A. OCEAN QUAHOG ASSESSMENT SUMMARY FOR 2006

State of Stock: The ocean quahog stock (Figure A1) is not overfished and overfishing is not occurring. Estimated fishable stock biomass during 2005 was 3.039 million mt, which is above the management target of ½ virgin biomass = 1.987 million mt (Figures A2 and A3). Estimated fishing mortality during 2005 for the exploited region (all areas but Georges Bank, Figure A1) was F= 0.0077 y^{-1}, which is below the management target level $F_{0.1}$ = 0.0278 y^{-1} (Figures A4 and A5). These estimates for ocean quahog in the US Exclusive Economic Zone (EEZ) do not include Maine waters (Figure A1), which were assessed separately (see below). However, biomass and landings for Maine waters are minor and would have no appreciable effect on estimates for the whole stock.

Projections: Based on example calculations (below), biomass is projected to decline gradually through 2010. The scenario with landings equal to a 5.333 million bushel quota (24,189 mt meats) corresponds to current regulations, although recent landings have been less than the quota.

Example stock projections (biomass, landings and fishing mortality during 2006-2010) with three annual quota levels and with $F=F_{0.1}$. The current (2006) quota is 5.333 million bushels (24 thousand mt meats). Biomass and landings are thousand mt meats. Fishing mortality are annual rates. Mortality rates assume that incidental mortality at 5% of landings.

Year	Biomass All Regions (1000 mt)	Biomass less GBK (1000 mt)	Landings (1000 mt)	F All Regions (y^{-1})	F less GBK (y^{-1})
Quota = 4 million bushels (18,144 mt meats)					
2006	3,016	1,753	13	0.004	0.008
2007	2,995	1,731	18	0.006	0.011
2008	2,967	1,703	18	0.006	0.011
2009	2,940	1,676	18	0.007	0.011
2010	2,912	1,649	18	0.007	0.012
Quota = 5.333 million bushels (24,189 mt meats)					
2006	3,016	1,753	13	0.004	0.008
2007	2,995	1,731	24	0.009	0.015
2008	2,961	1,697	24	0.009	0.015
2009	2,927	1,663	24	0.009	0.015
2010	2,893	1,630	24	0.009	0.016
Quota = 6 million bushels (27,215 mt meats)					
2006	3,016	1,753	13	0.004	0.008
2007	2,995	1,731	27	0.010	0.017
2008	2,957	1,694	27	0.010	0.017
2009	2,921	1,657	27	0.010	0.017
2010	2,884	1,620	27	0.010	0.018
F = $F_{0.1}$=0.028 y^{-1} in exploited regions (F=0 for GBK)					
2006	3,016	1,753	13	0.004	0.028
2007	2,960	1,696	44	0.016	0.028
2008	2,905	1,642	42	0.015	0.028
2009	2,853	1,589	40	0.015	0.028
2010	2,802	1,538	39	0.015	0.028

Status Table: Ocean Quahog

Year:	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	Min[1]	Max[1]	Mean[1]
Quotas:													
EEZ	20.2	19.6	18.1	20.4	20.4	20.4	20.4	20.4	22.7	24.2	13.6	27.2	21.5
Maine	--	--	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	< 0.1	0.3	0.3
Landings:[2,6]													
Maine	0.14	0.22	0.22	0.28	0.36	0.33	0.39	0.36	0.31	0.29	< 0.1	0.4	< 0.1
EEZ	19.9	19.4	17.7	17.1	14.4	16.7	17.6	18.5	17.3	13.3	10.4	22.4	18.0
Total	20.1	19.6	17.9	17.4	14.7	17.1	17.9	18.8	17.6	13.6	10.4	22.5	18.1
Biomass:[3,6]	3,296	3,263	3,231	3,202	3,173	3,148	3,121	3,093	3,065	3,039	3,039	3,973	3,478
Fishing mortality:[4,6]	0.0099	0.0099	0.0091	0.0090	0.0077	0.0091	0.0097	0.0103	0.0098	0.0077	0.0039	0.0104	0.0084
Recruitment:[5,6]	15.2 (all years)												

[1] Min, max and means for 1978-2005 (EEZ landings, EEZ quota, biomass and fishing mortality), 1990-2005 (Maine landings), or 1998-2005 (Maine quota).
[2] Landings (1000 mt) not adjusted for incidental mortality, which is assumed to be 5% of landings. Discards are very low.
[3] Biomass (1000 mt) for entire stock.
[4] Fishing mortality (annual rates) for whole stock less GBK.
[5] Recruitment (1000 mt per year) is an estimated average assuming zero recruitment in SVA, DMV and GBK.
[6] See assessment for regional estimates.

Stock Distribution and Identification: Ocean quahogs occur from Norway to Spain, intermittently across the North Atlantic, around Iceland, and down the North American coast to Cape Hatteras. Commercial concentrations occur in US waters on the continental shelf off the coast of Maine and between Georges Bank and the Delmarva Peninsula (Figure A1), to at least 90 m.

All ocean quahog in US waters are assessed and managed as a single stock (Figure A1). The EEZ portion of the ocean quahog stock includes federal waters (between 3 and 200 nm from shore) off southern Virginia, Delmarva, New Jersey, Long Island, Southern New England, and on Georges Bank (excluding Maine). The exploitable stock is the EEZ less Georges Bank because no fishing occurs on Georges Bank because of potential paralytic shellfish poisoning (PSP). Ocean quahog in Maine and the EEZ were assessed separately and results from both assessments are included in this summary.

The EEZ is used to characterize the condition of the ocean quahog stock during 1978-2005 as a whole because almost all of the stock (>99% of fishable biomass) is in EEZ waters. Biomass and fishing mortality estimates for Maine waters are available for 2005 only. However, biomass and landings for Maine waters are relatively minor and would not appreciably change biomass or fishing mortality estimates for the stock as a whole.

Catches: EEZ quotas have been set on an annual basis since 1979. EEZ landings (Figure A6) increased from 0 in 1975 to about 15,000 mt (meats) in 1979, peaked at 22,000 mt in 1992, and averaged about 17,000 mt after 2000. EEZ landings generally account for about 98-100% of total US landings. The EEZ quota has not been attained in recent years, partly due to low market demand. Ocean quahogs in EEZ landings range between 50 and 120 mm SL and are marketed primarily as meats in chowders and sauces.

Catches are assumed to be 5% greater than landings in stock assessment calculations for ocean quahog in EEZ and Maine waters to account for incidental mortality during fishing. Incidental

mortality may occur when ocean quahogs contact fishing equipment (i.e. dredge and sorting equipment) without being landed.

Fishing effort from logbooks for ocean quahog in the EEZ shifted offshore and north over last two decades as traditional fishing grounds in the south were fished down, catch rates dropped, and as processing plants were relocated to the north (Figure A7). The fishery was concentrated off Delmarva and Southern New Jersey from the 1970s to mid-1980s. During the late 1980s and early 1990s, the fishery expanded northward into the Northern New Jersey and Long Island regions. In 1995, it expanded to the Southern New England region which accounted for the bulk of landings during 1997. After 1997, the fishery shifted back to the Long Island region, which accounted for about 60% of EEZ landings on average during 2002-2005. During 2001-2005, the fishery was concentrated in eleven 10' squares which were mostly off Long Island.

There are two principal fishing grounds for ocean quahogs in Maine waters, which cover about 60 nm^2 in total. Total annual landings in Maine waters ranged from 3 to 387 mt during 1990-2002 (Figure A8). After the 2002 peak, landings have declined and were 295 mt in 2005. Annual fishing effort in Maine waters peaked in 2002 at about 20,000 hours and then declined to about 17,000 hours in 2005 (Figure A9). Fishing effort in Maine waters (number of trips and hours fished from logbooks) in 2005 was greater than in any region of the EEZ. Ocean quahogs from Maine waters are relatively small, ranging 35-70 mm SL during 2005 and are marketed in the fresh and half-shell market at relatively high prices.

The most productive eastern fishing grounds were reopened by the State of Maine in late 2005 after three years of closure due to paralytic shellfish poison (PSP contamination). Effort and landings are therefore expected to increase in 2006.

Data and Assessment: Ocean quahogs were last assessed in 2003 (SAW-38). The 2003 assessment included complete data and estimates for the EEZ. Data from a preliminary survey in Maine waters during 2003 were also included, but fishing mortality and biomass during 2003 were not calculated for Maine waters because an efficiency estimate for the Maine survey dredge was not available. Information from the current ocean quahog assessments follows.

EEZ: NEFSC clam survey data for 1982-2005, fishery data for 1978-2005, new information about fishery selectivity, survey selectivity, and survey dredge efficiency from cooperative depletion studies were used to estimate fishable biomass during 1978-2005. Estimates for most regions (all but Southern Virginia and Georges Bank) were derived from a delay-difference model (KLAMZ). Biomass on Georges Bank (where no fishing occurs) was assumed to be stable at the level of the average efficiency corrected swept area biomass (ESB) during 1997-2005. For Southern Virginia a cumulative catch ("VPA") model was used instead of the KLAMZ model because survey data were insufficient. Discards were assumed to be zero and indirect mortality from commercial dredging was assumed to be 5% in both EEZ and Maine waters.

Maine: Biomass and fishing mortality of ocean quahogs in 2005 were calculated from landings data, together with a special survey carried out by the State of Maine in 2005 and survey dredge efficiency estimates. These estimates apply only to the area surveyed, which includes the primary fishing grounds. The assessment for Maine excludes waters outside of the survey area.

Biological Reference Points: Biomass reference points for ocean quahogs refer to the whole stock (as represented by the EEZ), while fishing mortality reference points refer to the exploited region only. The biomass target is one-half of the virgin biomass and the fishing mortality target is the $F_{0.1}$ fishing mortality in the exploited region (which excludes Georges Bank where no fishing occurs due to risk of PSP). The management thresholds are one quarter of the total virgin biomass (i.e., 1/2 B_{MSY}), and $F_{25\%}$ in the exploited region. Estimated biomass in 1978 is used as a proxy for virgin biomass and one-half of the biomass in 1978 is used as a proxy for B_{MSY}. Biomass reference points were recalculated in this assessment based on estimates of fishable biomass in 1978 for each region (see below).

Fishing mortality reference points were recalculated for this assessment (assuming the same natural mortality as in the previous assessment, $M=0.02$ y^{-1}) using a length-based per recruit model and new information about maturity and fishery selectivity.

Reference Point	Last assessment	New
$F_{0.1}$ (target)	0.0275 y^{-1}	0.0278 y^{-1}
F_{MAX}	0.1810 y^{-1}	0.0760 y^{-1}
$F_{25\%}$ (threshold)	0.0800 y^{-1}	0.0517 y^{-1}
$F_{50\%}$	0.0200 y^{-1}	0.0180 y^{-1}
Virgin biomass	2.30 million mt meats	3.973 million mt meats
$B_{MSY} = \frac{1}{2}$virgin (target)	1.15 million mt meats	1.987 million mt meats
$B_{Threshold} = \frac{1}{2} B_{MSY}$	0.575 million mt meats	0.993 million mt meats

The new estimate of $F_{25\%}$ (threshold) is substantially lower because of improved information about maturity and fishery selectivity. The biomass reference points are higher primarily because of new estimates of survey dredge efficiency. Other factors that affect the estimates are inclusion of biomass on GBK that is too deep to be sampled in the standard NEFSC survey (13% of total GBK stock biomass) and use of fishable biomass rather than 70+ mm biomass.

A length based per recruit model was used to calculate biological reference points for Maine waters, but only for purposes of comparison (i.e., they are not used to determine stock status). For ocean quahogs off Maine, $F_{max} =0.0561$, $F_{0.1}=0.0247$ and $F_{50\%} =0.013$ y^{-1}. No biomass reference points were calculated for Maine waters.

Fishing Mortality: $F= 0.0077$ y^{-1} in 2005 for the exploitable portion of the EEZ (excluding GBK) (Figure A5). For the whole EEZ in 2005, $F=0.0045$ y^{-1} (Figure A4). For Maine waters, $F=0.022$ y^{-1} in 2005.

Recruitment: Mean annual recruitment to the whole stock was small (<1% per year during 2005). There is some evidence of recruitment and small ocean quahogs in most regions.

A pulse of recruitment in LI, first noticed in survey data in 1978, has recruited into the fishable stock, based on survey data collected in 2005. Very small ocean quahogs (< 5 mm) were detected in one of the Maine fishing grounds in the 2005 state survey.

The timing and potential contribution of new recruits to the fishable biomass is important but uncertain in the EEZ and in Maine waters. Growth is slow so that initial recruitment of year classes to the fishery is delayed for about two decades and full recruitment may require an additional twenty years, depending on the region. Successful reproductive events are regional and may be separated by decades.

Stock Biomass: Fishable stock biomass in 2005 was 3.039 million mt (Figure A3). Estimated virgin biomass in 1978 was 3.973 million mt (Figure A2). The ocean quahog population is a relatively unproductive stock that is being fished down from its virgin state towards its B_{MSY} reference point (½ virgin biomass, estimated as 50% of biomass during 1978). After several decades of relatively low fishing mortality, the stock is still above the B_{MSY} reference point.

Based on survey data, LPUE data and biomass estimates for 1977-2005, declines in stock biomass are most pronounced in southern regions. In particular, stock biomass is below the ½ virgin level in the Southern Virginia, Delmarva, and New Jersey regions.

An increasingly large fraction of the stock (84% during 2005 compared to 52% during 1978) now occurs in northern regions (LI, SNE and GBK). GBK is of particular importance because it contained 32% of total biomass in 1978 and 42% of total biomass in 2005.

Fishable biomass in Maine waters in 2005 was estimated to be 22,000 mt. Logbook data show that LPUE levels have declined since the peak in 2002, but remain relatively high overall (Figure A8). The Maine fishery is small, relative to the rest of the EEZ, and unique. In particular, the Maine fishery exploits relatively small ocean quahogs at a rate $F=0.022$ y^{-1} that is approximately three times higher than on the remainder of the exploitable stock.

Special Comments: Agency, academic and industry personnel have devoted considerable effort to estimating efficiency of the NEFSC clam survey dredge during the 1997-2005 surveys. Progress was made since the last assessment but survey dredge efficiency remains the chief source of uncertainty. Depletion experiments designed to measure dredge efficiency should continue to be part of each NEFSC clam survey.

Rate of indirect mortality due to fishing (currently assumed to be 5% of landings) is uncertain. Indirect mortality may be significant in Maine waters where fishing effort levels per unit area are highest.

The FMP currently uses the fishing mortality rate that generates 25% of the maximum spawning stock potential ($F_{25\%}$) as a threshold reference point. Threshold reference points for fishing mortality should be estimates or proxies for F_{MSY}. $F_{25\%}$ is probably not an appropriate proxy for F_{MSY} in a long-lived organism like ocean quahog. F_{MSY} proxies, targets and thresholds should be re-evaluated. Current quota levels keep fishing mortality rates substantially below $F_{25\%}$ and biomass is currently well above the target.
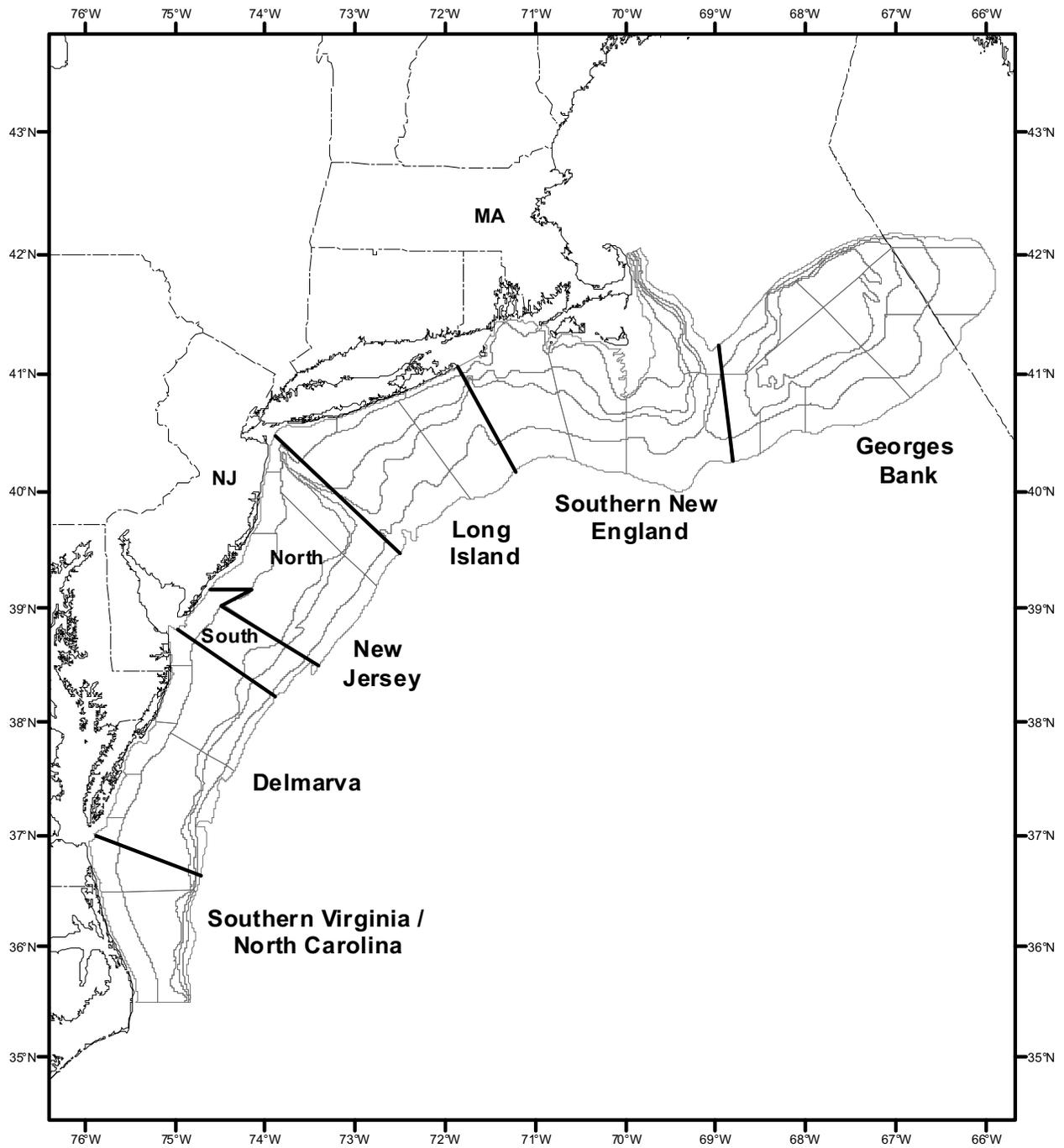
Questions about productivity of ocean quahog are becoming more important as the stock is fished down from high virgin levels to B_{MSY}. Additional studies focusing on recruitment, natural mortality, growth and stock response to reduced biomass levels are required.

Sources of Information:

Dahlgren, T, J. Weinberg, and K. Halanych. 2002. Phylogeography of the ocean quahog (*Arctica islandica*): influences of paleoclimate on genetic diversity and species range. Mar. Biol. 137: 487-495.

Murawski, S.A., J.W. Ropes and F.M. Serchuk. 1982. Growth of the ocean quahog, *Arctica islandica*, in the Middle Atlantic Bight. Fishery Bulletin 80: 21-34.

Northeast Fisheries Science Center (NEFSC). 2004. Ocean quahogs. In: 38th Northeast Regional Stock Assessment Workshop (38th SAW) Stock Assessment Review Committee (SARC) Consensus Summary of Assessments. NEFSC Ref. Doc. 04-03, 246 p.[1]

Northeast Fisheries Science Center (NEFSC). 2004. Ocean quahog. In: 38th Northeast Regional Stock Assessment Workshop (38th SAW) Advisory Report. NEFSC Ref. Doc. 04-04, 24 p.[2]

Powell, E. and R. Mann. 2005. Evidence of recent recruitment in the ocean quahog *Arctica islandica* in the Mid-Atlantic Bight. J. Shellfish Res. 24: 517-530.

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[1] Available online at: http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0316/
[2] Available online at: http://www.nefsc.noaa.gov/nefsc/publications/crd/crd0317/

A1. Stock assessment regions for ocean quahog in the US EEZ, with survey strata and stock assessment regions. For ocean quahog, the southern and northern portions of the New Jersey region are combined. The Maine fishing area is along the Maine coast north of the 43° 50' N.
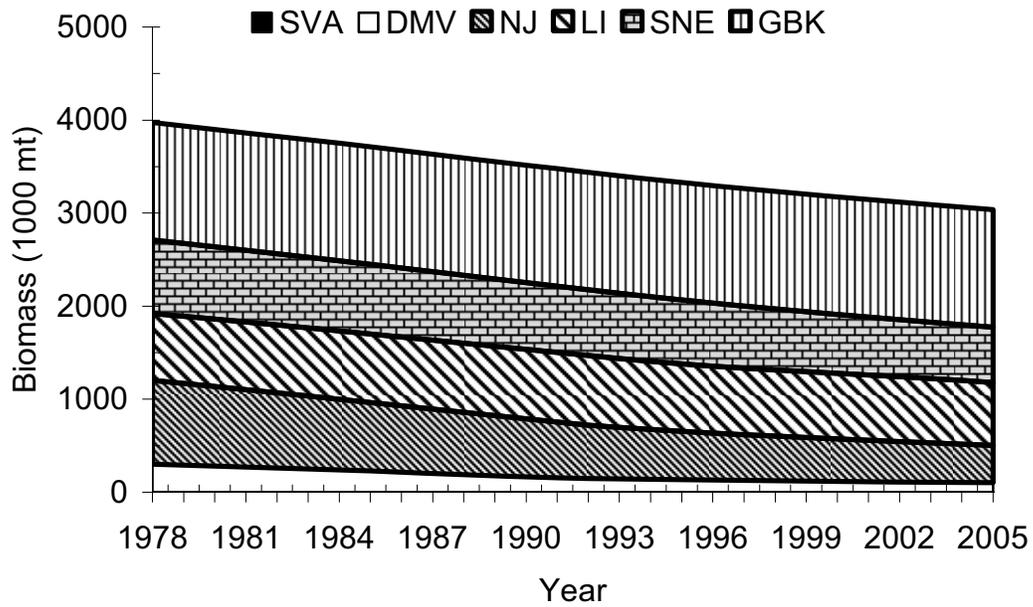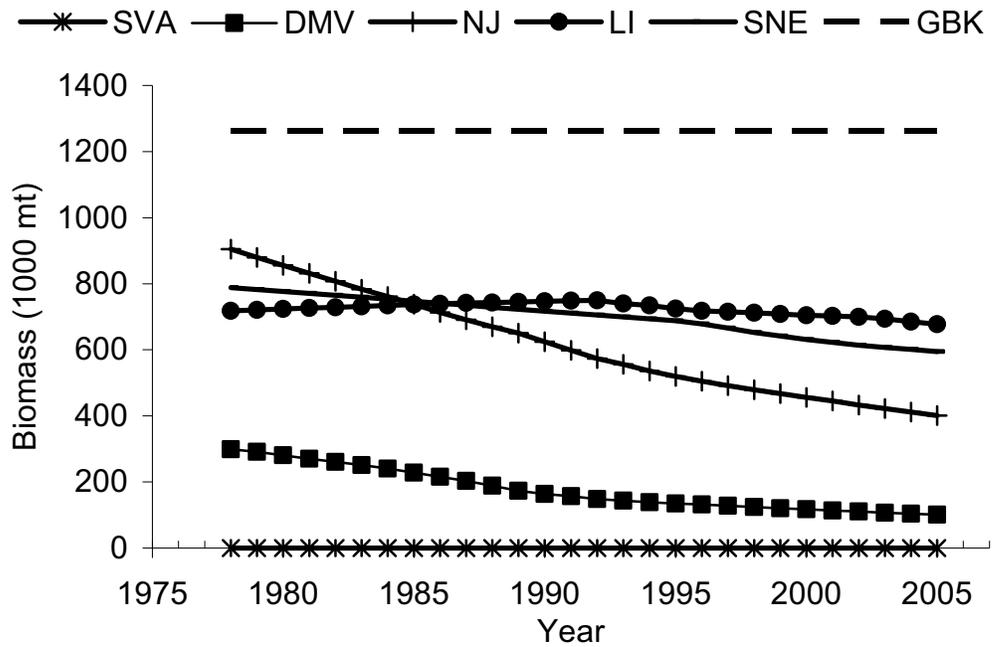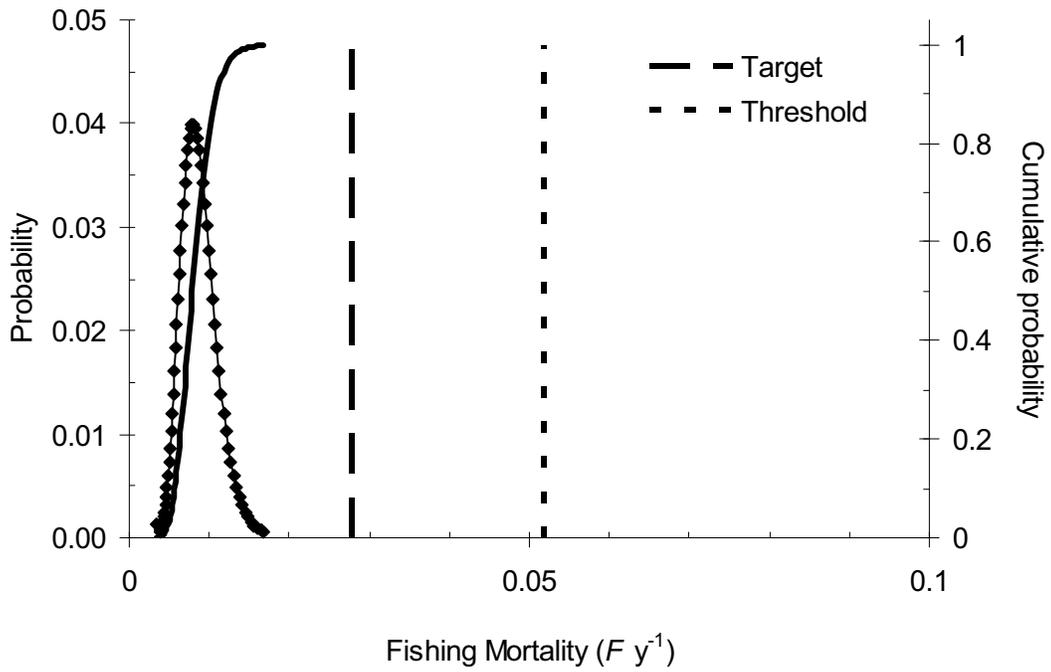
A2. Fishable biomass by region (*top*) and for the entire ocean quahog stock (*bottom*). Figures for SVA are near zero and do not show clearly in plots.
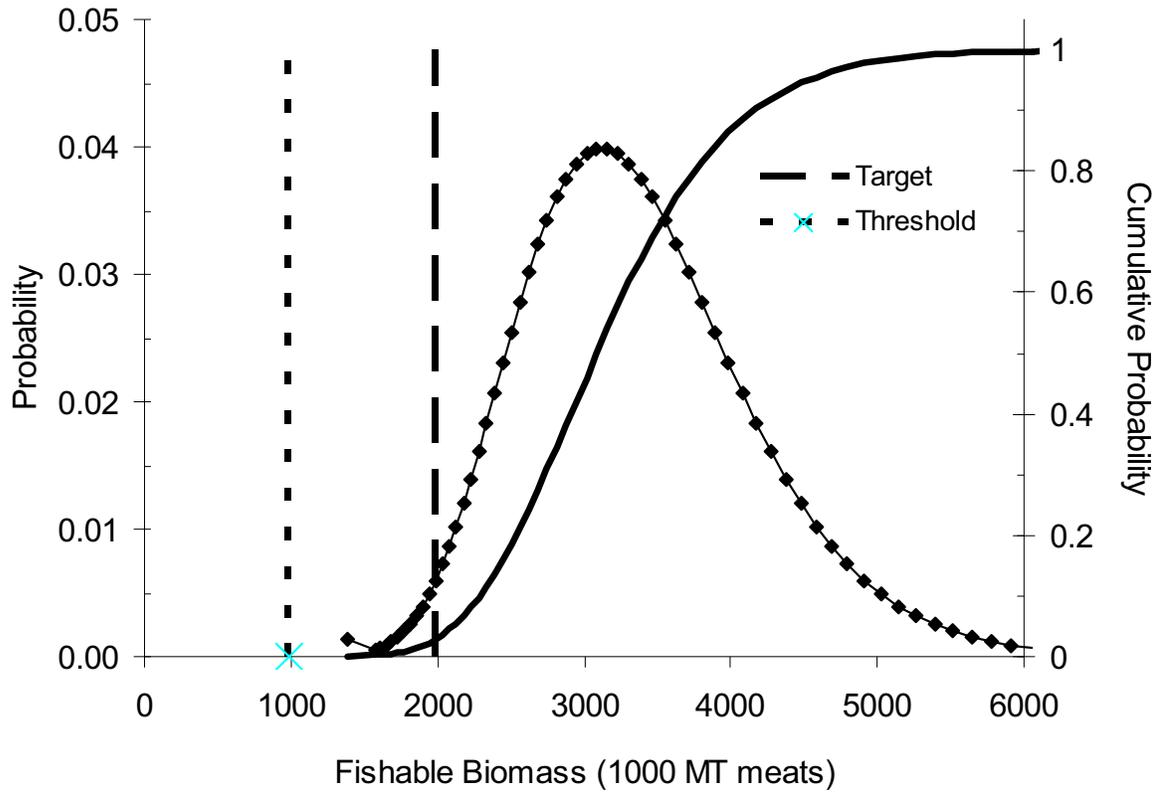
A3. Confidence interval for the 2005 fishable biomass of ocean quahog in the EEZ (all regions, including Georges Bank). The biomass target and threshold are shown for comparison.
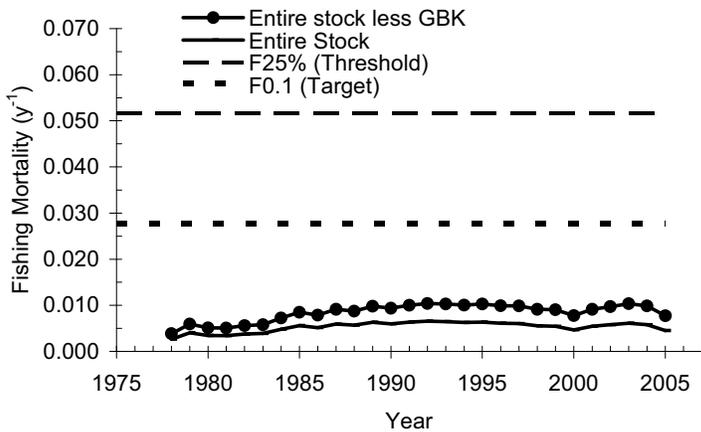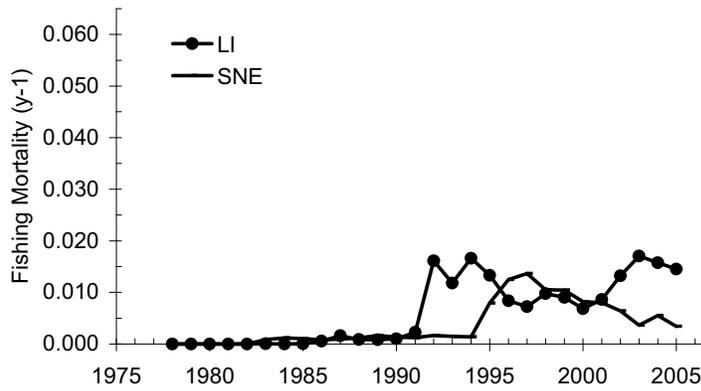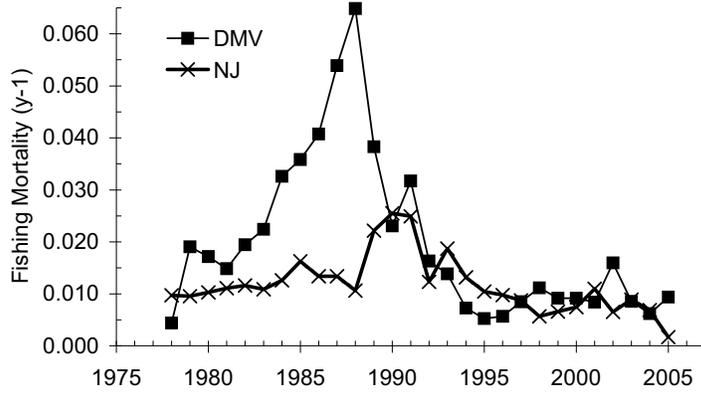
A4. Fishing mortality rates in southern regions (top), northern regions (middle) and for the exploitable portion (excluding Georges Bank) of the entire ocean quahog stock (bottom). Target and threshold reference points are shown for the exploitable portion of the stock in the bottom panel.

A5. Confidence interval for the 2005 fishing mortality estimate for ocean quahog in the exploitable region (EEZ less Georges Bank). The revised fishing mortality target and threshold are shown for comparison.
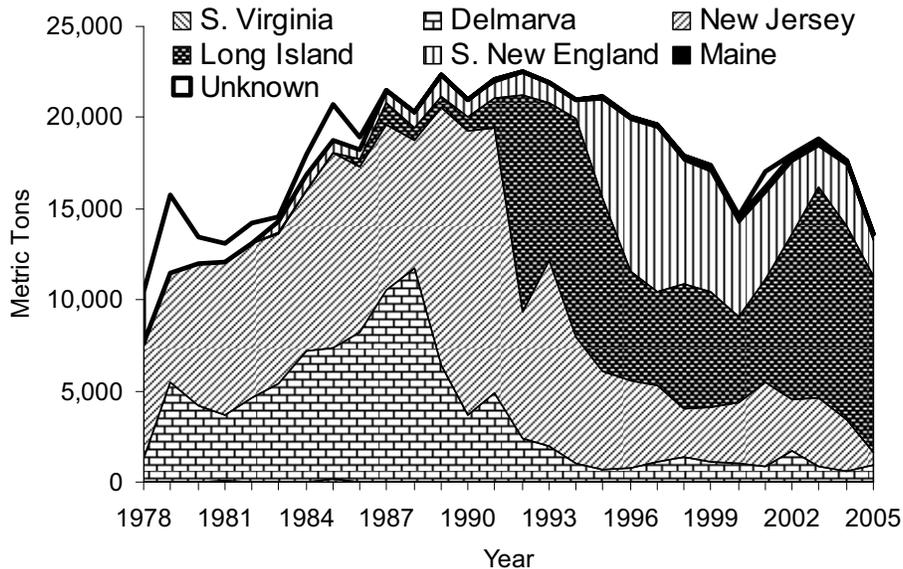
A6. Ocean quahogs landing (mt meats) in the EEZ by region during 1978-2005. Figures for SVA are near zero and do not show clearly in plots.
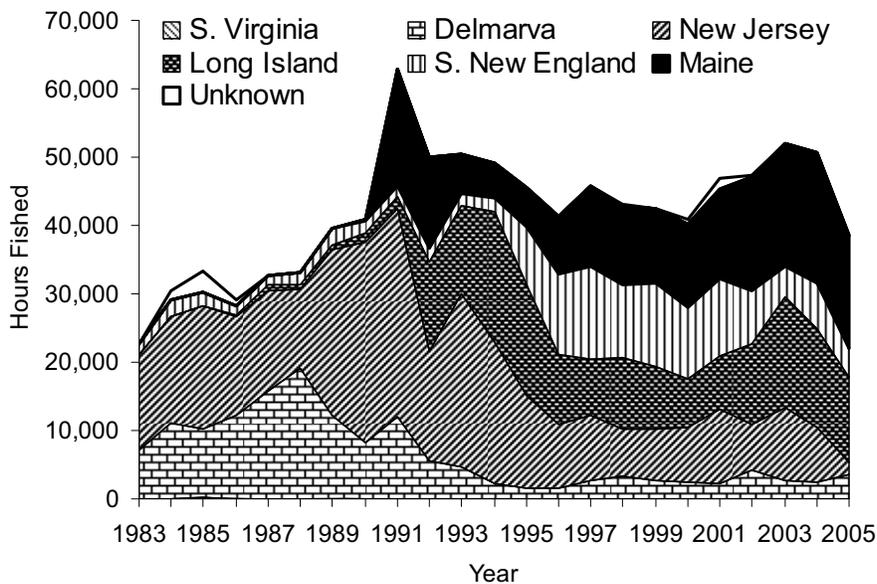
A7. Fishing effort (hours fished per year) for ocean quahog in the EEZ and Maine waters during 1983-2005 from mandatory logbooks. Figures for SVA are near zero and do not show clearly in plots.
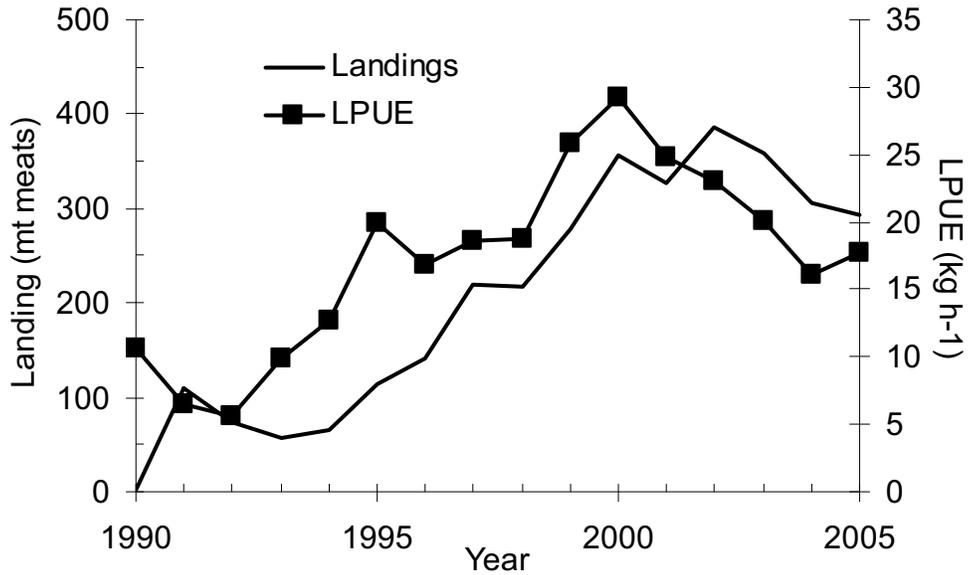
A8. Ocean quahogs landing (mt meats) and LPUE (kg meats hr^{-1}) in Maine waters during 1990-2005.
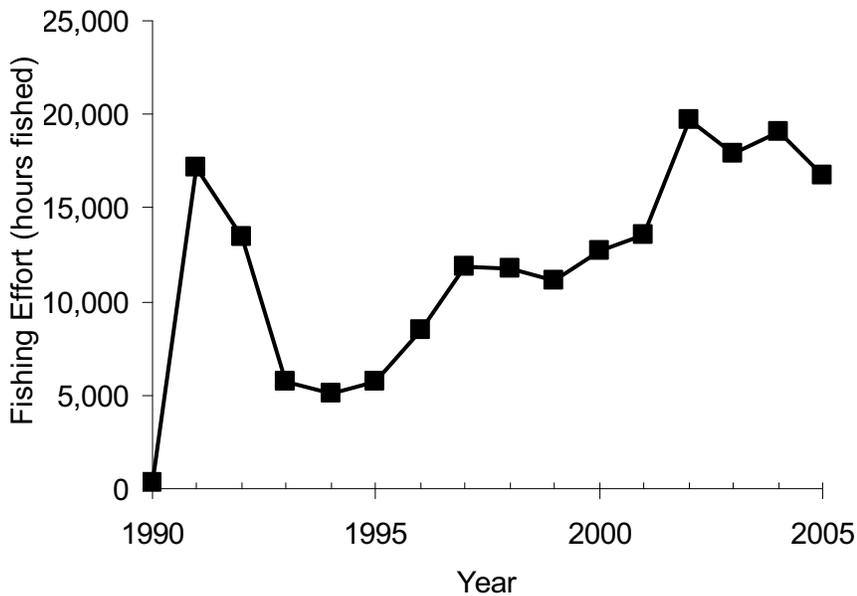
A9. Fishing effort (hours fished per year) for ocean quahog in Maine waters during 1990-2005 from mandatory logbooks.