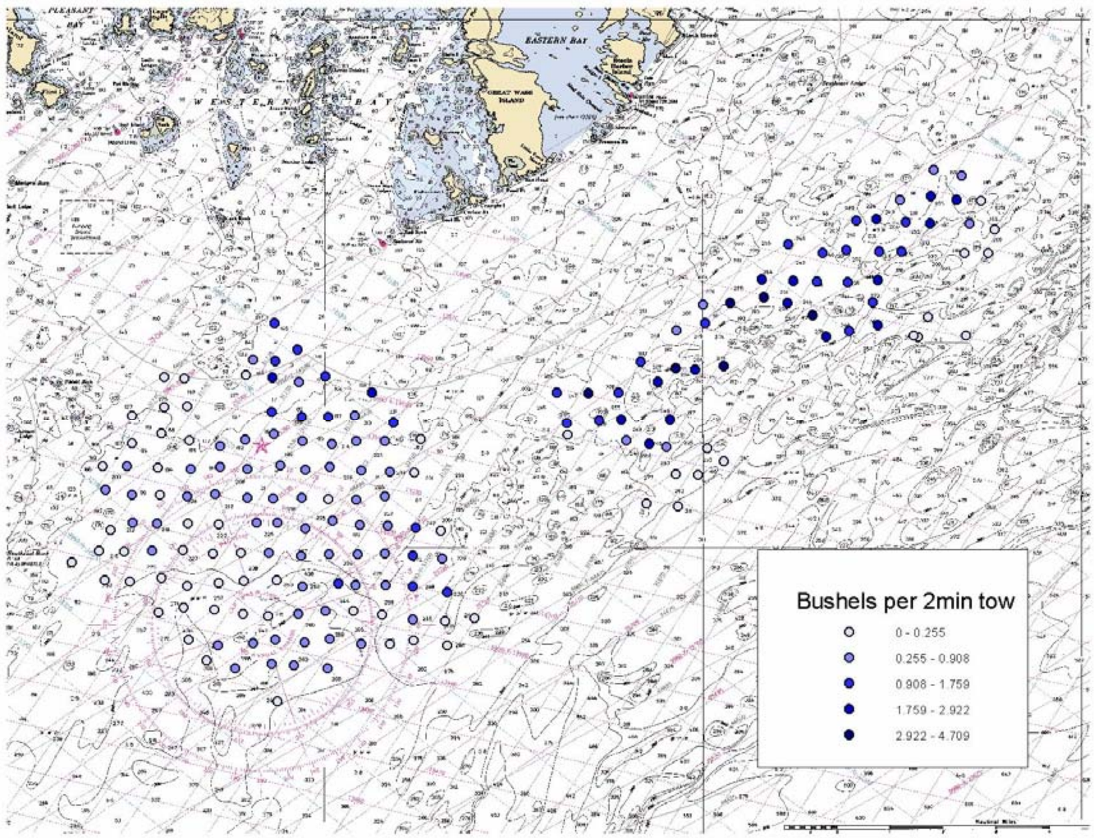


Appendix A8. Figure 8. The catch being processed on a standard shaker table.

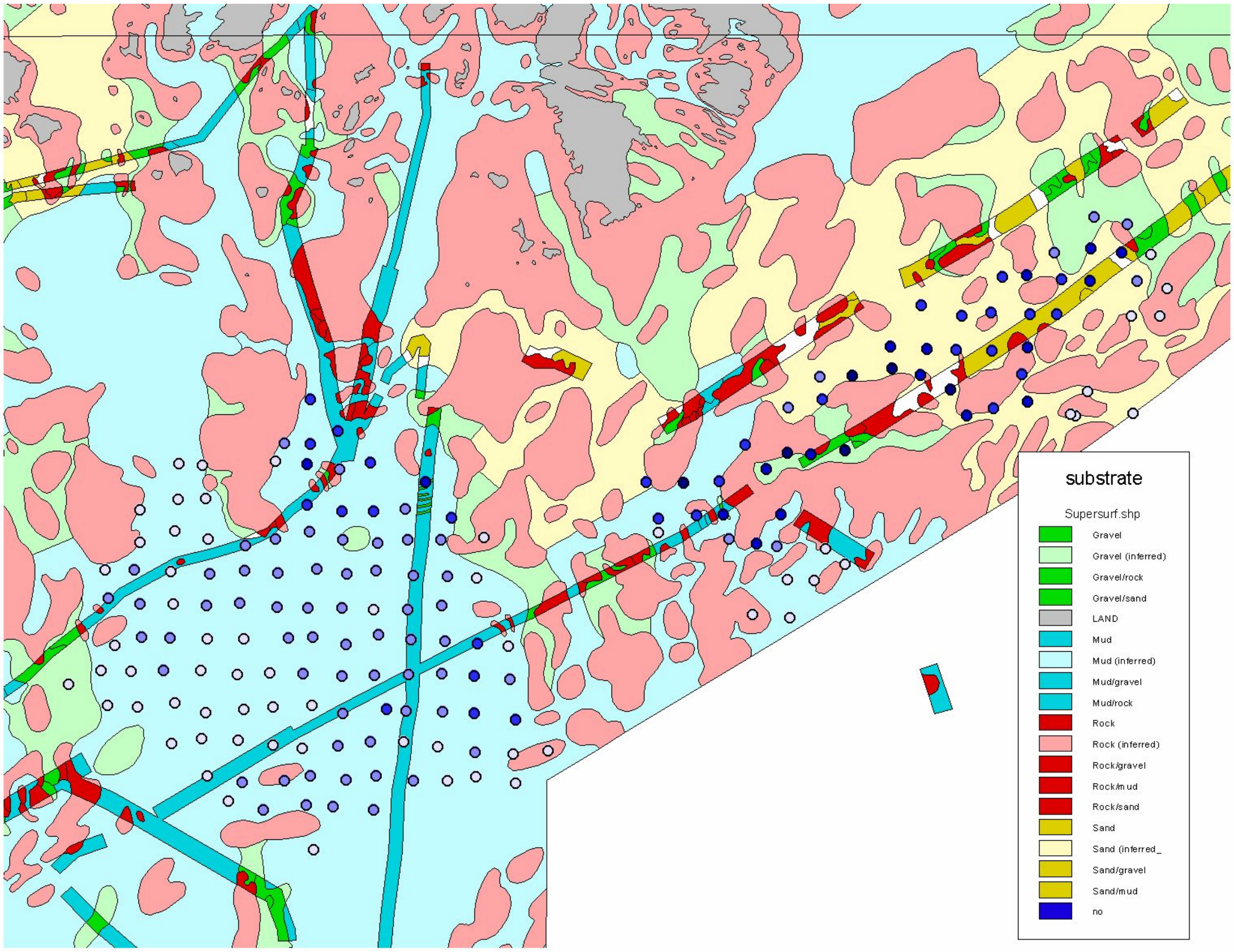
Appendix A8. Figure 9. Ocean Instruments 610 Boxcore along with a typical core sampled.



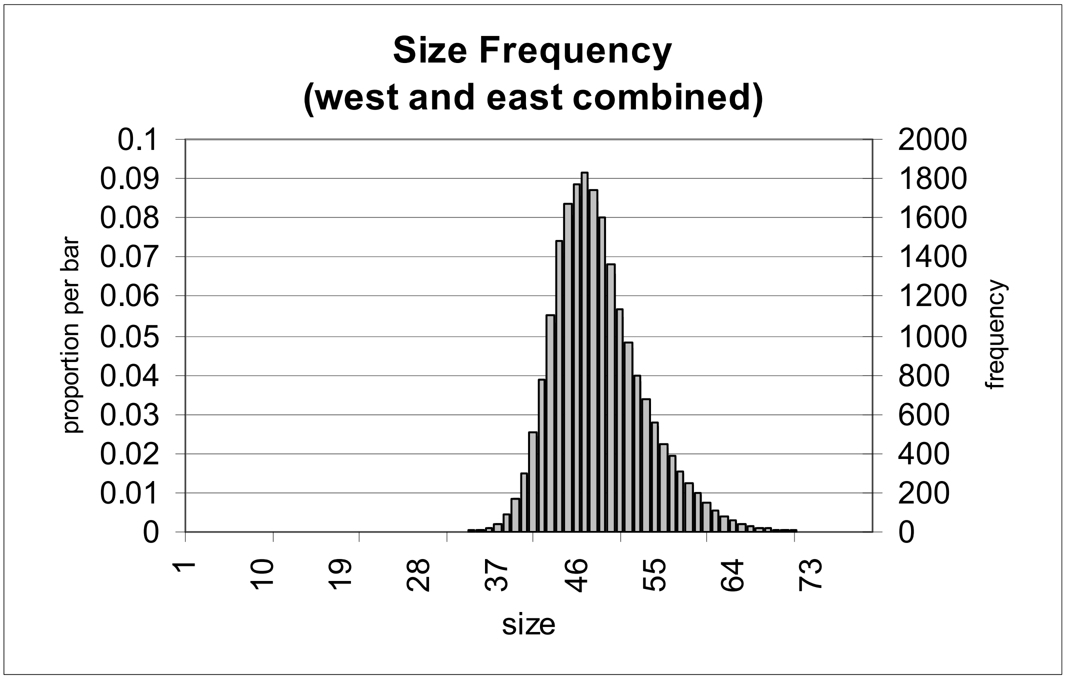
Appendix A8. Figure 10. Locations of Boxcore samples.
Areas with high quahog density were chosen from the abundance survey results.



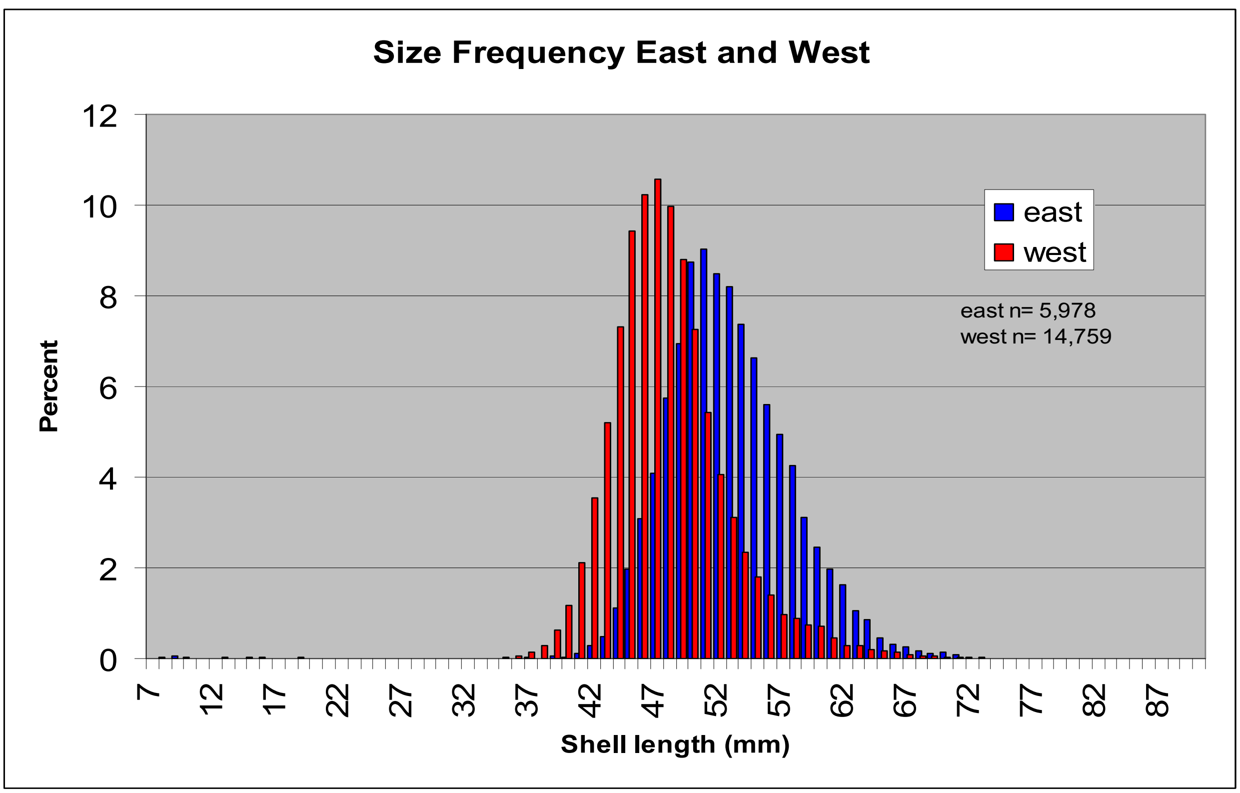
Appendix A8. Figure 11. Density Plot from towable 2005 survey locations.



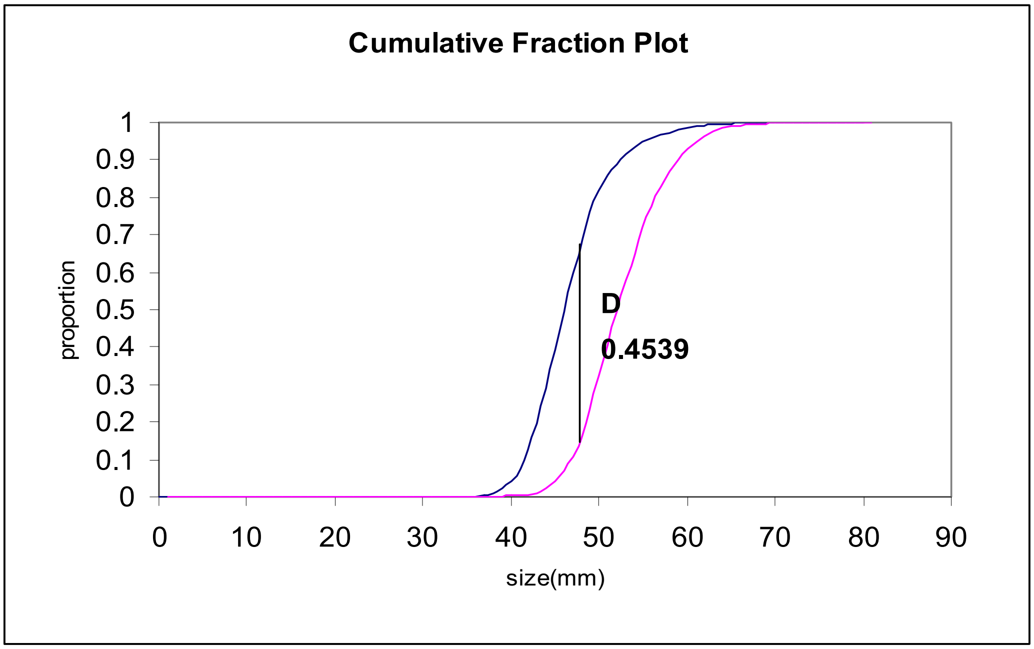
Appendix A8. Figure 12. Survey tows overlay on substrate data from Joe Kelly.



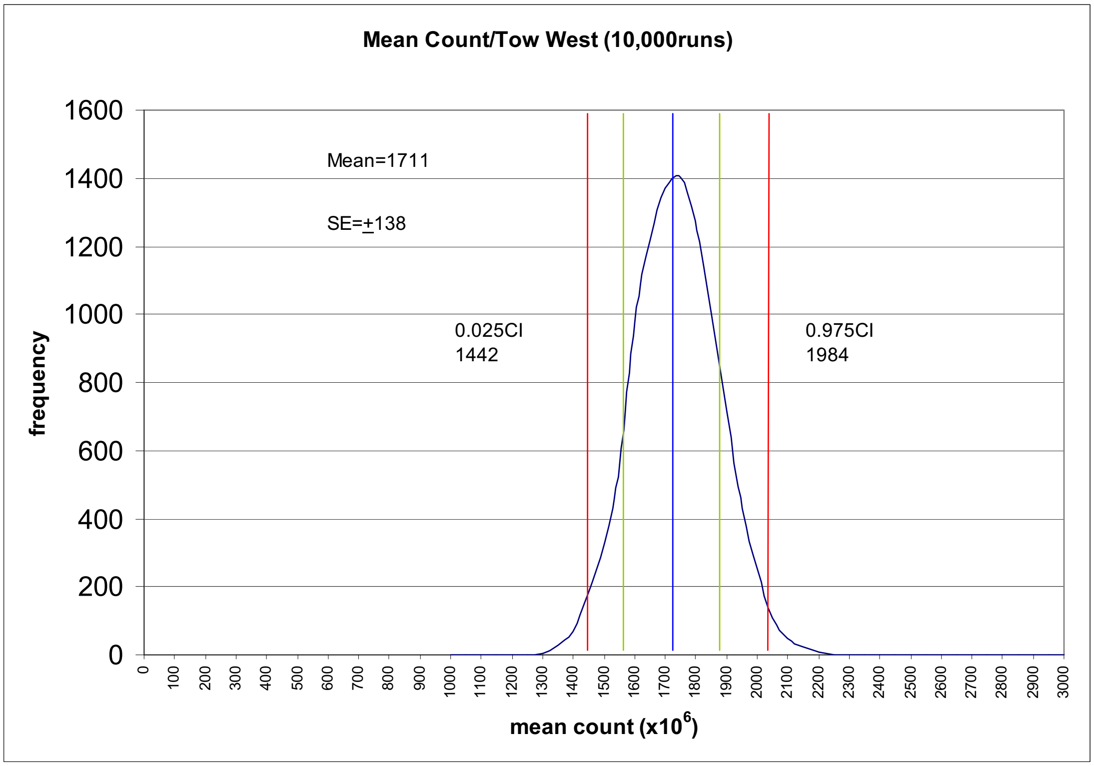
Appendix A8. Figure 13. Size frequencies for all tows in the western and eastern beds.



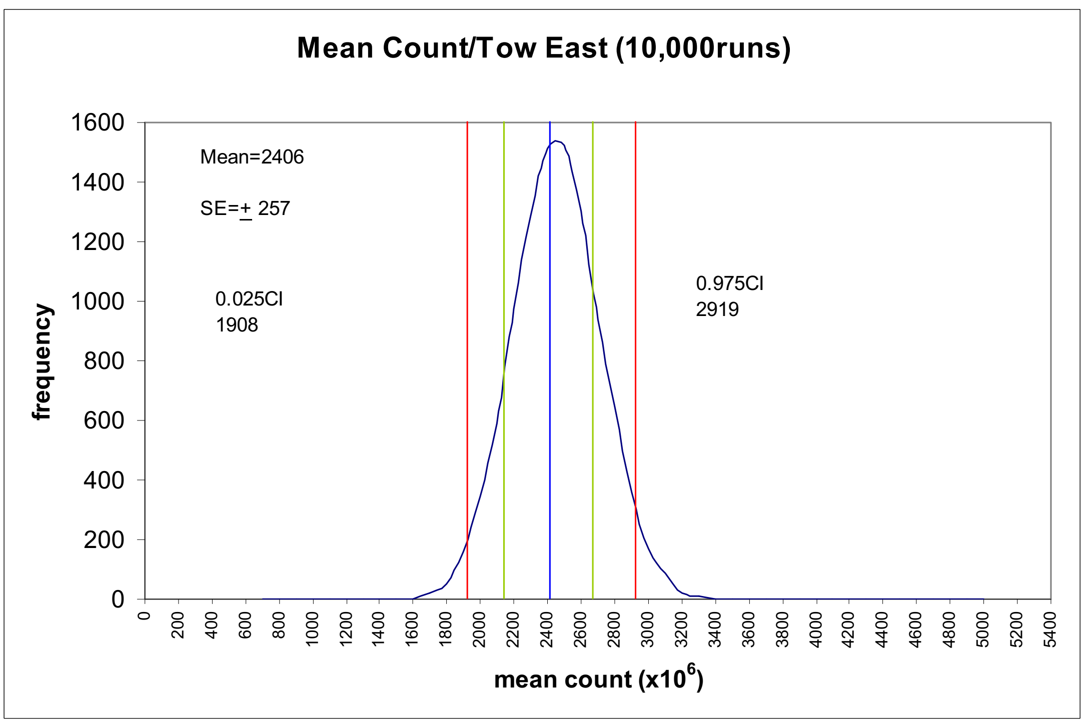
Appendix A8. Figure 14. Size frequencies for western and eastern bed. Used as basis for K/S test



Appendix A8. Figure 15. Cumulative distributions for length composition in the western and eastern beds. The curves are significantly different at the *p*=0.001 level.

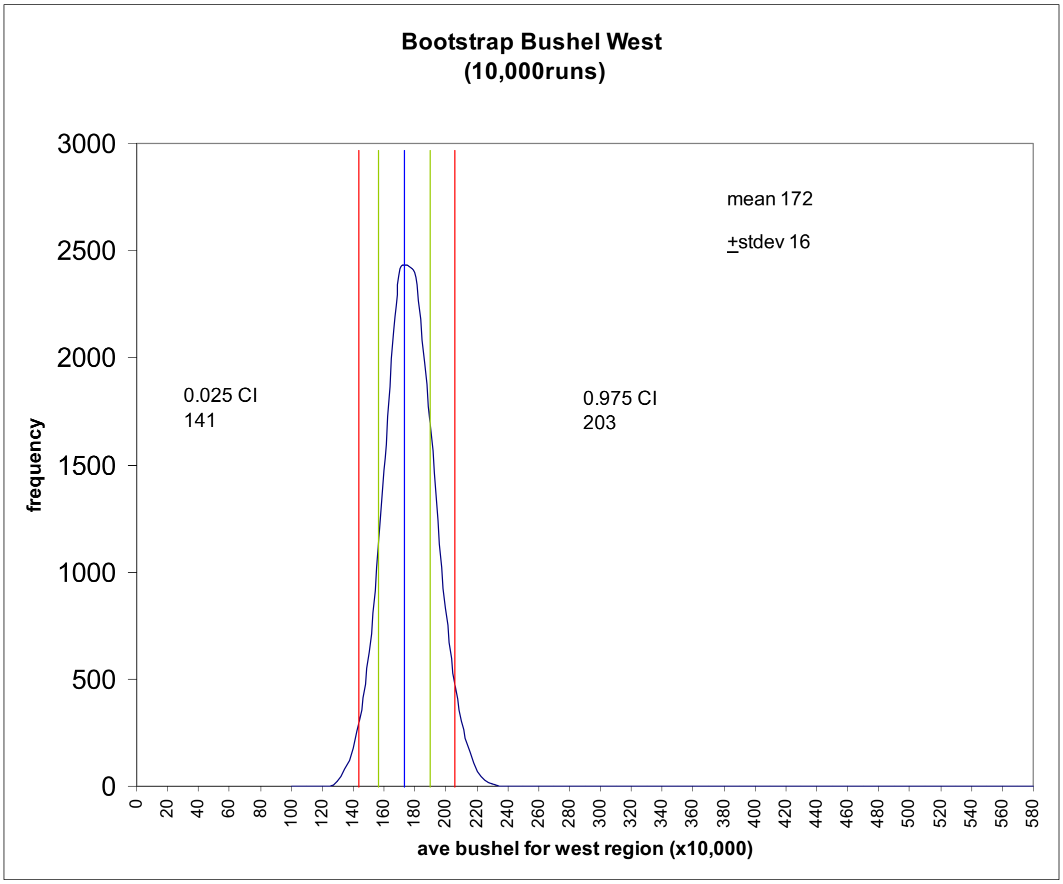


A

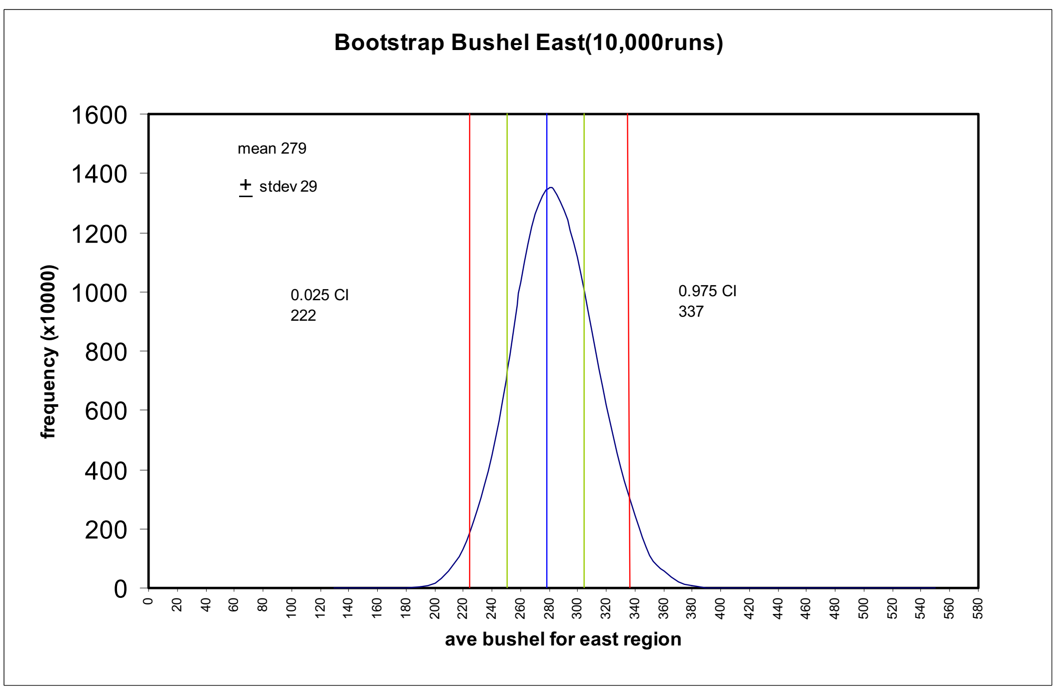


B

Appendix A8. Figure 16. Results from bootstrap runs on mean count per tow split by west (A) east (B) and on bushels per tow split west (C, next page) east (D, next page).

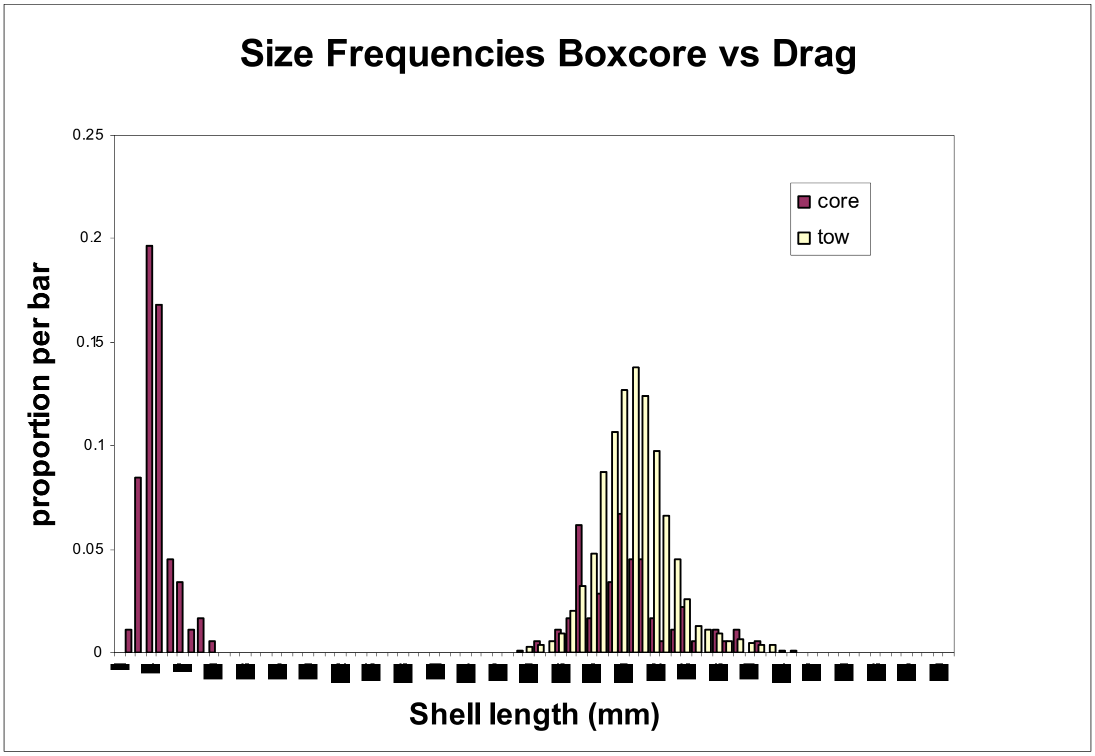


C

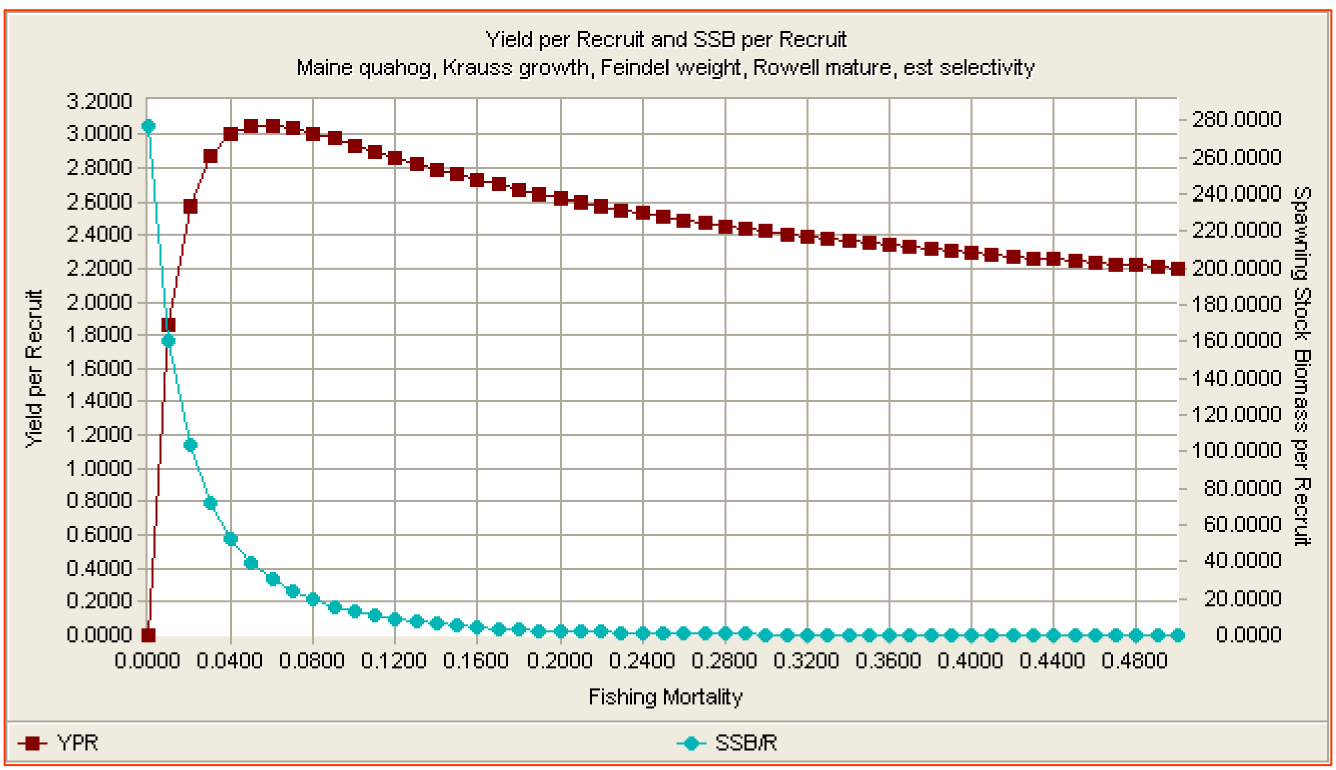


D

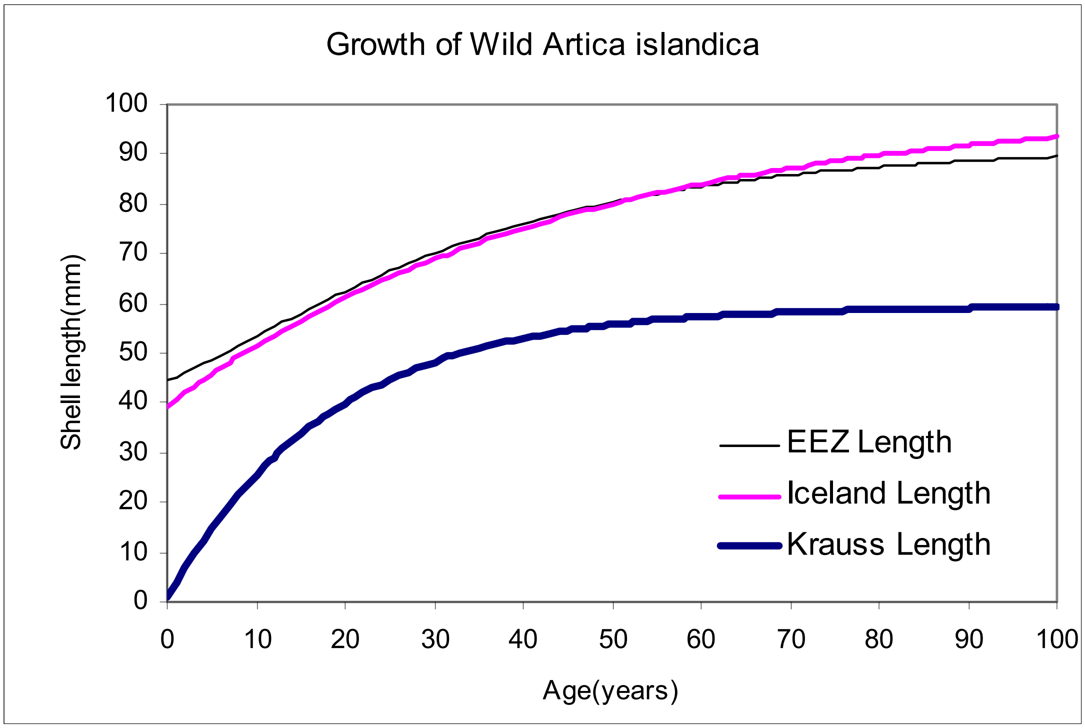
Figure 16. (cont.)



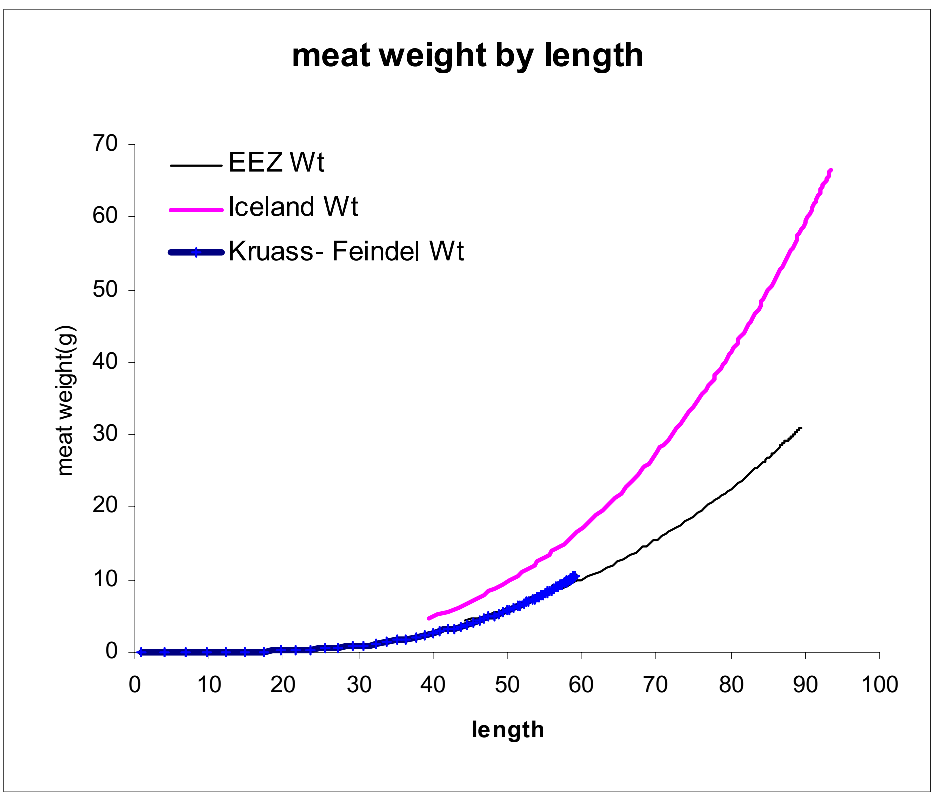
Appendix A8. Figure 17. Size frequencies from boxcore and follow on tows.



Appendix A8. Figure 18. Per recruit model results for Maine ocean quahogs.



Appendix A8. Figure 19. Three growth curves for quahog. Data for the Krauss curve was from Maine.



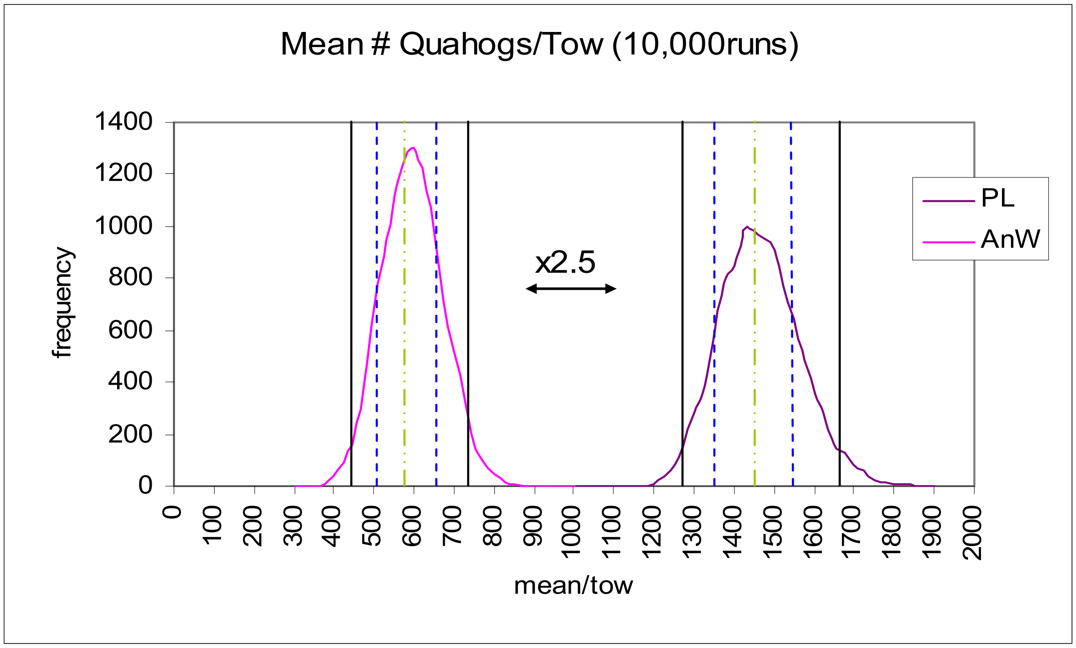
Appendix A8. Figure 20. Meat weight shell length relationships for three quahog stocks. Data for the Kruass-Feindel curve was from Maine.

Fully recruited length			
length	F-01	Fmax	F50%MSP
30	0.0196	0.0348	0.0109
35	0.0215	0.0419	0.0116
40	0.0242	0.0543	0.0126
45	0.0275	0.0801	0.0143
50	0.0319	0.168	0.018
55	0.0376	-1	0.0309

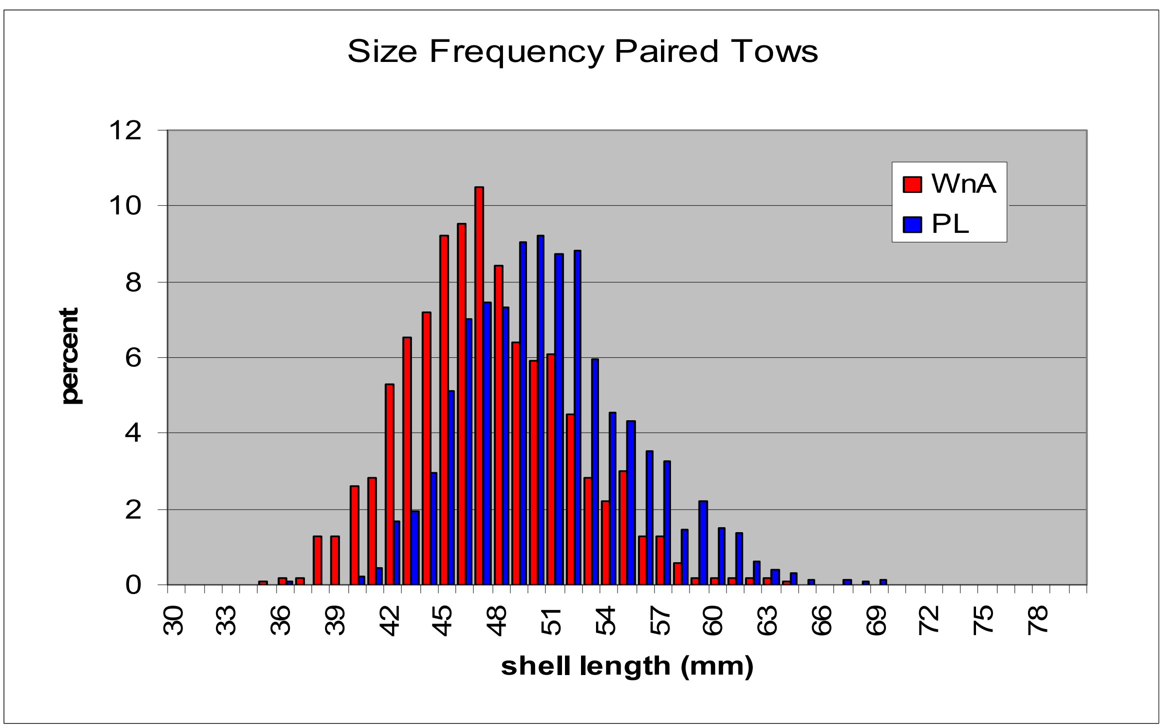
Fully Mature			
length	F-01	Fmax	F50%MSP
30	0.0253	0.0604	0.0168
35	0.0253	0.0604	0.0164
40	0.0253	0.0604	0.0157
45	0.0253	0.0604	0.0146
50	0.0253	0.0604	0.013
55	0.0253	0.0604	0.0105
60	0.0253	0.0604	-1
65	0.0253	0.0604	-1

Appendix A8. Figure 21. Sensitivity of YPR to size at recruitment and maturity.

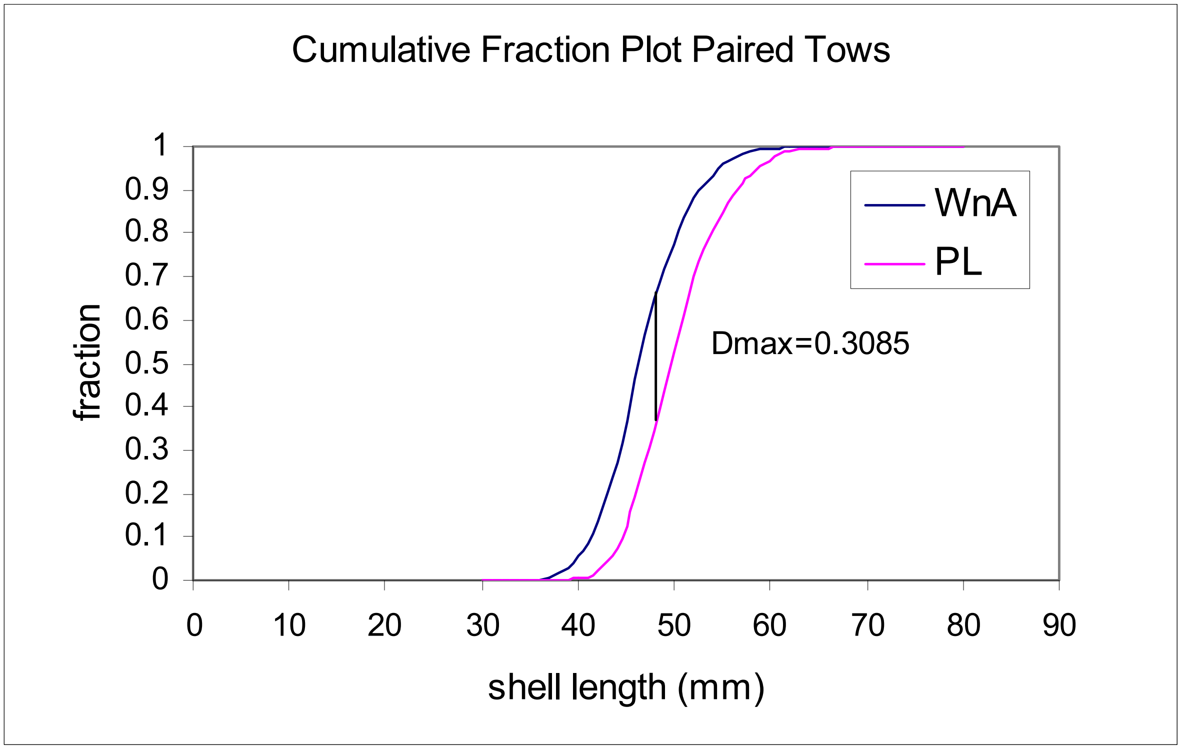
Appendix A8. Figure 22. Side by side towing operations underway.



Appendix A8. Figure 23. Results from both bootstrap runs for the paired tows between the F/V Promise Land and the F/V Whitney and Ashley. The F/V Promise Land has a catch ratio to the F/V Whitney and Ashley of 2.5:1



Appendix A8. Figure 24. Size frequencies for the two vessels in the paired tow experiments.



Appendix A8. Figure 25. Cumulative distribution plots for length data in paired tows.