Appendix 1: Updated Report on the Maine Ocean Quahog Resource and Fishery

Introduction

The Maine fishery for Ocean quahogs, although harvesting the same species as the rest of the EEZ fishery (*Artica islandica*), is prosecuted in a different way and fills a different sector of the shellfish market. Maine "mahogany quahogs" are harvested at a smaller size (starting at 38 mm or 1.5 inches in shell length, SL) and marketed as a less expensive alternative for *Mercenaria mercenaria* for home and restaurant consumption (Maine DMR 2003). The offshore beds targeted by the Maine fishery are made up of small ocean quahogs, the maximum size being only about 75mm.

The Maine fishery began to expand into Federal waters in the 1980s 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 the 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 surfclam/ocean quahog 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 Amendment 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. 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 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 conducted in 2005 was focused on estimating dredge efficiency and mapping quahog density on the commercial fishing grounds.

Estimates of biomass and mortality presented in this report are only for the two commercial beds south of Addison (west bed) and Jonesport/GreatWass (east bed), 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 can be met using the estimates from the primary fishing grounds then biomass outside the survey area can act as a *de facto* preserve.

Fishery Data

Data throughout this report are presented in metric units. In the case of landings and LPUE, values are reported in units of Maine bushels, which are about two-thirds the size of the "industry" bushels used as a measure of ocean quahog volume for the rest of the EEZ. To determine the meat yield of a Maine bushel of ocean quahogs, all quahogs

caught by the Maine survey (number and size composition estimated by subsampling) are converted to a total meat weight then divided by the total number of bushels caught (known). Shell length is converted to meat weight using the equation

$$W = 4.97x10^{-6} \text{ x } SL^{3.5696}$$

where W is meat weight and SL is shell length. The resulting meat yield (10.8 lbs) is for a Maine bushel of quahogs averaging around 57 mm SL.

Historically the bulk of ocean quahog fishing activity in Maine has taken place on two large quahog beds just off the coast north of 43°50' latitude: the east bed off the town of Addison and the west bed off Great Wass Island. The two beds cover an area of approximately 60 square nautical miles (Figure 1).

Harvesting takes place year round with the highest market demand during the summer holidays (Memorial Day through Labor Day). Most 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 (having 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.

There are no size limits for this fishery, and there is no discarding. The ocean quahogs fished from the two commercial beds off Maine are much smaller than most of the rest of the EEZ harvest, averaging between 50 and 60 mm SL (Figure 2), which suits the half-shell market. The ex-vessel price for Maine mahogany quahogs in 2011was over three dollars per pound of meats, about five times the price paid for ocean quahogs from the rest of the EEZ. Even though size of individual ocean quahogs has increased since the beginning of the fishery, all the catch brought up in a dredge is still acceptable for this market and are kept. The fishery has no regulatory closed days, although the beds are occasionally closed to fishing as a paralytic shellfish poisoning (PSP) precaution. Since the summer of 2007, there have been 77 days when the fishing areas were closed and 145 days when the open fishing areas were severely restricted in size due to PSP precautions. These closures usually happen during the summer months.

Maine ocean quahog landings have trended downwards since 2002 (Table 1, Figure 3). The exception to this trend is in 2006 when landings increased to 124,839 bushels after the re-opening of a highly productive portion of the fishing grounds that had been closed in previous years as a precaution against PSP. After the initial boost to landings from additional fishing ground, landings again began to decline. By the end of 2012 only 65,912 bushels out of a 100,000 bushel quota had been landed.

LPUE has been fairly stable since the early 1990s (Figure 3). Changes in LPUE were often the result of regulatory or fishing practice changes, such as the uptick in 2006 which mirrors the peak in landings from the re-opening of productive beds. Despite the intensity of the fishery, the fact that the LPUE has not fallen may be the result of the fishery moving onto the most productive beds (Figure 1), the clams growing larger in

size, and the reduction in total effort since the early 2000s. Since 2008, the number of valid ocean quahog license holders has fallen from 47 to 29, and hours fished per year by the fleet has dropped by more than half in the past 10 years (Figure 4).

Incidental mortality for Maine ocean quahogs is unknown. This is an important topic for future research, especially since Maine has a high level of dredging activity relative to the size of the fleet. For example, in 2008 the ocean quahog fleet fished approximately 10,776 hours, equivalent to 64,656 tows at ten minutes each. Using standard industry dredge dimensions and tow speeds this level of fishing activity represents 31.42 nm^2 of bottom swept by commercial dredges per year. Five percent is added to ocean quahog landings before calculating exploitation rates to make up for incidental mortality, but it is just an estimate based on the fishery for larger ocean quahogs in the rest of the EEZ.

Research Surveys

Surveys of the Maine ocean quahog resource were conducted in 2002, 2005, 2006, 2008 and 2011. With the limited funds dedicated for survey work on quahogs, it was decided to focus all survey efforts after 2002 on the two large ocean quahog beds off of Addison (west bed) and Great Wass Island (east bed) that are the primary commercial fishing grounds. Therefore survey estimates of biomass 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 the ocean quahog resource, and as a result the majority of fishing activity, occurs here.

The first step in designing the 2005 survey was to establish a 1 km^2 grid overlay (using Arcveiw 3.2) over the two beds. Based on number of days at sea available, it was estimated 260 stations could be completed during the survey, so the centers of 260 1 km^2 grids covering the commercial beds were selected as start points for survey tows. These points were transferred to The Cap'n Voyager Software for use on board the survey vessel.

In 2005 the west bed had been the only open fishing grounds for 3 years due to PSP closures. The east bed had been unfished for 3 years but had previously been a productive ocean quahog fishing ground. The 2006 survey took place 9 months after the east bed reopened. All areas were open during the 2008 and 2011 surveys.

<u>Survey gear and procedures</u>

The 2005 and 2006 surveys were conducted from the commercial vessel F/V Promise Land, a 12.8 m (42 ft) Novi Style dragger piloted by Capt. Michael Danforth. All survey tows during these two years were conducted using a dredge with the following 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). The dredge used by the F/V Promise Land during normal fishing activity was used for the survey. After the 2006 survey, The F/V Promise Land was sold and the captain left the fishery. The vessel contracted for the 2008 and 2011 surveys, The F/V Allyson J4, was about the same size as the F/V Promise Land and the captain, Bruce Porter, had been a

quahog fisherman for 24 years. The dredge used in 2008 and 2011 was also built for commercial use with the same specifications as the dredge on the Promise Land. The only difference between the dredges was a custom extension on the Promise Land dredge that could hold more sediment, making it roughly 400 lbs heavier than the one used in 2008 and 2011 (Figure 5). During tow operations it was noted that the teeth on the cutter bar of the new dredge shined to depth of 3 inches just as they had in the original dredge. From this we assumed that the new dredge was cutting to the same depth as the original. It was also felt that since the survey tows were short (two minutes compared to about ten minutes for a commercial tow) in order to avoid any overfilling and subsequent loss of catch the extensions on the catch box of the original dredge would not give it any advantage over the current dredge.

To conduct a survey station, the vessel approaches the center of the selected tow grid, and if suitable bottom is not present at the predetermined start point, the vessel starts crossing runs within the grid. If towable bottom cannot be found, then the grid location is deemed un-towable, a note is made, and the captain continues on to the next grid. When a suitable tow path is found within a grid the dredge is lowered to the bottom by free-spooling until the ratio of cable length to depth is 3:1. Once the desired cable length is reached the drum is locked, a two minute timer is started and a GPS point taken. The dredge is towed into the current at approximately 3.5 knots for two minutes, a second GPS point is taken and the dredge is brought to the surface. Before it is brought onboard, mud is cleaned from the dredge by steaming in tight circles keeping the dredge in the vessel's prop wash (Figure 6).

Once on board, the dredge is emptied and the catch photographed (Figure 7). The catch is placed on a shaker table (Figure 8), bycatch is noted and all live ocean quahogs are sorted out. A 5 liter subsample of ocean quahogs is taken from each tow to count and measure. The entire catch is processed if it is less than 5 L. The remainder of the catch is placed in calibrated buckets to determine total catch volume. The number of quahogs caught in a tow is estimated by counting the number of clams in the 5 L subsample and expanding to the total volume of the catch. All data are 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 each tow are standardized to a 200 m tow prior to further analysis. Due to a number of reasons such as placement of lobster gear, vessel availability and weather, the number of stations completed per survey has varied from 130 to 183.

Estimating dredge efficiency

Maine dry dredges are less efficient (2 to 17 percent, ME DMR 2003) than the hydraulic dredges used in the rest of the EEZ (up to 95 percent, Medcolf and Caddy 1971). A reliable estimate of dredge efficiency is needed to convert survey densities to a biomass estimate (NEFSC 2004). To assess the efficiency of the Maine dredge, boxcore samples were taken to directly estimate quahog density, then tows were made in the same area

with the survey dredge. Considering only ocean quahogs of sizes available to the dredge, the ratio of density estimated from the dredge tows to density estimated from the boxcore samples is an estimate of survey dredge efficiency (Thorarinsdottir and Jacobson 2005). The estimated dredge efficiency was 17.9 percent, with a 95% bootstrap confidence interval of 8.0%-34.4%. More details of the dredge efficiency experiments can be found in NEFSC 2009, Appendix B2.

Dredge survey results

The original 2005 survey visited 259 potential tow grids. 71% of the stations were towable (183) and 29% were untowable, mostly due to inappropriate substrate, but sometimes due to the presence of fixed gear. During future surveys only the 183 towable grids were revisited. In 2006 130 tows were completed, in 2008 181 tows were completed, and in 2011 183 tows were completed.

Tow distance, catch volume and counts were all standardized to a 200m tow.

For all surveys the highest concentration of biomass was in the eastern bed. The eastern section has had the most variable open and close status due to PSP. Substrate data (Figure 9) 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 show 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 in 2005; 2,014 in 2006; 4,055 in 2008 and 4,316 in 2011) show the quahogs in the eastern bed are larger (Figure 10). 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 different size compositions and densities, abundance and biomass are calculated separately for the two beds before making combined estimates for the entire survey area. Abundance estimates (see Table 2 and Figure 11) are calculated using a dredge efficiency that was estimated by applying 10,000 bootstrapped efficiency estimates from the three boxcore trips to 10,000 average abundance estimates from the surveys, and the swept area of the survey. Biomass estimates are made by dividing the population into 1 mm size bins based on survey size frequencies, then converting shell length (S*L*) to meat wet weight (*W*) using $W=4.97x10^{-6} x SL^{3.5696}$ (Maine DMR 2003).

Growth and per recruit modeling

A sample of 83 ocean quahogs from the east bed was recently (February 2013) aged at the University of Iowa, and although the data are preliminary, there is evidence that ocean quahogs are growing faster and larger there than previously thought. Kraus et al. (1992) estimated a growth curve for Maine ocean quahogs from the east bed which suggested Maine quahogs grow more slowly and to smaller sizes than ocean quahogs

from the mid-Atlantic bight, while the new data places east bed ocean quahogs in the middle of the EEZ and Kraus et al. curves (Figure 12).

Biological and fishery parameters from a variety of sources were used to carry out a per recruit analysis for ocean quahogs in Maine waters in 2005. The length-based per recruit model used was from the NOAA Fisheries Toolbox (Yield Per Recruit program, internet address: http://nft.nefsc.noaa.gov). Age at length and growth information was taken from Kraus et al. (1992). Length-weight parameters were from the 2002 Maine Quahog survey. Size at maturity estimates were based on Rowell et al. (1990) who found that ocean quahog females from Nova Scotia became fully mature at an average size of 49.2 mm. Fishery selectivity was modeled as a linear ramp function that was zero at 37 mm SL and one at 47mm, based on the facility of fitting live ocean quahogs of increasing size through the grates of a commercial dredge by hand (19.05 mm, 3/4 in. bar spacing). Clams from 34mm to 38mm SL 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 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 13). These may be reassessed when the new age and growth data have been fully vetted and can be used in the model.

Sensitivity analysis 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 quahog in Maine waters become fully recruited to the fishery. Commercial port sampling conducted in 2009 confirmed the size selectivity estimates used in the modeling (Figure 2).

Fishing mortality rate

Fishing mortality is estimated as catch in meat weight/average biomass. The survey biomass is used as a proxy for average biomass, as annual mortality rates are low. Following NEFSC (2004), the catch for each year 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. Maine ocean quahog catches, biomass estimates and *F* estimates for 2005, 2006, 2008 and 2011 are given below.

Year	Median Biomass estimate - mt meat weight	landings in mt meat, full year w/ %5 incidental mortality	*F* - whole year
2005	25,862	528	0.020
2006	19,012	642	0.033
2008	16,574	348	0.021
2011	19,577	446	0.023

Fishing mortality estimates for 2008 and 2011 are roughly equal to the $F_{0.1}$ generated by the per recruit model, but higher than the $F_{50\%}$.

Stock Status

Since the entire population of ocean quahogs in U.S. waters is managed as a single stock and overfishing definitions apply to the whole stock, it is not possible to evaluate the status of ocean quahogs in Maine as the biomass represents less than 1% of the EEZ stock as a whole. It is not possible to compare or evaluate current biomass levels relative to biological reference points associated with maximum productivity, depleted stock or historical levels because no appropriate biological reference points or historical biomass estimates are available.

$F_{0.1}$ 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 $F_{50\%}$ (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.

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Thorarinsdottir, G.G. and L. Jacobson. 2005. Fishery biology and biological reference points for management of ocean quahogs (*Artica islandica*) off Iceland. Fisheries Res. 75: 97-106

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Table 1. Maine landings, effort and landings per unit effort from vessel logbooks for all vessel classes combined. Only records with both effort and catch data were used to calculate LPUE, which in most years are 100% of the logbook entries as can be seen by comparing columns two and three below.

year	Landings (in Maine bushels)	Landings (records with both effort and catch)	Effort (hours fished)	Nominal LPUE (Maine bushels/hr)
1990	1,018	1,018	286	3.56
1991	36,679	34,360	17,163	2.00
1992	24,839	24,519	13,469	1.82
1993	17,144	17,144	5,748	2.98
1994	21,672	21,672	5,106	4.24
1995	37,912	37,912	5,747	6.60
1996	47,025	47,025	8,483	5.54
1997	72,706	72,706	11,829	6.15
1998	72,466	72,152	11,745	6.14
1999	93,015	92,285	11,151	8.28
2000	121,274	119,103	12,739	9.35
2001	110,272	110,272	13,511	8.16
2002	147,191	147,191	19,681	7.48
2003	119,675	119,675	17,853	6.70
2004	102,187	102,187	19,022	5.37
2005	100,115	100,115	17,063	5.87
2006	121,373	121,373	14,902	8.14
2007	102,006	102,006	14,018	7.28
2008	66,926	66,926	10,776	6.21
2009	56,808	56,808	9,928	5.72
2010	56,469	56,469	9,727	5.81
2011	65,307	65,307	9,145	7.14
2012	65,912	65,912	7,132	9.24

Table 2. Maine ocean quahog survey median abundance and biomass estimates.

Year	Bed	Median abundance estimate - billions	Median biomass estimate - mt meat weight	CV
2005	west	1.729	8,653	39%
	east	2.404	17,208	40%
	combined	4.134	25,862	39%
2006	west	1.996	10,166	41%
	east	1.225	8,846	41%
	combined	3.221	19,012	41%
2008	west	0.711	5,471	40%
	east	1.094	11,103	41%
	combined	1.805	16,574	40%
2011	west	0.754	7,053	40%
	east	1.231	13,277	41%
	combined	1.989	19,577	40%

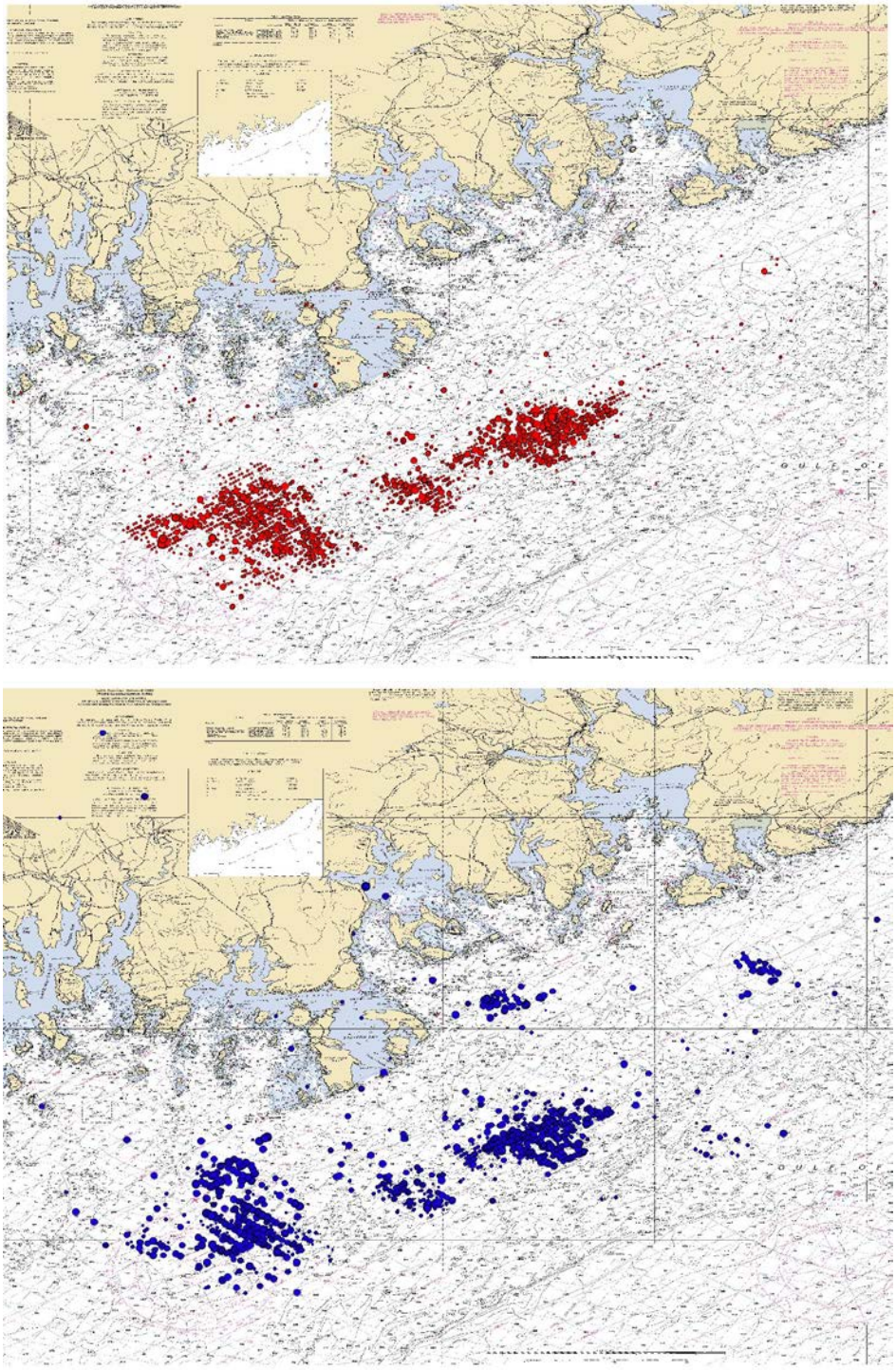


Figure 1. Locations of all reported commercial landings 2003-2008 (top) and 2009-2012 (bottom).

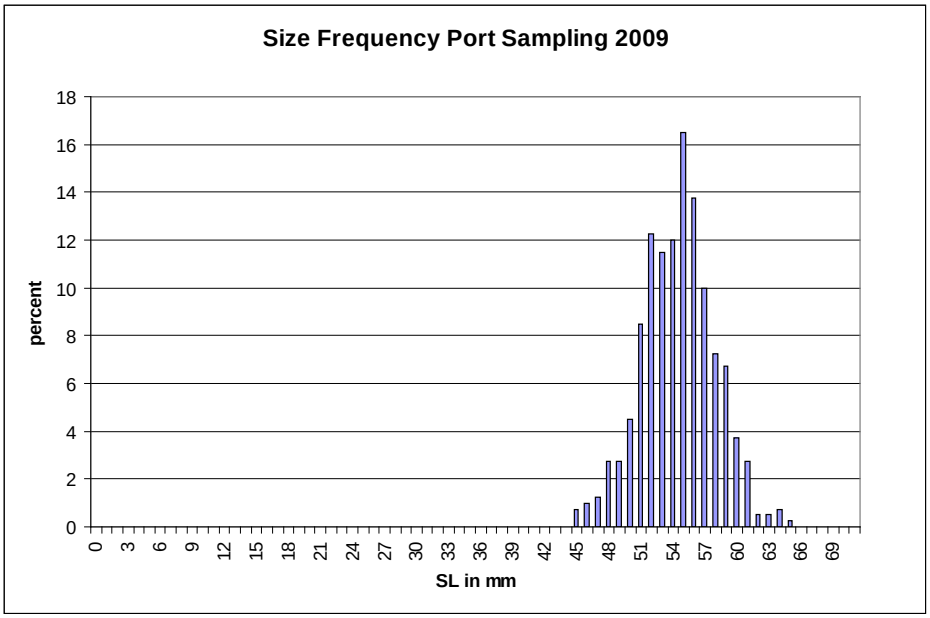


Figure 2. Size frequency for port samples collected in Jan- March 2009 from 6 different vessels.

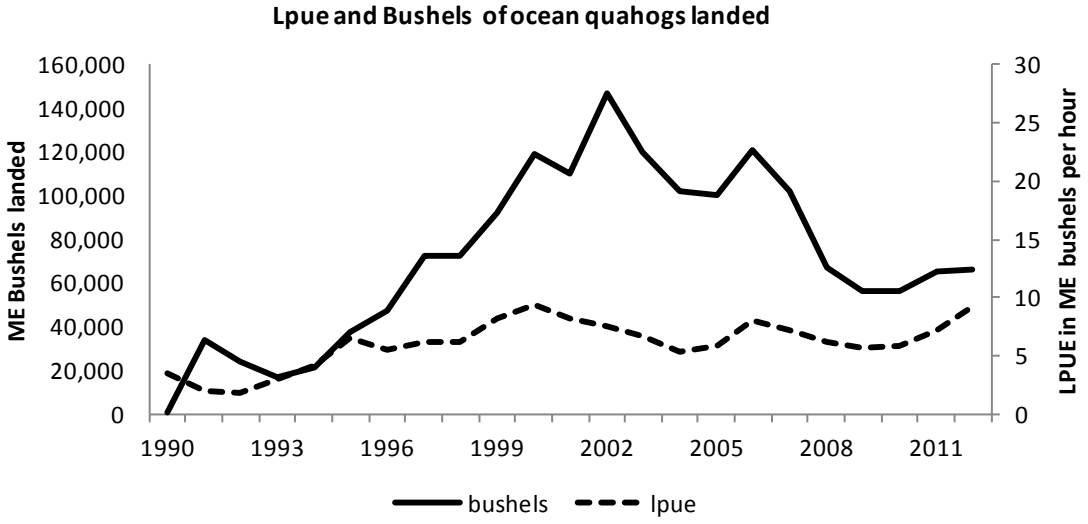


Figure 3. Commercial LPUE and Landings from clam industry logbooks.

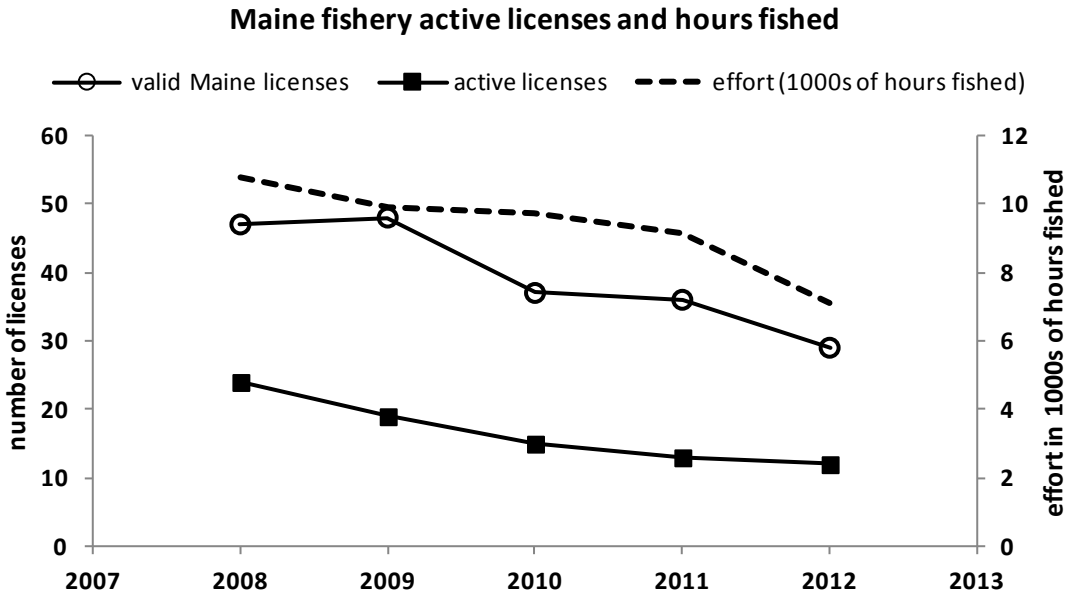


Figure 4. Number of valid and active (fished during the year) ocean quahog licenses for the Maine fishery, with fleet fishing effort in thousands of hours shown by the dotted line.

Figure 5. At left, the dredge used for the 2005 and 2006 surveys, weighing about 3,000 lbs. At right, the dredge used for the 2008 and 2011 surveys, weighing about 2,600 lbs.

Figure 6. After being brought to the surface, the catch is washed and mud rinsed away in the propeller wash of the survey vessel.

Figure 7. Typical catch from a two-minute survey tow. Note very low bycatch and uniform size of clams.

Figure 8. Processing the survey catch on shaker table, used to remove shell fragments and mud. This step is performed in commercial operations as well.

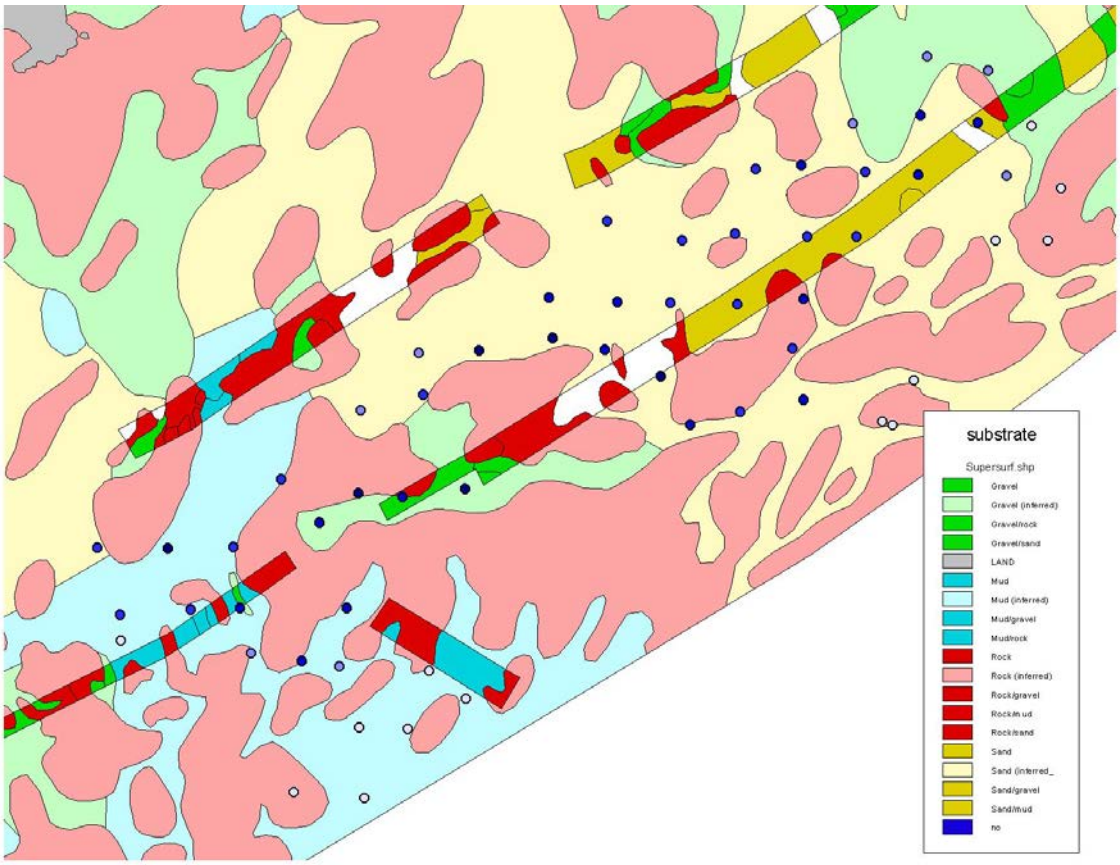


Figure 9. Substrate data from Kelly et al. (1998) showing coincidence of hard bottom edges with high density quahog tows from eastern bed. The tow locations are the dark blue dots, while pink is rock, light blue is mud, yellow is sand and green is gravel substrate.

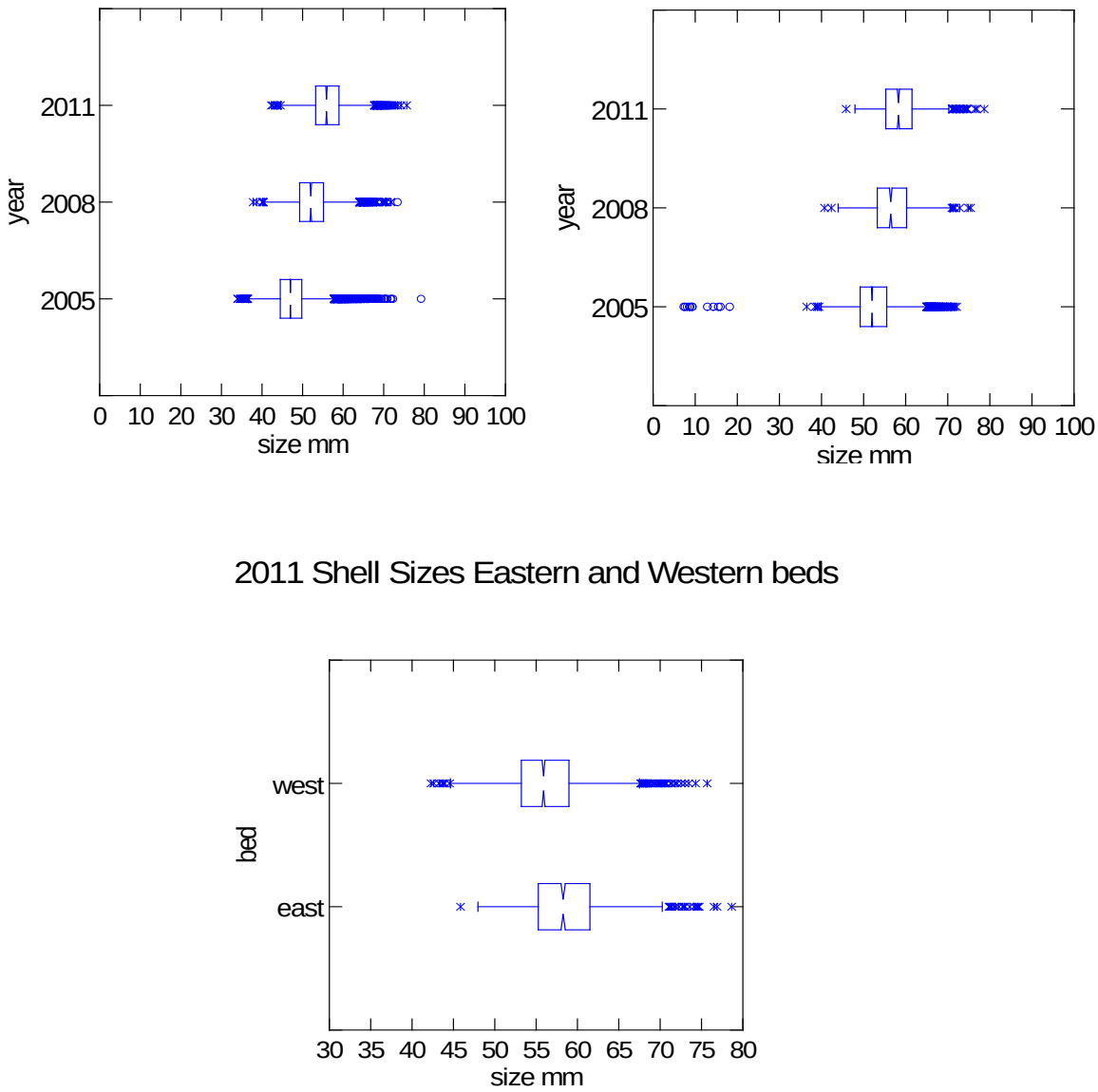
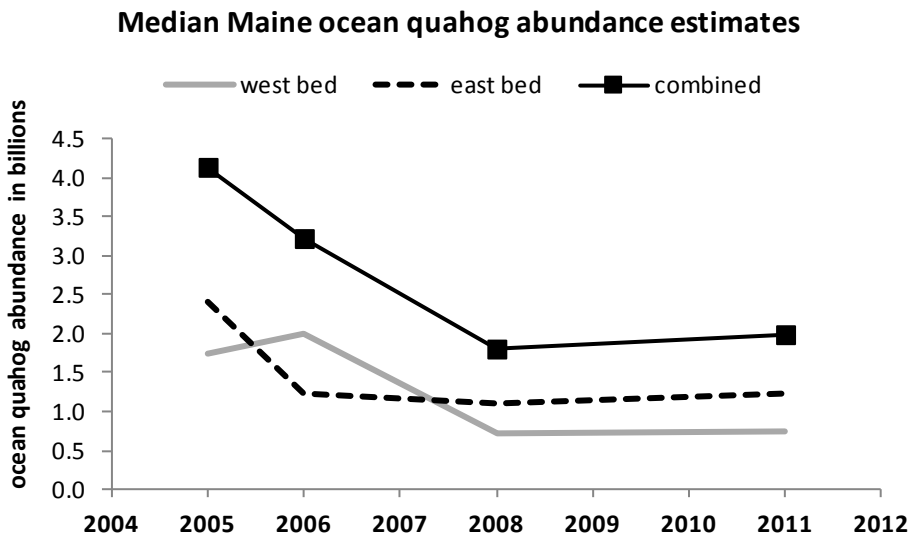


Figure 10. Growth in Maine ocean quahogs between the 2005 and 2011 surveys for the west bed (top left) and the east bed (top right), and 2011 size frequencies for both beds shown together. These quahogs appear to be growing faster than previous Maine growth data (Kraus et al. 1992) would predict. For instance, the mean growth of 5mm between 2005 and 2008 (three years) in the western bed would be expected to take eight years and the 4.45mm increase during the same three years in the eastern bed would be expected to take 14 years.



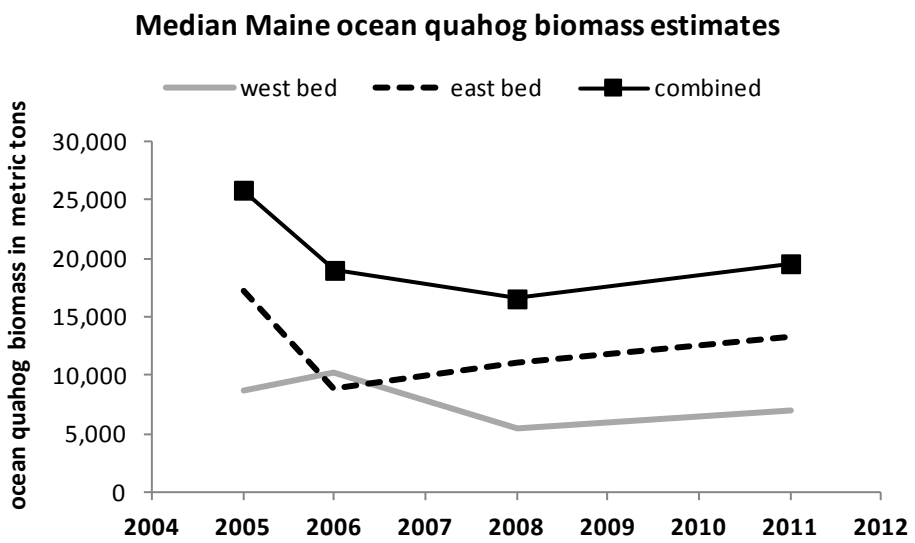


Figure 11. Estimates of abundance in billions of individual ocean quahogs (top) and biomass in metric tons of meats for 2005 - 2011.

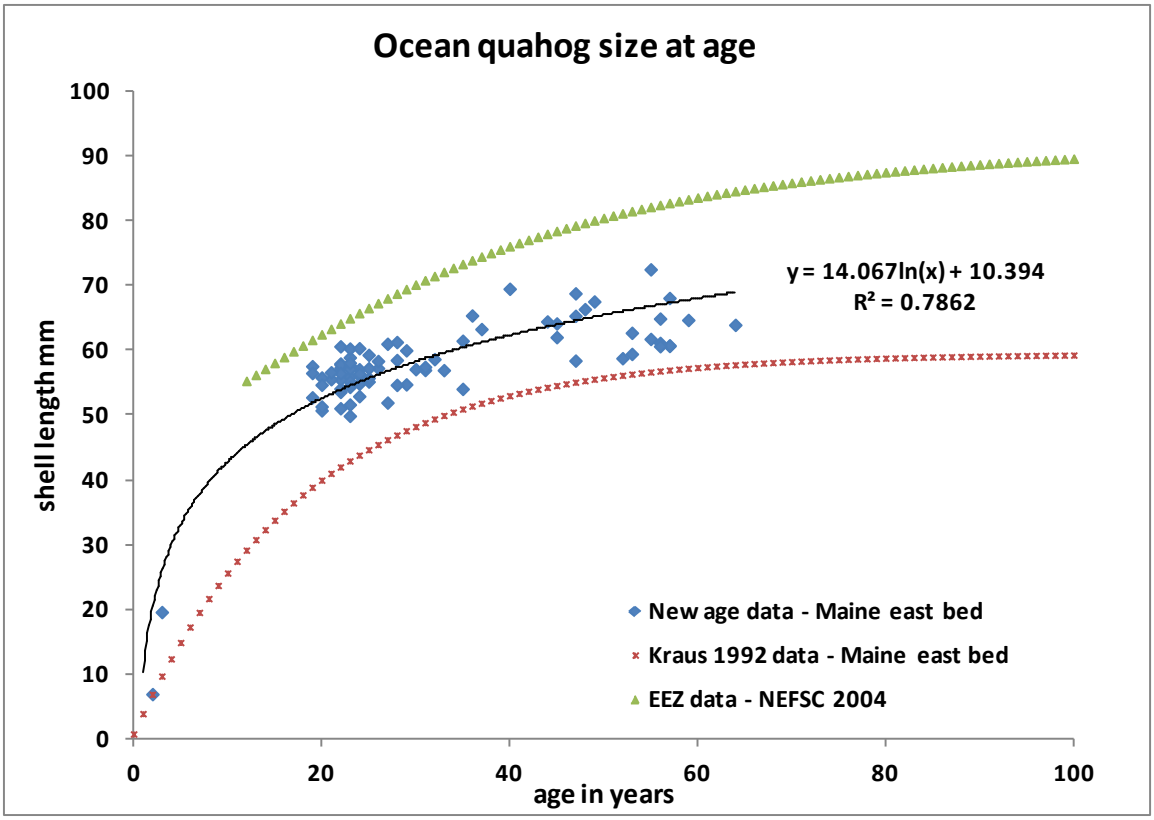


Figure 12. Ocean quahog shell length at age from a major commercial bed off the Maine coast (east bed), and the mid-Atlantic Bight. The blue symbols represent preliminary new age data from the Maine east bed, and the lines represent growth curves from published studies: Kraus et al. 1992 (Maine east bed, bottom) and NEFSC 2004, (Mid-Atlantic Bight, top).

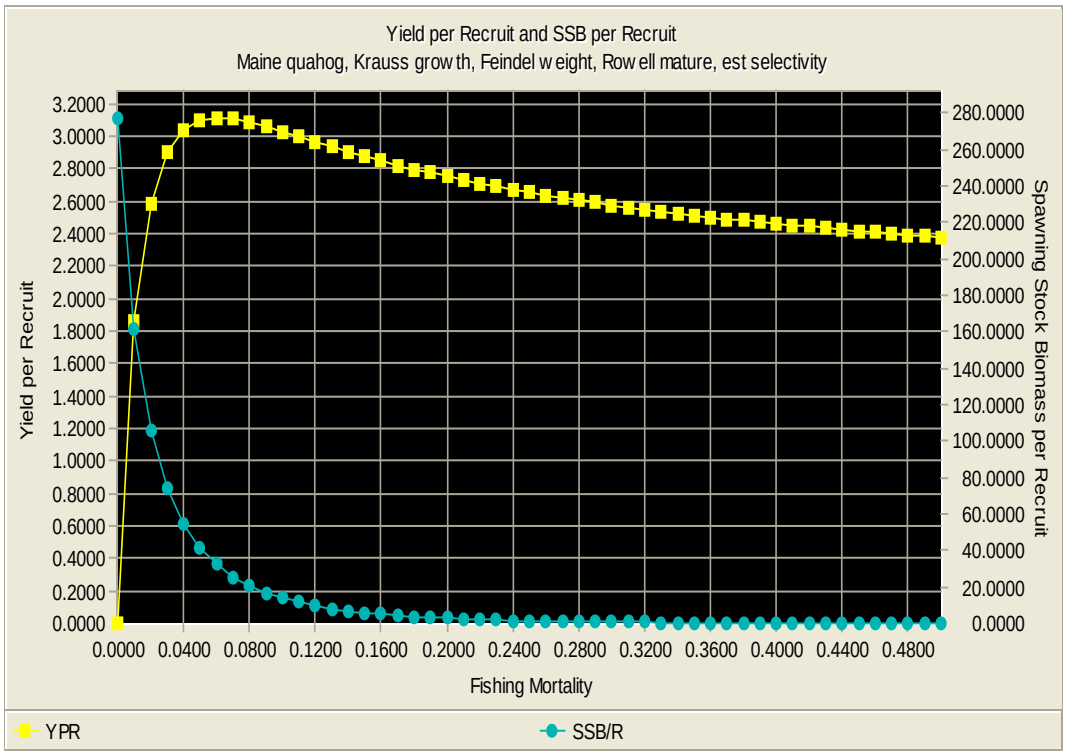


Figure 13. Results of yield per recruit analysis from 2005.