C. ASSESSMENT OF ATLANTIC SURFCLAM

Report of the Invertebrate Subcommittee (see Appendix C1 for membership)

1.0 TERMS OF REFERENCE (TOR) AND SUMMARY

1. Characterize the commercial and recreational catch including landings and discards. *Completed, see Section C3.*

2. Estimate fishing mortality, spawning stock biomass, and total stock biomass for the current year and characterize the uncertainty of those estimates. If possible, also include estimates for earlier years. *Completed, see Section C5.*

3. Either update or redefine biological reference points (BRPs; proxies for B_{MSY} and F_{MSY}), as appropriate. Comment on the scientific adequacy of existing and redefined BRPs. *Completed, see section C6. Biomass reference points were updated based on new estimates of historical biomass levels and criteria in the Surfclam and Ocean Quahog Fisheries Management Plan. Fishing mortality reference points did not require updating. Current reference points were adequate for this assessment because stock biomass is relatively high and fishing mortality rates are low. However, it was noted that implicit assumptions about* B_{MSY} *and biomass during 1999 may not be valid and should be reevaluated.*

4. Evaluate current stock status with respect to the existing BRPs, as well as with respect to updated or redefined BRPs (from TOR 3). *Completed, see section C7. The stock is not overfished and overfishing is not occurring.*

5. Recommend what modeling approaches and data should be used for conducting single and multi-year stock projections, and for computing TACs or TALs. *Completed, see Section C8. A consistent set of stock assessment modeling, integrated bootstrap and stochastic projection software is now available that can deal with auto correlated recruitment patterns in surfclam. It is not necessary to describe approaches for setting TAC or TAL levels because the fishery is managed with constant quota levels.*

6. If possible:

    a. Provide numerical examples of short term projections (2-3 years) of biomass and fishing mortality rate, and characterize their uncertainty, under various TAC/F strategies. *Completed, see Section C9. Example projections under a wide range of scenarios indicate that surfclam biomass will decline over the next 2-3 years to levels near the* B_{MSY} *proxy level that used is used by managers as a target. The recent and expected declines are due to poor recruitment and slow growth. There is no indication that the stock will become overfished or that overfishing will occur. Uncertainty is very high, particularly for longer term projections.*

   b. Compare projected stock status to existing rebuilding or recovery schedules, as appropriate. *Not relevant. surfclam are not overfished and no rebuilding schedule exists.*

7. Review, evaluate and report on the status of the SARC/Working Group Research Recommendations offered in recent SARC reviewed assessments. *Completed, see Section C10.*

<u>Plain terms summary</u>

1) The following abbreviations are used to identify stock assessment and fishing regions for surfclam (Figure C1).

Region (south to north)	Abbreviation
Southern Virginia	SVA
Delmarva	DMV
New Jersey	NJ
Long Island	LI
Southern New England	SNE
Georges Bank	GBK

2) Overall, total surfclam biomass has declined during recent years due to slow growth and poor recruitment, particularly in southern regions. Despite declines, total stock biomass is still at a relatively high level. Fishing mortality is low in all regions.

3) Stock conditions are relatively good in northern regions such as LI, SNE and GBK where the bulk of the stock was found during 2005 and little fishing occurs. Stock conditions are poorer in southern regions, DMV and SVA in particular, where fishing has occurred since the 1980's and a relatively small fraction of the stock was found during 2005. Conditions in NJ, where most of the fishing and a large fraction of the stock occur, are intermediate.

4) The surfclam stock is not overfished and overfishing is not occurring. Overfishing and overfished stock conditions are not likely to occur in the near future.

5) Total landings from the EEZ stock during 2005 were less than the quota due, based on industry sources, to market factors.

6) The majority of landings during recent years were from the NJ region although some landings were also taken from DMV in the south. Landings in the northern SNE and LI regions increased during recent years were minor. No fishing occurs on GBK due to risk of paralytic shellfish poisoning (PSP).

7) Over time, surfclam biomass has shifted towards the north. During 2005, the largest fraction of stock biomass was in GBK, rather than in NJ or DMV.

8) Fishing effort and catch have shifted north during recent years as catch rates in the south have declined.

9) Total fishing effort increased during recent years while landings per unit effort (LPUE) decreased for the fishery as a whole.

10) LPUE has declined in NJ and drastically in DMV. LPUE in the LI region appears to be increasing.

11) Growth rates for surfclam in NJ, and particularly in DMV, have slowed in recent years so that the age at recruitment to the fishery has increased by 1-2 years. Delayed recruitment and slower growth after reaching fishable size reduce potential fishery yield by a substantial amount. Slower growth is due to environmental factors.

12) Recruitment has declined during recent years for the stock as a whole and is at or near record low levels in most regions.

13) Stock biomass for the entire stock was at record high levels during the late 1990s. Since then stock biomass has declined. In 2005, total stock biomass was about the same as before the peak.

14) Biomass trends for NJ were similar to trends for the entire stock. Biomass trends for DMV indicate steeper and continuous declines since the record high levels for DMV during the early 1980s.

15) Recent declines in biomass are due to negative surplus production. This means that factors that increase stock biomass including growth and recruitment have not been large enough to offset natural (not related to fishing) losses.

16) Fishing mortality rates are low in all regions. The environment, rather than fishing, apparently caused the recent declines in biomass.

2.0 INTRODUCTION

This stock assessment for the offshore subspecies of Atlantic surfclam (*Spisula solidissima solidissima*) was prepared for SAW/SARC-44 along with a stock assessment for ocean quahog (*Arctica islandica*). No information is provided about the smaller coastal form (*S. s. similis*) that occupies relatively southern inshore habitats (Hare and Weinberg 2005). The geographic distributions of the two subspecies overlap to a limited extent in the south and in some inshore waters to the north. However, *S. s. similis* is reproductively isolated from *S. s. solidissima* and not important to the commercial fishery.

The same methods were used in the assessments for surfclam and ocean quahog although the surfclam assessment was completed after the ocean quahog assessment and incorporates a number of improvements. Interested persons and reviewers should read the ocean quahog assessment (i.e., Assessment A in this volume) first because the methods used for both species are described there in detail. Improvements to methods for surfclam and other details relevant only to surfclam are described below.

Distribution and biology

Atlantic surfclam is a relatively large fast growing bivalve distributed in the western North Atlantic Ocean, along the coast of North American from the southern Gulf of St. Lawrence to Cape Hatteras (Figure C1). Individuals larger than 16 cm shell length (SL) are relatively common in NEFSC surveys. Commercial concentrations are found primarily off New Jersey, the Delmarva Peninsula, and on Georges Bank. Surfclam are found from the intertidal zone to a depth of about 60 m but densities are low at depths greater than 40 m. See Cargnelli et al. (1999) for a complete review of life history and distributional information. The distribution of Atlantic surfclam and the distribution of a related species (*S. similis*) overlap in the south and some inshore waters to the north (Hare and Weinberg 2005).

It is likely that all Atlantic surfclam along the northeast coast belong to the same biological population. Surfclam are common in both inshore state (≤ 3 mi from shore) and offshore federal waters. Federal waters consist of the Exclusive Economic Zone (EEZ), between 3 and 200 mi from shore. The stock assessment applies only to the EEZ segment of the surfclam population in federal waters, however, because the EEZ is the management unit specified in the Fishery Management Plan for the Atlantic Surfclam and Ocean Quahog Fisheries (FMP). Surfclam in New Jersey and New York state waters support valuable fisheries that are managed by state authorities.

Surfclam in the EEZ are managed as a unit stock but there is substantial regional variability in exploitation rates and biological characteristics. A variety of calculations and estimates in this assessment are presented for smaller stock assessment regions which are defined below (Figure C1). Previous assessments separated the New Jersey (NJ) region into Northern New Jersey (NNJ) and Southern New Jersey (SNJ) components. In this assessment, the NJ region is treated as a single entity. SNJ and NNJ were combined to simplify the assessment and because data for SNJ were too limited and variable to be analyzed separately.

There is uncertainty about the timing of annual mark (annulus) formation in surfclam chondrophores, which are cut from shells and used to age surfclams taken in NEFSC clam surveys. There is additional uncertainty about indentifying the first annual mark (Jacobson et al. 2006). Despite these questions of interpretation, surfclam annual rings are relatively easy to count. In this assessment, the number of annual marks and age are assumed to be the same and the assumed birth date is January 1 so that, for example, a member of the 2004 year class taken during the 2005 NEFSC clam survey would be age 1 at the time of capture and expected to show one ring. Ages for surfclams taken in the commercial fishery that operates year round are more uncertain. Surfclams age 20+ are relatively common and the maximum observed age exceeds 35. See Jacobson et al. (2006) for information about procedures used to estimate surfclam age.

Surfclams are capable of reproduction at age 1, although full maturity may not be reached until age 2. Spawning occurs during late summer and early fall. Eggs and sperm are shed directly into the water column. Recruitment to the bottom occurs after a planktonic larval period of about three weeks.

Weinberg (1998) and Weinberg and Helser (1996) show that growth rates vary among regions, over time and in response to surfclam density levels. Based on NEFSC clam survey data (Figure C2), growth rates appear to have declined for surfclams in the southern DMV region and to a lesser extent in the NJ region since 1993. Slower growth in surfclams in DMV during recent years coincides with mortality in near shore areas off DMV probably due to warm water (Weinberg 2005) and lower occurrence of surfclams with 25+ annual marks in survey data (Figure C2).

Length-weight parameters used in this assessment to convert numbers of surfclams of different shell lengths in surveys to meat weight equivalents are region specific and based on fresh (unfrozen) material (Table C1). Length-weight parameters vary among locations and over time. Although length-weight data are collected periodically during NEFSC clam surveys, recent assessments used the same length-weight relationship for the sake of simplicity and consistency (NEFSC 2003). A simple and consistent approach is used because length-weight data are not available for the commercial catch (which targets clams with high meat yield) and because length-weight information for early surveys was based on frozen material.

Management

The fishery for Atlantic surfclams and ocean quahogs in the EEZ are unique in being the first US fishery managed under an individual transferable quota (ITQ) system. ITQ management was established during 1990 by the Mid-Atlantic Fishery Management Council under Amendment 8 to the Fishery Management Plan for the Atlantic Surfclam and Ocean Quahog Fisheries (FMP). Management measures include an annual quota for EEZ waters, which was 26.2 thousand mt meats per year during 2001-2005, and mandatory logbooks that describe each fishing trip. See Murawski and Serchuk (1989) and Serchuk and Murawski (1997) for detailed information about history, management and fishery operations. MAFMC (2006) describes recent fishery conditions and management for both surfclams and ocean quahogs.

Previous assessments

Stock assessments are generally done after NMFS clam surveys, which are conducted every 2-3 years. In the most recent stock assessment for surfclam, NEFSC (2003) concluded that the stock was above the management target level (the stock was not overfished) and that fishing mortality was below the management threshold value (overfishing was not occurring). The stock was characterized as declining from a relatively high biomass level at the rate of about 5% per year due to negative surplus production and, in particular, relatively low recruitment. Conclusions from this stock assessment are similar. See NEFSC (1993; 1995; 1998; 2000) for earlier surfclam stock assessments.

Beginning with NEFSC (1998), the primary emphasis in surfclam stock assessments was: 1) use of sensors to evaluate survey dredge performance; 2) estimating survey dredge efficiency via cooperative “depletion studies”; and 3) calculation of efficiency corrected swept-area biomass. Previous stock assessments used stock assessment models with variable results. In this assessment, data from all available depletion studies are analyzed using consistent and improved methods. The updated information is used in a stock assessment model that is successfully applied to the stock as a whole and to the important DMV and NJ regions.

3.0 COMMERCIAL CATCH (TOR-1)

In using landings data for surfclams, 1 industry standard bushel (1.88 ft^3) was assumed to produce 17 lbs or 7.711 kg of useable meats. Fishery landings in this assessment are reported as meat weights for ease in comparison to survey data and in calculations but were originally recorded in units of cages (1 cage = 32 industry bu). LPUE data, however, are reported in this assessment as landings in bushels per hour fished.

As in previous assessments (NEFSC 2003), catch in all stock assessment analyses is the sum of landings plus a 12% upper bound for incidental mortality that may occur during fishing operations (i.e. assumed catch = 1.12 times landings). It is important to realize that the 12% figure is an upper bound and that actual incidental mortality is likely to be lower. Incidental mortality in the surfclam and ocean quahog fisheries is likely lower than might be expected because the total area fished is modest. The total area fished is relatively low because fishermen operate efficiently under ITQ management and target only areas of highest density. Moreover, the ITQ fishery operates with little or no regulation induced inefficiency (e.g. inefficiency due to area closures, trip limits, size limits, etc.). Discard of small surfclams occurred during 1982-1990 when size limits were used to regulate the surfclam fishery (Table C2) but are currently near zero. Recreational catch is near zero.

Size selectivity of commercial clam dredges and harvesting equipment has not been characterized quantitatively in detail. Based on commercial length data and experimental results, NEFSC (2003) assumed that surfclams in NJ were fully available to the commercial fishery at 120 mm SL and that surfclams in other regions were fully available to the commercial fishery at 110 SL.

In this assessment, surfclams 120+ mm SL are assumed to be the fishable stock in all regions. In contrast, that NEFSC (2003) used 120+ mm for NJ and 110+ mm SL for other regions. Fishing mortality estimates in this assessment, for example, compare total catch (landings plus an assumed 12% upper bound for incidental mortality) to the fishable stock 120+ SL. The bulk of the fishery and much of the stock occurs in NJ, where NEFSC (2003) assumed recruitment at 120 mm SL. Based on commercial length data in NEFSC (2003) and shown below, there is no strong evidence that size at recruitment differs among regions. Consistent use of 120 mm SL simplifies the assessment and makes biomass and fishing mortality estimates for combined regions easier to interpret.

Age at recruitment

Age at recruitment to the surfclam fishery depends on growth rates and, in particular, the ages at which surfclams reach 120 mm SL. Growth curves used in stock assessment modeling (described later) fit to survey age data indicate that surfclam recruited to the DMV fishery at about age 5 ½ y during 1982-1992 and at about age 7 ½ y during 1994-2005. Growth curves for NJ show that surfclams reached 120 mm SL and recruited to the fishery at about age 5 y during 1982-1992 and at about age 6 y during 1994-2005. Changes in age at recruitment should have substantial effect on potential fishery yield. Assuming a natural mortality rate of M=0.15 y^{-1}, for example, numbers of recruits to the fishery per surviving larvae would be decreased by about 26% due to natural mortality during the two additional years prior to recruitment. This effect is likely compounded by other reductions in productivity due to slower growth after recruitment to the fishery occurs.

Landings, fishing effort and prices

Landings and fishing effort data for 1982-2005 were from mandatory logbooks. Data for earlier years were from NEFSC (2003) and MAFMC (2006).

Landings data for surfclams are relatively accurate in comparison to other fisheries because of a comprehensive system for tracking landings in the ITQ fishery. Effort data are, however not reliable for 1985-1990, due to regulations that restricted the duration of fishing to 6 hr. Effort data are relatively reliable during later years.

Surfclam landings were primarily from the US EEZ during 1965-2002 (Table C3 and Figure C3). EEZ landings peaked during 1973-1974 at about 33 thousand mt. EEZ landings were relatively high during 2001-2005 and varied between 21 and 25 thousand mt. Landings reached the quota in most years but were less than the quota during 2005 because of limited markets (according to industry sources).

The bulk of EEZ landings were from DMV during 1979-1980 and from NJ during every year since 1981 (Table C4 and Figure C4). During 2001-2005 DMV landings were modest with relatively small amounts reported from the LI and SNE regions. Trends in fishing effort were similar (Table C5 and Figure C5).

Nominal exvessel prices for the inshore and EEZ fisheries increased from about \$8 bu^{-1} during 1982 to \$10 bu^{-1} during 1994 and then declined to about \$9.50 bu^{-1} during 2000-2005 (Figure C6). Using 1980-1982 as a basis, prices declined in real terms from about \$9 bu^{-1} during 1982 to about \$5 bu^{-1} during 2005. Based on industry sources (D. Wallace, pers. comm.), the "break-even" price for surfclams during 2005 (i.e. price necessary to cover variable costs such as fuel, crew shares, food, etc.) was about \$4-\$5 bu^{-1} (nominal, 2005 dollars).

Landings per unit effort

Nominal landings per unit effort (LPUE) based on logbooks was computed as total landings divided by total fishing effort for all vessels and all trips (Table C6 and Figure C7). In addition, standardized LPUE indices (Table C7 and Figure C7) were computed from a log-linear GLM model with year, month and vessel effects for each region (see Assessment A. Ocean quahog, in this Report). GLM models were fit to tow by tow logbook data for vessels in size class 3 and 4 (51-150 and 151-500 GRT) which are the bulk of the EEZ fishery. There were no records with zero catch and it was not necessary to add a constant before applying the log transformation to the data. Year effects were used as the index of LPUE after they were adjusted to the average of June catch rates for a single vessel that fished in all regions.

For surfclams, year, vessel and month effects were statistically significant for all regions. Although month effects were statistically significant, they were small, of little practical importance and because they did not show meaningful seasonal trends.

Trends in nominal and standardized LPUE were similar (Figure C7). In particular, LPUE declined steadily from peak levels during 1994 to relatively low levels during 2005 in the DMV region. LPUE declined slowly but steadily in the NJ region during 1991-1995 and in LI after 2000. LPUE levels during 2005 were at or near record lows. In contrast to other regions, LPUE levels in SNE increased rapidly after 1998 as the small fishery in SNE developed.

LPUE is not an ideal measure of fishable biomass trends for sessile and patchy stocks like surfclam because fishermen target high density beds and change their operations to maintain relatively high catch rates as stock biomass declines (Hilborn and Walters 1992). However, trends in LPUE and fishable biomass based on the NEFSC clam survey were similar during recent years for DMV and NJ where fishing has been heaviest and fishing grounds are widespread (Figure C29). In contrast, LPUE and survey trends were not similar for LI and SNE where less fishing has occurred and the fishery is not as widespread. The correlation in trends for DMV and NJ was likely due to reduced surfclam densities in many habitat areas where significant densities occurred. Previous assessments noted that the fishery in DMV and NJ and surfclam stock overlap relatively completely.

Spatial patterns in fishery data

Average landings, fishing effort and LPUE per year from logbooks were calculated for ten-minute squares (TNMS) during 1981-1990, 1991-1995, 1996-2000, and 2001-2005. For plots, data for TNMS with very low levels of landings and data for TNMS outside the range of the fishery (obvious errors) were omitted.

Spatial patterns in fishery data (Figure C8 to C9) show relatively high landings and fishing effort in the south mostly offshore in DMV and SVA during 1981-1990 with some activity near shore in NJ and in northern regions of SNE south of Cape Cod. In later years, fishing activity was mostly in NJ. During 1991-1995, there were no landings or effort in SVA or SNE, reduced activity in DMV, and increased activity in NJ with expansion to offshore regions. During 1996-2000, activity in DMV decreased and the fishery moved north with some activity off southern LI. During 2001-2005, landings and effort increased in DMV and SNE with some activity SNE southeast of Cape Cod.

TNMS with relatively high LPUE levels (Figure C10) were mostly off NJ and DMV in all years. During 2001-2005, LPUE levels were high in offshore NJ, with several areas of high LPUE in DMV and SNE southeast of Cape Cod.

Important TNMS

TNMS "important" to the fishery were identified by choosing the twenty TNMS with the highest mean landings per year during 1981-1990, 1991-1995, 1996-2000 and 2001-2005 (see Assessment A. Ocean quahog, in this Report). Trends in landings, effort and LPUE were plotted (Figures C11-C13) for each to show changes in conditions within individual TNMS. Compared to less productive ocean quahog, landings, effort and LPUE were relatively high for some TNMS after many years of fishing activity.

Fishery length composition

Taken together, port sample length data for DMV and NJ in the south indicate that the surfclam stock consisted of a wider range of sizes during the early 1980s (Figure C14 to C3-15). As expected, the port sample data for both regions appear to reflect the relatively strong 1991 year class which would have recruited to the fishery during the early and mid-1990s (see below). Although sampling levels are low and the data are difficult to interpret, smaller surfclam in landings from DMV and NJ during 2005 might be due to recruitment of the 1998 year class at age 7 (see below).

Port samplers routinely collected shell length measurements for 30 randomly selected surfclams from landings after selected fishing trips. Numbers of trips sampled and numbers measured were low (Table C8), particularly during recent years and care is required in interpreting trends. Numbers of trips sampled is probably the best measure of the potential information in port sample length data because lengths tend to be similar for individuals from the same trip (Pennington et al., 2002).

Commercial length composition data for DMV indicate that surfclams landed during 1982-2005 were mostly 120+ mm SL during most years although smaller individuals were evident during 1992-1994 and 2005 (Figure C14). The apparent reduction in shell length during 2005 is difficult to interpret due to modest sampling (Table C8). Relatively large surfclams were landed in DMV during 1982-1985 indicating that large surfclams were more common in DMV at that time.

There were more port samples from NJ than DMV during most years (Table C8). Commercial length composition data for NJ indicate that most of the surfclams landed during 1982-2005 were at least 120 mm SL, although smaller individuals were evident during 1982-1985, 1993-1998 and 2005 (Figure C15).

Port sample data for LI are limited to 1983, 1993 and 2005 (Figure C16) and samples sizes are modest (Table C8). The data for 2005 show substantial numbers of small individuals. However, the data suggest that most of the landings in LI are at least 120+ mm SL.

Port sample data for SNE are limited to 1982-1990 (Figure C17) and samples sizes are modest (Table C8). The data suggest that most of the landings in SNE are at least 120+ mm SL.

Fishery age composition

Fishery age composition data for DMV and NJ during 2005 (Figure C18) from port sample lengths and survey age-length keys indicate that most of the 2005 landings were ages 5+ y. The strong 1992 (age 13 y in 2005) and 1998 (age 7 in 2005) year classes were important to the fishery during 2005.

Apparently strong year classes in the fishery length and age composition data for DMV and NJ may have due to low port sampling in some years and lack of age data for the commercial catch. However, survey age composition data (described later) suggest the same recruitment patterns.

Fishery age composition data for DMV and NJ do not show evidence of strong incoming year classes that would recruit to the fishery prior to 2010 (Figure C18). However, small surfclam are not selected by commercial dredges.

4.0 NEFSC CLAM SURVEY TREND DATA

NEFSC survey strata used to track surfclam trends (Table C9) are different than used for ocean quahog because surfclams live in relatively shallow water where ocean quahog are usually not found. After borrowing to fill holes (survey strata with no tows, see Assessment A. Ocean quahog, in this Report) a few holes remained (Table C9). Remaining holes were filled for swept-area biomass calculations but not for trend analysis using a model described below. As pointed out earlier (i.e., see Assessment A. Ocean quahog, in this Report NEFSC), NEFSC survey data are used only from surveys during 1986-2002 because of limited sampling during other years.

A cooperative surfclam survey was conducted in SVA, DMV and NJ during 2004 (Weinberg et al. 2005). It is used in calculation of swept area biomass but not for trend analysis.

Tows with poor survey dredge performance

NEFSC developed a set of objective criteria based on sensor data used to identify NEFSC clam survey tows with poor dredge performance (see Assessment A. of this Report). These criteria were used in this assessment to identify tows in the 2005 survey with poor dredge performance.

Dredge performance during the 2002 survey

Sensor data from the 2002 survey review were reviewed to see if dredge performance problems during 2005 also occurred during 2002. If so, the dredge performance issues might occur during most surveys.

Because of time constraints the review for 2002 was limited to a visual inspection of sensor data plots for a sample (213 out of 556) of stations. Details are available in Appendix C2 but the visual criteria used to judge dredge performance were the same as used in a preliminary analysis of the 2005 SSP data. In particular, manifold pressure and angle of attach were reviewed for significant deviations from "normal" values.

In general, results showed that poor dredge performance problems are likely to arise due to a number of factors that affect either manifold pressure or the angle of attack for the dredge while in operation on the bottom. The main reason for a poor dredge performance differed during 2002 and 2005 (Appendix C3). Compared to the survey during 2002, the 2005 survey had a high number of poor incidents due to manifold blockage that occurred when a screen over the pumps water intake failed and allowed small stones to lodge in the manifold nozzles. In 2002 the main problem was the dredge pump being shut off early.

It is important to realize that most of the tows with poor dredge performance would have been excluded from stock assessment analyses anyway due to haul and tow data routinely collected by the survey watch chief or chief scientist at each station. After tows with haul or gear problems were omitted, many of the remaining tows with poor dredge performance would be excluded from trend and swept area biomass calculations because they were nonrandom (Figures C19-C20).

Based on rates of occurrence during the 2002 and 2005 surveys, it was hypothesized that poor dredge performance occurs regularly during NEFSC clam surveys. Random stations during the 2002 and 2005 surveys with poor dredge performance and not otherwise were therefore used in estimation of survey trends for surfclam. In practical terms, it would have been impossible to exclude such tows consistently in all years because sensors were not used prior to 1997. As shown below, tows with poor dredge performance during 2002 and 2005 had an imperceptible effect on survey trend indices and swept area biomass estimates with the exception of the LI area during 2005.

Survey dredge performance during depletion studies

Based on data for 2002 and 2005 surveys, the frequency of tows with poor dredge performance[29] was relatively high during depletion experiments by the *R/V Delaware II*, probably because repeated tows in the same area loosened sediments which obstructed

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[29] During the 2005 survey, tows with poor dredge performance occurred at survey stations: 1, 2, 14, 17, 20-26, 28, 29-34, 45, 48, 56, 58, 67, 75, 76, 108, 218, 225, 262, 282, 405, 411, 413, 414, 417, and 422-424. Based on a sample from the 2002 survey, tows with poor dredge performance occurred at survey stations: 4, 32, 42, 44, 45, 52, 76, 82, 90, 101, 103, 105, 106, 111, 118, 125, 137, 140, 141, 218, 250, 254, 278, 360, 368, 382, 386, 394, 458, 496, 498, and 506.

the intake and exhaust nozzles on the survey dredge. Surfclam depletion experiments by the *R/V Delaware II* during the 1997, 1999 and 2002 surveys were therefore not used in this stock assessment.

Based on the sampled tows and visual analysis, the frequency of tows with poor dredge performance (Table C10) during 2002 was about 15%, almost twice as high as in 2005 (8%). In both cases, roughly 30% of the tows with poor dredge performance were made during depletion experiments.

In contrast to trend analysis, 2005 survey stations with poor dredge performance and not otherwise were excluded from swept-area biomass calculations. The goal of swept-area biomass calculations was to obtain the best biomass estimate possible and consistency from year to year was not as important. No stations with poor dredge performance were omitted from the 2002 survey because not all stations were examined and the determination was subjective.

Imputed survey data for remaining holes

Negative binomial GLM models were fit to survey catch data for surfclam to impute survey data for remaining holes (Table C9). Imputed data were used only in swept area biomass calculations and were not used in trend analysis due to lack of time and because the approach was experimental. Effects of imputed values on survey trends and swept-area biomass were minor because most holes had already been filled by borrowing (Table C12). Residual plots for SVA, GBK, and SNE (Figures C21-C23 suggest that the model was a reasonable approach that performed acceptably. Pending further evaluation, imputed survey data might be used in place of borrowing for future surfclam assessments.

Models used to impute missing survey data were fit in Splus using the glm.negbin() function available in the MASS library of functions for Splus and R statistical analysis software (Venables and Ripley 1997). The linear predictor had categorical year and stratum effects and the log link was employed so that year and stratum effects were multiplicative. Parameters were estimated by maximum likelihood assuming that the observed survey data were drawn from a negative binomial distribution with mean estimated by the model and a variance parameter common to all observations. The primary advantage of the negative binomial model was that it accommodated noisy data and tows with zero catch in a natural manner without adding constants and taking logs or otherwise changing the data.

A separate model was fit to tow by tow mean kg/tow (standardized using Doppler tow distances) for surfclam 120+ mm SL in each stock assessment region. All data for successful random tows during 1982-2002 were used. The imputed values used to fill remaining holes were predictions from the model for year and strata combinations missing in the original survey data.

2005 survey results

Based on CVs for means in stratified random sampling, the 2005 NEFSC clam survey was reasonably precise for well sampled regions (Table C11). Of particular interest, small recruit surfclams (50 to 119 mm SL) were taken from near shore strata in southern DMV (Figure C4.6) where warm water probably caused extensive mortality during 1999-2004 (Weinberg 2005; Weinberg et al. 2005). However, no large fishable surfclams (120+ mm) were found in near shore strata off southern DMV (Figures C24-

C25). See NEFSC (2005) for a summary of survey station locations and catches during the 2005 NEFSC clam survey.

Survey trends

Survey trend data (Figures C26–C28) were more variable for small surfclams than for large surfclams. Based on survey trend data, fishable biomass (120+ SL) declined in southern regions SVA, DMV and NJ. The decline in SVA was gradual beginning in the mid-1980s. The declines in DMV and NJ were relatively rapid beginning in the mid-1990s. Fishable biomass in LI may have increased gradually after 1982 but the survey data are variable and difficult to interpret.

Recruitment indices 2005 were at or near record lows for all regions surveyed with the exception of LI and GBK which was not surveyed in 2005 (Figures C26-C27). During the 2002 survey, recruitment in GBK was relatively high.

With the exception of LI during 2005, tows with poor dredge performance during 2002 and 2005 had an imperceptible effect on estimated trends in fishable biomass (Figure C28).

Year effects and the 1994 survey

Trends in NEFSC survey data (Table C11) for small recruit surfclams (mean n tow-1, 50-119 mm SL) and large fishable surfclams (mean kg tow, 120+ mm SL) showed some evidence of year effects when estimates for the same year and region increased or decreased together (Figure C26). Year effects in NEFSC clam survey may be due to changes in survey dredge equipment or protocols between surveys (NEFSC 2003).

Based on survey trend data, it was decided to include the 1994 survey in all analyses for surfclam. In contrast, previous surfclam assessments (NEFSC 1998; 2000; 2003) included 1994 survey data in graphics but excluded the data from swept area biomass and other analyses because of hypothesized year effects that may have increased catch rates. In particular, the voltage supplied to the pump on the dredge was reportedly set at 480 V, rather than 460 V as specified and higher voltage during the 1994 survey may have increased catch rates (NEFSC 2003). However, based on additional survey data there is insufficient evidence of a year effect during the 1994 survey for surfclam. Moreover, field tests with the survey dredge operating with 460 and 480 V were inconclusive (J. Weinberg, pers. comm.). Additionally, a comparison of tows during the 2002 and 2005 survey with good and poor dredge efficiency suggested that surfclam catches were not sensitive to dredge performance (Appendix C3).

The decision to use 1994 survey data for surfclams in stock assessment analyses does not apply to ocean quahogs. Evidence for a strong year effect due to high voltage appears stronger for ocean quahogs (see Assessment A. in this Report).

Survey length and age data

Survey length composition data show a wide range of lengths for surfclam in SNE, LI, and NJ with relatively few large surfclam in DMV and a relatively narrow range of lengths in GBK (Figures C30-C34). Survey length data for LI during 2005 was too variable to be interpreted. It may be possible to track a recruitment event in the survey length data for LI beginning in 1983. Length data for SVA are scant.

Survey age composition data for NJ and DMV show the strong 1992 and 1998 year classes relatively consistently and clearly (Figure C34b). During 2005 these two year classes dominated the population as 7 and 13 year-olds. There is some evidence of a recruitment event in the age composition data for age 2 surfclams in DMV during 2005.

5.0 STOCK BIOMASS AND FISHING MORTALITY (TOR-2)

Efficiency corrected swept area biomass estimates were based on NEFSC and cooperative clam survey data for 1997, 1999, 2002, 2004 and 2005 and cooperative depletion experiments. They are a key source of information about the scale (magnitude, thousand mt) of surfclam biomass during recent years in this assessment.

Efficiency corrected swept area estimates are relatively direct, model-free and independent estimates of biomass and fishing mortality. Surfclams have proven difficult to model in some cases (e.g. NEFSC 2003) and it is useful to have another method available for estimating recent biomass and fishing mortality. Fishing mortality, in particular, can be estimated on a regional basis as the ratio of catch and efficiency corrected swept area biomass. Fishing mortality rates are low for surfclams and the June survey occurs when the stock is near the average annual level so that the ratio of catch and biomass gives nearly the same result as solving the catch equation exactly. Swept area biomass and fishing mortality estimates were not made for years with surveys prior to 1997 because no sensor-based tow distance data were available.

NEFSC clam survey trend data are the main source of information about trends in fishable biomass and recruitment since 1982. Survey data (mean kg/tow, based on sensor tow distances) for trend and swept area analyses were from random stations with no problems recorded on standard survey logs. Some survey stations with poor dredge performance identified using sensors during 2005 were omitted from swept area biomass calculations. As described above, negative binomial GLM models were used to impute missing survey data used to fill remaining holes in NEFSC data.

The KLAMZ delay-difference stock assessment model was used to make estimates for surfclams in DMV, NNJ and for the entire stock. The assessment model is advantageous because it estimates long term biomass and fishing mortality levels during 1982-2005, "balances the books" to ensure that all assumptions can be reconciled, and smoothes out measurement errors in swept area biomass and survey trend data. The KLAMZ model was not applied to SNE, LI and GBK in this assessment because the survey data are difficult to interpret and very little fishing has occurred in northern regions.

In the previous assessment (NEFSC 2003), the KLAMZ model was used only for DMV because it did not give reasonable results for southern and northern New Jersey (which were modeled separately). The KLAMZ model and data used in this assessment involve improvements that enhance model performance. In particular, the southern and northern New Jersey regions are combined in this assessment to form the NJ region with relatively precise survey data. Additional survey data for 2004 and 2005 are available and show clear trends over the last decade.

All of the methods for estimating surfclam biomass and fishing mortality levels and calculating variances are described in Assessment A. Ocean Quahogs, in this same Report. A few differences in methodology for surfclams are described below where relevant.

Survey and commercial dredge efficiency

As for ocean quahogs (in Assessment A. Ocean Quahogs of this Report), the best estimate of survey dredge efficiency for surfclams in this assessment was the median of estimates from all available depletion studies (Table C13). In particular, the best estimate of efficiency for commercial dredges was the median E=0.765 (mean 0.704, CV=0.081, n=19) and the best estimate for the NEFSC survey dredge was e=0.226 (mean=0.262, CV=0.17, n=16).

All commercial efficiency estimates for surfclam in this assessment were from Rago et al.'s (2006) "Patch" model fit to data from depletion studies by commercial vessels. Survey dredge efficiencies were estimated for depletion experiments with setup tows by *R/V Delaware II* during NEFSC clam surveys. In contrast to ocean quahog and as described above, depletion studies carried out entirely by the *R/V Delaware II* were not used because of problems with survey dredge performance during repeated tows in the same location. A variety of *ad-hoc* estimators for survey dredge efficiency used by NEFSC (2003) for surfclams were not used in this assessment because they have unknown statistical characteristics and were not necessary.

Eight new depletion studies have been carried out since the last assessment, three during 2004 and five during 2005 (Table C14). Additionally, it was necessary to reanalyze depletion experiment data from fourteen depletion experiments during 1997-1999 so that consistent methodology and corrected estimators were used in all cases.

Assumed length at full recruitment

The most important difference in estimating dredge efficiencies for surfclam in this assessment and in the previous assessment was the assumed length at full recruitment to the commercial gear used in each depletion experiment. Surfclams were assumed in this assessment to be fully recruited to commercial gear used in depletion experiments at 150 mm SL.[30] Elsewhere, in mortality and biomass calculations for this assessment, surfclams are assumed to recruit to the commercial fishery and become fishable at about 120 mm SL. However, full recruitment is likely to occur at some larger size.

Depletion experiments for surfclams included vessels that specialize in surfclam (e.g. *F/V Jersey Girl* in Table C14) and vessels that specialize in ocean quahog (e.g. *F/V Lisa Kim*). Gear on quahog vessels is designed to catch relatively small ocean quahog efficiently. Thus, surfclams likely recruit to gear on ocean quahog vessels at a smaller size than gear used on surfclam vessels. However, it was important too choose an assumed length at full recruitment that was high enough to assure full recruitment to both types of gear in all experiments. A single length criterion was important for the sake of efficient data processing and consistency of surfclam density estimates.

NEFSC (2005) used 90 mm SL as the assumed size at full recruitment for ocean quahog because commercial selectivity at that size was at least 85% at 90 mm SL based on a commercial fishery selectivity curve. No directly estimated selectivity curves are available for surfclams. However, a "relative" selectivity curve that relates catches in commercial surfclam gear to catches in the NEFSC survey dredge indicates that 85% relative selectivity occurs at 145-150 mm SL (Figure C30 in NEFSC 2004). A review of

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[30] Surfclam appear to recruit to the NEFSC survey dredge by about 120 mm SL. Surfclam recruit to the NEFSC survey dredge at smaller sizes that to commercial dredges because the survey dredge is made with closely spaced bars and a wire mesh liner. Moreover, survey catches are not sorted mechanically on a shaker table to remove trash and undersized objects.

length data from surfclam depletion experiments with setup tows indicated that 150 mm SL would suffice as the assumed size of full selectivity in all experiments.

The disadvantage in choosing a relatively large assumed size at full recruitment was that data from the SC2002-4, SC2004-3 and SC2005-6 depletion experiments were not useable. In these experiments, catches of surfclams 150+ mm SL were either zero or too low and variable.

Relationships between efficiency and other variables

There were no clear relationships between Patch model estimates and environmental variables such as depth and sediment size (Figure C35 and C36). With one exception, there were no clear relationships among Patch model estimates themselves (Figure C35 and C36).

The apparent negative relationship between estimates of efficiency and initial surfclam density from the Patch is potentially important (Figure C36). However, the pattern is readily explained as an artifact of the natural statistical correlation between the two parameters in the Patch model. Sites for depletion experiments are chosen to have relatively high surfclam densities. If efficiency decreases at high surfclam densities and experiments are conducted at sites with high density, then mean efficiency for the stock as a whole (in areas of high and low density) might be underestimated. If efficiency is underestimated, then stock biomass might be overestimated and fishing mortality under estimated.

As described in Rago et al. (2006) and illustrated by a typical bivariate likelihood profile for density and efficiency estimates from the Patch model (Figure C37), uncertainty in initial density and efficiency estimates take the form of an elongated “banana” shaped region so that lower estimates of initial density are associated with higher estimate of efficiency and *vice-versa*. In other words, sets of parameters with density low and efficiency high tend to fit the data from a depletion experiment as well as sets with density high and efficiency low. This type of statistical correlation is common in nonlinear parameter estimation (Bard 1974). In linear regression modeling, it takes the form familiar statistical correlation between estimates of the slope and intercept of the regression line.

A simple simulation analysis using linear regression and a simulated Leslie-Davis depletion experiment showed the same relationship between efficiency and density estimates, although no relationship was included in the simulation scenario. The Patch model is quite similar to a linear regression problem because, in effect, it is the result of applying Leslie-Davis depletion models to a number of depletion experiments sites simultaneously (Rago et al. 2006). Leslie-Davis depletion models were fit originally by simple linear regression (Ricker 1975).

Sensitivity of Patch model estimates to smoothing position data

As described in Assessment A. Ocean quahogs, in this Report, position data from depletion experiments was smoothed and interpolated prior to use in the Patch model. NEFSC (2006) carried out a number of analyses to determine the sensitivity of Patch estimates to assumptions and procedures but did not consider smoothing.

Procedures and equipment improved steadily in each survey. Precision of position data was relatively low for 1997 depletion experiments because Loran was used to measure location (accuracy 30-40 ft) and position data were recorded at relatively long time intervals (e.g. 1 minute). In later years, more precise differential GPS was used to measure location to a precision of about 6-9 ft and at shorter intervals of 1-6 seconds.

To accommodate differences in precision of location data among depletion experiments, the Patch model was fit with and without smoothing to data from one surfclam depletion experiment in each survey year. Results (Table C15) show that smoothed data produces higher estimates of initial density and lower estimates of dredge efficiency than unsmoothed data. Area swept during each depletion tow decreased by 1-20% when using smoothed data (Table C15).

Building a bridge

Assessment A. Ocean quahogs, of this Report (see Tables A14-A15) evaluated effects of the many changes made in estimation of dredge efficiency for ocean quahog. Results from those analyses for ocean quahog are probably also applicable to surfclam.

As with ocean quahog and with the exception of experiments in 2002, revised efficiency estimates for surfclam were lower and more precise (lower CVs) than estimates previous estimates (Table C16). However, care is required in making comparisons with efficiency estimates in NEFSC (2003) because previous estimates were from a variety of estimation procedures. In addition, previous estimates from the Patch model were usually made under different assumptions, data for different sizes of surfclam were included and less accurate formulas may have been used.

Efficiency corrected swept area biomass

The best estimate of survey dredge efficiency (e=0.226) was used to estimate efficiency corrected swept area biomass (Table C17) and fishing mortality (Table C18) for surfclams 120 mm SL is 1997, 1999, 2002 and 2005.

2004 Cooperative Survey

Additional information was available from a cooperative survey carried out during 2004 by the *F/V Lisa Kim* in SVA, DMV and NJ (Weinberg et al. 2005). Swept-area biomass estimates in Weinberg et al. (2005) were recalculated using the median commercial dredge efficiency (E=0.714, Table C19) from six depletion experiments by the *FV Lisa Kim* during 2004-2005 (Table C14). The updated calculations excluded some nonrandom tows that may have been used inadvertently by NEFSC (2003).

Cooperative 2004 survey analyses in this assessment used catch data for surfclams 120+ mm SL (all sizes in the fishable biomass) because the *F/V Lisa Kim* normally targets ocean quahog and is equipped to catch relatively small commercial size ocean quahog, which are smaller than commercial size surfclam. As described above, the assumed size at full recruitment was 150 mm SL in other analyses because commercial vessels were used in some experiments that target surfclams use gear that retains larger clams. Survey length composition data from the depletion experiments indicated that surfclams probably recruited to the dredge on the *F/V Lisa Kim* at about 120 mm SL.

Results from the 2004 survey (Table C20) confirmed downward trends in biomass evident in biomass estimates for DMV and NJ based on NEFSC surveys during 1997-2005 (Table C21; Figure C38). In particular, the 2004 estimates from the cooperative survey were nearly intermediate between biomass estimates from the 2002 and 2005 NEFSC surveys. The 2004 survey did not cover all strata in SVA and catch rates for SVA were too variable to be used in estimating biomass (Figure C38).

KLAMZ modeling

KLAMZ delay-difference models for surfclam biomass dynamics were similar to those used by in the Ocean quahog Assessment (see Assessment A. of this Report) for ocean quahog.[31] A few changes were made to model surfclams more realistically. These changes involved configuration of survey trend data, assumptions about recruitment, growth patterns that changed over time, and application to the stock as whole as well as to individual regions. Surfclams require slightly different modeling approaches because more data are available, surfclams are inherently more productive and their population dynamics are more variable, surfclams grow relatively quickly, growth varies over time, surfclams have a higher assumed natural mortality rate (M=0.15 y^{-1} instead of 0.02 y^{-1}), and recruitment patterns are substantially different. Many of these factors appear to be influenced by density dependent factors (Weinberg 1998), oceanographic conditions and bottom temperatures in particular (Weinberg 2005).

The most important challenges in modeling surfclams stem from variability in NEFSC clam survey data for recruits and fishable sizes, and lack of survey data between triennial NEFSC clam surveys. In a nutshell, recruitment trend data change too rapidly to be readily tracked by the triennial survey data. LPUE trend data are available and can be compared to model results but were not used in fitting KLAMZ models for surfclams due to well known problems relating commercial catch rates and trends in stock biomass (Hilborn and Walters 1992). Catch data used in KLAMZ models for surfclams included discards that occurred prior to 1993 when size limits were used to manage the fishery (Table C2).

Despite problems, a number of factors enhance the utility of the KLAMZ model for surfclam. Most importantly, direct estimates of stock biomass based on depletion studies and swept area estimates are easily incorporated in the assessment model. The KLAMZ model is flexible and has a number of features that can be used to take advantage of various aspects of surfclam biology. Landings data for surfclams are relatively accurate because of accounting procedures inherent in the ITQ fishery management program. Survey data for surfclams include CVs that characterize sampling variability and that can be used to determine when the model fits the survey data "too well" (i.e. better than could be expected based on the inherent precision of the data). Auxiliary information is available for many important parameters (e.g. survey dredge efficiency and swept area biomass and growth). Surfclams are relatively long lived (~35 y) and expected rates of change in fishable stock biomass are lower for relatively long-lived organisms.

Year effects and correlated measurement errors (the same year effect in survey data for recruits and fishable size groups in the same year) are a concern in using survey data for surfclams. Simulation analyses have not been carried out using the KLAMZ model, but detailed simulation analyses with the abundance-based Collie Sissenwine model (ASMFC 2006) which is similar to KLAMZ showed that model performance (mean squared error, bias and variance) actually improved when survey data for recruits and fishable size groups had strong correlated year effects.

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[31] See Appendix A5 of the ocean quahog assessment (NEFSC 2007) for a complete technical description of the KLAMZ model.

Growth curves

Growth is a key part of biomass dynamics in the KLAMZ delay-difference model. Survey data for surfclams in KLAMZ models (particularly for new recruits) are calculated based on assumptions about growth.

The Schnute-Deriso delay difference equation in the KLAMZ model (Schnute 1985) uses a version of the von Bertalanffy model for growth in weight with two parameters. In particular, $\rho = e^{K}$ where K is from a von Bertalanffy model for weight, and $J_t = W_{k-1,t} / W_{k,t}$, where $W_{k,t}$ is predicted weight at age k when recruitment occurs based on the growth curve for year t. The von Bertlanffy parameters W_{max} and t_0 are implicit in J_t. In delay-difference model calculations (Schnute 1985), the parameters J_t may change over time but K is constant in all years.

Survey mean length at age data for NJ and DMV in each survey (Figure C2) were converted to mean weights at age in each survey by applying region specific length-weight relationships (Table C1). The growth curves used different W_{max} and t_0 parameters for 1982-1992 and 1994-2005, but used the same K parameter in all years (Table C22). Growth parameters for NJ were used also in modeling the whole stock.

Survey indices

NEFSC clam survey data in the KLAMZ model were for recruit (Table C23) and fishable size groups (Table C11). The recruit index was mean kg/tow for surfclam in the survey that were 120 to L_{k+1} mm SL, where L_{k+1} is the predicted size at age k+1 and k is the predicted age at recruitment (L_k = 120 mm SL) based on a growth curve. The fishable index was survey mean kg/tow for surfclams 120+ mm SL. Recruit trend data were assumed to track trends in the biomass of new recruits. Trend data for fishable surfclams were assumed to track trends in total fishable biomass (new recruits plus survivors from the previous year). Surveys were assumed to occur in the middle of the year because the NEFSC clam survey is carried out during late May-early July.

As described above, survey data for surfclams 120 to L_{k+1} mm SL were used in both the recruit and fishable biomass trend indices. This strategy was intentional and meant to link the relatively noisy recruit and more stable fishable survey data indices in the model, to reduce potential problems stemming from uncertainty about where to split the index for fishable biomass, and to help insure that the survey scaling factor for both recruit and fishable indices would be about the same. In practical terms, it had little effect on the survey data themselves because recruit kg/tow was small relative to kg/tow for the remaining fishable size groups.

NEFSC (2003) used a more complicated system of survey trend data for prerecruits, recruits and remaining fishable size groups. Fishable sizes were 100+ or 120+ mm SL, depending on area. Prerecruit size groups were L_{k-1} to either 100 or 120 mm SL based on region specific von Bertalanffy growth curves. The prerecruit index was lagged in the model by one year so that data collected in year t would be used in the model to estimate recruitment in year t+1. The prerecruit index was not used in this assessment because it is highly variable for surfclams with noisy trends that are difficult to resolve given the rest of the survey and catch data in the model.

For convenience in interpreting model results, survey mean kg/tow data for fishable surfclams in the entire stock were scaled up to approximate efficiency corrected swept area biomass before use in the KLAMZ model. The scaling factor was the average ratio of the survey data and efficiency corrected swept area biomass during 1995-2005 surveys (see below and Table C25). With this adjustment, the survey scaling factors for fishable biomass trends estimated in the KLAMZ model are expected to be close to one. The adjustment to the survey data did not affect biomass or fishing mortality estimates.

Survey dredge efficiency and swept-area biomass

Following NEFSC (2003), efficiency corrected swept area biomass estimates were included in the assessment model as a measure of scale but not as measures of trend. In fitting the model, the likelihood of the estimated scaling parameter for swept area biomass was calculated based on a lognormal prior distribution with mean 1.0 and arithmetic CV = 0.5. The relatively large CV means that the prior information about the scaling parameter was relatively "weak". However, experience shows that the prior information tends to have a strong impact when survey data are limited and there is little other information in the model data about biomass scale.

Recruitment assumptions

Following NEFSC (2003) surfclam recruits were estimated in the KLAMZ model as a random walk with steps constrained by a variance parameter. A smooth, random walk process is probably not ideal from a biological perspective because of the possibility of strong year classes in surfclams but the approach was necessary because of the lack of annual recruitment data. The random walk approach keeps the recruitment estimate in year *t* at the same level as in year *t-1*, unless there is a good reason in terms of goodness of fit to change it. For surfclams in the KLAMZ model, the random walk approach was used primarily to fill gaps in information due to not having a recruit index for each year, to avoid excessive variation in recruitment and to ensure that some recruitment was estimated for each year.

In modeling surfclam population dynamics with random walk recruitment, it is important to control the "random walk recruitment variance" σ_R^2 (NEFSC 2003) which measures variability in the size of successive steps taken during the random walk (i.e. variance in [$\ln(R_1/R_2)$, $\ln(R_2/R_3)$, $\ln(R_3/R_4)$, etc.], where R_t is the recruitment estimate for year *t*) . As σ_R^2 approaches zero, recruitment estimates become smooth and tend towards a constant value with no changes from year to year. As σ_R^2 becomes large, estimated recruitments will change randomly and more widely from one year to next.

Following NEFSC (2003), initial KLAMZ model runs assumed a 20% CV for steps in the random walk so that $\ln\left(\sigma_R^2\right) = \ln(0.2^2)$. The constraint was relaxed gradually in subsequent runs until the model was just able to fit the survey data without pattern in residuals. In final runs, $\ln\left(\sigma_R^2\right) = \ln(0.3^2)$ for NJ and the entire stock, and $\ln\left(\sigma_R^2\right) = \ln(0.35^2)$ for DMV. In each case, the CV for fit to the survey data (residual CV) was compared to CVs for the actual survey data to determine if σ_R^2 was too large and the model was fitting the survey data more closely than could be expected based on the precision of the survey data. The goal was basically to find the simplest model (fewest effective recruitment parameters) that would adequately explain the survey data for surfclam. Choices were subjective but had only modest effects on biomass and fishing mortality estimates for surfclam, because many different recruitment patterns imply similar biomass and recruitment levels.

Results-whole stock

Survey data for the entire stock in the KLAMZ model were filled as described above. However, no provision was made for filling remaining holes that could not be filled by borrowing (Table C9). Mean surfclam densities for strata with data (original or filled) were used to compute the weighted mean density for the stock as a whole (i.e. strata with no data were ignored in computing the mean density for the stock as a whole). However, the mean density for the stock as a whole was applied to the entire stock area, which included the area of strata with no data. The effects of remaining wholes were reduced in whole stock runs because remaining wholes were a relatively small proportion of the total number of strata and total area of the stock.

The KLAMZ model fit survey biomass trend data reasonably well although the fishable biomass trend datum for 1994 was not completely reconciled in the model fit (Figure C40). The model fit the recruit index better than the fishable biomass index, although the latter was more precise based on survey CVs. LPUE and swept area biomass trends did not affect model estimates, but estimated biomass trends from the model were similar to trends in LPUE after 1999 and to trends in swept area biomass for in all years.

The survey scaling parameter for the scaled fishable biomass index was Q=1.26 and reasonably close to one. The survey scaling parameter for efficiency corrected swept area biomass was Q=0.99 indicating that the trend data, landings and model estimates were compatible with the prior information about Q for efficiency corrected swept area biomass estimates.

Model results suggest that surfclam biomass increased from 1981-1997 to record high levels due to high surplus production (relatively good recruitment and fast growth rates) which occurred during the mid 1980s and early 1990s (Table C24 and Figure C41). Surplus production declined steadily after 1993 as recruitment declined, the stock aged and growth rates slowed. Surplus production was negative after 1997 while stock biomass declined steadily. By 2005, stock biomass had declined to about the same level as in 1986-1992 but was still relatively high in historical terms. Fishing mortality rates were much lower than natural mortality and probably inconsequential during 1981-2005.

Bootstrap analysis (2000 iterations) indicated a tendency towards negative bias in biomass and fishing mortality estimates during peak recruitment years, but good model performance and little bias overall. CVs and confidence intervals from bootstrapping indicate that biomass and fishing mortality estimates were reasonable precise, particularly for recent years (Table C24; Figures C42-C43), probably due to the swept area biomass data for 1997-2005. Recruitment was estimated less precisely than biomass and fishing mortality (Table C24; Figure C44). The model did not completely converge during a substantial fraction of bootstrap runs (roughly 50%), due to uncertainty in estimated recruitments (Table C24). In other words, a range of recruitment patterns probably explained the survey data equal well.

Results-DMV and NJ

The KLAMZ model for DMV fit survey index data quite well (Figure C45). The model for NJ fit reasonably well although the fishable biomass indices for NJ during 1994 and 1997 were not reconciled (Figure C46). Survey scaling factors for scaled fishable biomass trends and efficiency corrected swept area biomass were reasonably close to one in all cases.

Model results for DMV indicate that biomass declined continuously from relatively high levels during the early 1980s due to declining recruitment, slow growth, and surplus production levels that were usually negative (Figure C47). Model results for NJ were similar to results for the whole stock but biomass declined more steeply during recent years to lower levels during 2005 (Figure C48). Fishing mortality appears to have been a minor factor in both areas during 1981-2005 (Figures C47-C48).

Stock biomass by region

Average ratios for survey data (Doppler standardized) and efficiency corrected swept area biomass were calculated for each region (Table C25) and used to rescale survey trend data to approximate swept area biomass levels (Table C23). The proportions of swept area biomass in each region were used to prorate fishable biomass estimates from the KLAMZ model for the entire stock during years with NEFSC clam surveys into regional components. Results clearly show the shift over time in biomass from southern to northern regions (Figures C49 to C50).

Recruitment parameters

Recruitment estimates for surfclam from the KLAMZ model were made with limited survey data and are complicated to interpret. Under these conditions, recruitment estimates for surfclam should probably be regarded as "nuisance" parameters of less interest than biomass and fishing mortality estimates. As nuisance parameters, recruitment estimates basically amount to adjustments in the KLAMZ model that implicitly account for model misspecification, survey noise, survey year effects, changes in recruitment, natural mortality and variability in growth not explicitly included in the modeling framework.

Proportions of total fishable biomass at various density levels

As described in the first assessment in this Report (A. Ocean quahogs), best biomass estimates and survey data were combined to partition best biomass estimates into components found in areas with relatively high and low biomass density levels. Biomass density is important to profitability of the ocean quahog fishery because it determines commercial catch rates. Biomass density was measured as survey catch per tow (fishable kg/tow) because commercial catch rate data for random locations and the entire stock area were not available.

Results (Table C26) show reductions in stock within high density areas in the southern DMV and SVA regions. During 2005 (Table C27), the largest component (29% or 47 thousand mt meats) of total fishable stock biomass was on GBK in the highest (25+ kg/tow) biomass density category. In contrast, stock biomass levels in density categories larger than 10 kg/tow were low for other regions.

6.0 BIOLOGICAL REFERENCE POINTS (TOR-3)

According to the Surfclam and Ocean Quahog FMP, overfishing occurs whenever the fishing mortality rate on the entire stock is larger than F_{MSY}. The stock is overfished if total biomass falls below $B_{Threshold}$ (estimated as ½ B_{MSY}). When stock biomass is less than the biomass threshold, the fishing mortality rate threshold is reduced from F_{MSY} in a linear fashion to zero.

The current best proxy for F_{MSY} is $F = M = 0.15$ y^{-1}. The proxy for B_{MSY} is one-half of the estimated fishable biomass during 1999 which was estimated to be 1,460 thousand mt in this assessment based on KLAMZ model results for the entire stock. Revised biomass reference points are higher than previous values (see table below) because of new information about the efficiency of the dredge used in NEFSC clam surveys.

Reference Point	Last assessment	Revised
F_{MSY}	M=0.15 y^{-1}	Same
B_{1999}	1,460 thousand mt meats	1,799 thousand mt meats
B_{MSY} =½B_{1999} (target)	730 thousand mt meats	900 thousand mt meats
$B_{Threshold}$ = ½ B_{MSY}	365 thousand mt meats	490 thousand mt meats

Status determinations by comparisons of biomass estimates and biomass reference points are almost unaffected by new information about dredge efficiency because the changes in biomass estimates and the B_{MSY} proxy "cancel out" when current biomass is compared to or divided by the B_{MSY} proxy (Figure C51). Comparison of fishing mortality estimates and the F_{MSY} proxy are more sensitive because fishing mortality estimates depends on dredge efficiency but the F_{MSY} proxy does not (Figure C52).

Fortunately, conclusions in this assessment about fishing mortality and reference points are robust because fishing mortality rates for the stock are relatively low. In particular, conclusions about stock status would not change unless either the mortality estimate or threshold was changed by 7 fold (Figure C52).

Critique

Current reference points for surfclams suffice for use in this assessment because surfclam biomass is relatively high (at near average levels) and fishing mortality is low. However, biomass referenced points should be reconsidered the next time the stock is assessed.

Use of ½ B_{1999} as a proxy for B_{MSY} implicitly assumes that the stock was at carrying capacity during 1999. The carrying capacity assumption should be reevaluated based on the longer time series of data that are currently available. In addition, it may be useful to consider possible climate change effects on B_{MSY} and F_{MSY} proxies as evidenced by loss of surfclams in the south near the coast of the Delmarva Peninsula (Weinberg 2005).

7.0 STOCK STATUS (TOR-4)

The Atlantic surfclam stock is not overfished and overfishing is not occurring. Estimated fishable stock biomass during 2005 (120+ mm shell length, SL) was 1,170 thousand mt meats, which is above the management target of ½ 1999 biomass = 900 thousand mt meats (Figure C51). Estimated fishing mortality during 2005 was F= 0.0192 y^{-1}, which is below the management threshold $F_{MSY} \cong M = 0.15$ y^{-1} (Figure C52).

8.0 PROJECTION METHODS (TOR-5)

For the first time, a fully integrated assessment model, variance estimation and stochastic projection approach was used to provide example projections for surfclam stock biomass and fishing mortality. In particular, simulation runs for projection analysis were carried out using the same delay difference equation as used in the KLAMZ model and were initialized exactly as in the last year of each bootstrap run.

Projections can be made for assumed levels of constant fishing mortality or assumed constant catch levels, and can be carried out for time periods of any length. In projections for surfclams with assumed levels of catch, likely levels of incidental mortality should be considered and probably included. For example, constant quota levels can be increased by 12% to accommodate incidental mortality and to obtain a more realistic estimate of fishery impacts. A large number of individual stochastic simulation runs (e.g. 1000) should be carried out in projection analysis. Normally, the number of simulation runs is the same as the number of bootstrap runs because bootstrap results are saved for later use by the projection software. It is possible, however, to make more than one projection from each bootstrap run.

Each simulation run in the projection analysis starts with the terminal conditions estimated in one bootstrap run. Thus, uncertainty about current stock biomass, age structure, recent recruitments and other factors is included in the projection analysis.

Uncertainty in future conditions is included by simulating random future recruitments. For surfclams, random recruitments (R_t) were chosen to mimic a random walk with user specified mean and lag-1 autocorrelation. Projected recruitments were modeled as a random walk to match assumptions in the stock assessment model. As described above, the random walk recruitment assumption in the stock assessment model was pragmatic and may not be ideal from a biological perspective. The algorithm for surfclams in this assessment was:

$$\sigma = \sqrt{\ln\left(CV^2 + 1\right)}$$

$$b = \frac{\sigma^2}{2}$$

$$s = \sqrt{1 - \rho^2}$$

$$j_t \sim N(0,1)$$

$$\delta_t = s j_t$$

$$\gamma_t = \rho\gamma_{t-1} + \delta$$

$$R_t = \overline{\mathrm{R}}\mathrm{e}^{\gamma_t\sigma - b}$$

where j_t is drawn from the standard normal distribution, ρ is the lag-1 autocorrelation for successive log scale recruitments [i.e. the correlation of $\ln(R_t)$ and $\ln(R_{t+1})$, specified by the user], σ is the standard deviation of log scale recruitments based on an arithmetic scale CV (specified by the user), $\overline{R}$ is the mean arithmetic recruitment (specified by the user), and b is a bias correction factor. The term γ_t is normally distributed with mean zero, standard deviation 1.0 and lag-1 autocorrelation ρ. At the end of the projection analysis, the model calculates the means and CVs for biomass, recruitment, catch and fishing mortality at the beginning of each year.

Based on the KLAMZ model run for the entire stock, ρ=0.72, CV=0.53, and $\overline{R}$ = 121 thousand mt in example projection calculations. The simulation runs were for 2005-2015 (10 y beyond the last year in the KLAMZ model).

Procedures for setting TAL and TAC levels

It is not necessary to describe approaches for setting TAC or TAL levels in the surfclam fishery because it is managed using constant quota levels.

9.0 EXAMPLE PROJECTIONS (TOR-6)

Example projections were carried out assuming the following conditions during 2006-2015: i) constant fishing mortality = 0.15; ii) constant landings at the minimum quota level = 1.85 million bu; iii) constant landings at mean level during 2003-2005; and iv) constant landings at the maximum quota level = 3.4 million bu. In each case, landings in bushels were converted to meat weights and increased by 12% to account for potential incidental mortality during fishing.

Results (Table C28 and Figure C53) indicate that current downward trends in biomass will persist during the next few years because of the tendency for runs of good and bad recruitment in surfclams. Declines are largest for the F=0.15 scenario. Results for the status quo and maximum quota scenarios are very similar.

Projected biomass levels out by about 2015 in all scenarios. However, CVs are very large in all years and, in particular, larger than 250% after 2008. The high CV levels indicate very high uncertainty in projected results, particularly after 2008.

10.0 RESEARCH RECOMMENDATIONS (TOR-7)

Research recommendations from the previous assessments are listed below (not in priority order).

i) Consider using year-, region- or episodic natural mortality rates. *This was discussed in the working group but deferred until a later assessment when the necessity for incorporating this feature might be more pressing.*

ii) Develop a forward casting age-structured, numbers-based stock assessment model. *This work is in progress for sea scallop, ocean quahog and surfclam. In the interim, the KLAMZ model is implicitly age structured and numbers based, although it does not make full use of survey and fishery age or length data. NEFSC convened an age readers workshop during 2006 (Jacobson et al. 2006) to address questions about age data and results will be useful in formulating the new model. NEFSC has begun to characterize variability in survey length data and the results are expected to be useful in modeling as well.*

iii) Reconcile survey trends for pre- and new- recruits relative to trends in survey data for older recruits. *Pre-recruit survey indices were not used for modeling in this assessment because they are too variable. Survey data procedures for modeling were redesigned to ease interpretation.*

iv) Reconcile survey data with consistently declining trends in LPUE during the last decade. *Recent trends in survey and LPUE data were similar in this assessment for southern regions, where fishing is heaviest, and for the stock as a whole.*

v) Focus on analysis of declining LPUE trends and examine new approached for describing fishing power among commercial clam vessels. *This issue was addressed by standardizing LPUE data in models that included individual vessel effects. Thus, it was not necessary to characterize fishing power based on GRT, horsepower, etc.*

vi) Collect commercial age and length data to monitor and predict recruitment and for use in length and age structured models. *Length data but no age data are currently being collected from port samples. Sampling rates for length data should be increased particularly for new northern fishing grounds. All available survey age, length and commercial length data were used at least qualitatively in this assessment to characterize and predict recruitment.*

vii) Reexamine coefficients used to convert commercial catches in bushels to meat weights. *No progress.*

viii) Consider using a sensor that tracks dredge position, rather than the ships position, during surveys and depletion studies. *New acoustic sensor equipment was tried experimentally during the 2005 survey but with poor results.*

ix) Conduct surveys more frequently than every three years in critical areas. *A cooperative survey in the SVA, DMV and NJ areas was carried out during 2004, in the interim between the 2002 and 2005 NEFSC clam surveys.*

x) Select a new set of fixed stations in unfished areas to monitor dredge efficiency changes between surveys. *Fixed station analysis was abandoned in this assessment due to variable environmental conditions that may affect density in unfished areas.*

xi) Consider new technological methods that rely less heavily on estimating dredge efficiency. *No progress.*

xii) Consider new methods to estimate variability in the spatial distribution of biomass. *All depletion studies were reanalyzed for this assessment producing estimates of the negative binomial parameter k, which measures spatial patchiness in the density of surfclams within depletion study areas. However, this topic is of relatively low importance.*

xiii) Continue to bring outside experts to Invertebrate Working Group meetings. *One outside expert was included in each of the meetings for this assessment.*

The following are new research recommendations (not in priority order).

a) Refine logbook data collection, focusing on spatial details. Resolve apparent problems with locations for some records. Can recent data show patterns on finer spatial scales (e.g. for 1-minute rather than 10-minute squares)?

b) Improve collection and use of port sample data form the commercial fishery.

c) Characterize relationships between shell height, width and length for potential use in understanding the size selectivity of commercial and survey dredges and commercial sorting gear.

d) Test the Patch model for depletion experiments with simulations focusing on potential effects of uncertainty about position data and including all effects of cell size and smoothing.
e) Determine the size selectivity of survey and commercial fishing equipment experimentally.
f) Improve procedures for filling holes in the survey data using statistical models with year and spatial effects. Determine if filling holes is preferable to borrowing data from previous and subsequent surveys.
g) Review survey age data carefully to determine if strong year classes can be used to estimate mortality rates outside of a stock assessment model (e.g. "empirical" Z estimates).
h) Further investigate spatial trends in survey data.
i) Devote sufficient time and resources to fully develop and improve dynamic population models.
j) Review the technical basis of the current B_{MSY} proxy given new data and possible climate effects.
k) Utilize New Jersey and New York inshore clam survey data more fully in the EEZ surfclam assessment.

11.0 ACKNOWLEDGMENTS

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SURFCLAM TABLES

Table C1. Length-weight parameters for Atlantic surfclam, by region. Parameters are for the relationship $W=e^{a}L^{b}$, where W is meat weight in grams, L is shell length in mm, and a and b are parameters in the table.

Region	a	b
SVA	-7.05830	2.30330
DMV	-9.48913	2.86018
NJ	-9.31210	2.86371
LI	-7.98370	2.58020
SNE	-7.98370	2.58020
GBK	-8.27443	2.65422

Table C2. Discard estimates for surfclam in the commercial fishery during 1982-1994 from Table D4 in NEFSC (1995).

Year	Discard (mt meats)					Landings (mt meats)	Discards / Landings	Catch	Size limit (mm)
	NNJ	SNJ	NJ	DMV	Total				
1982	3,684	215	3,899	2,295	6,194	16,688	37%	22,882	140
1983	2,122	385	2,507	2,127	4,634	18,592	25%	23,226	140
1984	2,266	458	2,724	2,015	4,739	22,888	21%	27,627	133
1985	1,938	248	2,186	1,725	3,911	22,480	17%	26,391	127
1986	2,328	233	2,561	239	2,800	24,520	11%	27,320	127
1987	1,414	61	1,475	415	1,890	21,744	9%	23,634	127
1988	1,317	13	1,330	106	1,436	23,377	6%	24,813	127
1989	1,048	6	1,054	258	1,312	21,887	6%	23,199	127
1990	1,089	57	1,146	123	1,269	24,018	5%	25,287	127
1991	495	36	531	5	536	20,615	3%	21,151	--
1992	918	102	1,020	4	1,024	21,685	5%	22,709	--
1993	0	0	0	0	0	21,859	0%	21,859	--
1994	0	0	0	0	0	21,942	0%	21,942	--

Table C3. Atlantic surfclam landings in state waters and the EEZ with EEZ surfclam quotas (mt meat weights). Total landings for 2002-2005 from dealer records. EEZ landings for 2002-2005 from MAFMC (2006). Other figures from logbooks or NEFSC (2003). Landings for state waters + unknown areas were estimated as total landings - EEZ landings.

Year	Total Landings	EEZ Landings	State Waters + Unknown Area Landings	Percent from EEZ	EEZ Quota
1965	19,998	14,968	5,030	75	
1966	20,463	14,696	5,767	72	
1967	18,168	11,204	6,964	55	
1968	18,394	9,072	9,322	49	
1969	22,487	7,212	15,275	32	
1970	30,535	6,396	24,139	21	
1971	23,829	22,704	1,125	95	
1972	28,744	25,071	3,673	87	
1973	37,362	32,921	4,441	88	
1974	43,595	33,761	9,834	77	
1975	39,442	20,080	19,362	51	
1976	22,277	19,304	2,973	87	
1977	23,149	19,490	3,659	84	
1978	17,798	14,240	3,558	80	13,880
1979	15,836	13,186	2,650	83	13,880
1980	17,117	15,748	1,369	92	13,882
1981	20,910	16,947	3,963	81	13,882
1982	22,552	16,688	5,864	74	18,506
1983	25,373	18,592	6,781	73	18,892
1984	31,862	22,888	8,974	72	18,892
1985	32,894	22,480	10,414	68	21,205
1986	35,720	24,520	11,200	69	24,290
1987	27,553	21,744	5,809	79	24,290
1988	28,824	23,377	5,447	81	24,290
1989	30,424	21,887	8,537	72	25,184
1990	32,556	24,018	8,538	74	24,282
1991	30,037	20,615	9,422	69	21,976
1992	33,831	21,685	12,146	64	21,976
1993	33,527	21,859	11,668	65	21,976
1994	31,048	21,942	9,106	71	21,976
1995	28,733	19,627	9,106	68	19,779
1996	28,775	19,771	9,004	69	19,779
1997	26,298	18,611	7,687	71	19,779
1998	24,509	18,240	6,269	74	19,779
1999	26,685	19,570	7,115	73	19,779
2000	31,093	19,749	11,344	64	19,779
2001	31,237	22,017	9,220	70	21,976
2002	32,645	24,006	8,639	99	24,174
2003	31,526	25,017	6,509	100	25,061
2004	28,327	24,197	4,130	92	26,218
2005	26,911	21,163	5,748	81	26,218
Min	15,836	6,396	1,125	21	13,880
Max	43,595	33,761	24,139	100	26,218
Mean	27,635	19,787	7,848	73	20,914

Table C4. EEZ surfclam landings (mt meats) by stock assessment area and year based on NEFSC (2003) for 1979 and logbook data for 1980-2005. Logbook landings from unknown areas in each year were prorated to known areas based on proportions of landings in known areas.

Year	SVA	DMV	NJ	LI	SNE	Other	Total EEZ
1979	0	11,836	1,350	0	0	0	13,186
1980	64	12,788	2,878	17	0	0	15,748
1981	568	7,472	8,820	88	0	0	16,947
1982	1,705	6,679	8,086	94	125	0	16,688
1983	2,225	7,173	8,095	264	836	0	18,592
1984	1,796	5,978	11,904	7	382	2,819	22,888
1985	741	7,856	11,246	0	452	2,185	22,480
1986	529	2,853	17,730	17	1,223	2,168	24,520
1987	378	1,302	18,017	0	1,140	907	21,744
1988	557	1,149	19,420	0	1,512	739	23,377
1989	439	3,123	16,531	0	1,361	433	21,887
1990	1,502	3,546	17,887	0	998	86	24,018
1991	0	1,634	18,913	15	33	21	20,615
1992	0	1,221	20,398	61	5	0	21,685
1993	0	3,414	18,365	62	3	14	21,859
1994	0	3,454	18,417	71	0	0	21,942
1995	0	2,752	16,497	0	378	0	19,627
1996	0	2,233	17,430	26	82	0	19,771
1997	0	1,540	16,998	73	0	0	18,611
1998	0	484	17,517	117	121	0	18,240
1999	0	648	18,749	157	16	0	19,570
2000	0	2,039	17,487	121	102	0	19,749
2001	0	3,282	17,719	935	81	0	22,017
2002	64	4,489	18,271	1,130	52	0	24,006
2003	0	1,432	21,693	1,625	267	0	25,017
2004	0	1,482	19,197	906	2,612	0	24,197
2005	0	1,668	16,850	759	1,885	0	21,163
Min	0	484	1,350	0	0	0	13,186
Max	2,225	12,788	21,693	1,625	2,612	2,819	25,017
Mean	391	3,834	15,425	242	506	347	20,746

Table C5. EEZ fishing effort (all vessels, hours fished) for surfclam by stock assessment area and year based on logbook data. The fraction of logbook effort from unknown areas in each year was prorated to known areas based on fishing effort in known areas.

Year	SVA	DMV	NJ	LI	SNE	Other	Total EEZ
1991	0	1,254	17,243	21	107	293	18,917
1992	0	797	21,379	67	0	0	22,243
1993	0	2,423	18,232	57	15	5	20,732
1994	0	1,930	21,494	70	0	0	23,494
1995	0	1,560	18,625	0	1,059	0	21,244
1996	0	1,577	20,995	40	287	0	22,899
1997	0	1,098	20,383	77	0	0	21,558
1998	0	289	19,609	134	518	0	20,550
1999	0	734	18,146	151	149	0	19,179
2000	0	1,859	16,787	115	368	0	19,128
2001	0	2,536	18,462	962	148	0	22,108
2002	112	5,505	19,825	1,241	62	0	26,746
2003	0	2,367	25,071	1,827	176	0	29,441
2004	0	3,161	26,453	1,267	1,108	0	31,989
2005	0	2,654	24,335	1,206	1,340	0	29,534
Min	0	289	16,787	0	0	0	18,917
Max	112	5,505	26,453	1,827	1,340	293	31,989
Mean	7	1,983	20,469	482	356	20	23,317

Table C6. Nominal landings per unit effort (LPUE, bushels h^{-1}) for surfclam fishing (all vessels) in the US EEZ based on logbooks. Nominal LPUE is the ratio of total reported landings and total hours fished. Landings and fishing effort from unknown areas were prorated to area before LPUE was calculated.

Year	SVA	DMV	NJ	LI	SNE	Other	All areas
1991			142	95	40	9	141
1992		199	124	119			126
1993		183	131	143	28	390	137
1994		232	111	132			121
1995		229	115		46		120
1996		184	108	85	37		112
1997		182	108	122			112
1998		217	116	114	30		115
1999		115	134	135	14		132
2000		142	135	137	36		134
2001		168	124	126	71		129
2002	74	106	120	118	108		116
2003		78	112	115	197		110
2004		61	94	93	306		98
2005		82	90	82	183		93
Min	74	61	90	82	14	9	93
Max	74	232	142	143	306	390	141
Mean	74	155	118	115	91	199	120

Table C7. Standardized annual LPUE (bushels per hour) based on log-linear GLM models. Results are scaled to LPUE during June for an arbitrary vessel that fished in all areas.

	DMV		NJ		LI		SNE	
Year	LPUE	CV	LPUE	CV	LPUE	CV	LPUE	CV
1990	241	0.69	138	0.05				
1991	206	0.69	107	0.05				
1992	232	0.69	101	0.05				
1993	237	0.69	110	0.05				
1994	322	0.69	98	0.05				
1995	287	0.69	96	0.05			8	0.59
1996	215	0.69	91	0.05			6	0.66
1997	202	0.69	88	0.05	157	0.49		
1998	210	0.70	97	0.05	105	0.50	24	0.83
1999	185	0.69	101	0.05	119	0.48	39	0.99
2000	185	0.69	93	0.05	130	0.49	28	0.97
2001	200	0.69	78	0.05	116	0.47	44	0.62
2002	119	0.69	85	0.05	104	0.47	83	0.64
2003	86	0.69	75	0.05	91	0.47	109	0.56
2004	69	0.69	63	0.05	71	0.47	72	0.54
2005	85	0.69	54	0.04	60	0.46	81	0.53
Min	69	0.69	54	0.04	60	0.46	6	0.53
Max	322	0.70	138	0.05	157	0.50	109	0.99
Average	193	0.69	92	0.05	106	0.48	50	0.69

Table C8. Numbers of commercial trips sampled and numbers of surfclam measured in port samples from landings during 1982-2005, by region. Numbers of measurements for 1982-1999 are from NEFSC (2003, Table C5) and numbers of trips during 1982-1999 were estimated assuming 30 individuals sampled per trip, as specified in port sample instructions.

Year	DMV		NJ		LI		SNE	
	Trips	Lengths	Trips	Lengths	Trips	Lengths	Trips	Lengths
1982	259	7,756	249	7,477			1	30
1983	197	5,923	375	11,253			1	30
1984	102	3,066	425	12,751			3	90
1985	61	1,832	256	7,674			5	150
1986	42	1,260	171	5,130			11	330
1987	24	730	30	900			19	569
1988	14	420	30	900			27	810
1989	29	866	31	919			15	449
1990	30	892	30	901			7	209
1991	36	1,080	76	2,272				
1992	39	1,170	57	1,710				
1993	46	1,392	31	928				
1994	4	119	30	900				
1995	24	720	17	510				
1996	38	1,154	37	1,117				
1997	54	1,622	32	957				
1998	52	1,560	23	690				
1999	57	1,720	29	856				
2000	20	600	111	3,315	1	30		
2001	33	970	42	1,260				
2002	7	210	37	1,111				
2003	2	60	80	2,455	5	150		
2004			36	1,080	2	60		
2005	19	581	61	1,834	11	330		
Min	2	60	17	510	1	30	1	30
Max	259	7,756	425	12,751	11	330	27	810
Mean	52	1,552	96	2,871	5	143	10	296

Table C9. Numbers of random survey stations in NEFSC and cooperative clam surveys by stratum, region and survey year. The 2004 survey was cooperative and carried out on a commercial vessel. All others were NEFSC clam surveys carried out on the *R/V Delaware II*. Numbers of NEFSC clam survey stations for 2005 include a few tows with poor dredge performance used to trends but not for swept area biomass. For NEFSC surveys, figures in plain text are the number of original random tows (without borrowing). Bold and outlined figures are for NEFSC survey data are "holes" (strata in with no stations), which where filled by borrowing data from the same stratum during previous and/or subsequent cruises. Black cells are remaining zeroes for NEFSC survey data that could not be filled by borrowing. Only SVA, DMV and NJ were sampled during 2004 (cells for strata not sampled are crosshatched). Survey data for GBK during 1982-1984 and 2005 (stippled) should not be used in most analyses due to limited sampling.

		Survey Year											
Region	*Stratum*	*1982*	*1983*	*1984*	*1986*	*1989*	*1992*	*1994*	*1997*	*1999*	*2002*	2004	*2005*
SVA	1	**10**	10	14	7	10	10	11	10	**10**	■	▨	■
	2	■	■	■	**1**	1	2	1	1	**1**	■	▨	■
	5	4	9	13	8	8	8	7	8	**16**	8	8	8
	6	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	**3**	*2*	2	*1*
	80	**6**	6	9	3	7	7	8	7	**7**	■	▨	■
	81	**4**	4	7	3	5	5	5	5	**5**	5	▨	**5**
DMV	*9*	*30*	*26*	*35*	*29*	*37*	*37*	*39*	*39*	*38*	*39*	37	*36*
	10	*2*	*2*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	*3*	3	*3*
	13	*19*	*18*	*25*	*20*	*20*	*20*	*21*	*22*	*19*	*20*	20	*18*
	14	*2*	*2*	*3*	*3*	*3*	*3*	*5*	*3*	*3*	*3*	3	*3*
	82	1	1	1	1	1	1	1	1	2	2	2	**2**
	83	2	2	2	2	2	2	2	2	2	2	2	2
	84	4	3	3	4	4	4	4	4	3	4	4	4
	85	6	5	4	5	5	5	5	5	5	5	3	3
	86	2	2	3	3	3	2	3	3	3	3	3	3
NJ	*17*	11	11	18	12	12	12	12	14	12	12	12	12
	18	3	3	**6**	3	3	3	3	3	3	3	3	3
	21	18	18	22	19	20	20	23	26	39	29	27	20
	22	3	3	**6**	3	3	3	5	3	3	3	3	3
	25	9	9	13	8	9	9	9	12	8	9	9	9
	26	2	2	**5**	3	3	3	3	3	3	3	3	3
	87	8	7	10	9	9	9	9	9	9	16	14	8
	88	15	15	24	17	20	20	20	21	23	20	20	17
	89	15	15	21	15	18	17	17	19	18	18	17	15
	90	2	2	3	2	2	2	2	2	2	2	2	2
LI	*29*	11	10	**20**	10	10	10	10	10	11	10	▨	10
	30	7	8	**14**	6	6	6	6	6	7	6	▨	7
	33	4	4	**8**	4	4	4	5	4	4	4	▨	4
	34	2	2	**4**	2	2	2	5	2	2	2	▨	2
	91	3	2	4	4	3	3	3	3	3	3	▨	3
	92	2	2	3	2	2	2	2	2	2	2	▨	2
	93	1	1	2	1	1	1	1	1	1	2	▨	1

Table C9. (continued)

		Survey Year											
Region	*Stratum*	*1982*	*1983*	*1984*	*1986*	*1989*	*1992*	*1994*	*1997*	*1999*	*2002*	*2004*	*2005*
SNE	*37*	7	4	**7**	3	**6**	3	5	4	4	3		**3**
	38	3	2	**5**	3	3	3	5	3	3	3		2
	41	6	5	7	5	6	6	6	6	5	6		6
	45	3	7	9	4	4	4	4	4	4	3		3
	46	2	5	5	3	2	3	5	3	3	2		3
	47	4	3	4	2	2	4	5	4	3	1		7
	94	1	2	**2**		**1**	1	2	2	**4**	2		**2**
	95	4	14	11	4	4	4	4	4	4	4		**4**
	96	**12**	12	**13**	1	1	3	2	4	**4**			
GBK	*54*		**3**	3	3	**6**	3	3	3	**3**			
	55	3	**3**	**3**	3	1	3	3	3	2	2		**2**
	57			**2**	2	1	2	5	2	2	2		**2**
	59	1	4	**5**	1	2	6	5	5	4	5		**5**
	61	8	1	**6**	5	**12**	7	6	6	6	6		**6**
	65			**3**	3	**5**	2	4	3	**4**	1		**1**
	67		**5**	5	5	7	7	7	7	**7**			
	68	**1**	**8**	7	3	6	6	5	5	**5**			
	69	2	5	**11**	6	6	6	7	6	8	**8**		
	70	1	2	**6**	4	**8**	4	4	4	3	2		**2**
	71		**2**	2	3	1	2	3	3	1	2		**2**
	72	2	**10**	8	1	8	8	8	8	6	**6**		
	73	1	1	**4**	3	6	6	6	6	5	6		**6**
	74	3	**4**	1	3	**7**	4	4	4	3	3		**3**

Table C10. Bad tows identified using objective criteria in the 2005 survey and by eye in the 2002 survey using sensor data.

Statistic	2005	2002
All tows		
Total	433	556
N examined	399	213
% examined	92%	38%
Number w/poor dredge performance	33	32
Proportion w/poor dredge perfomance	0.08	0.15
Depletion tows only		
Total	*30*	*75*
N examined (estimate)	28	29
Number bad	8	10
Proportion w/poor dredge perfomance		
Assuming 100% examined*	27%	13%
Expanded based on % reviewed	29%	35%

* Minimal estimate assuming that all depletion tows were examined

Table C11. NEFSC clam survey data for surfclam abundance (mean N/tow) and biomass (mean KG/tow). Data are for two size groups: small recruits (50-119 mm SL) and large fishable (120+ mm SL). Survey holes (strata with no sampling) were filled by borrowing but no imputed survey data were used.

Region	Year	Small recruits (50-119 mm SL)				Large fishable (120+ mm SL)				N Tows	N Positive Tows	N Strata Sampled
		N / Tow	CV	KG / Tow	CV	N / Tow	CV	KG / Tow	CV			
SVA	1982	3.529	0.88	0.134	0.91	0.920	1.00	0.257	0.87	25	5	5
SVA	1983	6.600	0.62	0.249	0.64	0.620	1.00	0.405	0.60	30	9	5
SVA	1984	7.849	0.37	0.303	0.40	0.310	1.00	1.609	0.30	44	16	5
SVA	1986	1.498	0.35	0.058	0.41	0.750	1.00	1.553	0.74	23	11	6
SVA	1989	3.109	0.75	0.083	0.71	0.830	1.00	0.758	0.82	32	10	6
SVA	1992	18.151	0.86	0.760	0.90	0.770	1.00	0.812	0.79	33	17	6
SVA	1994	43.379	0.46	0.784	0.31	0.440	1.00	0.427	0.38	33	19	6
SVA	1997	10.309	0.44	0.294	0.46	0.460	1.00	0.030	0.44	32	14	6
SVA	1999	9.317	0.41	0.234	0.35	0.460	1.00	0.084	0.47	47	19	6
SVA	2002	13.693	0.61	0.360	0.62	0.550	1.00	0.399	0.55	15	5	3
SVA	2005	3.646	0.66	0.051	0.57	.	0.00	0.000	.	14	4	3
DMV	1982	157.134	0.46	6.621	0.44	21.360	0.23	2.687	0.29	68	37	9
DMV	1983	30.679	0.54	1.534	0.61	31.205	0.46	3.168	0.35	61	30	9
DMV	1984	184.102	0.74	5.247	0.61	34.911	0.28	3.555	0.28	79	47	9
DMV	1986	58.771	0.43	3.120	0.46	74.792	0.38	6.703	0.32	70	44	9
DMV	1989	16.705	0.54	0.813	0.55	31.237	0.26	3.065	0.24	78	37	9
DMV	1992	13.494	0.28	0.580	0.38	28.855	0.29	2.918	0.24	77	52	9
DMV	1994	68.704	0.33	2.787	0.43	60.964	0.21	5.958	0.20	83	63	9
DMV	1997	77.184	0.17	3.346	0.20	54.528	0.24	4.928	0.22	82	61	9
DMV	1999	29.612	0.28	1.543	0.28	26.363	0.22	2.406	0.20	78	44	9
DMV	2002	16.467	0.28	0.594	0.28	20.698	0.21	2.235	0.19	81	50	9
DMV	2005	6.437	0.42	0.252	0.43	4.757	0.26	0.508	0.28	74	40	9
NJ	1982	33.102	0.30	1.787	0.31	32.777	0.22	4.084	0.20	85	50	10
NJ	1983	27.780	0.51	1.627	0.55	25.382	0.22	3.147	0.20	85	54	10
NJ	1984	15.932	0.23	0.714	0.22	29.970	0.20	3.731	0.18	126	68	10
NJ	1986	10.335	0.21	0.493	0.20	29.677	0.18	4.172	0.18	91	59	10
NJ	1989	9.877	0.29	0.489	0.31	31.527	0.15	4.160	0.13	99	60	10
NJ	1992	16.462	0.33	0.849	0.42	23.221	0.16	3.193	0.15	98	62	10
NJ	1994	67.394	0.20	2.664	0.18	82.766	0.17	11.014	0.16	103	84	10
NJ	1997	17.910	0.16	1.012	0.17	83.720	0.13	11.442	0.12	112	83	10
NJ	1999	8.021	0.25	0.389	0.28	50.578	0.21	6.903	0.17	120	77	10
NJ	2002	10.678	0.16	0.464	0.16	35.035	0.17	5.503	0.17	115	94	10
NJ	2005	7.808	0.20	0.397	0.22	19.090	0.18	2.818	0.17	92	60	10
LI	1982	0.032	1.00	0.002	1.00	3.994	0.61	0.641	0.62	29	1	7
LI	1983	0.175	0.61	0.005	0.60	0.407	0.72	0.055	0.72	29	3	7
LI	1984	0.561	0.30	0.021	0.36	1.635	0.34	0.248	0.34	55	12	7
LI	1986	0.581	0.39	0.022	0.40	1.715	0.61	0.285	0.61	29	7	7
LI	1989	2.237	0.87	0.089	0.88	3.484	0.72	0.475	0.74	28	4	7
LI	1992	5.733	0.44	0.301	0.47	2.544	0.33	0.275	0.32	28	9	7
LI	1994	4.232	0.17	0.213	0.20	7.243	0.19	0.901	0.21	32	11	7
LI	1997	1.444	0.49	0.082	0.53	4.171	0.64	0.563	0.63	28	6	7
LI	1999	1.608	0.64	0.047	0.50	10.710	0.65	1.433	0.61	30	8	7
LI	2002	0.854	0.45	0.034	0.44	1.944	0.67	0.304	0.67	29	7	7
LI	2005	1.415	0.34	0.060	0.38	12.624	0.50	1.658	0.47	29	7	7
SNE	1982	2.584	0.29	0.112	0.35	12.402	0.41	1.776	0.42	42	14	9
SNE	1983	0.839	0.40	0.040	0.44	7.883	0.39	1.267	0.39	54	18	9
SNE	1984	0.810	0.36	0.034	0.43	10.838	0.34	1.676	0.34	63	18	9
SNE	1986	1.115	0.14	0.027	0.26	4.125	0.68	0.644	0.69	25	8	8
SNE	1989	1.178	0.43	0.044	0.44	4.569	0.33	0.687	0.33	29	10	9
SNE	1992	1.147	0.56	0.032	0.51	2.491	0.58	0.399	0.58	31	9	9
SNE	1994	1.265	0.52	0.061	0.58	1.693	0.53	0.265	0.54	38	10	9
SNE	1997	2.947	0.31	0.120	0.35	12.279	0.30	1.913	0.30	34	13	9
SNE	1999	2.601	0.42	0.089	0.47	4.296	0.66	0.725	0.66	34	15	9
SNE	2002	1.006	0.69	0.057	0.72	3.852	0.27	0.601	0.22	24	5	8
SNE	2005	0.261	0.49	0.008	0.51	1.986	0.19	0.355	0.19	30	6	8
GBK	1986	19.998	0.79	0.719	0.78	4.967	0.52	0.708	0.55	44	20	14
GBK	1989	5.214	0.34	0.285	0.42	24.858	0.73	3.004	0.73	75	36	14
GBK	1992	15.535	0.40	0.706	0.46	7.894	0.33	0.956	0.34	66	43	14
GBK	1994	30.010	0.33	1.610	0.34	45.843	0.39	5.853	0.41	70	47	14
GBK	1997	58.550	0.31	3.002	0.33	23.517	0.25	2.730	0.25	65	45	14
GBK	1999	24.014	0.41	1.340	0.41	29.590	0.31	3.385	0.30	59	34	14
GBK	2002	22.093	0.52	1.163	0.54	27.052	0.43	3.250	0.41	43	21	11

C:\Assessments\Surfclam2006\Surveys\Trends\[SurveyTrends-20.xls]Table 1.

Table C12. Original mean kg/tow for surfclam in regions that had strata with remaining holes and mean kg/tow with remaining holes filled. Remaining holes were filled with imputed values from a negative binomial GLM model. Estimates of mean kg/tow for swept area biomass were computed from estimates for trends using the mean ratio of doppler and sensor distances during 1997-2005 for each region.

Cruise	Region	Mean kg/tow for trends		Mean kg/tow for swept-area biomass		CV for trends	
		Imputed	Original	Imputed	Original	Imputed	Original
198204	GBK	0.059				0.219	
198204	SVA	0.243	0.257			0.874	0.870
198305	GBK	0.485				0.678	
198305	SVA	0.383	0.405			0.597	0.600
198403	SVA	1.522	1.609			0.296	0.300
198604	SNE	0.609	0.680			0.688	0.690
200206	GBK	3.411	3.250	1.847	1.890	0.349	0.410
200206	SNE	0.715	0.601	0.418	0.396	0.264	0.220
200206	SVA	0.263	0.399	0.157	0.268	0.517	0.550
200507	SNE	0.317	0.355	0.185	0.224	0.190	0.190
200507	SVA	0.000	0.000	0.000	0.000	310	

Table C13. Summary of commercial dredge efficiency, population density and negative binomial parameter *k* estimates from the Patch model, setup tow densities and NEFSC survey dredge efficiency estimates from setup tows, by year. All estimates are for surfclam 150+ mm SL.

Statistic	N successful experiments	Population Density (N ft^{-2})	Depletion Vessel Efficiency	*k*	Setup Density (N ft^{-2})	NEFSC Dredge Efficiency
1997						
Mean	5	0.023	0.79	4.758	0.0061	0.317
Median		0.017	0.89	3.261	0.0069	0.27
Lower 80% bound		0.012	0.613	3.134	0.0049	0.225
Upper 80% bound		0.033	0.967	6.382	0.0072	0.409
SE		0.007	0.115	1.059	0.0008	0.06
CV (SE / Mean)		0.296	0.146	0.223	0.1281	0.189
1999						
Mean	6 commercial depletion, 5 with setup tows	0.035	0.652	20.534	0.0061	0.189
Median		0.025	0.726	12.841	0.0058	0.199
Lower 80% bound		0.024	0.469	10.137	0.0051	0.13
Upper 80% bound		0.046	0.835	30.93	0.007	0.248
SE		0.007	0.124	7.044	0.0006	0.039
CV (SE / Mean)		0.211	0.19	0.343	0.1012	0.205
2002						
Mean	2	0.014	0.584	16.792	0.007	0.516
Median		0.014	0.584	16.792	0.007	0.516
Lower 80% bound		0.012	-0.268	-26.157	-0.0032	-0.282
Upper 80% bound		0.016	1.437	59.74	0.0173	1.313
SE		0.001	0.277	13.955	0.0033	0.259
CV (SE / Mean)		0.038	0.474	0.831	0.474	0.503
2004						
Mean	2 commercial depletion experiments	0.024	0.736	5.939	NA	NA
Median		0.024	0.736	5.939	NA	NA
Lower 80% bound		0.004	0.517	0.22	NA	NA
Upper 80% bound		0.043	0.955	11.658	NA	NA
SE		0.006	0.071	1.858	NA	NA
CV (SE / Mean)		0.268	0.097	0.313	NA	NA
2005						
Mean	4	0.037	0.717	4.078	0.005	0.158
Median		0.034	0.676	4.593	0.005	0.158
Lower 80% bound		0.023	0.551	3.121	0.004	0.105
Upper 80% bound		0.051	0.882	5.035	0.006	0.21
SE		0.008	0.101	0.584	0	0.032
CV (SE / Mean)		0.229	0.141	0.143	0.084	0.203
All years						
Mean	19 commercial depletion, 16 with setup tows	0.029	0.704	10.988	0.006	0.262
Median		0.025	0.765	5.676	0.006	0.226
Lower 80% bound		0.024	0.628	7.073	0.005	0.203
Upper 80% bound		0.033	0.779	14.903	0.007	0.32
SE		0.004	0.057	2.943	0	0.044
CV (SE / Mean)		0.128	0.081	0.268	0.076	0.168

Table C14. Summary of depletion experiments, setup tows, Patch model estimates, and survey dredge efficiency estimates for surfclam. All depletion results are for surfclam 150+ mm SL. Depletion experiments *by R/V Delaware II* are not shown.

Experiment and Study Area							Depletion Tows					Patch Model						Survey setu p tows				
Experiment Name	Original Name	Region	Approx. latitude (decimal degrees)	Approx. longitude (decimal degrees)	Depth (m)	Mean Sediment Size (microns)	Depletion Study Vessel	Depletion Date	Ship Position Data (source / nominal accuracy / time interval)	Depletion tows: N used, [N with bushel count and length samples]	Depletion vessel blade width (ft)	Cell size (ft)	Population Density (*D*, >=150 mm SL, N ft^{-2})	Depletion vessel efficiency (*E*, fully recruited, >= 150 mm SL)	Negative binomial parameter (*K*)	Gamma (indirect effects, γ)	Goodness of fit (-log likelihood)	Survey id, [station id] (N tows) {N tows with length data}	Catch density (*d*, >= 150 mm SL, N ft^{-2})	CV for catch density (se / mean)	NEFSC survey dredge efficiency (*e*, fully recruited)	Notes
SC1997-2	PP-1	NNJ (Pt. Pleasant)	40.05317	73.83917	26		Sherri Ann	6/9/1997	Loran / 9-12 M / 1 Minute	39 [9]	8.33	16.67	0.0492	0.3540	7.5313	0.5	210.3	199703 [183-190] (8) {4}	0.0081	0.1498	0.1645	Forty depletion tows total but tow 1 (and samples) omitted. Setup tows during calibration survey 199703 prior to 199704 clam survey.
SC1997-3	AC2-1	NNJ (Atlantic City)	39.39317	73.91033	30		Jersey Girl	6/10/1997	Loran / 9-12 M / 1 Minute	13 [4]	10.83	21.67	0.0172	0.7646	2.6272	0.5	66.1	199703 [169, 175-181] (8) {8}	0.0042	0.1011	0.2463	Setup tows during calibration survey 199703 prior to 199704 clam survey.
SC1997-4	AC2-2	NNJ (Atlantic City)	39.39317	73.91033	30		Jersey Girl	6/10/1997	Loran / 9-12 M / 1 Minute	31 [4]	10.83	21.67	0.0157	0.9900	3.2368	0.5	95.8	Same as SC1997-2	0.0042	0.1011	0.2698	Setup tows during calibration survey 199703 prior to 199704 clam survey.
SC1997-5	AC1-1	NNJ (Atlantic City)	31.36500	73.89833	30		Judy Marie	6/11/1997	Loran / 9-12 M / 1 Minute	17 [4]	8.33	16.67	0.0137	0.9500	3.2606	0.5055	86.9	199703 [166-168, 170-174] (8) {8}	0.0069	0.1173	0.5016	Same as above plus -> Previous analyses at SAW-26 (NEFSC 1998) omitted depletion tow 10, which was included here
SC1997-6	AC1-2	NNJ (Atlantic City)	39.36500	73.89833	30		Judy Marie	6/11/1997	Loran / 9-12 M / 1 Minute	19 [4]	8.33	16.67	0.0171	0.8902	7.1339	0.5	99.2	Same as SC1997-5}	0.0069	0.1173	0.4022	Same as above plus -> Previous analyses at SAW-26 (NEFSC 1998) omitted depletion tows 17 and 19, which were included here
SC1999-2	JG-1 (S99 5)	NNJ	39.68133	73.74667	24	0.88	Jersey Girl	9/14/1999	Loran / 9-12 M / 1 Minute	4 [1]	10.83	21.67	0.0249	0.8453	10.2855	0.5	21.5	199903 [105-108] (4) {4}	0.0075	0.2273	0.3004	
SC1999-3	JG-2 (s99-5)	NNJ	39.68133	73.74667	24	0.88	Jersey Girl	9/14/1999	Loran / 9-12 M / 1 Minute	5 [2]	10.83	21.67	0.0631	0.4625	9.3468	0.5	30.0	Same as SC1999-2	0.0075	0.2273	0.1186	
SC1999-4	JG-3 (S99-6)	NNJ	39.52133	73.77867	26	0.67	Jersey Girl	9/14/1999	Loran / 9-12 M / 1 Minute	6 [2]	10.83	21.67	0.0251	0.9900	15.3974	0.5	31.5	199903 [112-115] (4) {4}	0.0050	0.1398	0.1990	
SC1999-5	CH-1 (S99 DEII)	DMV	36.90200	74.97583	35	1.13	Christy	9/25/1999	Loran / 9-12 M / 1 Minute	28 [6]	10.83	21.67	0.0193	0.1641	5.6765	0.5	92.8	19903 [367-370] (4) {0}				No length data for setup tows
SC1999-6	MJ-1 (s99-3, NJ Inshore Site 1)	NNJ	39.56333	73.91167	26	1.08	Melissa J	9/28/1999	Loran / 9-12 M / 1 Minute	4 [1]	10.83	21.67	0.0245	0.8357	32.4987	0.5	18.7	199903 [82-85] (4) {4}	0.0058	0.4363	0.2374	Sarc31 list Blade at 13
SC1999-7	MJ-1 (s99-3, NJ Inshore Site 2)	NNJ	39.76800	73.91633	24	3.85	Melissa J	9/28/1999	Loran / 9-12 M / 1 Minute	10 [2]	10.83	21.67	0.0513	0.6164	49.9988	0.5	52.2	199903 [88-90] (3) {3}	0.0046	0.1742	0.0888	Sarc31 list Blade at 13
SC2002-2	SC02-2	NNJ	40.10908	73.84423	38	0.43	Jersey Girl	8/20/2002	GPS-D/3M/2 sec.	16 [3]	10.83	21.67	0.0144	0.8610	30.7464	0.5	74.1	200206 [87-91] (5) {1}	0.0037	0.2774	0.2563	
SC2002-3	SC02-3	SNJ	39.26923	73.78116	31	1.12	Jersey Girl	8/19/2002	GPS-D/3M/2 sec.	19 [see footnote]	10.83	21.67	0.0134	0.3071	2.8366	0.5	88.3	200206 [202-206] (5) {4}	0.0104	0.6116	0.7748	Depletion tows: 1) bushel count for tow 1 only (tows 2-19 had catch < 1 bu); 2) clams counted for all tows because catches were low; and 3) lengths measured for 10 for tows. Setup tows: zero clams caught at setup tow (station 206); only two clams measured at station 205
SC2002-4	SC02-4	DMV	38.85791	74.40888	31	0.48	Jersey Girl	8/20/2002	GPS-D/3M/2 sec.	18 [4]	10.83	21.67						200206 [335-339] (5) {1}				Zero clams >= 150 mm in tows 1-3, very low and variable catches in other tows.
SC2004-1	SC04-1	NJ	39.28611	73.87778	35		Lisa Kim	4/8/2004	GPS-D/3M/2 sec.	24 [5] (see note)	10	20.00	0.0301241	0.8072	4.0810	0.5000	130.753					200416 Cooperative Survey (shakedown leg) stations 15-38
SC2004-2	SC04-2	NJ	39.58278	74.02778	21		Lisa Kim	4/8/2004	GPS-D/3M/2 sec.	20 [4] (see note)	10	20.00	0.017376	0.6646	7.7973	0.5000	102.320					200416 Cooperative Survey (shakedown leg) stations 49-68
SC2004-3	SC04-3	DMV	38.27075	74.37920	38		Lisa Kim	7/3/2004	GPS-D/3M/10 sec.	20 [4] (see note)	10	20.00										200416 Cooperative Survey stations146-165; zero clams >= 150 mm in tow 1, very low and variable catches in other tows.
SC2005-2	SC05-02	NNJ	39.56383	73.90364	24	0.29	Lisa Kim	9/7/2005	GPS / 6 ft / 6 sec	17 [3]	10.00	20.00	0.0407	0.7633	4.7110	0.5	98.5	200507 [137, 377-381] (6) {5}	0.004	0.3635	0.1035	
SC2005-3	SC05-03	NNJ	39.89733	73.90591	38	0.24	Lisa Kim	9/8/2005	GPS / 6 ft / 6 sec	20 [4]	10.00	20.00	0.0590	0.5879	4.7883	0.5	120.6	200507 [21, 384-387] (5) {3?}	0.006	0.2999	0.1008	
SC2005-4	SC05-04	DMV	39.56972	73.54946	41	0.20	Lisa Kim	9/9/2005	GPS / 6 ft / 6 sec	20 [4]	10.00	20.00	0.0264	0.5341	4.4756	0.5	104.5	200507 [41, 391-393, 395] (5) {3}	0.006	0.2597	0.2143	
SC2005-5	SC05-05	NNJ	39.43615	73.37320	33	0.28	Lisa Kim	9/10/2005	GPS / 6 ft / 6 sec	17 [4]	10.00	20.00	0.0212	0.9823	2.3360	0.5	96.1	200507 [143, 397-402] (7) {5}	0.004	0.1809	0.2119	
SC2005-6	SC05-01	NNJ	38.26530	74.37947	26	0.19	Lisa Kim	9/7/2005	GPS / 6 ft / 6 sec	20 [4]	10.00	20.00						200507 [123-127, 354] (6) {6}				Low catches >= 150 mm SL in setup and depletion tows (less than 6% of total).

Table C15. Sensitivity analysis to determine effects of smoothing position data on Patch model estimates for surfclam 150+ mm SL. Model runs were preliminary.

Smoothing	Density	Efficiency	K	Gamma	Goodness of fit to catch data (-log-likelihood)	Area swept (ft^2)	Effective area swept (ft^2)	Number stations	Number position observations	Mean Observations per station	Shape of tow tracks based on original position data	Type Smooth
						SC1997-4						
No	0.0147	0.99	3.42	0.50	95.38	296,196	134,886	18	107	5.9	Curved, stair step	Linear or cubic polynomial
Yes	0.0157	0.99	3.24	0.50	95.82	288,202	133,535					
% Difference	-7%	0%	6%	0%	0%	3%	1%					
						SC1999-2						
No	0.0206	0.95	21.53	0.50	20.22	53,854	35,480	4	46	11.5	Linear, stair step	Quadratic polynomial
Yes	0.0249	0.85	10.29	0.50	21.54	52,268	30,236					
% Difference	-17%	12%	109%	0%	-6%	3%	17%					
						SC2002-2						
No	0.0134	0.94	30.21	0.50	74.42	279,668	162,865	16	2664	166.5	Linear or curved,	Spline
Yes	0.0144	0.86	30.75	0.50	74.13	276,021	152,182					
% Difference	-7%	9%	-2%	0%	0%	1%	7%					
						SC2005-2						
No	0.0350	0.93	5.35	0.50	97.55	287,369	117,195	17	905	53.2	Curved, wavy	Spline
Yes	0.0407	0.76	4.71	0.50	98.55	283,682	100,759					
% Difference	-14%	22%	14%	0%	-1%	1%	16%					

Table C16. NEFSC survey dredge efficiency estimates for surfclam in the 1997-2005 NEFSC clam surveys (revised and values used in the last assessment). CVs are the standard error / mean. "NA" means not available. Efficiency estimates shown in the table are averages, not medians.

Survey year	Revised (Patch model & setup tows)			From previous assessment (various types of estimates, NEFSC 2003)		
	Efficiency	CV	N	Efficiency	CV	N
1997	0.317	0.19	5	0.460	0.471	4
1999	0.189	0.20	5	0.276	0.349	5
2002	0.516	0.50	3	0.389	0.523	6
2005	0.158	0.20	5	NA	NA	NA
All	0.262	0.17	18	0.370	0.492	15

Table C17. Efficiency corrected swept-area biomass estimates (1000 mt) and CVs for the fishable stock of surfclam during 1997-2005 by stock assessment region. Figures for SVA and GBK during 2005 were taken from 2003 because no data were available for 2005.

	Estimate	CV
INPUT: Nominal tow distance (d_n, *nm*)	0.15	
INPUT: Dredge width (nm)	0.0008225	
Area swept per standard tow (*a*, nm^2)	1.23375E-04	10%

Area of assessment region (*A*, nm^2) - no correction for stations with unsuitable clam habitat

	Estimate	CV
S. Virginia and N. Carolina (SVA)	3,119	10%
Delmarva (DMV)	4,660	10%
New Jersey (NJ)	5,078	10%
Long Island (LI)	2,917	10%
Southern New England (SNE)	4,321	10%
Georges Bank (GBK)	5,772	10%
Total	25,867	

INPUT: Fraction suitable habitat (*u*)

	Estimate	CV
S. Virginia and N. Carolina (SVA)	100%	10%
Delmarva (DMV)	100%	10%
New Jersey (NJ)	100%	10%
Long Island (LI)	100%	10%
Southern New England (SNE)	100%	10%
Georges Bank (GBK)	88%	10%

Habitat area in assessment region (*A'*, nm2)

	Estimate	CV
S. Virginia and N. Carolina (SVA)	3,119	14%
Delmarva (DMV)	4,660	14%
New Jersey (NJ)	5,078	14%
Long Island (LI)	2,917	14%
Southern New England (SNE)	4,321	14%
Georges Bank (GBK)	5,079	14%

INPUT: Biomass fraction in unsurveyd deep water

	Estimate	CV
S. Virginia and N. Carolina (SVA)	0%	10%
Delmarva (DMV)	0%	10%
New Jersey (NJ)	0%	10%
Long Island (LI)	0%	10%
Southern New England (SNE)	0%	10%
Georges Bank (GBK)	0%	10%

INPUT: Original survey mean catch from fishable stock (kg/tow, for tows adjusted to nominal tow distance using sensors)

	Estimates for 1997	**CV**	**Estimates for 1999**	**CV**	**Estimates for 2002**	**CV**	**Estimates for 2005**	**CV**
S. Virginia and N. Carolina (SVA) 120+ mm	0.0142	43%	0.0532	52%	0.2676	58%	0.2676	58%
Delmarva (DMV) 120+ mm	2.3751	22%	1.4130	20%	2.2406	20%	0.4038	30%
New Jersey (NJ) 120+ mm	5.8453	12%	4.0036	17%	3.5823	16%	2.1776	17%
Long Island (LI) 120+ mm	0.3179	66%	0.7895	53%	0.1849	64%	1.9644	37%
Southern New England (SNE) 120+ mm	0.8868	32%	0.4839	67%	0.4180	26%	0.1851	***19%***
Georges Bank (GBK) 120+ mm	1.5228	25%	2.0445	31%	1.8469	35%	**1.8469**	35%

Swept-area biomass without efficiency correction (B', 1000 mt):

	Estimates for 1997	**CV**	**Estimates for 1999**	**CV**	**Estimates for 2002**	**CV**	**Estimates for 2005**	**CV**
S. Virginia and N. Carolina (SVA) 120+ mm	0.3597	47%	1.3447	56%	6.7651	61%	6.7651	61%
Delmarva (DMV) 120+ mm	89.7081	30%	53.3720	28%	84.6301	28%	15.2519	36%
New Jersey (NJ) 120+ mm	240.5850	23%	164.7861	26%	147.4441	26%	89.6280	26%
Long Island (LI) 120+ mm	7.5155	69%	18.6664	57%	4.3707	67%	46.4441	42%
Southern New England (SNE) 120+ mm	31.0590	38%	16.9471	70%	14.6411	33%	6.4817	28%
Georges Bank (GBK) 120+ mm	62.6950	32%	84.1714	37%	76.0380	40%	**76.0380**	40%
Total fishable biomass less GBK	369	17%	255	19%	258	18%	165	19%
Total fishable biomass	432	15%	339	17%	334	16%	241	18%
INPUT: Survey dredge efficiency (e)	0.226	17%	0.226	17%	0.226	17%	0.226	17%

Efficiency adjusted swept area fishable biomass (B, 1000 mt)

	Estimates for 1997	**CV**	**Estimates for 1999**	**CV**	**Estimates for 2002**	**CV**	**Estimates for 2005**	**CV**
S. Virginia and N. Carolina (SVA) 120+ mm	1.593	50%	5.955	58%	29.961	64%	29.961	64%
Delmarva (DMV) 120+ mm	397	34%	236	33%	375	33%	68	40%
New Jersey (NJ) 120+ mm	1,065	29%	730	31%	653	31%	397	31%
Long Island (LI) 120+ mm	33	71%	83	59%	19	69%	206	45%
Southern New England (SNE) 120+ mm	138	41%	75	72%	65	37%	29	32%
Georges Bank (GBK) 120+ mm	278	36%	373	41%	337	44%	337	44%
Total fishable biomass less GBK	1,635	24%	1,130	25%	1,142	24%	729	25%
Total fishable biomass	1,913	23%	1,503	24%	1,479	23%	1,066	25%

Lower bound for 80% confidence intervals on fishable biomass (1000 mt, for lognormal distribution with no bias correction)

	Estimates for 1997	**Estimates for 1999**	**Estimates for 2002**	**Estimates for 2005**
S. Virginia and N. Carolina (SVA) 120+ mm	0.867	2.983	14.208	14.208
Delmarva (DMV) 120+ mm	260	157	249	41
New Jersey (NJ) 120+ mm	743	494	445	269
Long Island (LI) 120+ mm	15	41	9	118
Southern New England (SNE) 120+ mm	83	33	41	19
Georges Bank (GBK) 120+ mm	177	226	197	197
Total fishable biomass less GBK	1,207	821	840	529
Total fishable biomass	1,434	1,112	1,100	780

Upperbound for 80% confidence intervals on fishable biomass (1000 mt, for lognormal distribution with no bias correction)

S. Virginia and N. Carolina (SVA) 120+ mm	2.926	11.888	63.180	63.180
Delmarva (DMV) 120+ mm	608	356	565	110
New Jersey (NJ) 120+ mm	1,528	1,078	958	586
Long Island (LI) 120+ mm	75	167	43	358
Southern New England (SNE) 120+ mm	229	172	103	43
Georges Bank (GBK) 120+ mm	435	614	574	574
Total fishable biomass less GBK	2,215	1,555	1,552	1,004
Total fishable biomass	2,551	2,031	1,988	1,456

Table C18. Fishing mortality estimates for surfclams based on catch and efficiency corrected swept-area biomass for fishable surfclams during 1997, 1999, 2002 and 2005.

INPUT: Upper bound incidental mortality allowance	12%
INPUT: Assumed CV for catch	10%

INPUT: Landings (1000 mt, discard ~ 0)	**Estimates for 1997**	**Estimates for 1999**	**Estimates for 2002**	**Estimates for 2005**
S. Virginia and N. Carolina (SVA)	0.000	0.000	0.064	0.000
Delmarva (DMV)	1.540	0.648	4.489	1.668
New Jersey (NJ)	16.998	18.749	18.271	16.850
Long Island (LI)	0.073	0.157	1.130	0.759
Southern New England (SNE)	0.000	0.016	0.052	1.885
Georges Bank (GBK)	0.000	0.000	0.000	0.000
Total	18.611	19.570	24.006	21.163
Catch (1000 mt, landings + upper bound incidental mortality allowance)				
S. Virginia and N. Carolina (SVA)	0.000	0.000	0.072	0.000
Delmarva (DMV)	1.725	0.726	5.028	1.868
New Jersey (NJ)	19.038	20.999	20.463	18.872
Long Island (LI)	0.081	0.176	1.265	0.850
Southern New England (SNE)	0.000	0.018	0.058	2.112
Georges Bank (GBK)	0.000	0.000	0.000	0.000
Total	20.844	21.919	26.886	23.702

INPUT: Efficiency Corrected Swept Area Biomass for Fishable Stock (1000 mt)	**Estimates for 1997**	**CV**	**Estimates for 1999**	**CV**	**Estimates for 2002**	**CV**	**Estimates for 2005**	**CV**
S. Virginia and N. Carolina (SVA) 120+ mm	2	50%	6	58%	30	64%	30	64%
Delmarva (DMV) 120+ mm	397	34%	236	33%	375	33%	68	40%
New Jersey (NJ) 120+ mm	1,065	29%	730	31%	653	31%	397	31%
Long Island (LI) 120+ mm	33	71%	83	59%	19	69%	206	45%
Southern New England (SNE) 120+ mm	138	41%	75	72%	65	37%	29	32%
Georges Bank (GBK) 120+ mm	278	36%	373	41%	337	44%	337	44%
Total fishable biomass less GBK	1,635	24%	1,130	25%	1,142	24%	729	25%
Total fishable biomass	1,913	23%	1,503	24%	1,479	23%	1,066	25%
Fishing mortality (y^{-1})								
S. Virginia and N. Carolina (SVA) 120+ mm	0.0000	51%	0.0000	59%	0.0024	64%	0.0000	64%
Delmarva (DMV) 120+ mm	0.0043	36%	0.0031	34%	0.0134	34%	0.0277	41%
New Jersey (NJ) 120+ mm	0.0179	30%	0.0288	33%	0.0313	32%	0.0475	33%
Long Island (LI) 120+ mm	0.0024	72%	0.0021	60%	0.0654	70%	0.0041	46%
Southern New England (SNE) 120+ mm	0.0000	42%	0.0002	73%	0.0009	38%	0.0736	34%
Georges Bank (GBK) 120+ mm	0.0000	NA	0.0000	NA	0.0000	NA	0.0000	NA
Total fishable biomass less GBK	0.0127	26%	0.0194	27%	0.0235	26%	0.0325	27%
Total fishable biomass	0.0109	25%	0.0146	26%	0.0182	25%	0.0222	27%

Lower bound for 80% confidence intervals for fishing mortality (y^{-1}, for lognormal distribution with no bias correction)	**Estimates for 1997**	**Estimates for 1999**	**Estimates for 2002**	**Estimates for 2005**
S. Virginia and N. Carolina (SVA) 120+ mm	NA	NA	0.0011	NA
Delmarva (DMV) 120+ mm	0.0028	0.0020	0.0087	0.0167
New Jersey (NJ) 120+ mm	0.0122	0.0191	0.0210	0.0316
Long Island (LI) 120+ mm	0.0011	0.0010	0.0292	0.0023
Southern New England (SNE) 120+ mm	NA	0.0001	0.0006	0.0483
Georges Bank (GBK) 120+ mm	NA	NA	NA	NA
Total fishable biomass less GBK	0.0092	0.0138	0.0169	0.0231
Total fishable biomass	0.0080	0.0105	0.0132	0.0159
Upper bound for 80% confidence intervals for fishing mortality (y^{-1}, for lognormal distribution with no bias correction)				
S. Virginia and N. Carolina (SVA) 120+ mm	NA	NA	0.0051	NA
Delmarva (DMV) 120+ mm	0.0068	0.0047	0.0206	0.0458
New Jersey (NJ) 120+ mm	0.0262	0.0433	0.0469	0.0715
Long Island (LI) 120+ mm	0.0056	0.0043	0.1465	0.0073
Southern New England (SNE) 120+ mm	NA	0.0006	0.0014	0.1121
Georges Bank (GBK) 120+ mm	NA	NA	NA	NA
Total fishable biomass less GBK	0.0177	0.0273	0.0328	0.0458
Total fishable biomass	0.0149	0.0202	0.0251	0.0311

Table C19. Patch model estimates for surfclam depletion experiments carried out by the F/V Lisa Kim during 2004-2005.

Statistic	N successful experiments	Population Density (N ft^{-2})	Depletion Vessel Efficiency	*k*	Setup Density (N ft^{-2})	NEFSC Dredge Efficiency
		F/V Lisa Kim (2004-2005)				
Mean	6 commercial depletion, 4 with setup tows	0.032	0.723	4.698	0.0051	0.158
Median		0.028	0.714	4.593	0.0051	0.158
Lower 80% bound		0.023	0.625	3.633	0.0044	0.1051
Upper 80% bound		0.042	0.822	5.763	0.0058	0.2101
SE		0.006	0.067	0.722	0.0004	0.032
CV (SE / Mean)		0.192	0.092	0.154	0.0839	0.203

Table C20. Revised surfclam efficiency corrected swept-area abundance and biomass estimates (120+ SL) from the cooperative 2004 clam survey and assuming dredge efficiency *E*=0.714. Estimates from Weinberg et al. (2005) assuming *E*=0.792 are shown for comparison.

Statistics	SVA	DMV	NJ
Revised			
N tows	15	77	110
Mean n/tow	0.143	23.253	71.079
Var	0.012	35.412	82.763
CV	0.78	0.26	0.13
Mean kg/tow	0.011	2.365	10.863
Var	0.000	0.348	1.907
CV	0.81	0.25	0.13
Area (sq nm)	1,074	4,660	5,078
Efficiency	0.714	0.714	0.714
Swept area abundance (10^6 clams)	1.7	1230.3	4098.1
Swept area biomass (mt)	128	125,139	626,302
Weinberg et al. (2005)			
Swept area biomass (mt)	300	143,000	535,000

Table C21. Efficiency corrected swept-area biomass estimates (1,000 mt) for SVA, DMV and NJ, which were covered during the 2004 cooperative surfclam survey.

Region	1997	1999	2002	2004	2005
SVA	1.59	5.96	29.96	0.13	29.96
DMV	397	236	375	125	68
NJ	1,065	730	653	626	397
Total	1,464	972	1,058	752	494

Table C22. Von Bertalanffy growth model parameters for surfclam weight at age in the DMV and NJ regions during 1982-1992 and 1994-2005 based on NEFSC survey data with estimates of meat weight (*W*, grams) and shell length (*L*, mm) at the age of recruitment (*k*), one year before recruitment (*k*-1) and one year after recruitment (*k*+1). The parameters for NJ were also used for the whole stock.

Parameter	NJ		DMV	
	1982-1992	1994-2005	1982-1992	1994-2005
$K\ (y^{-1})$	0.1449		0.1258	
r	0.8651		0.8818	
$t0\ (y)$	1.5365	1.6919	1.5176	1.6026
W_{max}	240.5	206.8	197.4	138.0
Age at recruitment *k* (y)	4.4	5.1	4.8	6.9
W_{k-1}	56.4	61.7	49.5	57.4
W_{k}	81.3	81.3	66.9	66.9
W_{k+1}	102.8	98.2	82.4	75.3
L_{k-1}	105.7	109.0	107.9	113.7
L_{k}	120.0	120.0	120.0	120.0
L_{k+1}	130.2	128.2	129.0	125.1
J	0.6945	0.7592	0.7388	0.8578

Table C23. NEFSC survey index trend data (doppler tow distance measurements) used in KLAMZ models for surfclam recruits and for fishable biomass in the whole stock..

	DMV recruit index			NJ recruit index			Whole stock recruit index			Whole stock fishable biomass index			
	Kg/Tow	CV	Size groups (mm SL)	Kg/Tow	CV	Size groups (mm SL)	Kg/Tow	CV	Size groups (mm SL)	Mean kg/tow	Approx. swept area biomass (mt)	CV	Size groups (mm SL)
1982	0.598	0.34	120-129	0.976	0.24	120-129	0.350	0.19	120-129	1.756	1,069	0.15	120+
1983	1.177	0.78	120-129	0.882	0.34	120-129	0.448	0.45	120-129	1.615	983	0.18	120+
1984	0.846	0.3	120-129	0.776	0.27	120-129	0.396	0.18	120-129	2.149	1,308	0.13	120+
1986	3.165	0.53	120-129	0.493	0.29	120-129	0.815	0.43	120-129	2.695	1,641	0.19	120+
1989	0.745	0.31	120-129	0.508	0.2	120-129	0.352	0.22	120-129	2.290	1,395	0.22	120+
1992	0.730	0.57	120-129	0.399	0.28	120-129	0.313	0.3	120-129	1.601	975	0.14	120+
1994	1.328	0.33	120-125	1.536	0.23	120-129	0.792	0.16	120-129	4.613	2,809	0.14	120+
1997	1.933	0.34	120-125	1.060	0.22	120-129	0.790	0.19	120-129	3.989	2,429	0.09	120+
1999	0.989	0.29	120-125	0.707	0.58	120-129	0.550	0.21	120-129	2.717	1,654	0.13	120+
2002	0.380	0.34	120-125	0.242	0.24	120-129	0.296	0.28	120-129	2.481	1,510	0.14	120+
2005	0.075	0.26	120-125	0.193	0.24	120-129	0.101	0.24	120-129	1.339	815	0.17	120+

Table C24. Estimated biomass, recruitment biomass and fishing mortality for the entire surfclam stock from the KLAMZ model. CVs are from 1000 bootstrap iterations.

Year	Biomass (1000 mt)	CV	Recruitment (1000 mt)	CV	Fishing mortality (y^{-1})	CV
1981	1,020	0.26	NA		0.0173	0.25
1982	1,036	0.23	96	0.17	0.0231	0.22
1983	1,059	0.20	110	0.20	0.0229	0.19
1984	1,083	0.18	109	0.17	0.0266	0.17
1985	1,141	0.16	147	0.26	0.0241	0.15
1986	1,225	0.15	170	0.20	0.0231	0.15
1987	1,271	0.14	130	0.30	0.0193	0.15
1988	1,290	0.15	106	0.28	0.0200	0.15
1989	1,289	0.14	93	0.15	0.0187	0.15
1990	1,285	0.15	96	0.31	0.0205	0.15
1991	1,283	0.15	102	0.32	0.0172	0.15
1992	1,290	0.15	109	0.15	0.0184	0.15
1993	1,476	0.13	289	0.30	0.0153	0.14
1994	1,613	0.12	231	0.13	0.0141	0.13
1995	1,709	0.09	201	0.33	0.0119	0.09
1996	1,780	0.07	185	0.32	0.0115	0.08
1997	1,842	0.07	189	0.14	0.0105	0.07
1998	1,824	0.05	116	0.35	0.0104	0.05
1999	1,799	0.04	121	0.17	0.0114	0.04
2000	1,723	0.04	76	0.36	0.0120	0.04
2001	1,628	0.04	62	0.36	0.0142	0.04
2002	1,531	0.04	63	0.18	0.0166	0.04
2003	1,415	0.05	43	0.24	0.0187	0.05
2004	1,292	0.05	32	0.22	0.0199	0.05
2005	1,170	0.06	27	0.16	0.0192	0.06

Table C25. Factors used to scale NEFSC survey trend data (mean kg/tow, 120+ mm, doppler tow distances) to approximate efficiency corrected swept-area biomass (based on sensor distance data and efficiency estimates.

SVA	*DMV*	*NJ*
68.462	119.917	114.584
LI	*SNE*	*GBK*
76.107	89.164	103.414

Table C26. Proportions of total fishable surfclam biomass during 1980-2005 at a range of survey biomass density levels, by region.

Years	Fishable biomass density levels (kg/tow) from survey data 0 to 4	5 to 9	10 to 14	15 to 19	20 to 24	25+	Sum of Proportions (check)	Total Number of Tows	Total Number of Surveys
Proportions of tows (and stock area) at each survey catch rate level:									
			Southern Virgina (SVA)						
1980-1989	0.94	0.03	0.01	0.02	0.01		1.00	154	5
1990-1999	0.99			0.01			1.00	107	3
2000-2005	1.00						1.00	29	2
			Delmarva (DMV)						
1980-1989	0.81	0.10	0.03	0.01	0.01	0.04	1.00	355	5
1990-1999	0.78	0.11	0.05	0.03	0.02	0.02	1.00	237	3
2000-2005	0.90	0.05	0.03	0.01		0.01	1.00	152	2
			New Jersy (NJ)						
1980-1989	0.71	0.12	0.06	0.04	0.02	0.05	1.00	484	5
1990-1999	0.56	0.13	0.10	0.05	0.05	0.11	1.00	330	3
2000-2005	0.69	0.11	0.11	0.03	0.01	0.04	1.00	206	2
			Long Island (LI)						
1980-1989	0.97	0.02	0.01				1.00	170	5
1990-1999	0.95	0.02	0.01		0.01		1.00	86	3
2000-2005	0.93	0.02	0.02	0.04			1.00	57	2
			Southern New England (SNE)						
1980-1989	0.87	0.03	0.05	0.02	0.01	0.02	1.00	202	5
1990-1999	0.90	0.02	0.04		0.01	0.02	1.00	90	3
2000-2005	0.96	0.04					1.00	48	2
			Georges Bank (GBK)						
1986-1992	0.87	0.05	0.03	0.02	0.01	0.02	1.00	126	3
1997-2002	0.79	0.04	0.04	0.02	0.01	0.10	1.00	119	3
All years	0.83	0.04	0.04	0.02	0.01	0.06	1.00	245	6
Mean survey catch rate (kg/tow) at each survey catch rate level (p_L):									
			Southern Virgina (SVA)						
1980-1989	0.267	6.206	11.779	16.929	21.086				
1990-1999	0.119			17.468					
2000-2005	0.171								
			Delmarva (DMV)						
1980-1989	0.853	7.528	11.999	16.412	21.738	50.956			
1990-1999	0.820	7.348	12.039	17.431	22.697	50.709			
2000-2005	0.518	6.800	11.471	17.350		25.869			
			New Jersy (NJ)						
1980-1989	1.018	7.559	12.270	17.662	22.426	52.603			
1990-1999	0.939	7.343	12.017	17.518	22.016	45.320			
2000-2005	1.216	7.215	12.195	15.867	22.468	32.093			
			Long Island (LI)						
1980-1989	0.095	6.554	13.132						
1990-1999	0.240	6.216	11.010		23.237				
2000-2005	0.121	7.404	10.151	17.446					
			Southern New England (SNE)						
1980-1989	0.311	8.573	11.768	18.272	22.628	43.811			
1990-1999	0.118	7.898	12.033		20.543	30.708			
2000-2005	0.640	6.301							
			Georges Bank (GBK)						
1986-1992	0.223	8.360	10.987	17.530	21.017	85.534			
1997-2002	0.500	7.110	10.928	17.167	22.838	40.544			
All years	0.351	7.792	10.954	17.385	21.927	46.971			
Proportions of stock biomass at each survey catch rate level (X_L) :									
			Southern Virgina (SVA)						
1980-1989	0.242	0.156	0.148	0.320	0.133		1.00		
1990-1999	0.431			0.569			1.00		
2000-2005	1.000						1.00		
			Delmarva (DMV)						
1980-1989	0.164	0.187	0.072	0.055	0.044	0.478	1.00		
1990-1999	0.162	0.197	0.142	0.131	0.097	0.271	1.00		
2000-2005	0.311	0.233	0.197	0.149		0.111	1.00		
			New Jersy (NJ)						
1980-1989	0.118	0.146	0.119	0.100	0.060	0.457	1.00		
1990-1999	0.055	0.102	0.129	0.094	0.104	0.516	1.00		
2000-2005	0.168	0.161	0.272	0.108	0.044	0.249	1.00		
			Long Island (LI)						
1980-1989	0.255	0.319	0.426				1.00		
1990-1999	0.296	0.187	0.166		0.350		1.00		
2000-2005	0.109	0.126	0.172	0.593			1.00		
			Southern New England (SNE)						
1980-1989	0.101	0.095	0.218	0.135	0.126	0.325	1.00		
1990-1999	0.062	0.102	0.310		0.132	0.395	1.00		
2000-2005	0.700	0.300					1.00		
			Georges Bank (GBK)						
1986-1992	0.067	0.138	0.121	0.145	0.058	0.471	1.00		
1997-2002	0.069	0.052	0.080	0.050	0.034	0.715	1.00		
All years	0.068	0.082	0.094	0.083	0.042	0.630	1.00		

Table C27. Proportions of total 2005 stock biomass at a range of survey density levels, by region.

	Survey catch rate level (kg/tow)						
Region	**0 to 4**	**5 to 9**	**10 to 14**	**15 to 19**	**20 to 24**	**25+**	**Total**
			Total 2005 biomass (mt meats)				
Southern Virginia (SVA)	36	0	0	0	0	0	36
Delmarva (DMV)	29	21	18	14	0	10	92
New Jersey (NJ)	61	59	99	39	16	91	365
Long Island (LI)	18	21	29	99	0	0	167
Southern New England (SNE)	28	12	0	0	0	0	40
Georges Bank (GBK)	33	25	38	24	16	336	471
Total	205	138	184	176	32	437	1,170
			Total 2005 biomass (bushels)				
Southern Virginia (SVA)	4,678	0	0	0	0	0	4,678
Delmarva (DMV)	3,713	2,786	2,350	1,777	0	1,325	11,951
New Jersey (NJ)	7,959	7,598	12,843	5,085	2,058	11,755	47,299
Long Island (LI)	2,354	2,721	3,731	12,823	0	0	21,628
Southern New England (SNE)	3,615	1,548	0	0	0	0	5,162
Georges Bank (GBK)	4,218	3,188	4,900	3,079	2,048	43,632	61,065
Total	26,537	17,841	23,823	22,764	4,106	56,712	151,783
			Percent of total 2005 biomass				
Southern Virginia (SVA)	3.082%	0.000%	0.000%	0.000%	0.000%	0.000%	3.082%
Delmarva (DMV)	2.45%	1.84%	1.55%	1.17%	0.00%	0.87%	7.87%
New Jersey (NJ)	5.24%	5.01%	8.46%	3.35%	1.36%	7.74%	31.16%
Long Island (LI)	1.55%	1.79%	2.46%	8.45%	0.00%	0.00%	14.25%
Southern New England (SNE)	2.38%	1.02%	0.00%	0.00%	0.00%	0.00%	3.40%
Georges Bank (GBK)	2.78%	2.10%	3.23%	2.03%	1.35%	28.75%	40.23%
Total	17.48%	11.75%	15.70%	15.00%	2.70%	37.36%	100.00%

Table C28. Example projection results for surfclam showing projected average biomass, and fishing mortality during 2006-2015 under three possible scenarios: i) constant landings at the minimum quota; ii) status-quo landings (i.e. mean landings during 2003 to 2005); iii) constant landings at the maximum quota; and iv) constant fishing mortality at the F_{MSY} proxy = M= 0.15 y^{-1}. CVs measure variability between simulation runs in the projection analysis for a scenario. CVs were similar for each scenario in the same year and the CVs shown in the table are averages for simplicity in presentation.

Year	Landings = min quota = 1.85 million bu	Status quo landings = mean 2003-2005 = 3.042 million bu	Landings = max quota = 3.4 million bu	$F = F_{MSY} = M =$ 0.15	CV
		Catch (landings + 12%, 1000 mt)			
All	16.0	49.7	49.7	variable	NA
		Biomass (1000 mt)			
2005	1,198	1,198	1,198	1,198	251%
2006	1,093	1,093	1,093	1,093	275%
2007	1,010	1,001	998	889	322%
2008	944	925	920	739	417%
2009	892	866	858	632	560%
2010	856	823	813	559	744%
2011	832	793	781	512	944%
2012	820	776	762	485	1150%
2013	819	769	754	472	1350%
2014	826	772	755	470	1532%
2015	839	781	763	474	1679%
		Fishing mortality (annual rate)			
2005	0.0188	0.0188	0.0188	0.0188	255%
2006	0.0156	0.0258	0.0288	0.1500	279%
2007	0.0169	0.0282	0.0317	0.1500	327%
2008	0.0181	0.0306	0.0345	0.1500	412%
2009	0.0193	0.0329	0.0372	0.1500	531%
2010	0.0202	0.0349	0.0396	0.1500	676%
2011	0.0210	0.0367	0.0418	0.1500	836%
2012	0.0216	0.0381	0.0435	0.1500	1009%
2013	0.0220	0.0392	0.0449	0.1500	1187%
2014	0.0222	0.0399	0.0458	0.1500	1369%
2015	0.0223	0.0403	0.0465	0.1500	1551%

SURFCLAM FIGURES

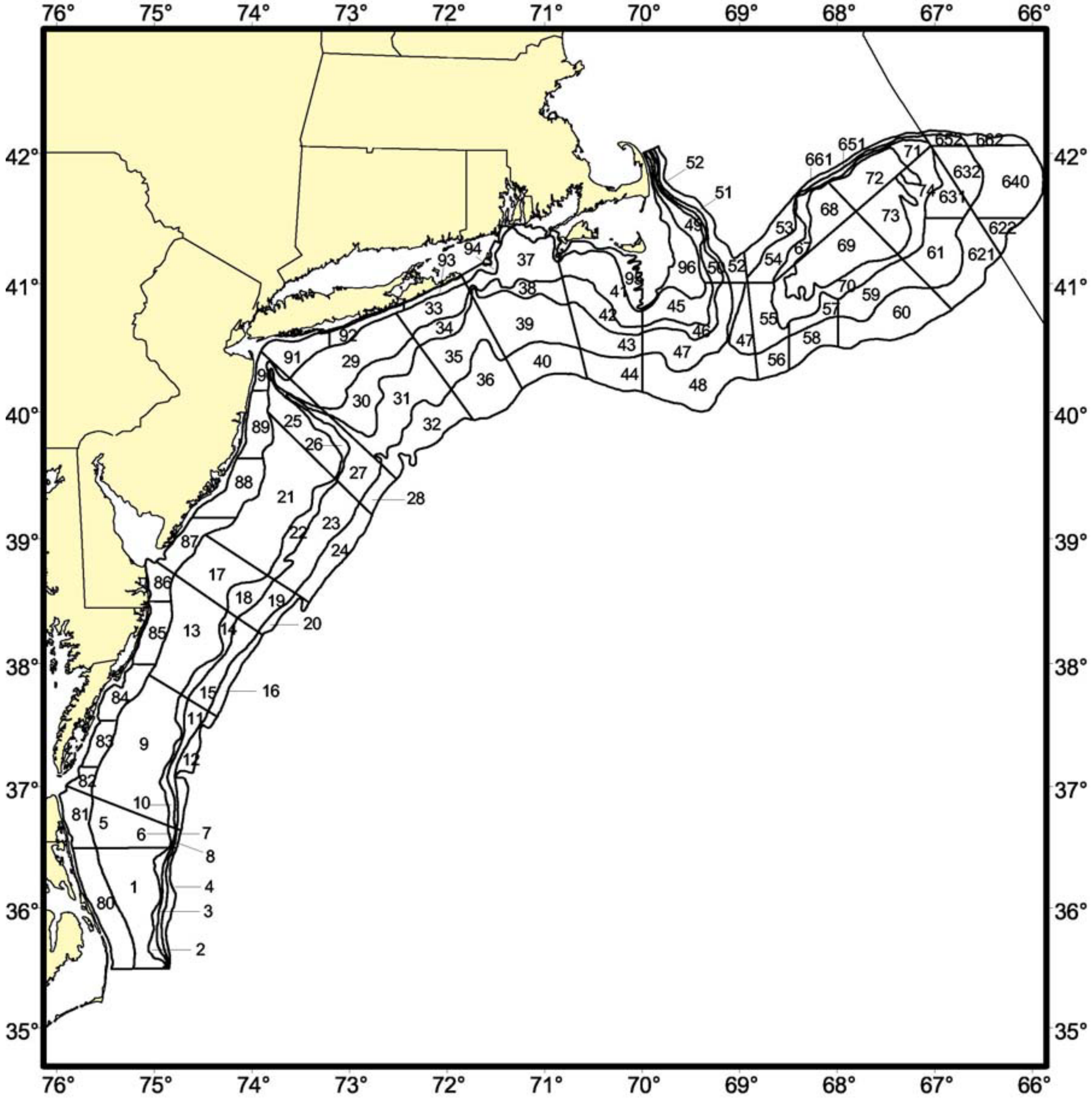
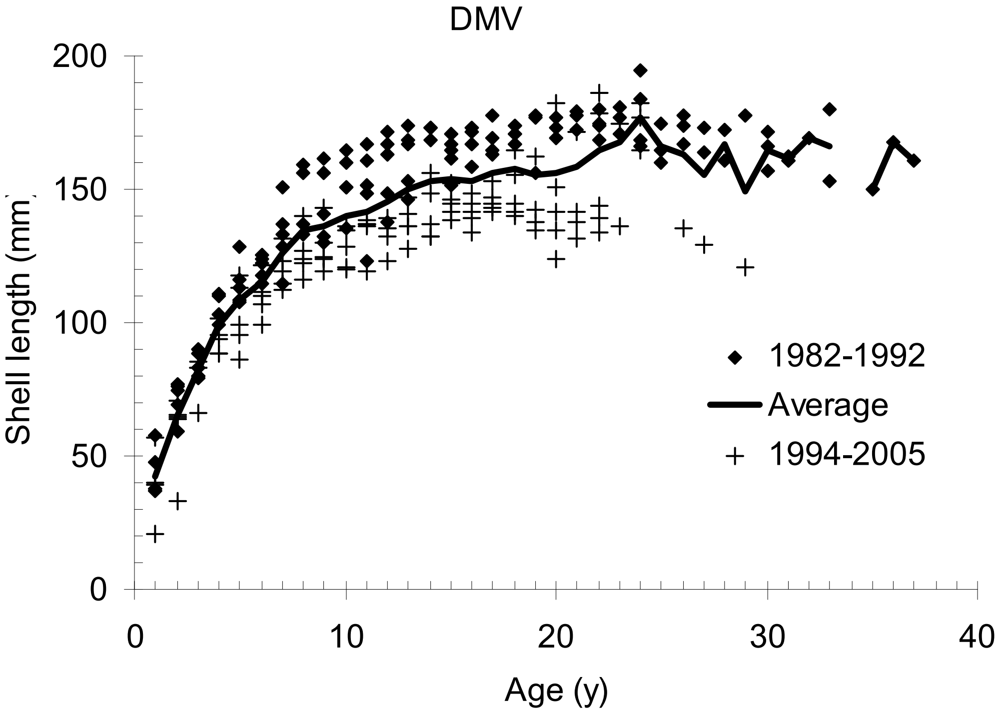


Figure C1. Surfclam stock assessment regions and NEFSC clam survey strata. Northern and southern New Jersey is combined to form the larger New Jersey (NJ) assessment region.



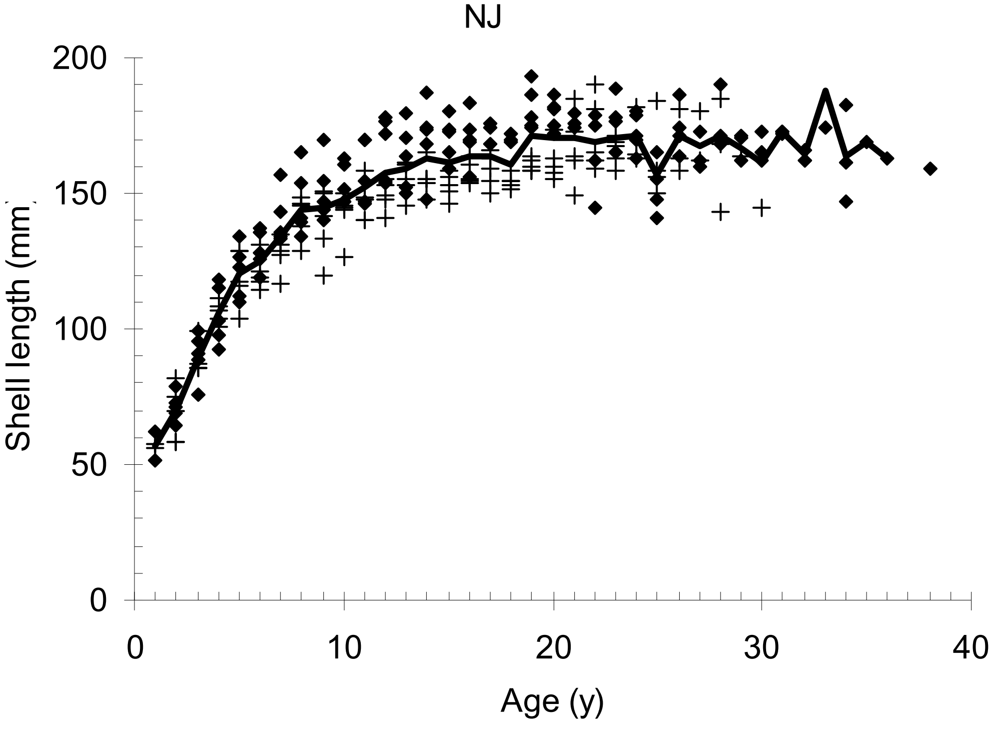


Figure C2. Size at age data for surfclam in DMV and NJ from NEFSC clam surveys during 1982-1992 and 1994-2005. The dark line shows average size at age in all years.

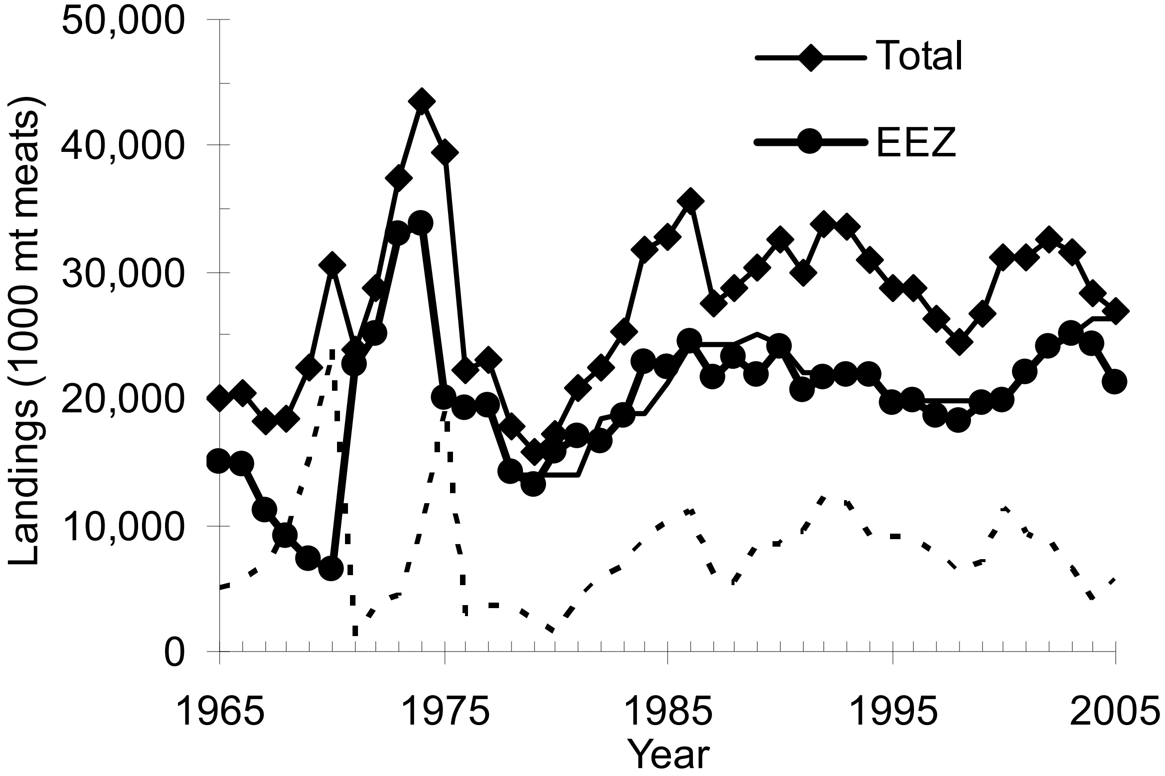


Figure C3. Atlantic surfclam landings and EEZ surfclam quotas (all converted to mt meats).

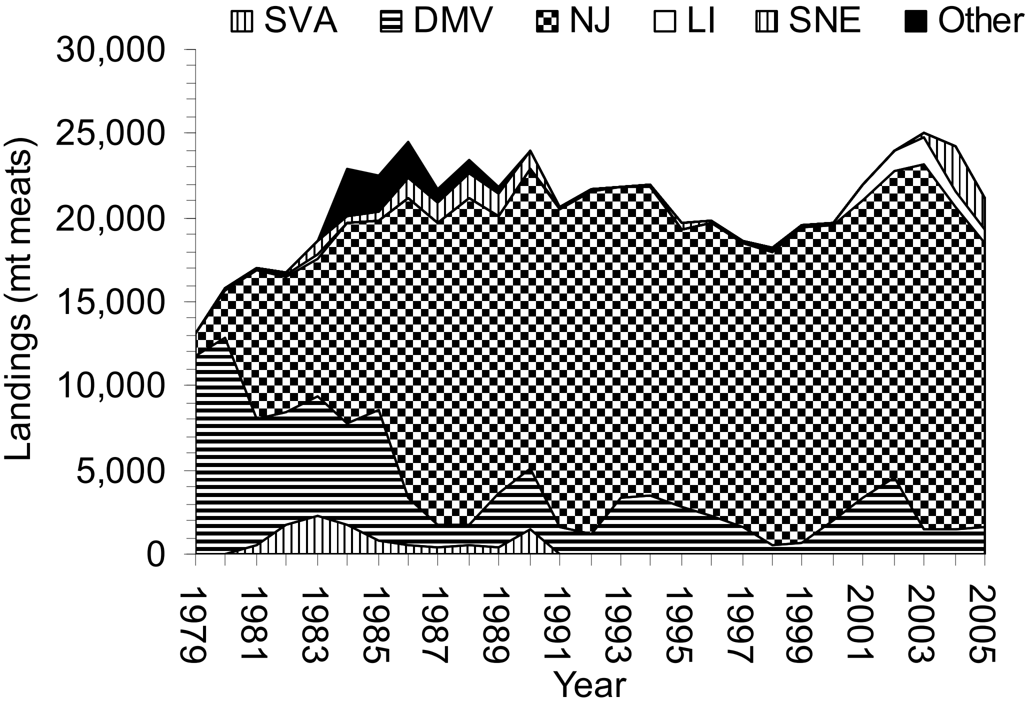


Figure C4. Surfclam landings from the US EEZ during 1979-2005 by stock assessment region.

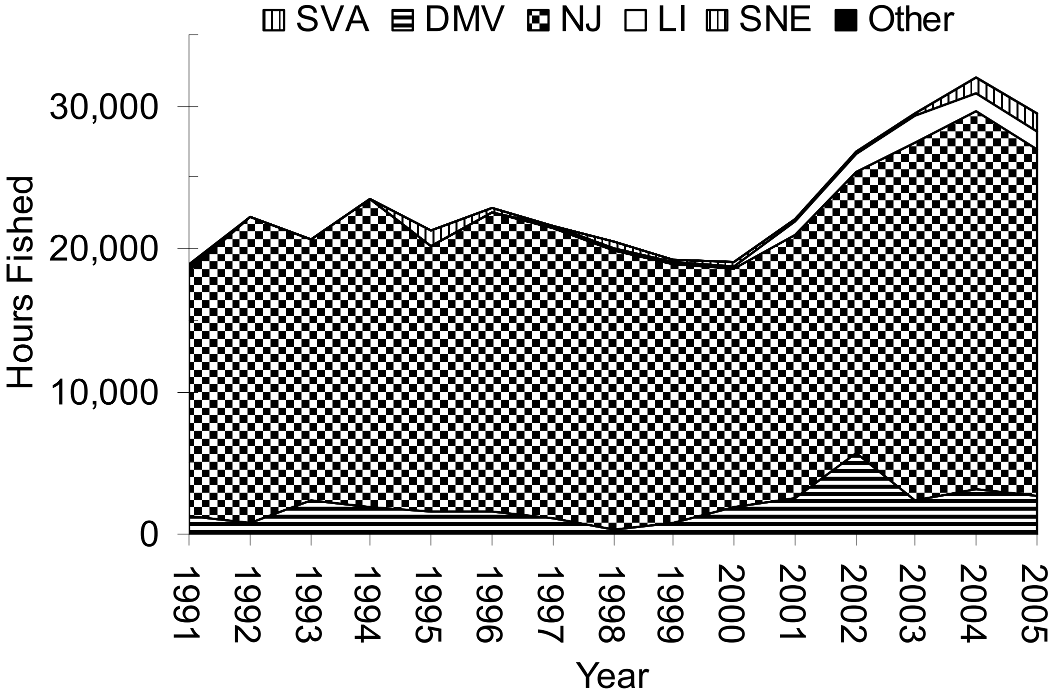


Figure C5. Total fishing effort (hours fished, all trips and all vessels) in the US EEZ during 1991-2005 by stock assessment region.

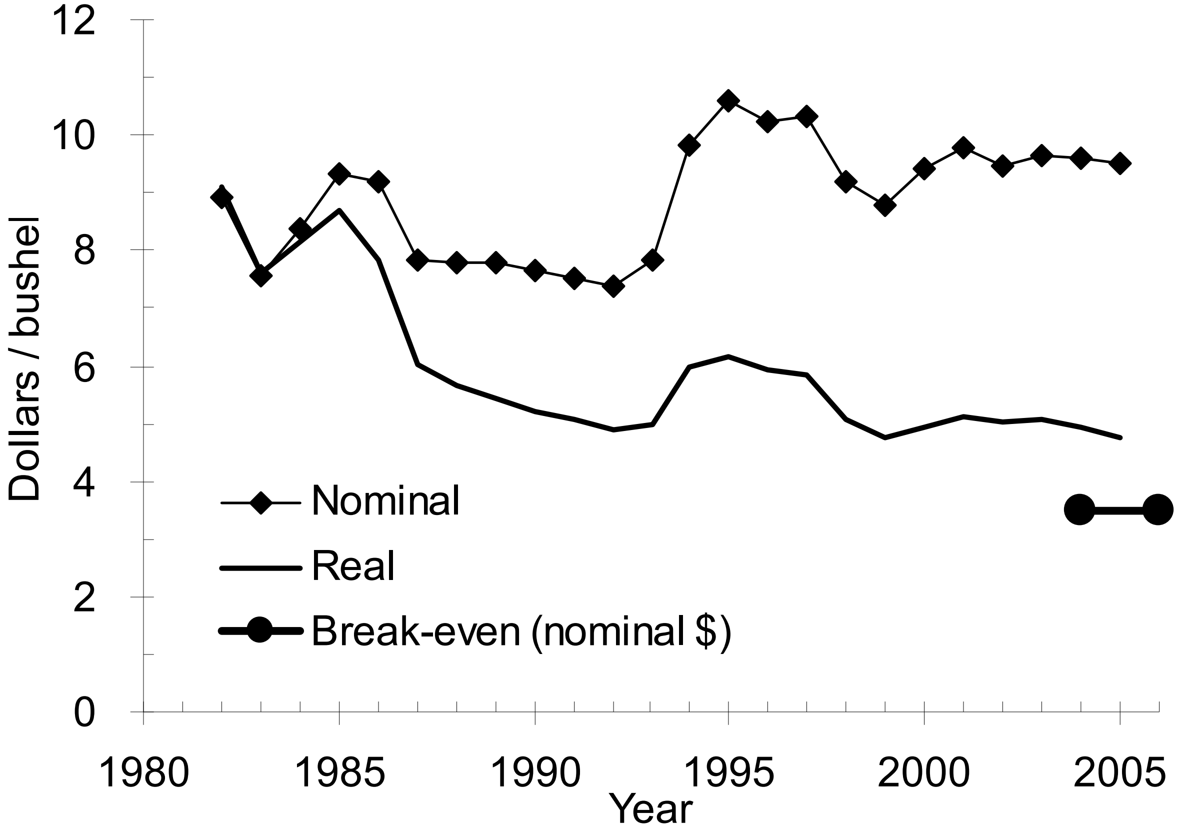


Figure C6. Real and nominal exvessel prices (US$ per bushel) for surfclam landed (EEZ and state waters) during 1982-2005. Real prices use 1980-1982 as the base year. The current "break-even" price (to meet variable costs) is about 3-4 $ bu-1 (nominal, in 2005 dollars) and shown for comparison.

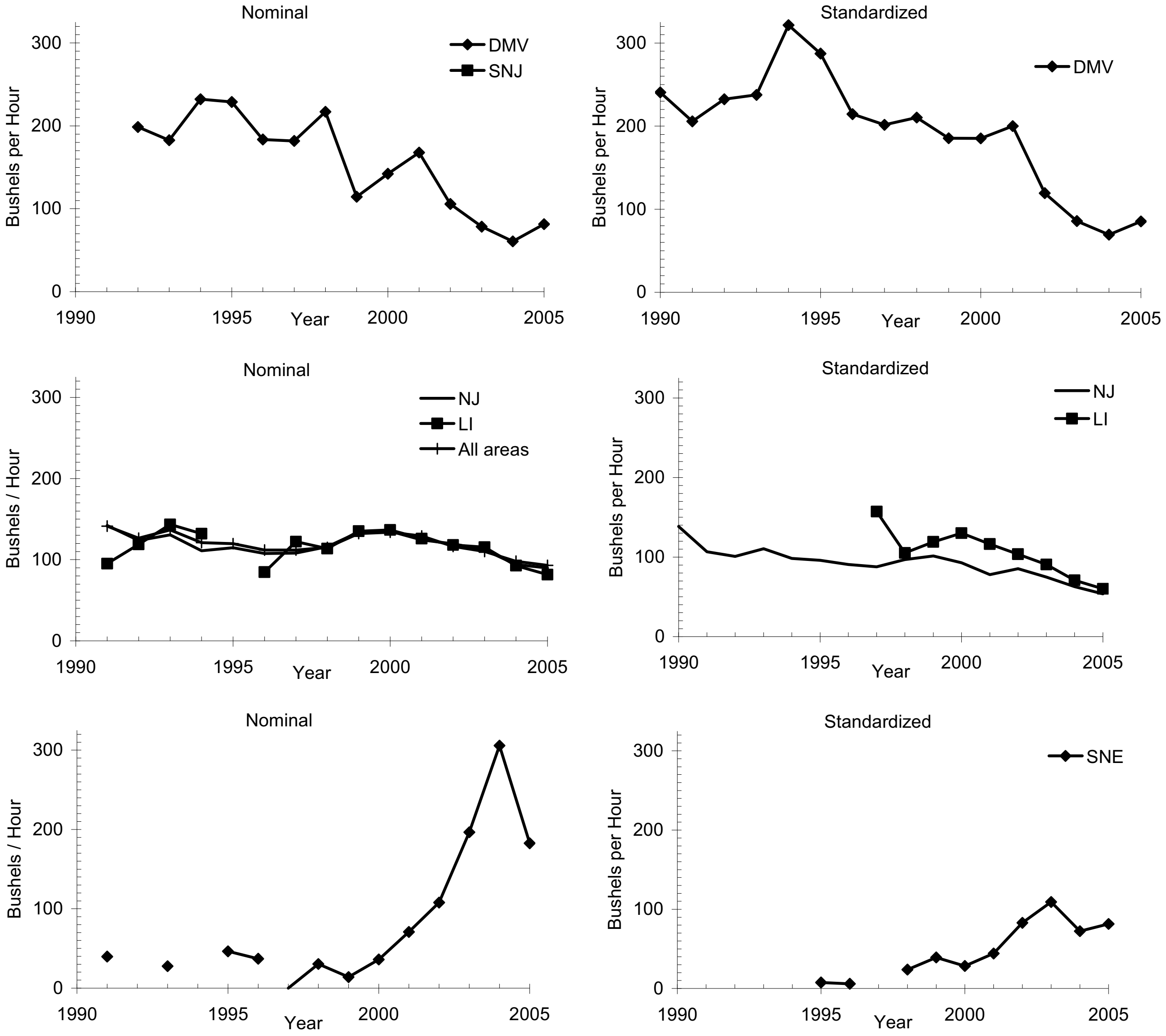


Figure C7. Nominal and standardized LPUE for surfclam in the EEZ, by region. Regions with similar trends are plotted together.

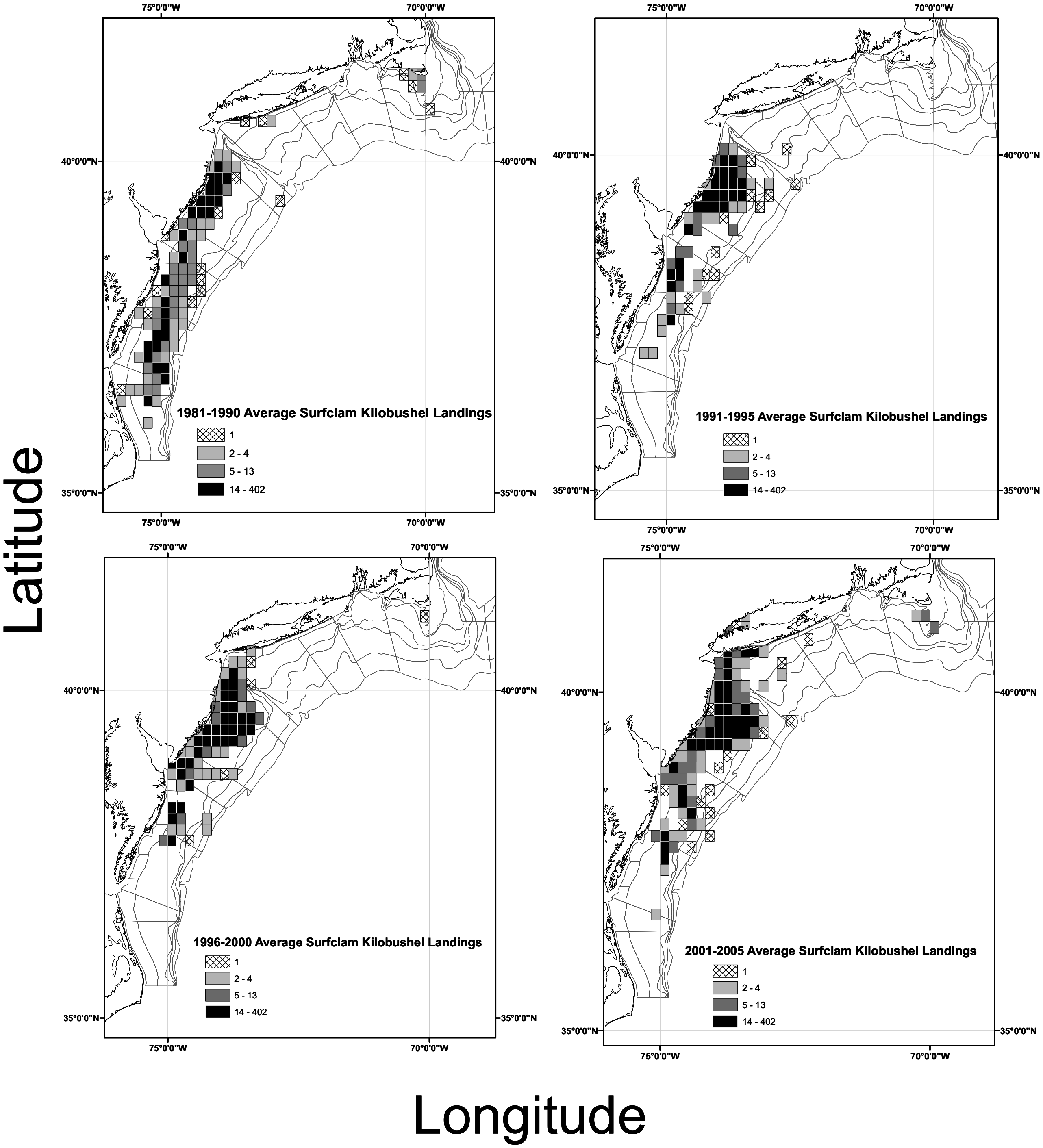


Figure C8. Spatial distribution of surfclam landings (annual means, 1 kilobushel = 1000 bu y-1) during 1981-1990, 1991-1995, 1996-2000 and 2001-2005 based on logbook data and ten-minute squares. Categories correspond approximately with quartiles during 1981-1990.

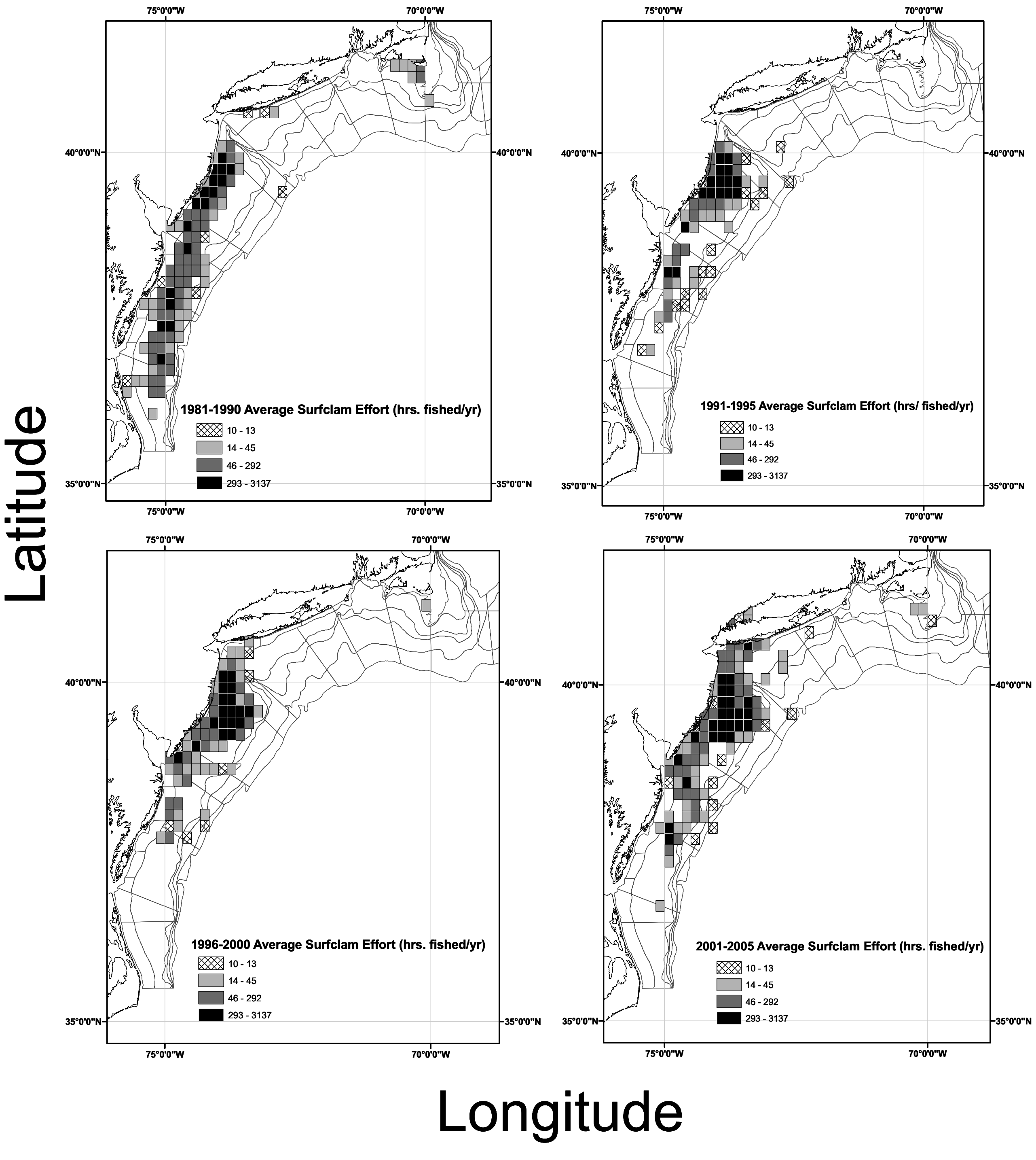


Figure C9. Spatial distribution of surfclam fishing effort (annual means, h y^{-1}) during 1981-1990, 1991-1995, 1996-2000 and 2001-2005 based on logbook data and ten-minute squares. Categories correspond approximately with quartiles during 1981-1990.

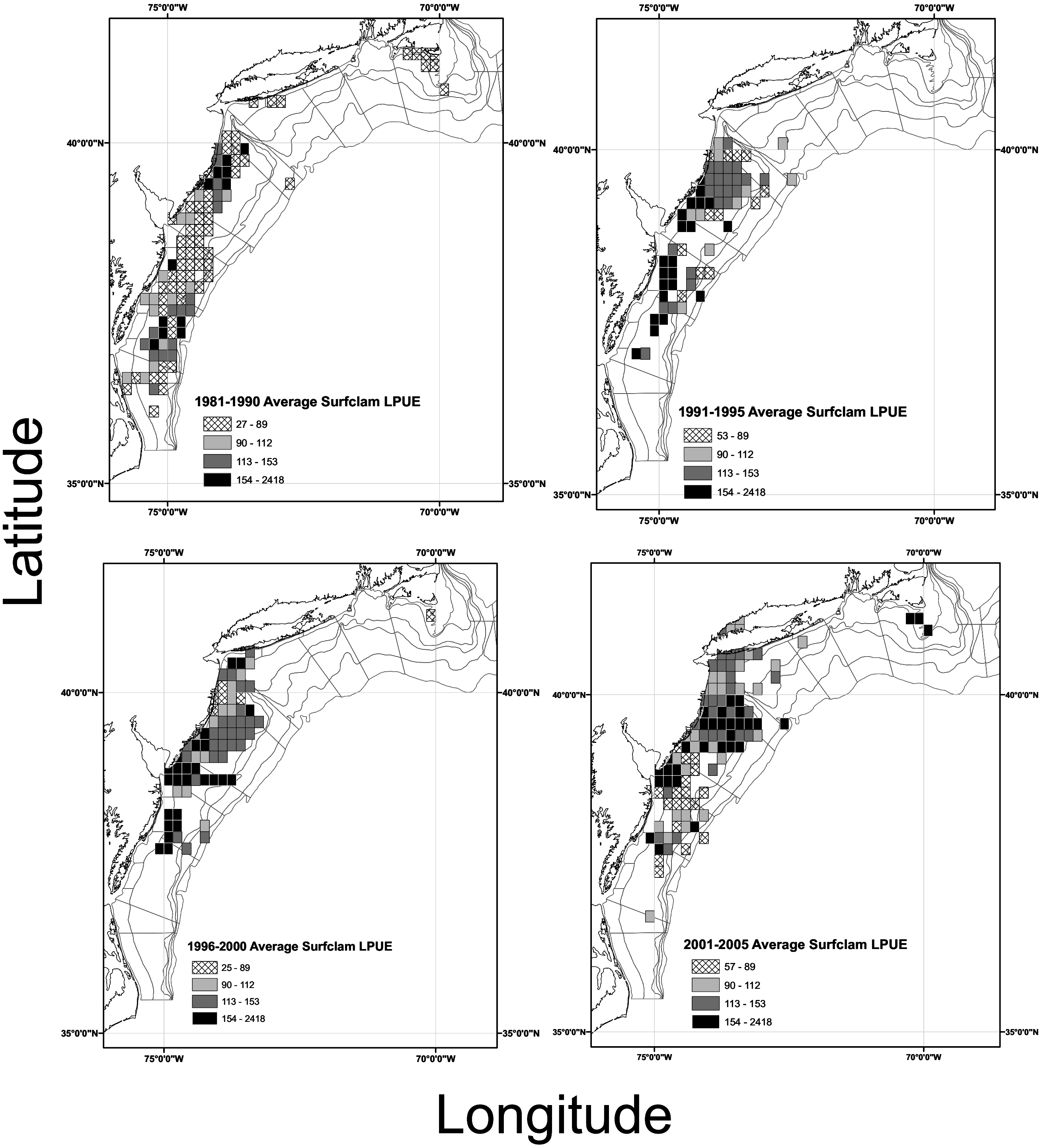


Figure C10. Spatial distribution of surfclam LPUE (annual means, bu h^{-1} y^{-1}) during 1981-1990, 1991-1995, 1996-2000 and 2001-2005 based on logbook data and ten-minute squares. Categories correspond approximately with quartiles during 1981-1990.

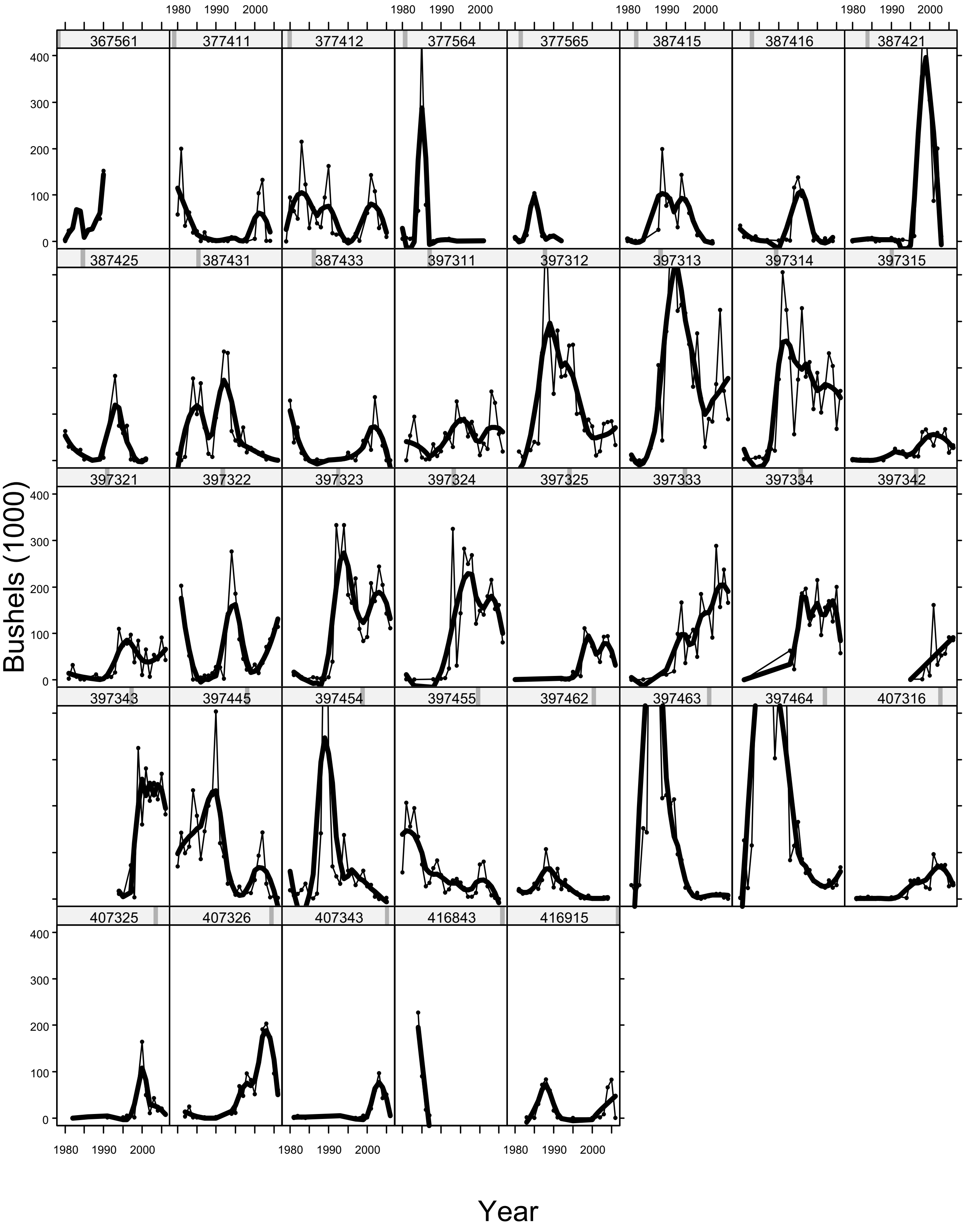


Figure C11. Annual surfclam landings (1000 bushels per year) for important ten-minute squares during 1980-2005 based on logbook data. The smooth dark line is a spline intended to show general trends.

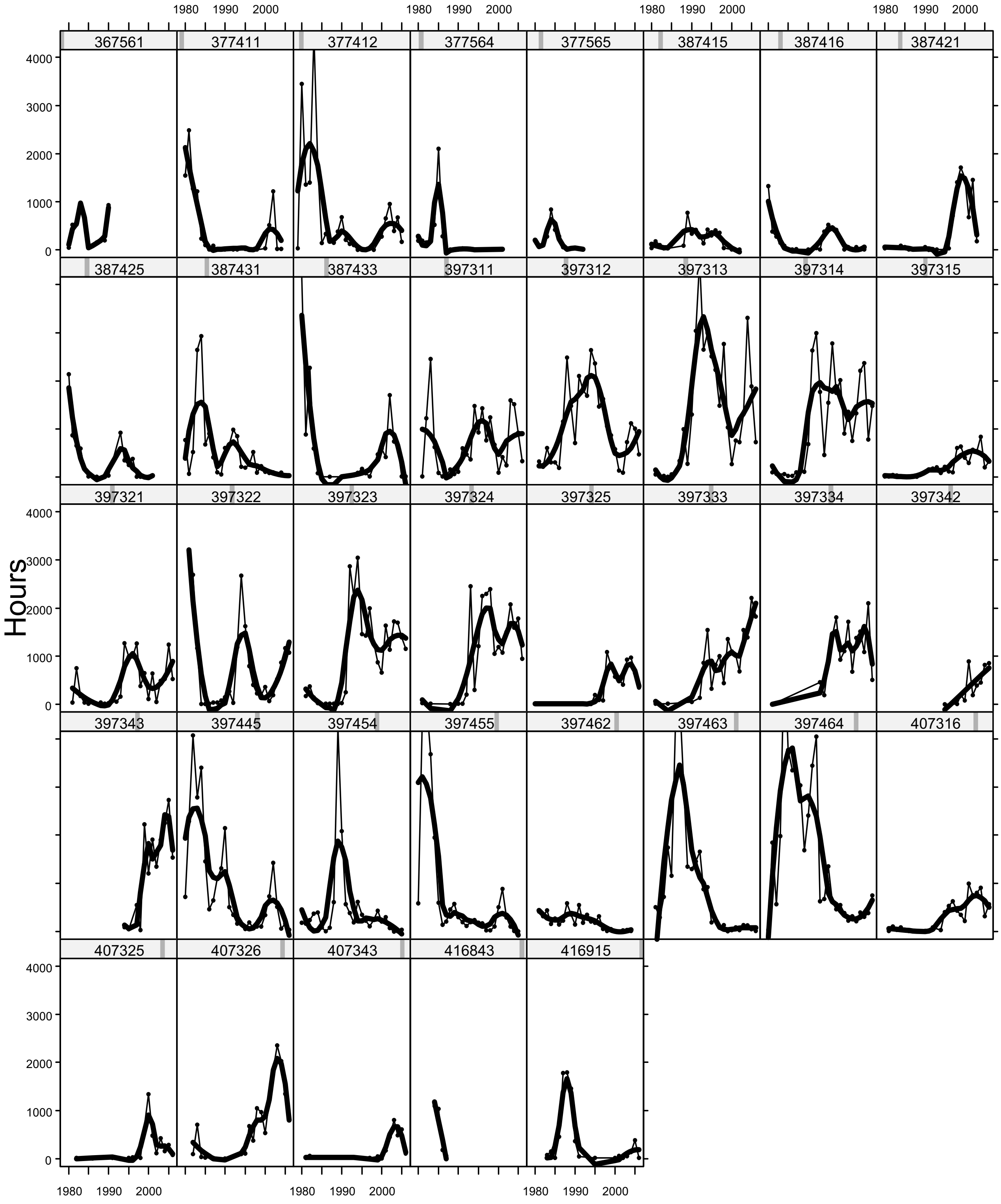


Figure C12. Annual surfclam fishing effort (hours of fishing per year) for important ten-minute squares during 1980-2005 based on logbook data. The smooth dark line is a spline intended to show general trends.

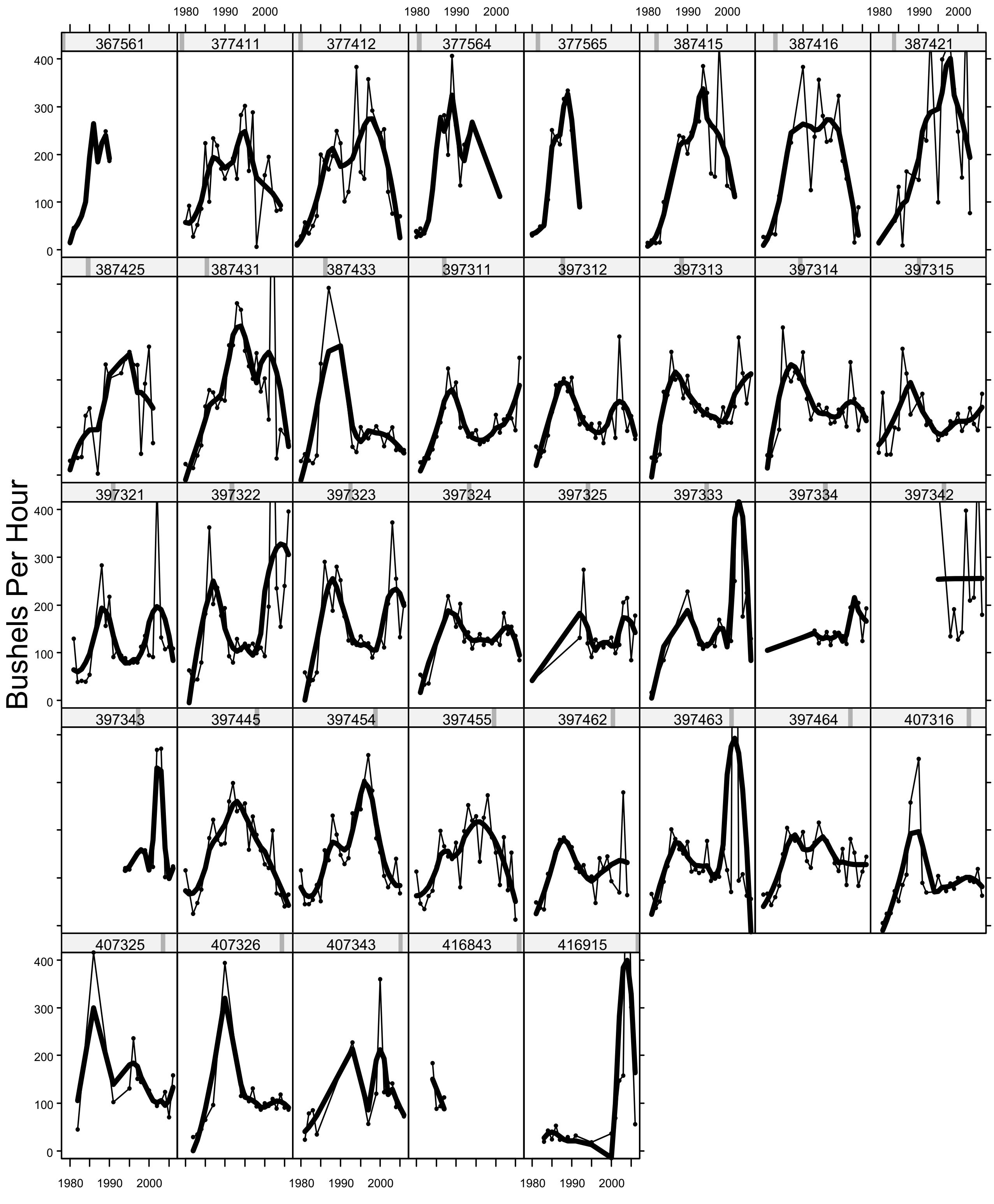


Figure C13. Annual surfclam landings per unit of fishing effort (LPUE, mean h^{-1}) for important ten-minute squares during 1980-2005 based on logbook data. The smooth dark line is a spline intended to show general trends.

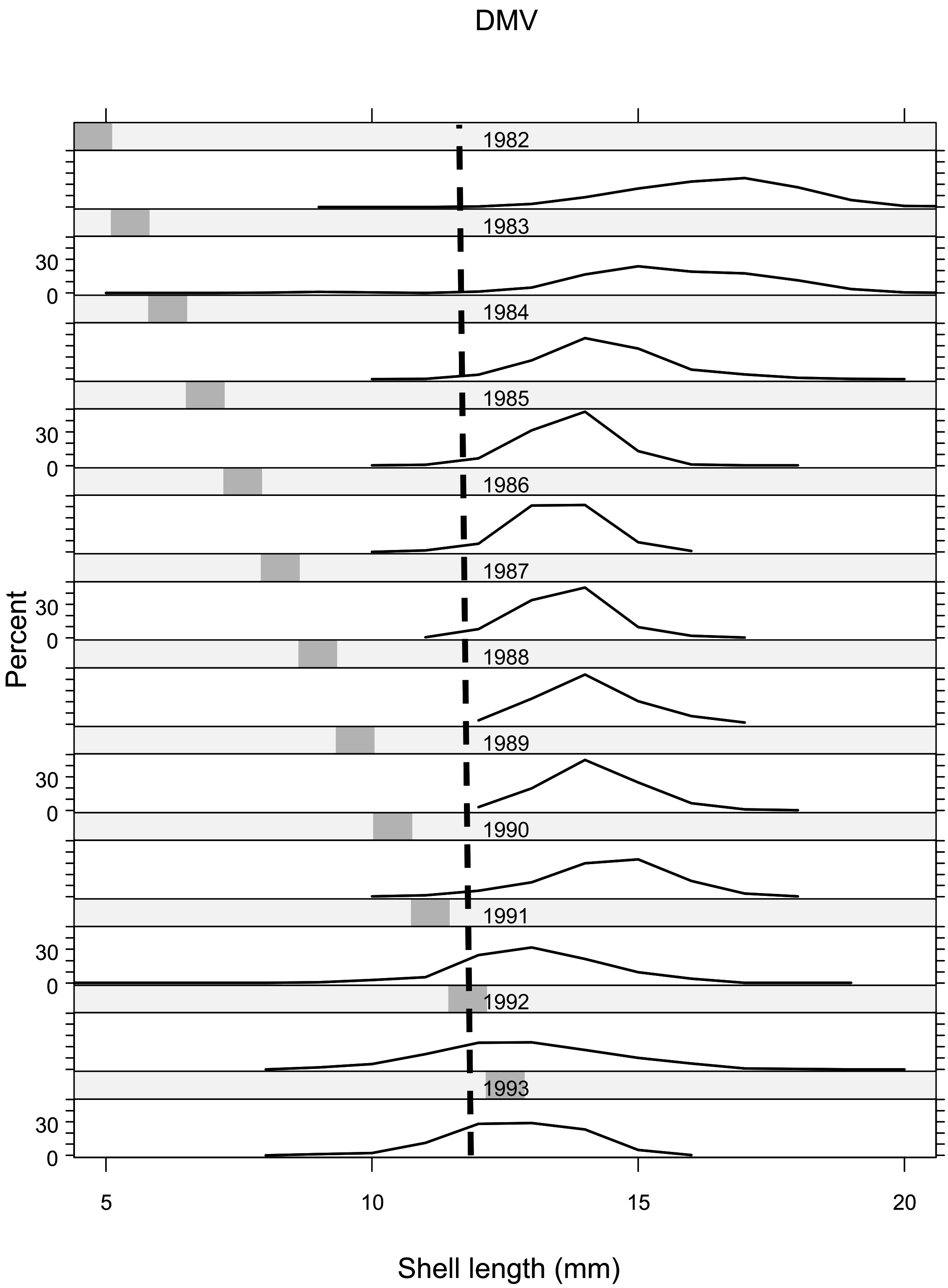


Figure C14. Commercial length composition data for surfclam caught in the DMV area, based on port samples. The dashed vertical line is at 120 mm SL.

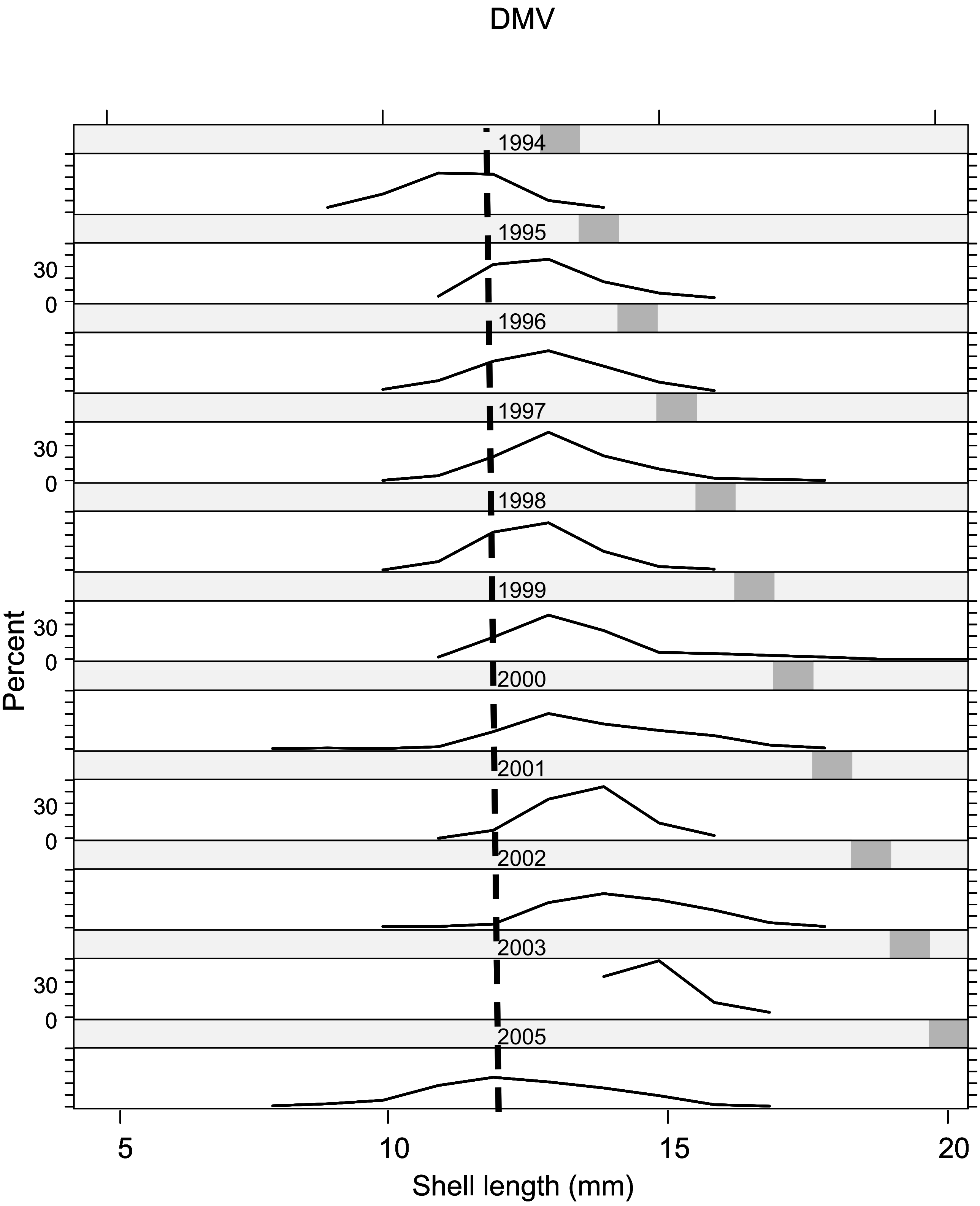
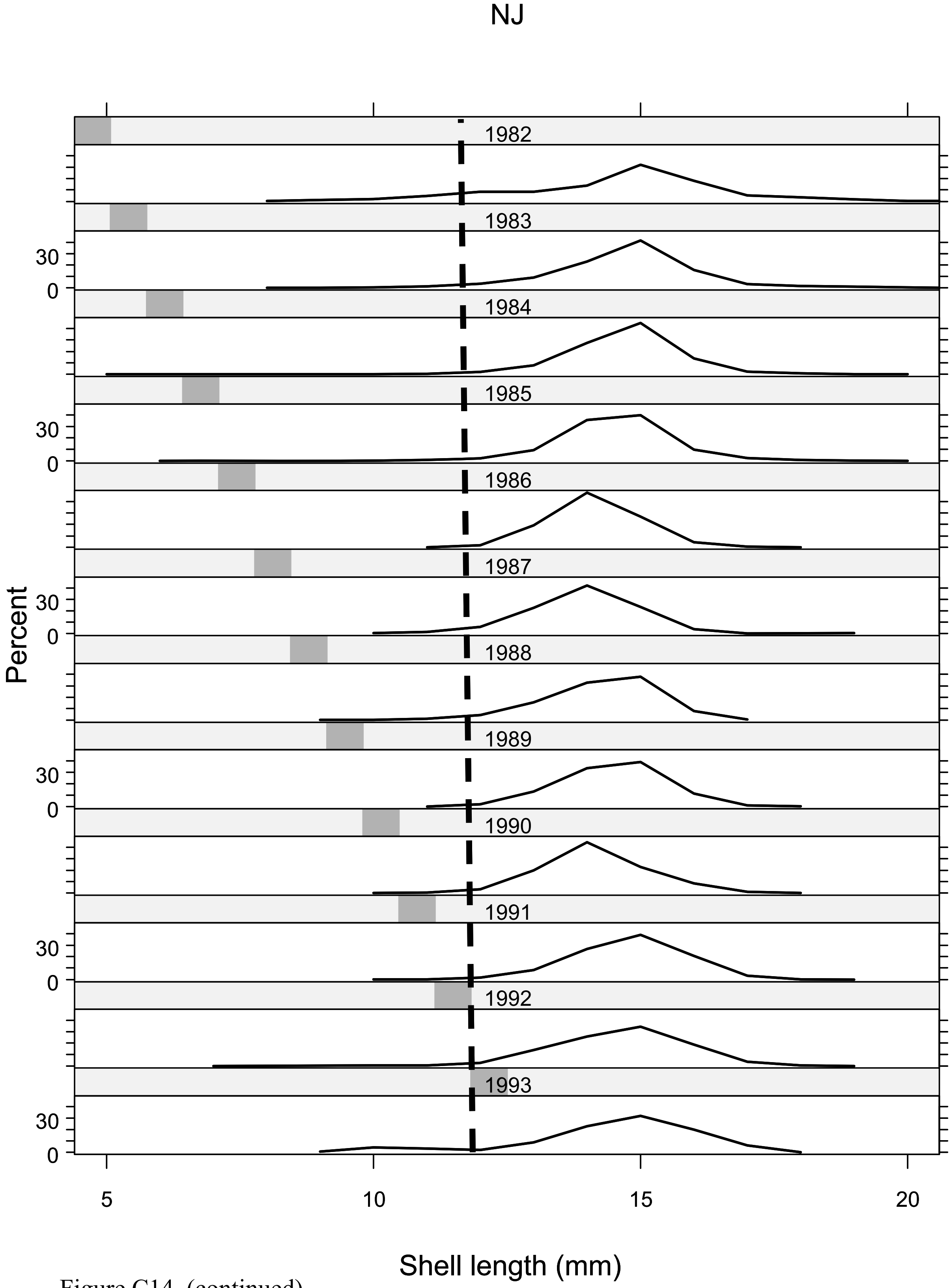


Figure C14. (continued)



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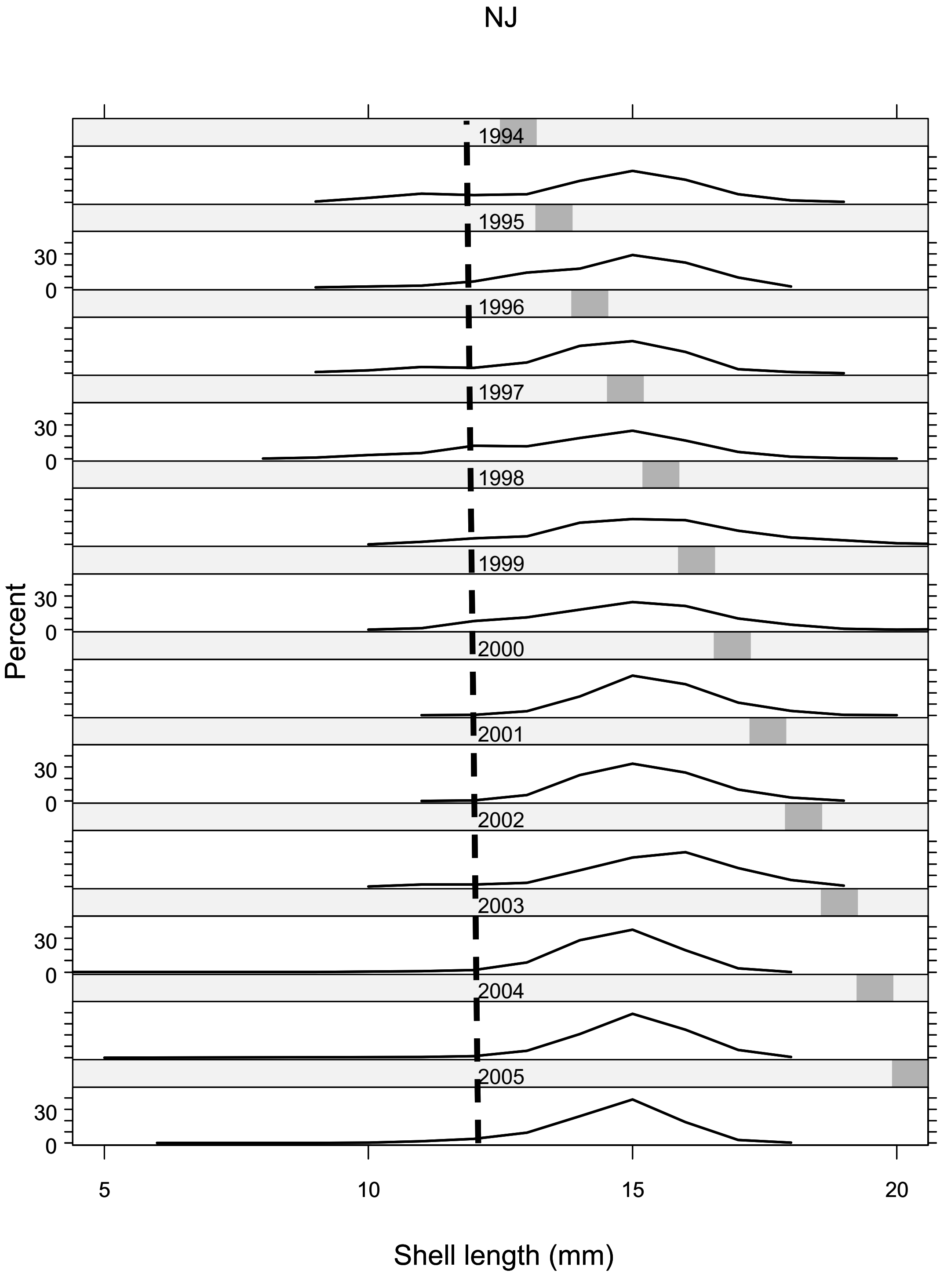


Figure C15. Commercial length composition data for surfclam caught in the NJ area, based on port samples. The dashed vertical line is at 120 mm SL.

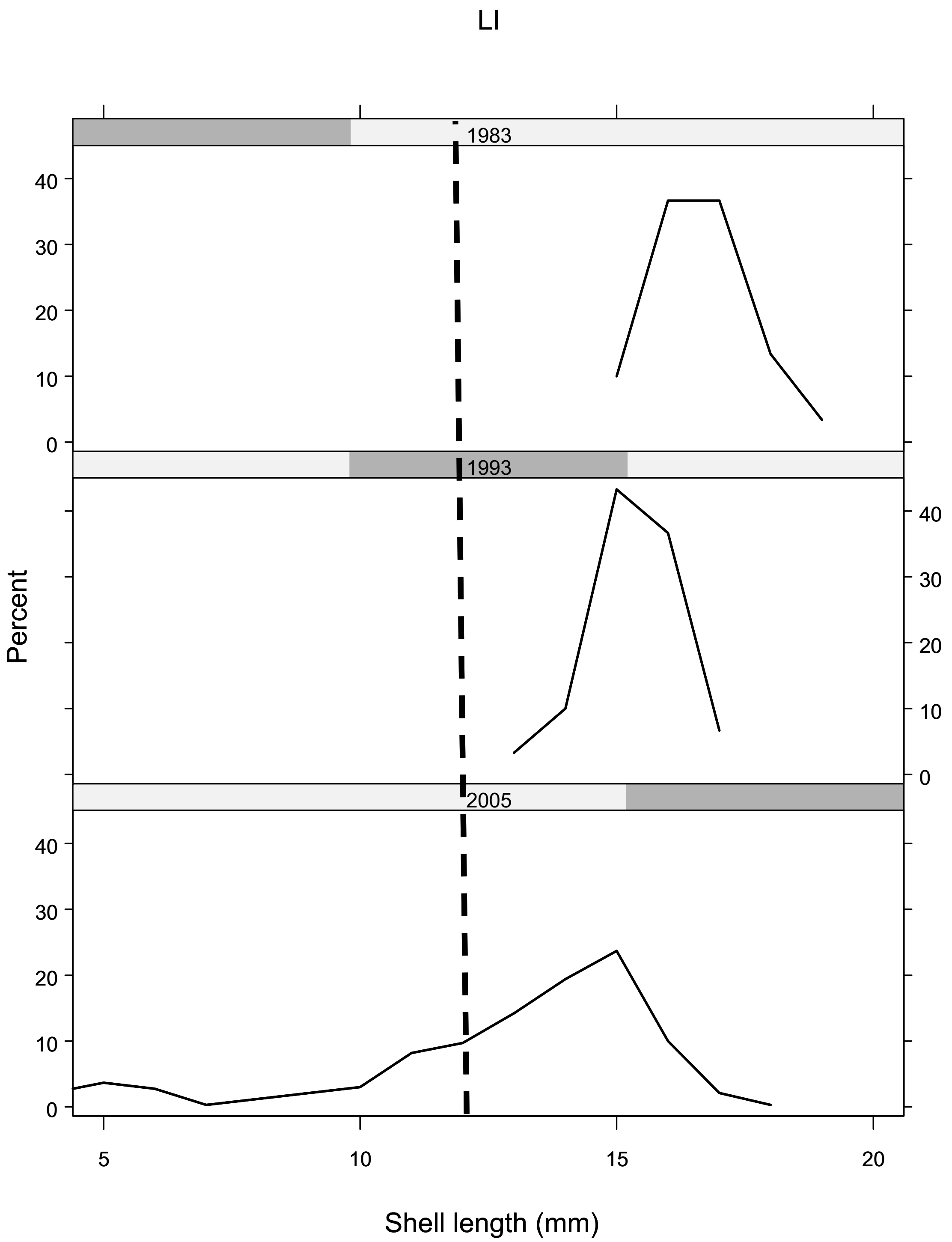


Figure C16. Commercial length composition data for surfclam caught in the LI area, based on port samples. The dashed vertical line is at 120 mm SL.

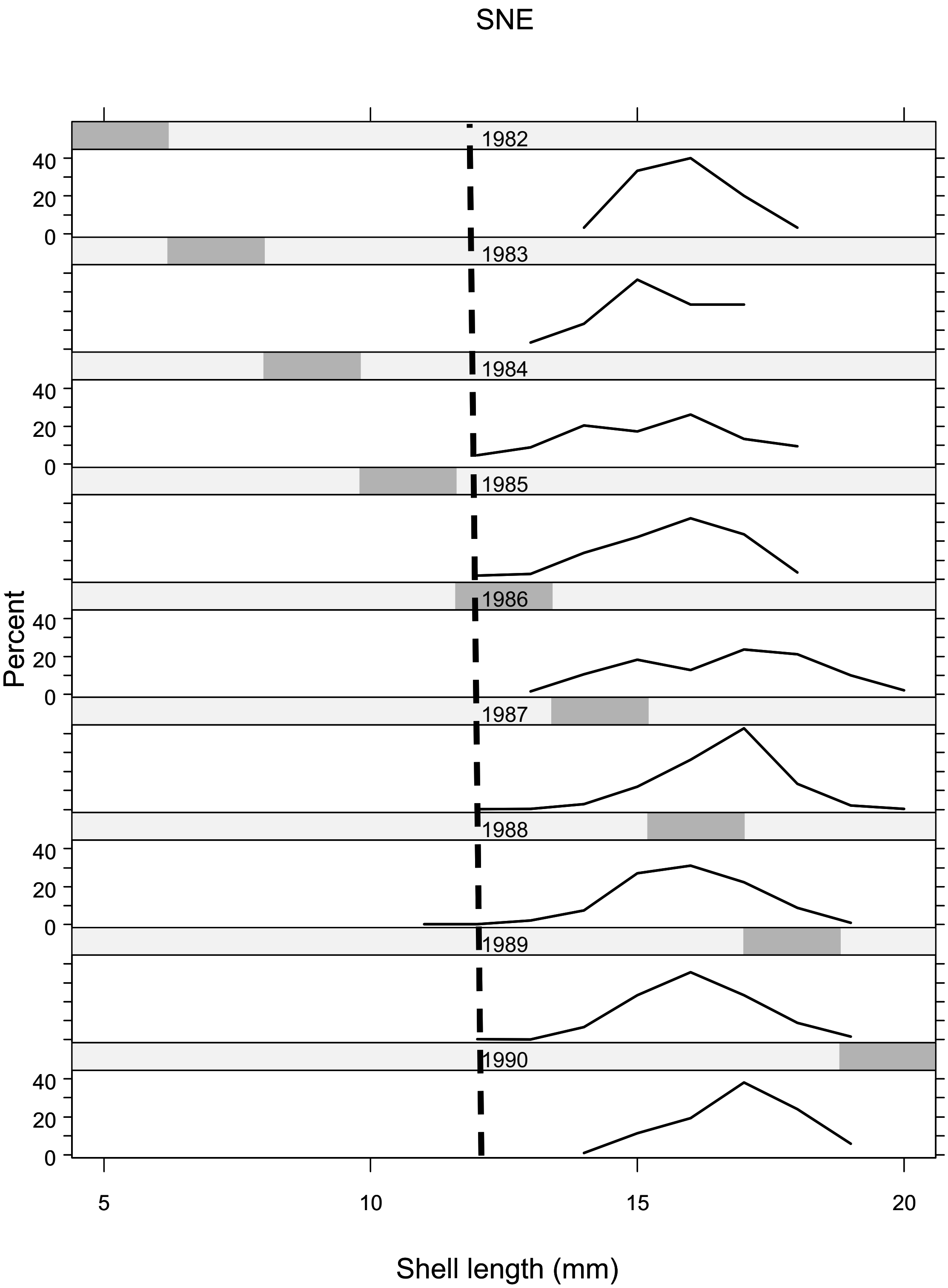


Figure C17. Commercial length composition data for surfclam caught in the SNE area, based on port samples. The dashed vertical line is at 120 mm SL.

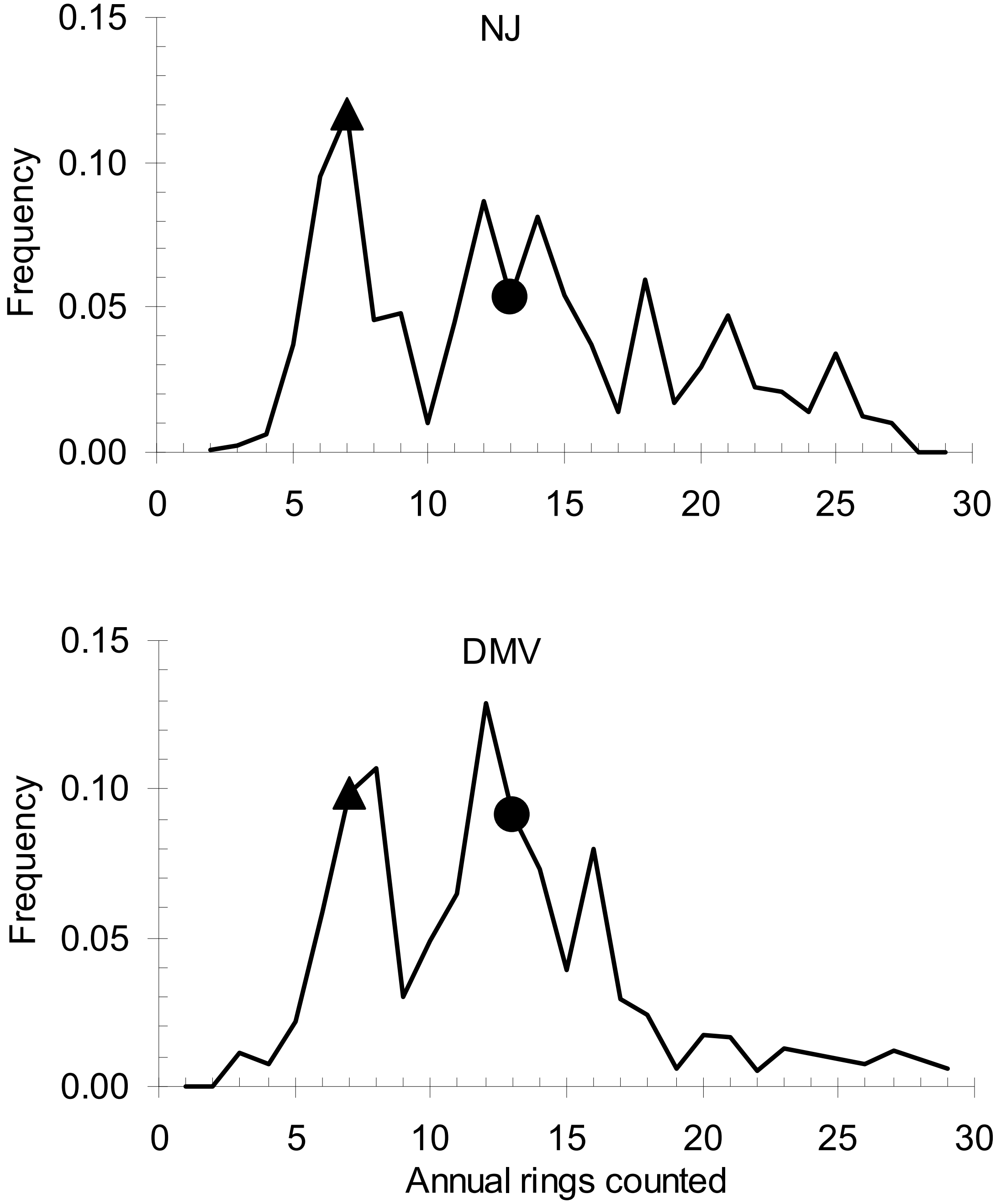


Figure C18. Commercial age composition data for surfclam in the NJ and DMV areas during 2005. There is uncertainty about timing of ring formation. Assuming rings form during the fall after the NEFSC clam survey, dark circles identify the 1992 (14 rings in 2005) year class and dark triangles identify the 1999 year class (7 rings in 2005).

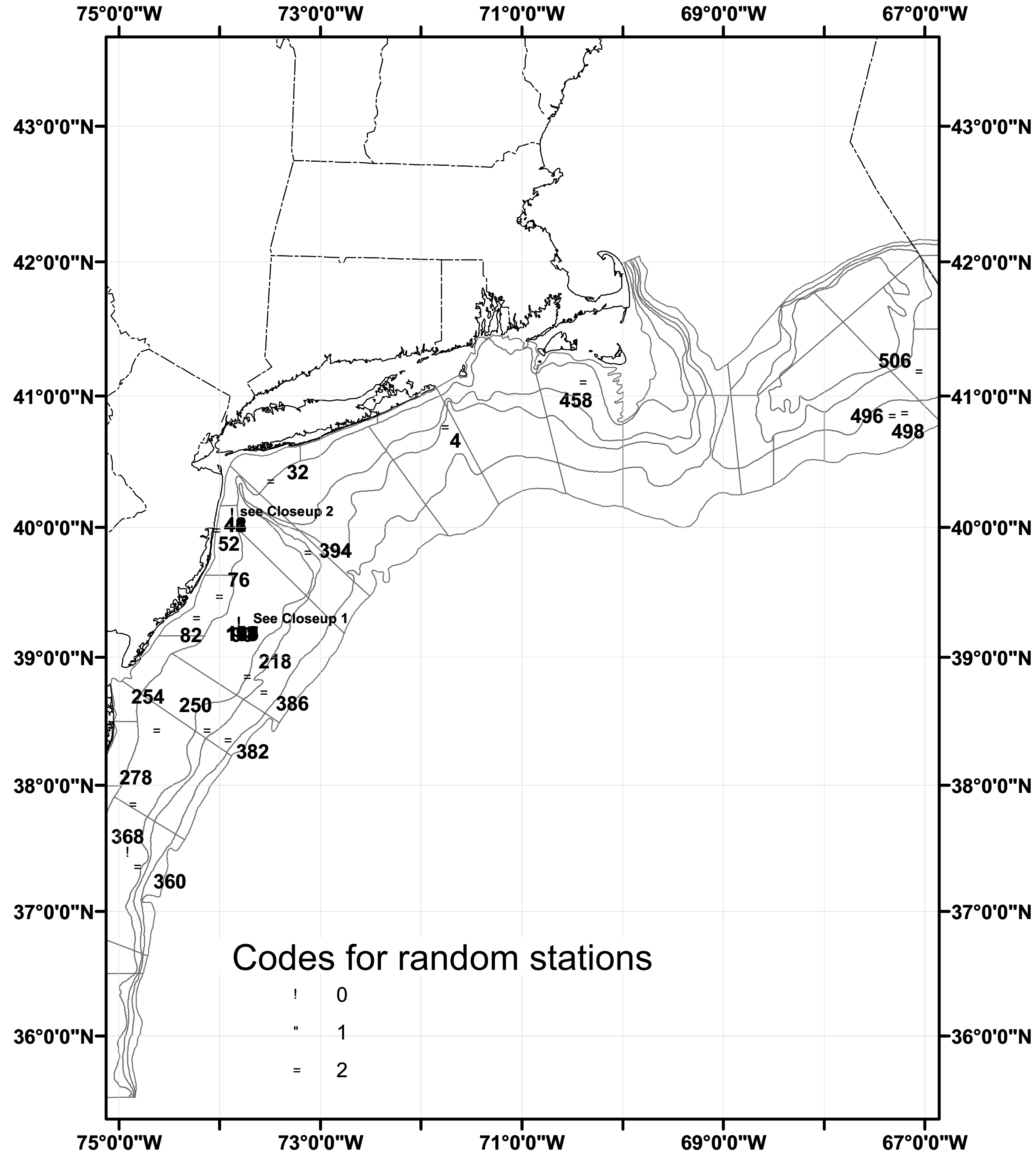


Figure C19. Locations of 2002 survey stations with poor dredge performance that would not have been excluded from trend and swept area trend analyses based on haul or gear damage codes, with station numbers. Codes 1 and 2 (dark squares and open circles) are random stations. Stations in close-up 1 are all from a depletion experiment.

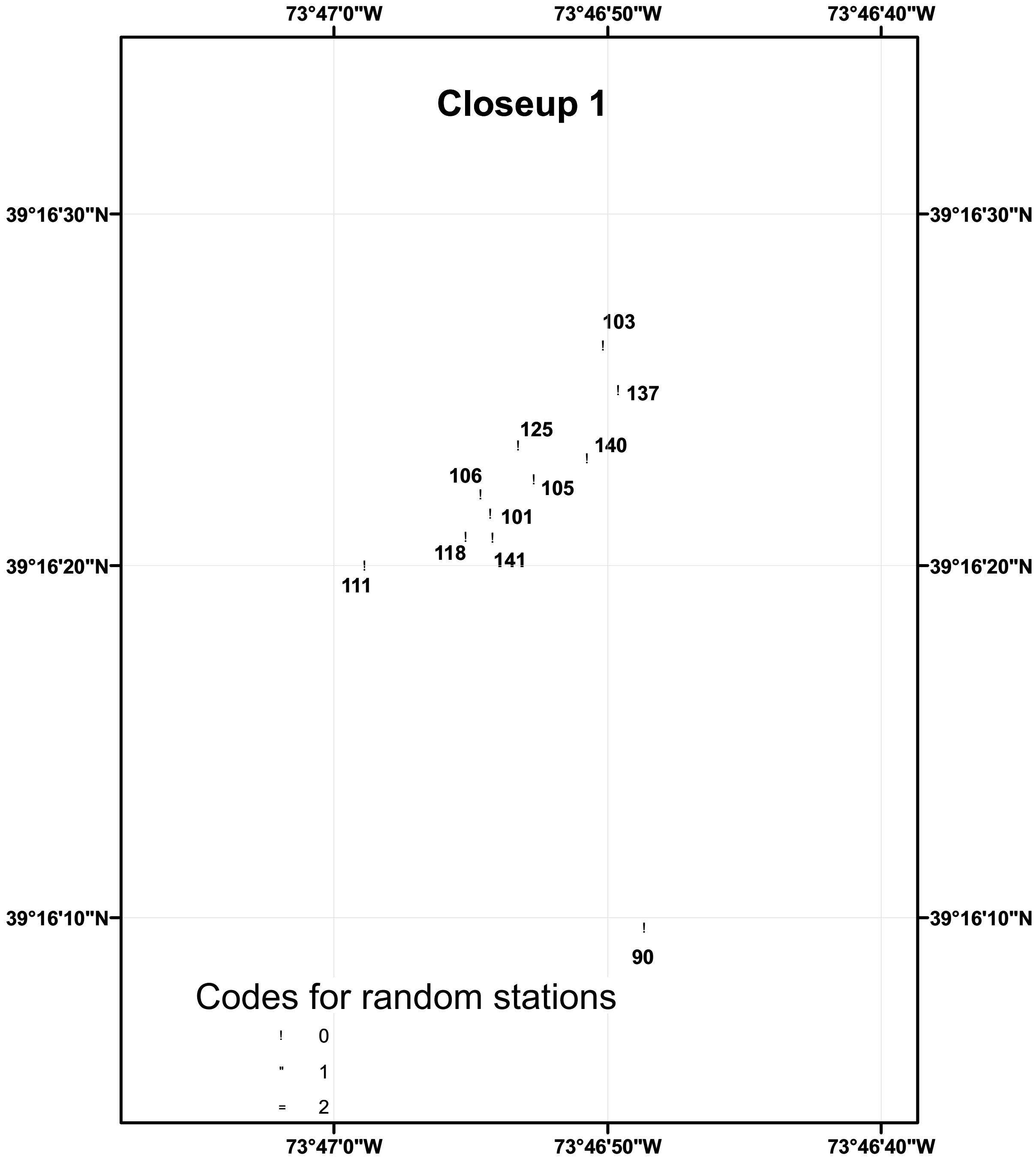


Figure C19 (continued)

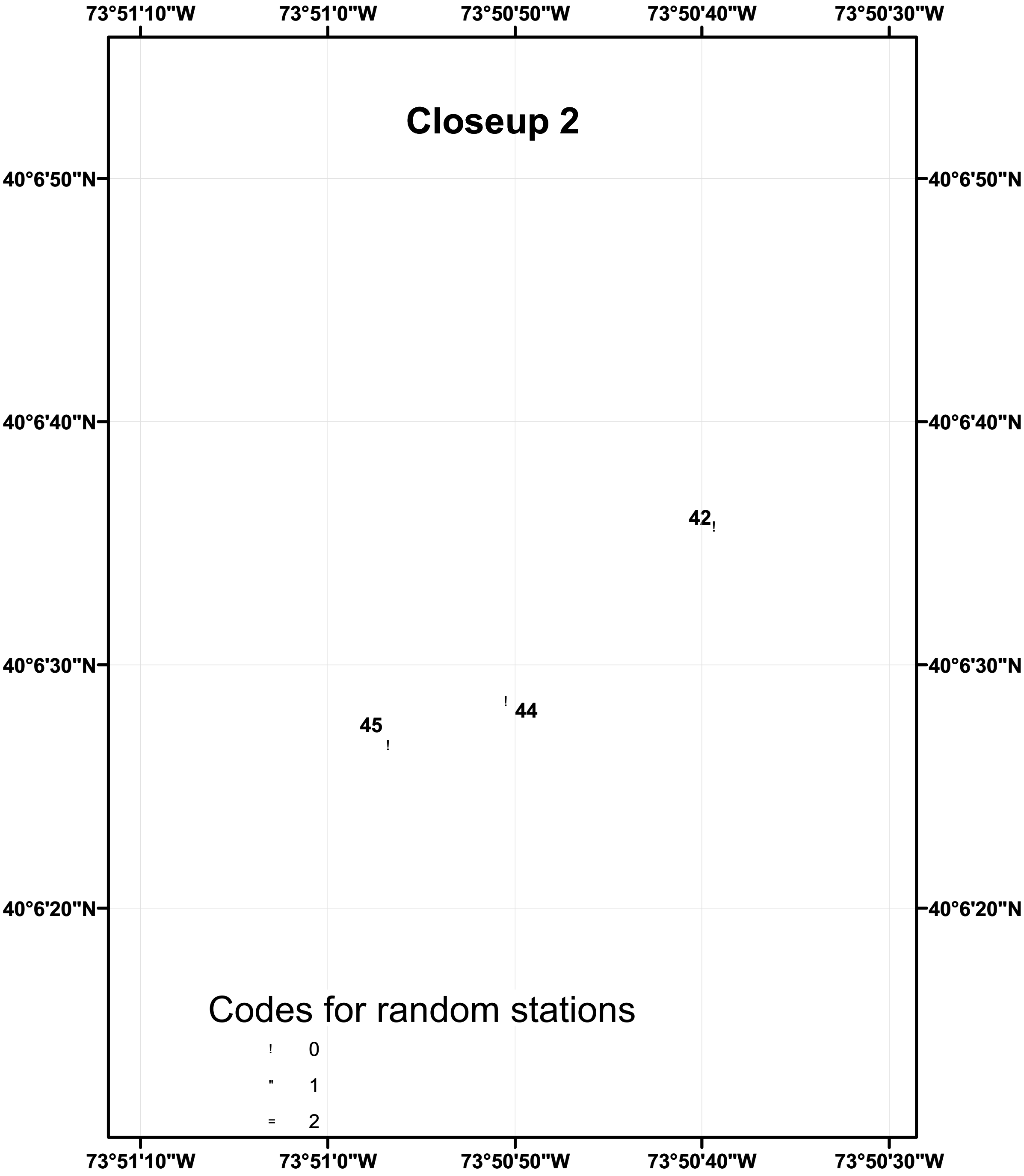


Figure C19 (continued)

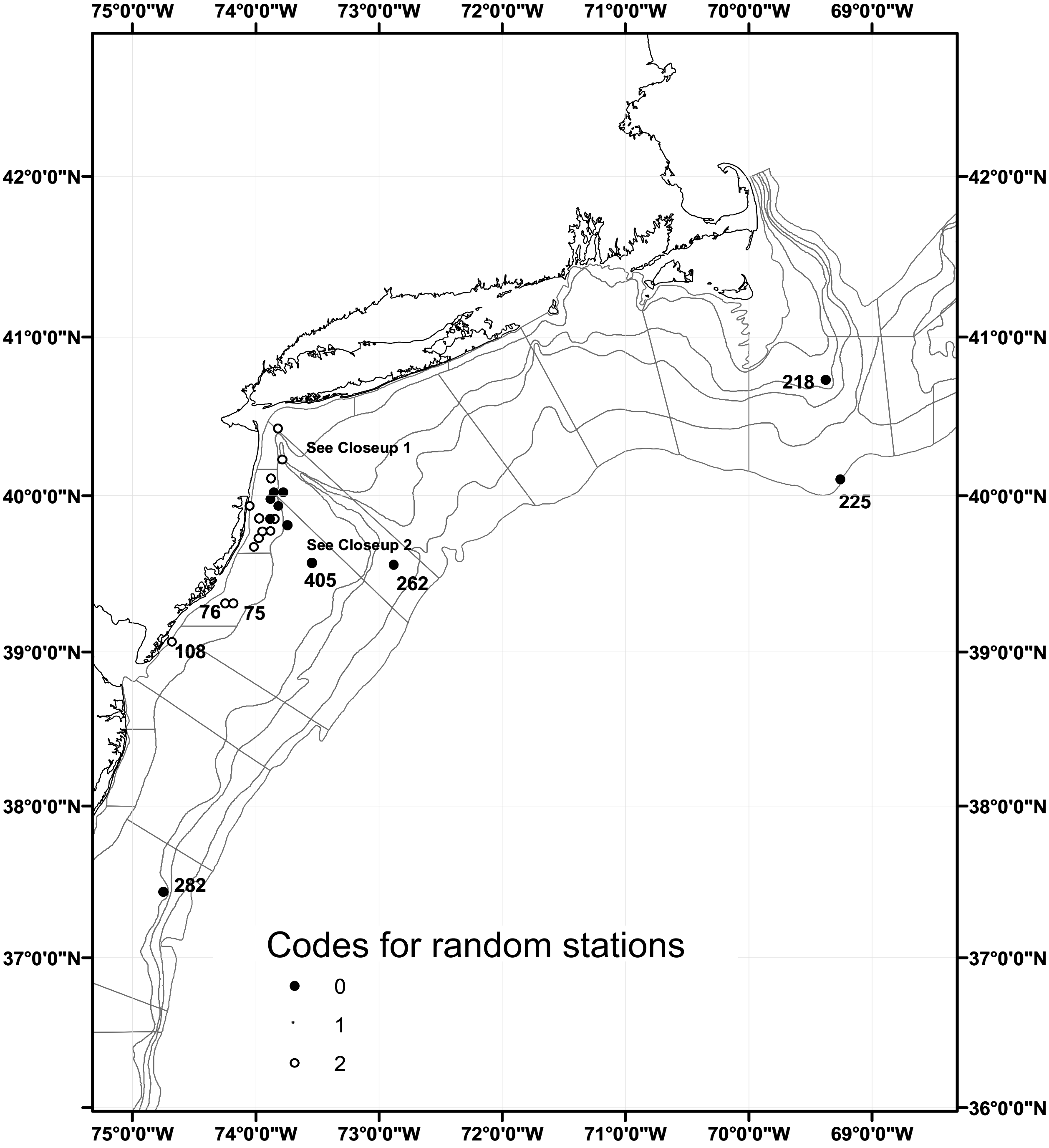


Figure C20. Locations of 2005 survey stations with poor dredge performance that would not have been excluded from trend and swept area trend analyses based on haul or gear damage codes, with station numbers. Codes 1 and 2 (dark squares and open circles) are random stations. Stations in close-up 2 are all from a depletion experiment.

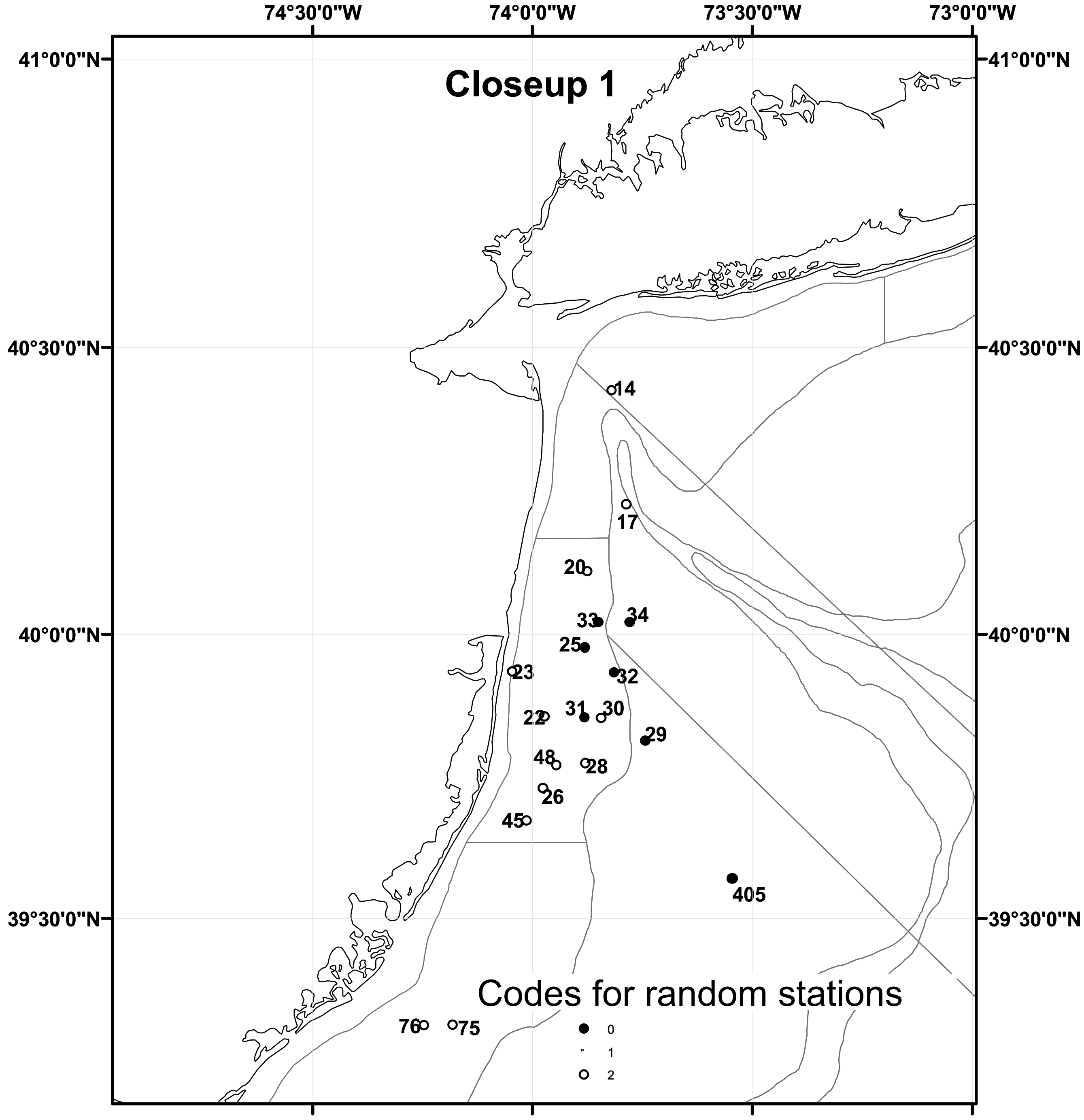


Figure C20 (continued)

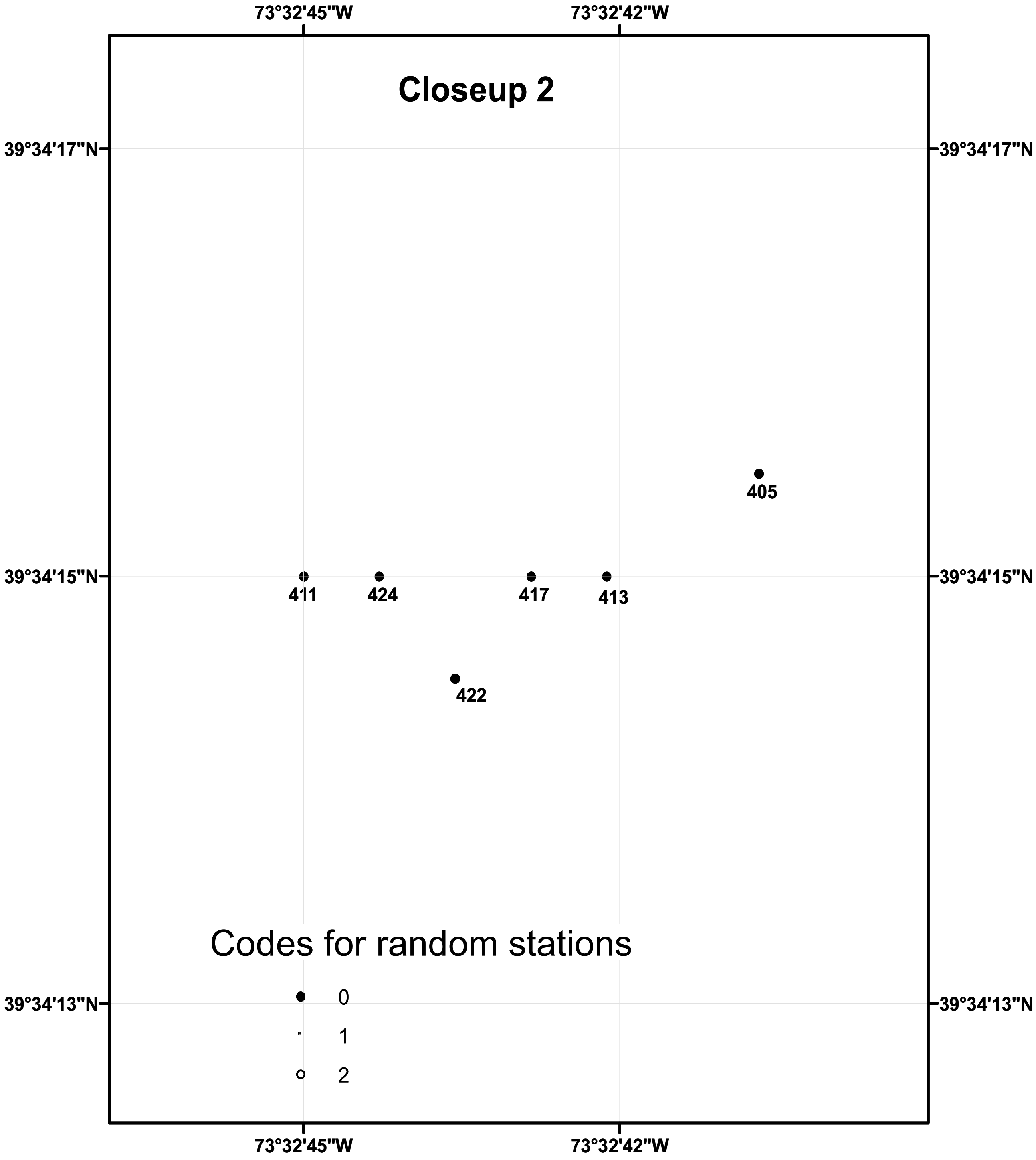


Figure C20 (continued)

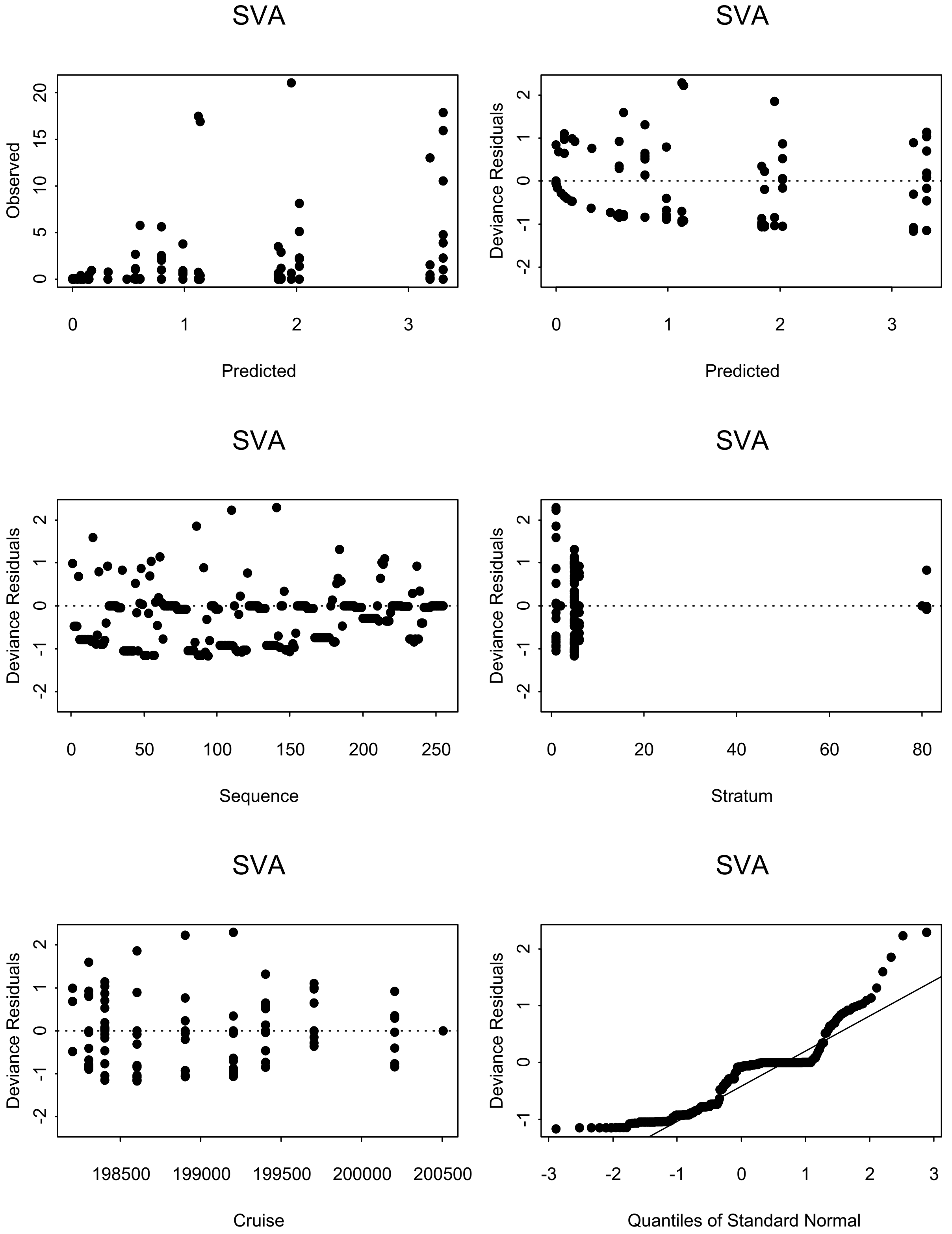


Figure C21. Residuals and diagnostics for negative binomial GLM model used to impute missing survey data for surfclam in SVA.

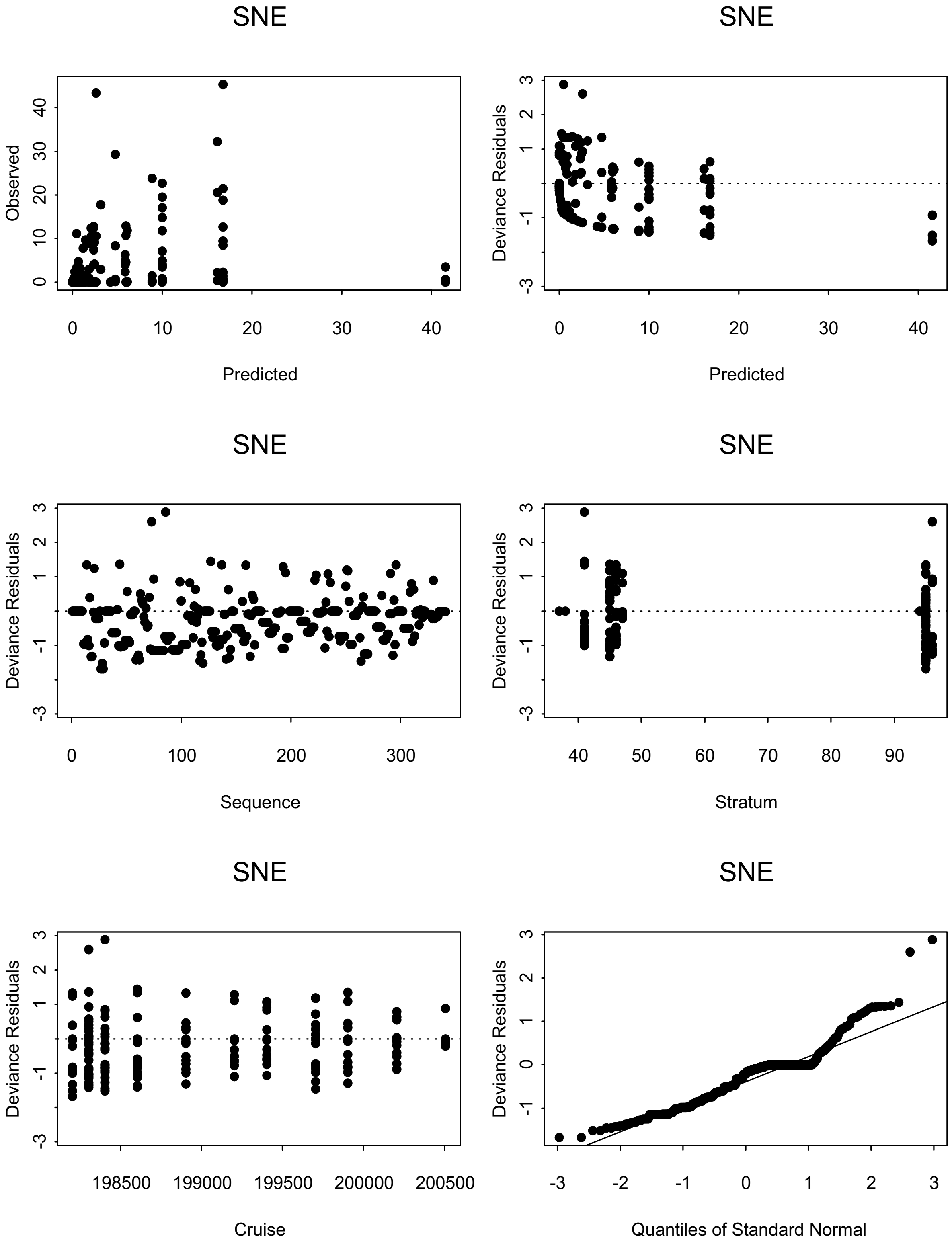


Figure C22. Residuals and diagnostics for negative binomial GLM model used to impute missing survey data for surfclam in SNE.

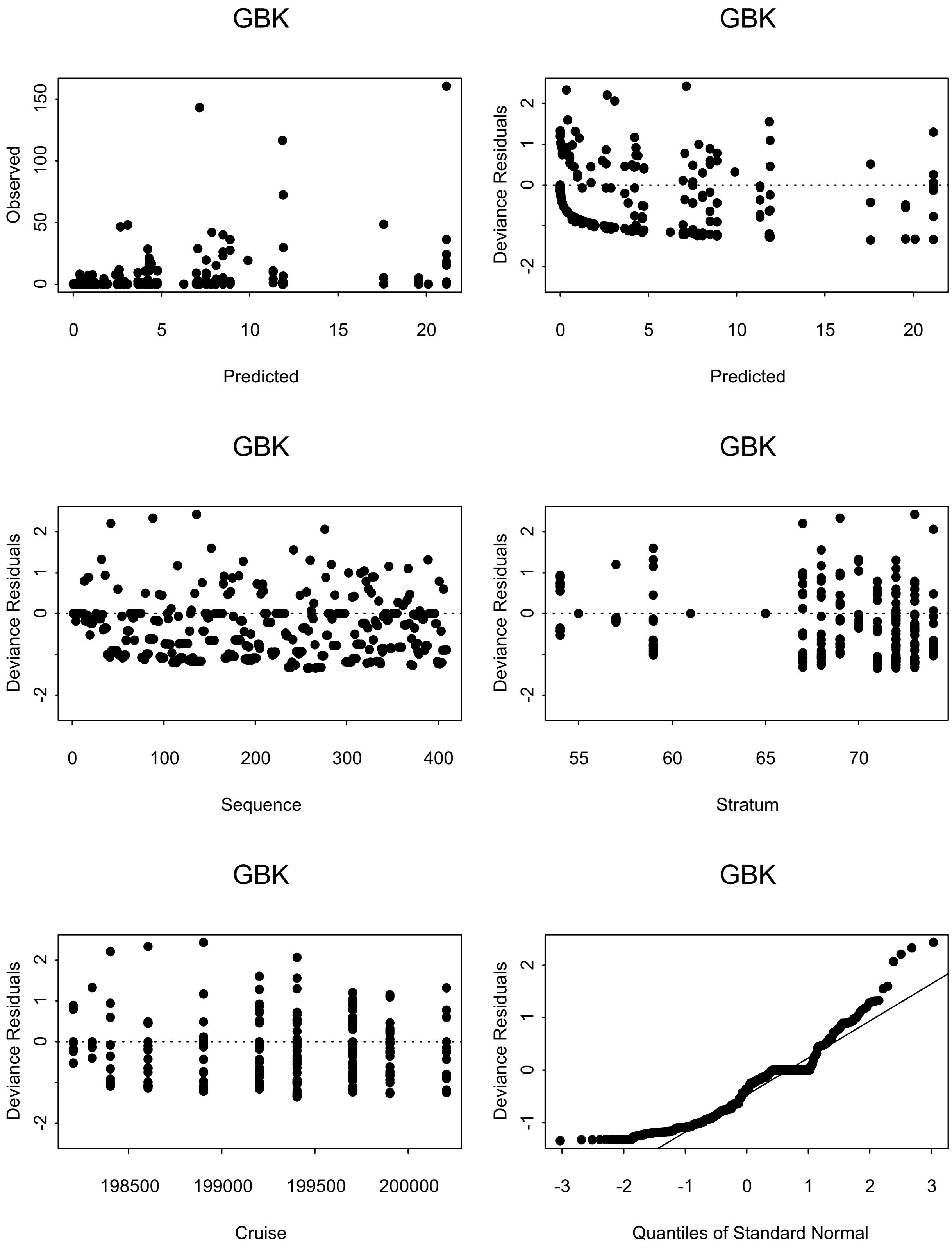


Figure C23. Residuals and diagnostics for negative binomial GLM model used to impute missing survey data for surfclam in GBK.

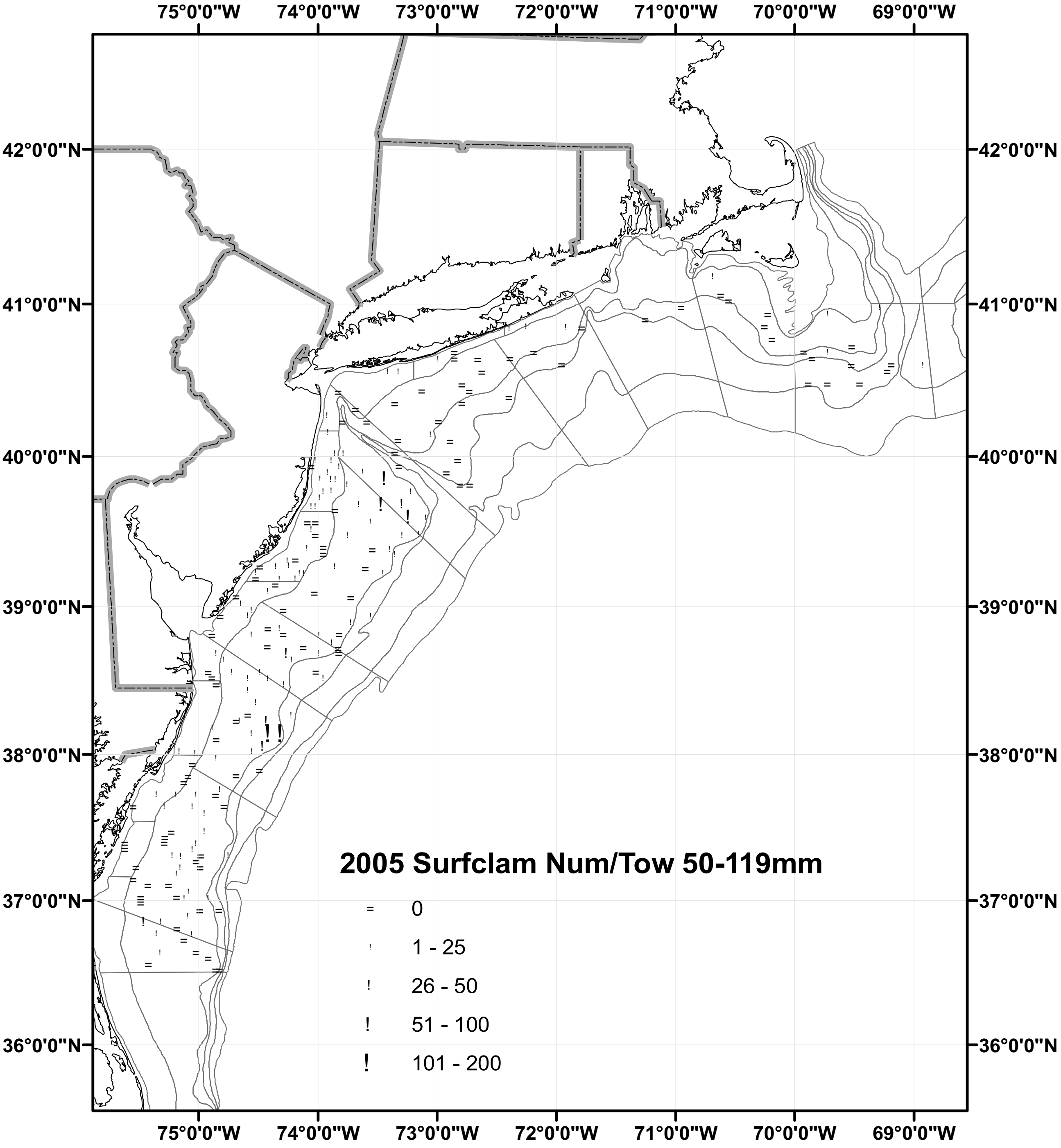


Figure C24. Location of successful random survey stations during the 2005 NEFSC clam survey with catches for small recruit surfclam 80-119 mm SL. Catches are numbers per tow, standardized by doppler distance with no borrowing.

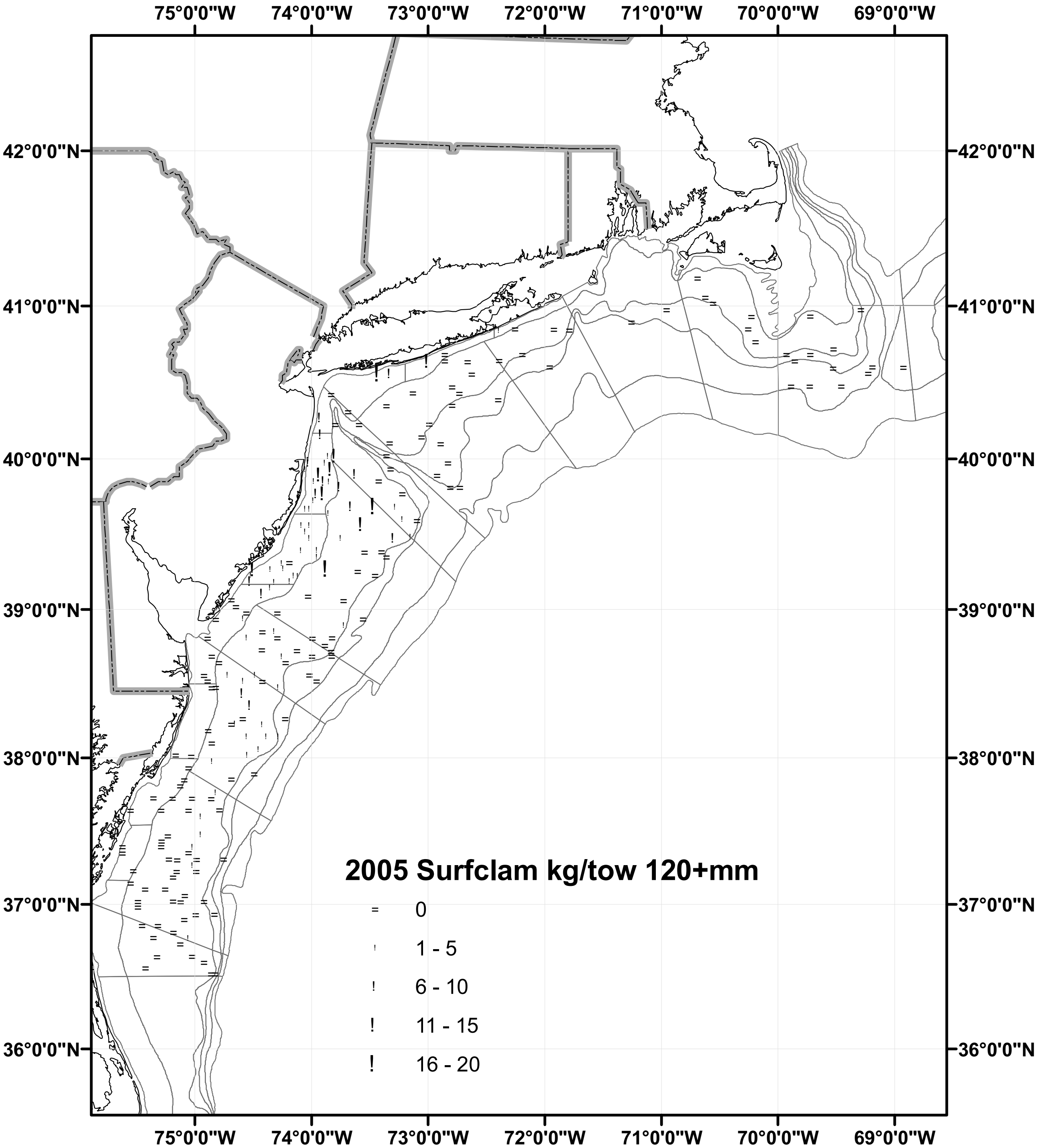


Figure C25. Location of successful random survey stations during the 2005 NEFSC clam survey with catches for large fishable surfclam 120+ mm SL. Catches are numbers per tow, standardized by doppler distance with no borrowing.

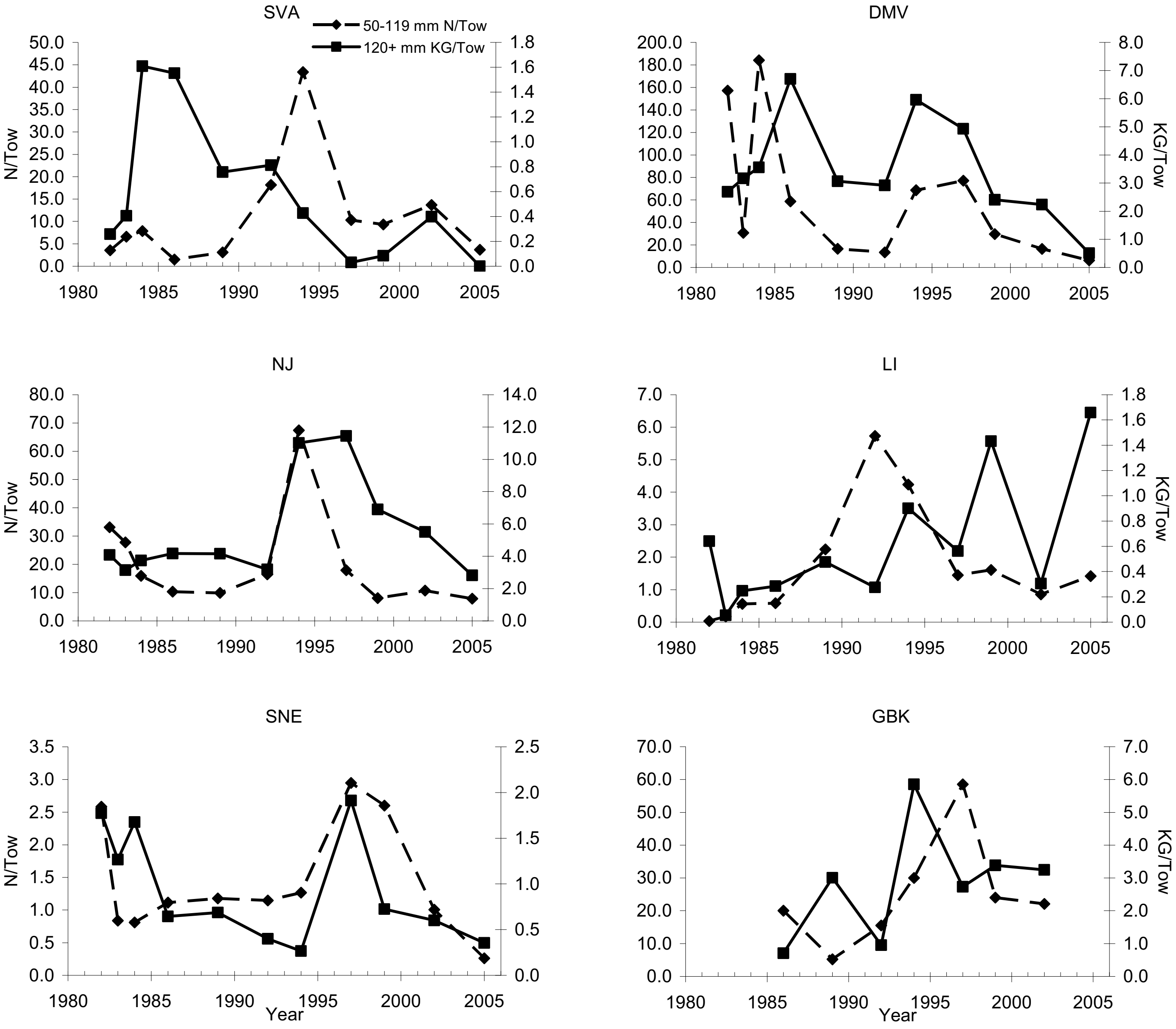


Figure C26. Trends in abundance (mean n tow^{-1}) for small recruit surfclam (50-119 mm) and trends in biomass (mean kg tow^{-1}) for large fishable (120+ mm) surfclam based on NEFSC clam surveys, by region.

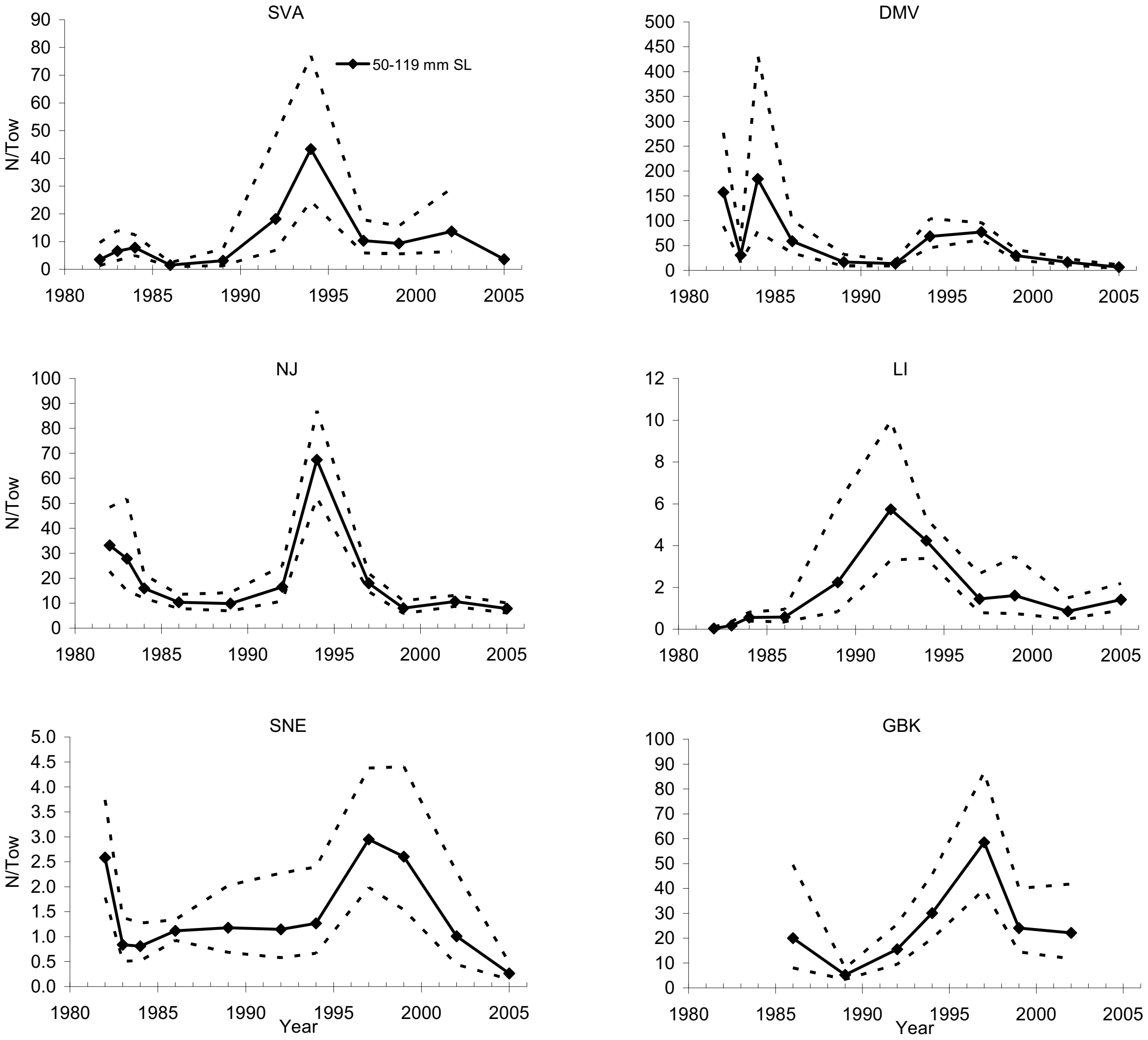


Figure C27. Trends in abundance indices (mean n tow^{-1}) for small recruit surfclam (50-119 mm SL) in NEFSC clam surveys, with 80% confidence intervals assuming lognormal measurement errors and arithmetic CVs for stratified random sampling based on Students-*t* distribution with the number of tows as degrees of freedom.

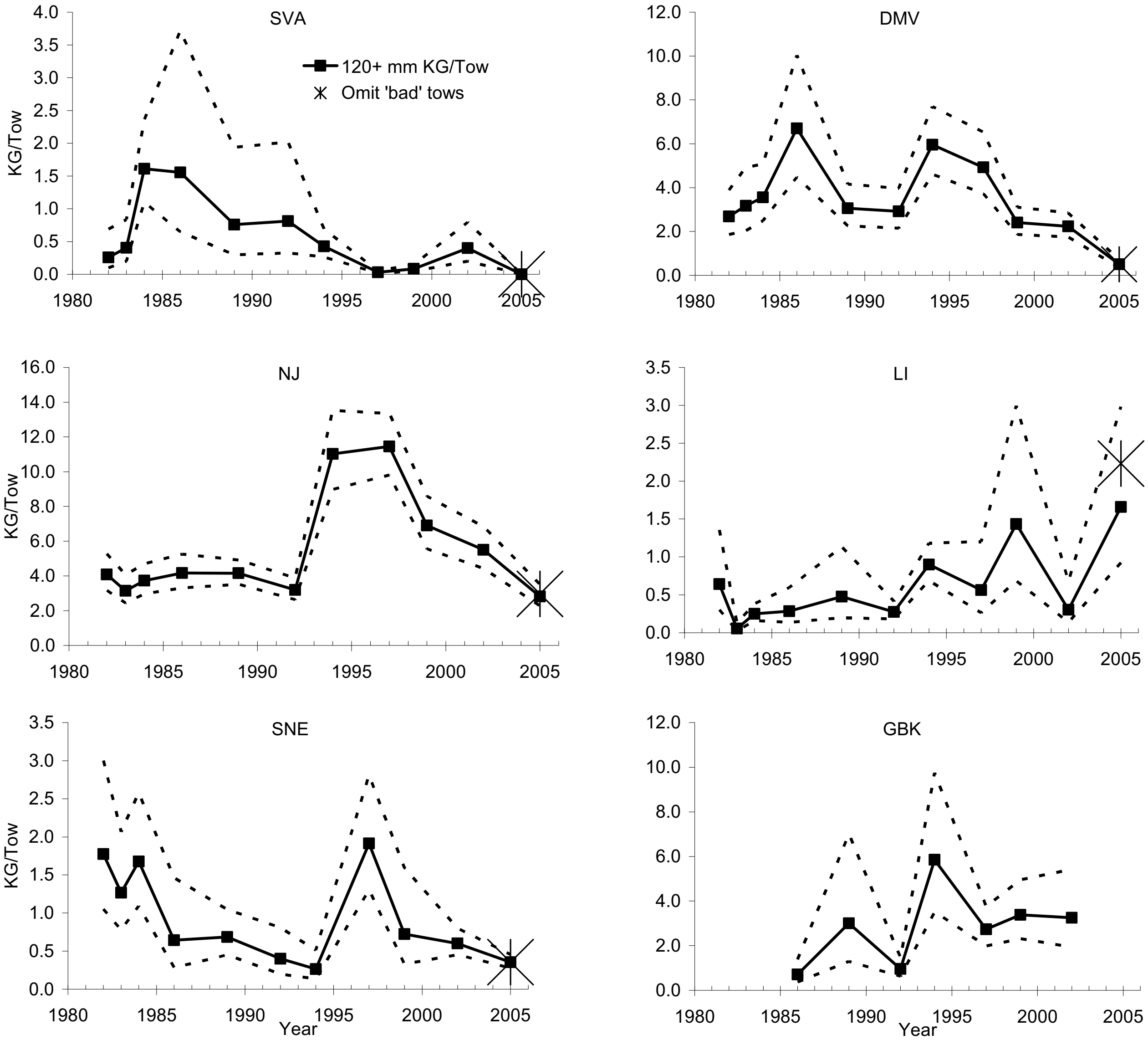


Figure C28. Trends in biomass indices (mean kg tow^{-1}) for large fishable surfclam (120+ mm SL) in NEFSC clam surveys, with 80% confidence intervals assuming lognormal measurement errors and arithmetic CVs for stratified random sampling based on Students-*t* distribution with the number of tows as degrees of freedom. Different symbols show effects of omitting tows with poor gear performance during 2005.

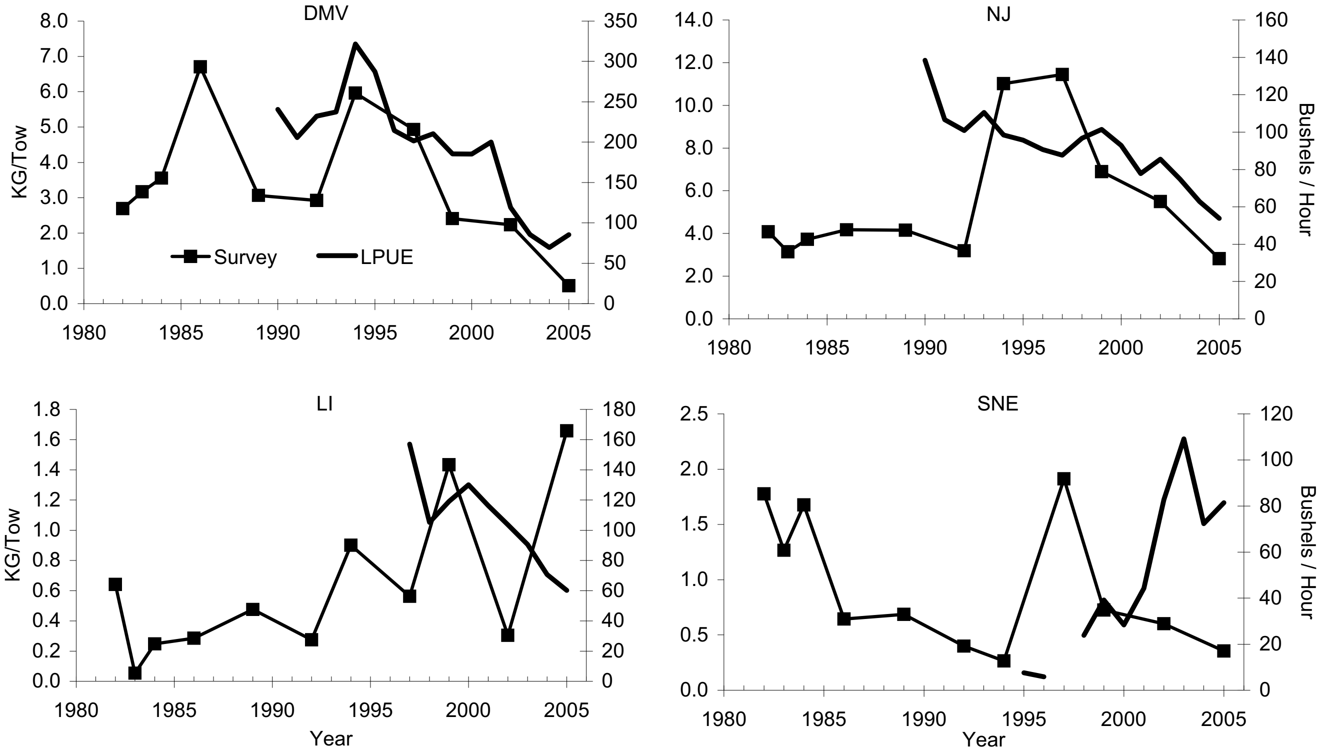


Figure C29. Trends in biomass indices for large fully large surfclam (mean kg tow^{-1}, 120+ mm SL) in NEFSC clam surveys and standardized LPUE in the commercial fishery.

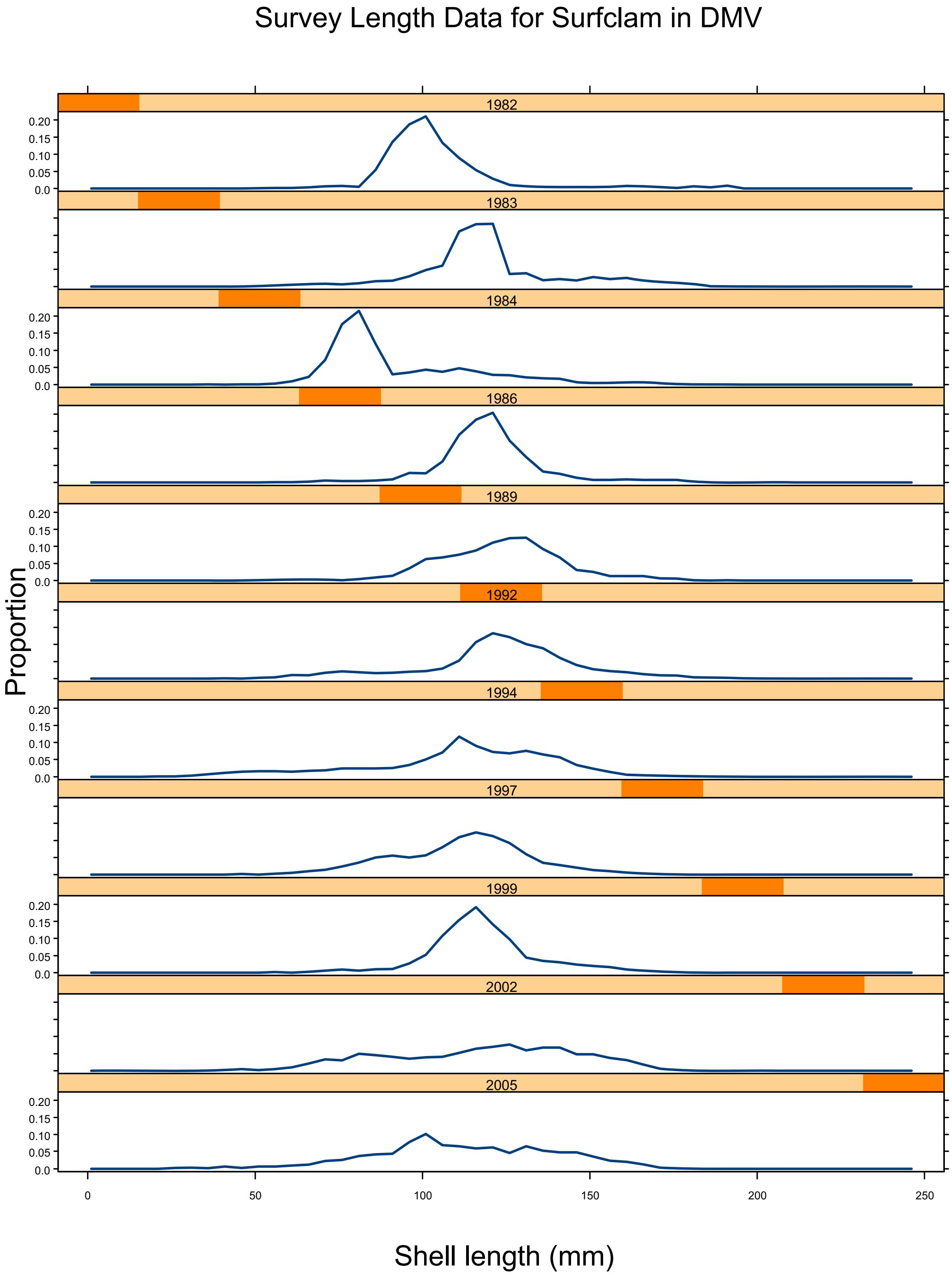


Figure C30. Survey length composition data for surfclam in the DMV region.

Survey Length Data for Surfclam in NJ

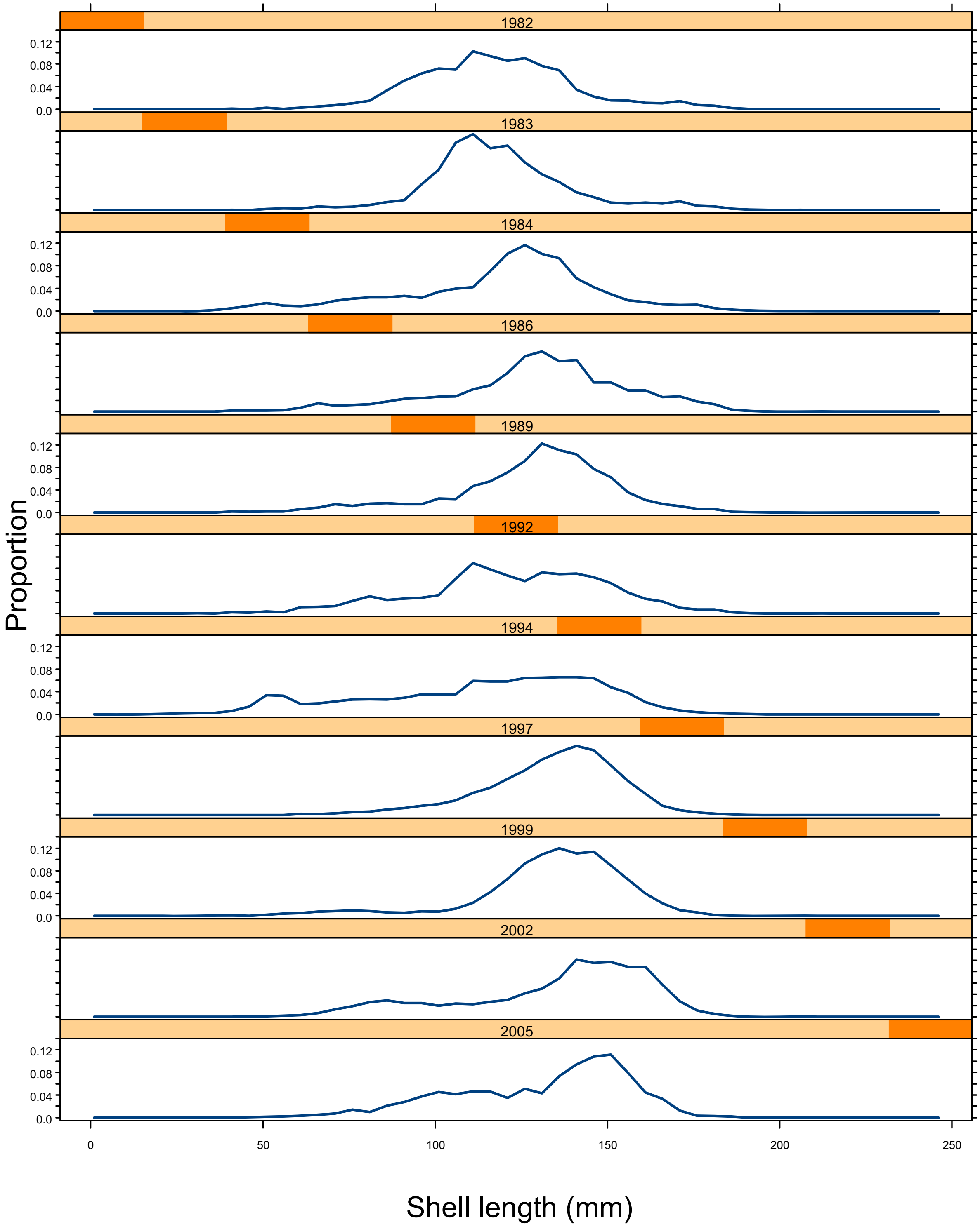


Figure C31. Survey length composition data for surfclam in the NJ region.

Survey Length Data for Surfclam in LI

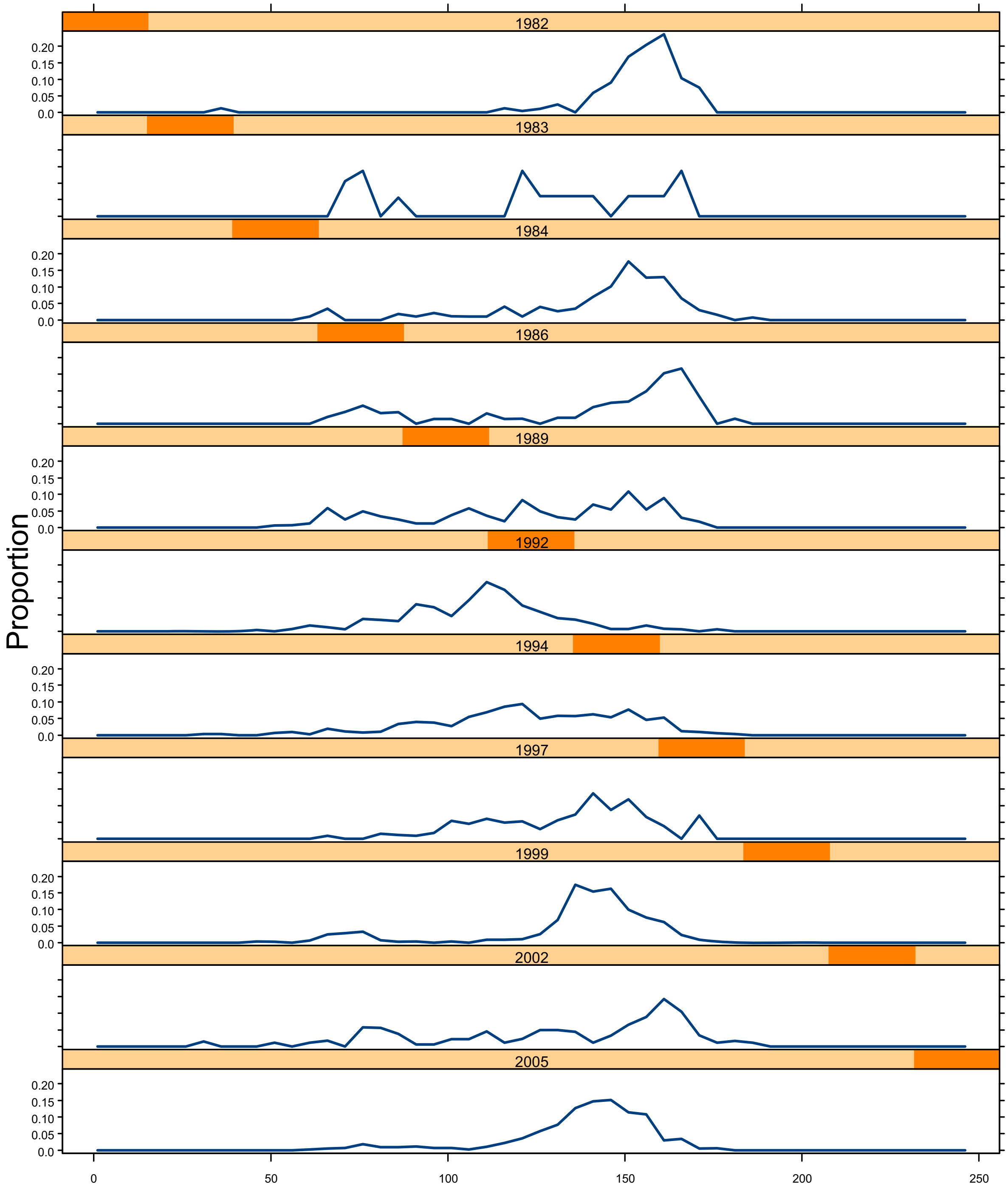


Figure C32. Survey length composition data for surfclam in the LI region.

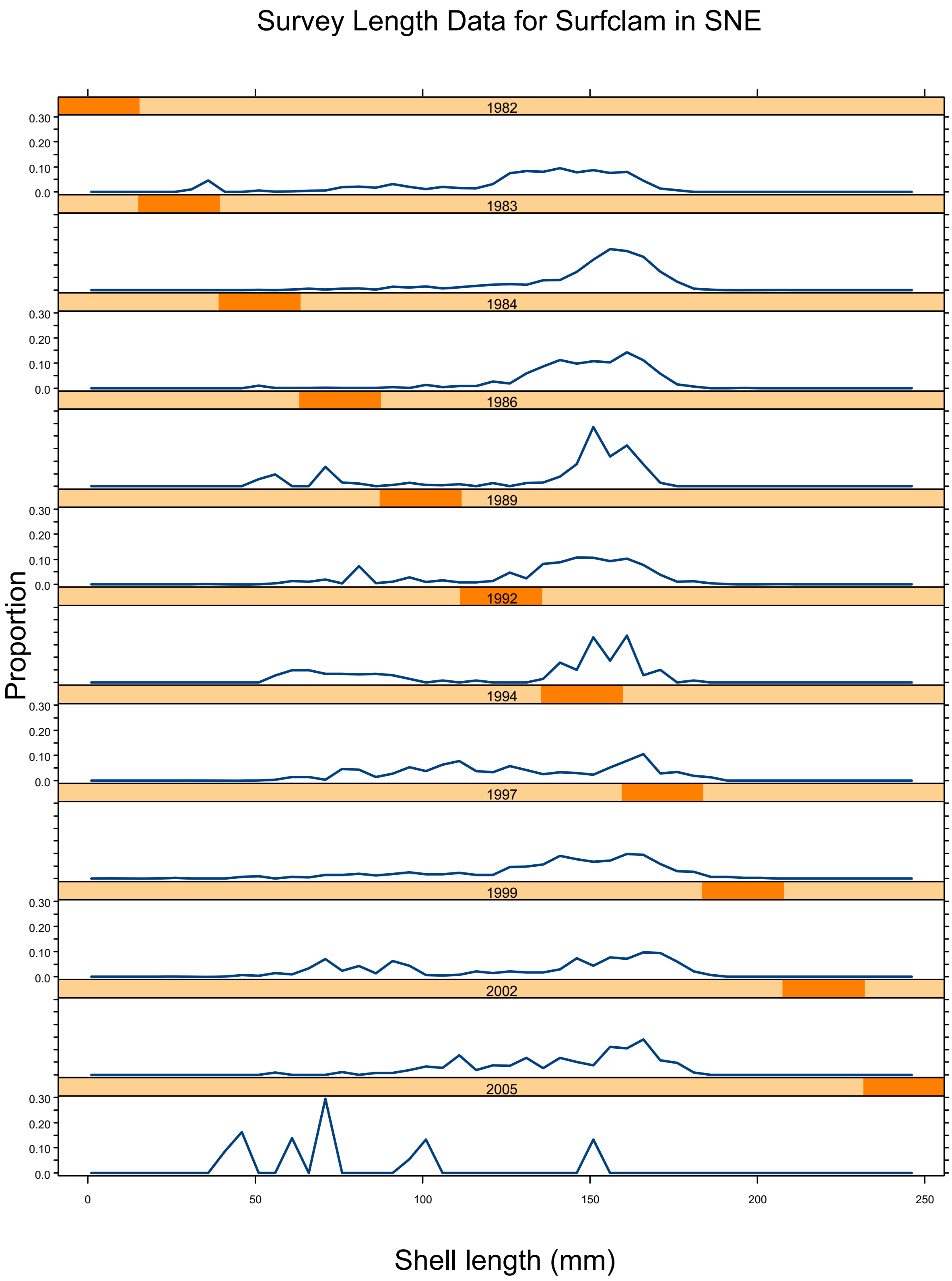


Figure C33. Survey length composition data for surfclam in the SNE region.

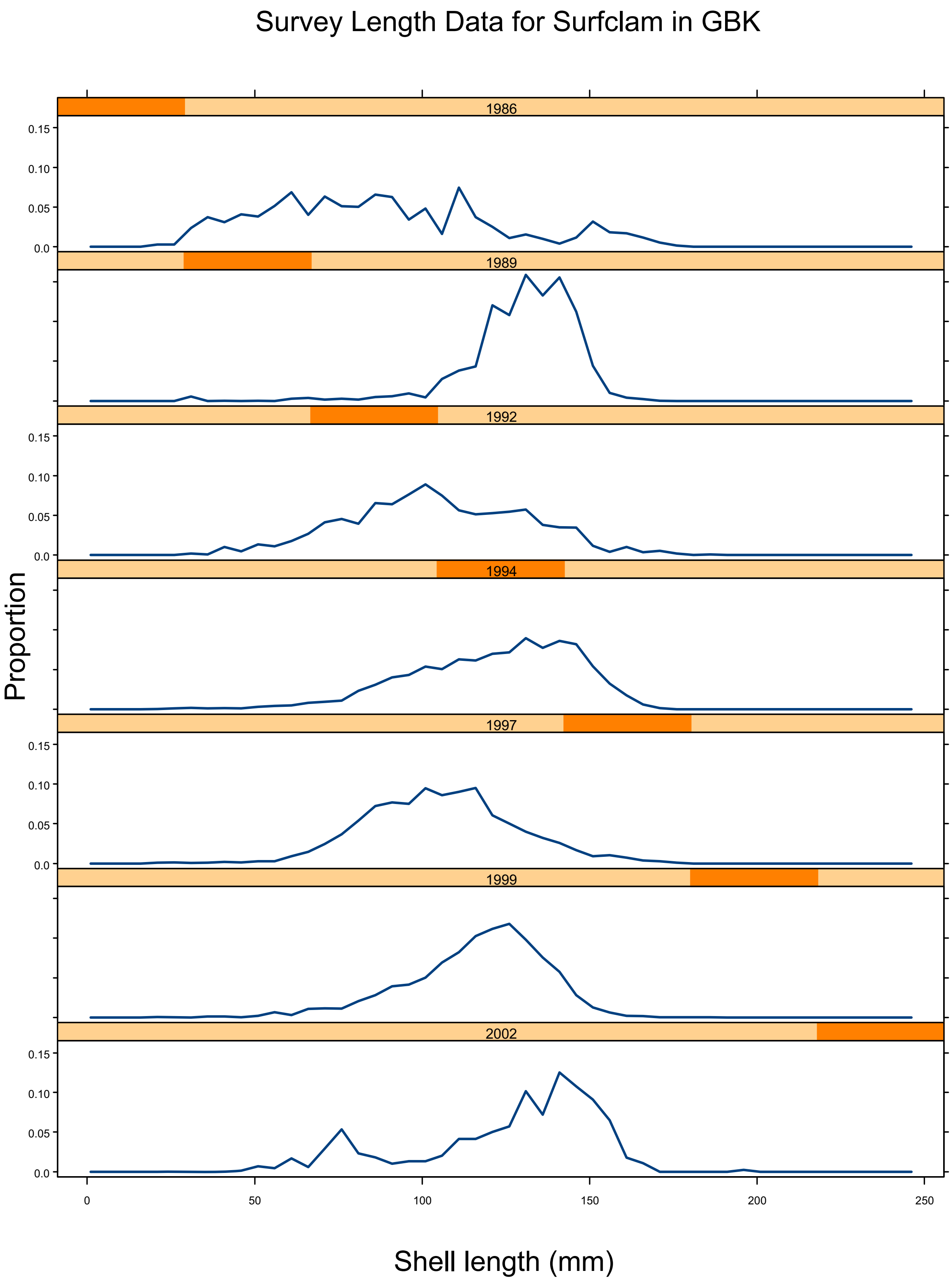


Figure C34a. Survey length composition data for surfclam in the GBK region.

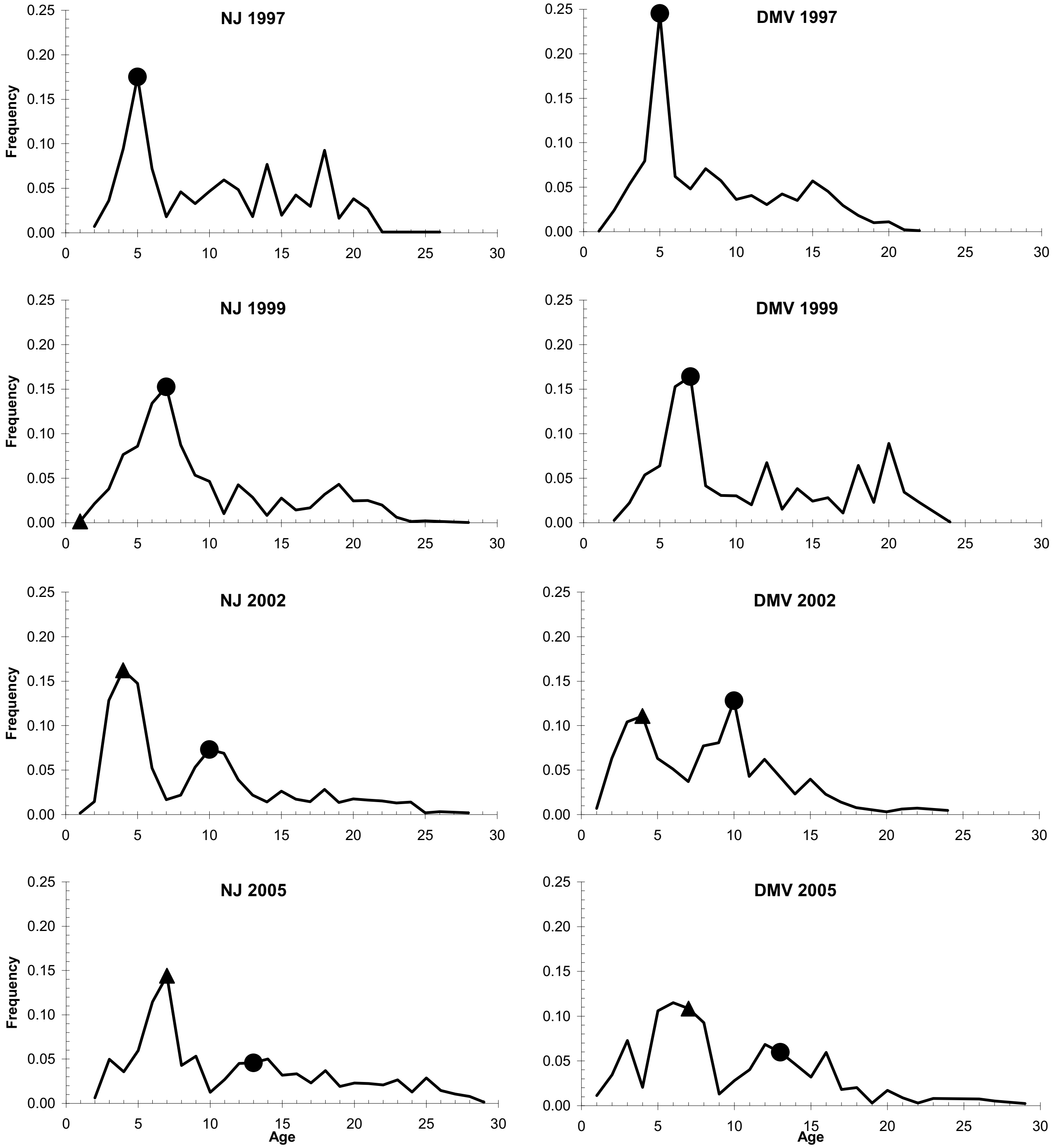


Figure 34b. NEFSC clam survey age composition data for surfclam in the NJ and DMV areas during 1997-2005. There is uncertainty about the timing of annual ring formation. Assuming rings form during the fall after the NEFSC clam survey, dark circles identify the 1992 year class (14 rings in 2005) and dark triangles identify the 1999 year class (7 rings in 2005).

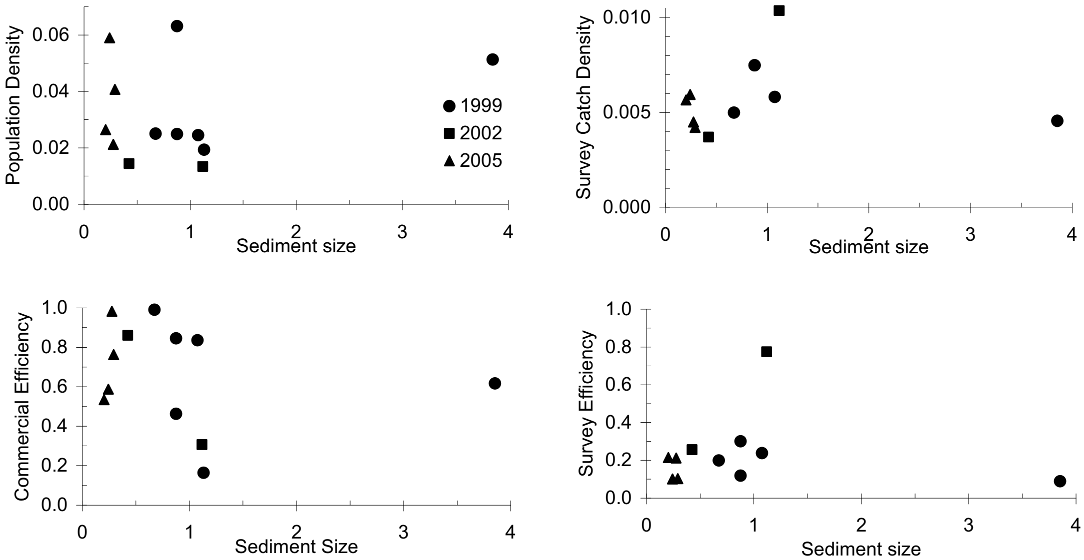


Figure C35. Relationships between depletion study variables and sediment grain size based on depletion studies during 1999, 2002 and 2005. Sediment data were not collected during 1997 and 2004.

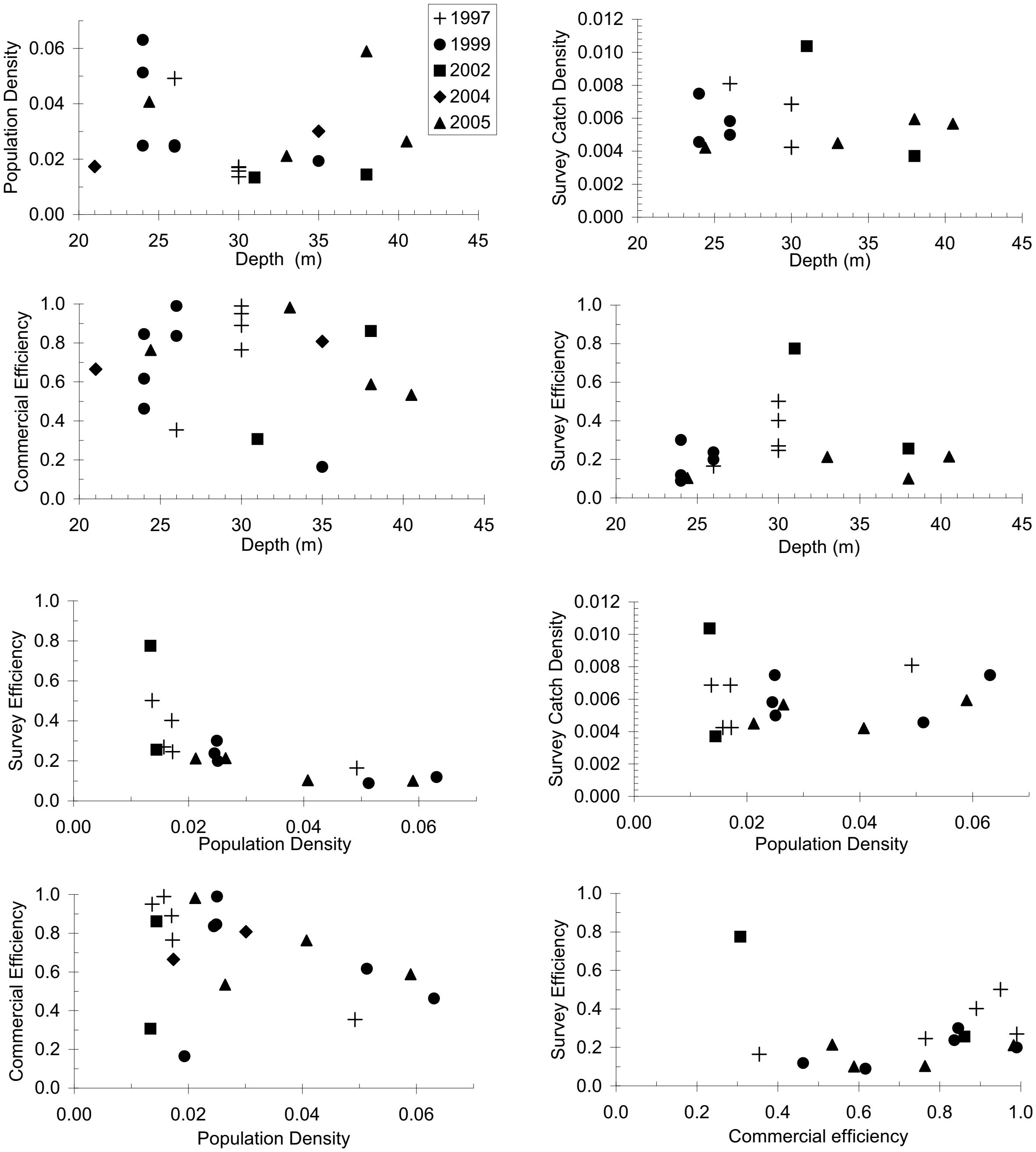


Figure C36. Relationships between depletion study variables based on all depletion studies during 1997- 2005.

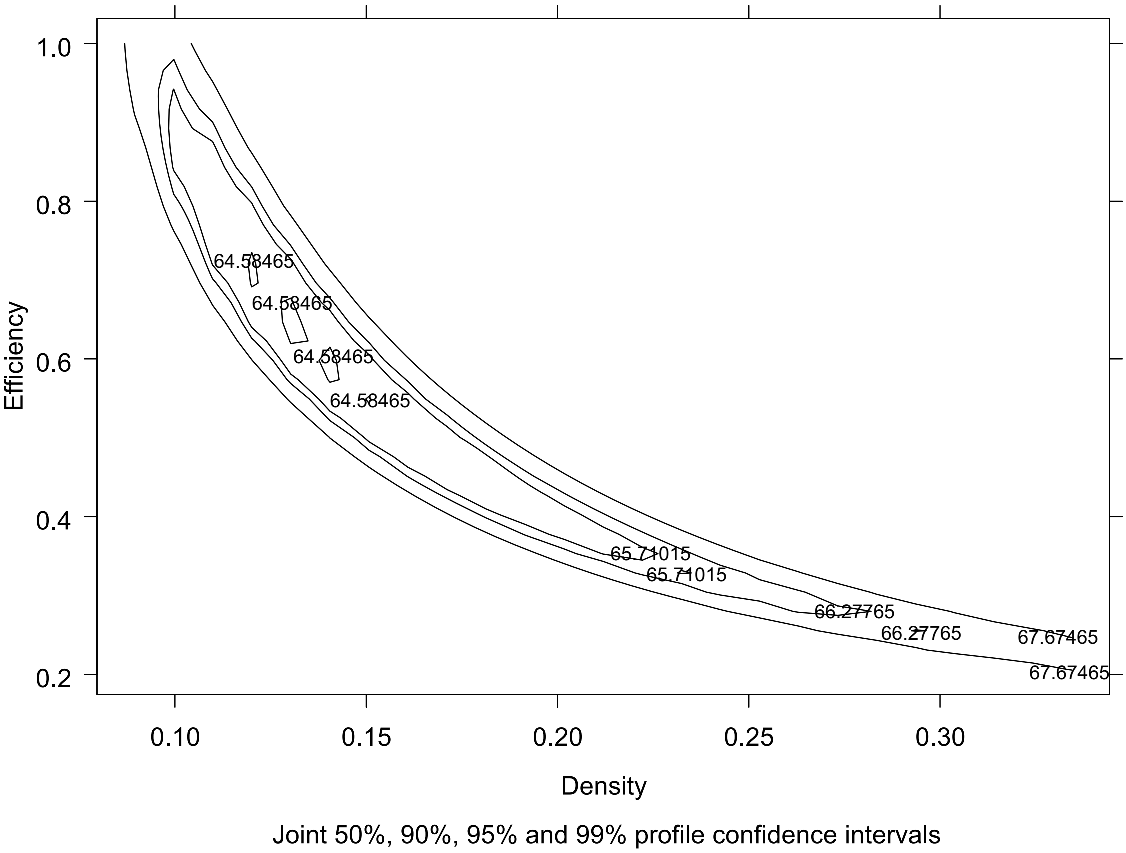


Figure C37. Likelihood profile analysis for efficiency and density estimates from the Patch model for the SC1999-7 surfclam depletion experiment. The joint 50% confidence interval for efficiency and density is the area within the outermost contour. The joint 99% confidence interval is the area inside the innermost contour lines. Contour lines for the joint 90% and 95% confidence intervals lie between.

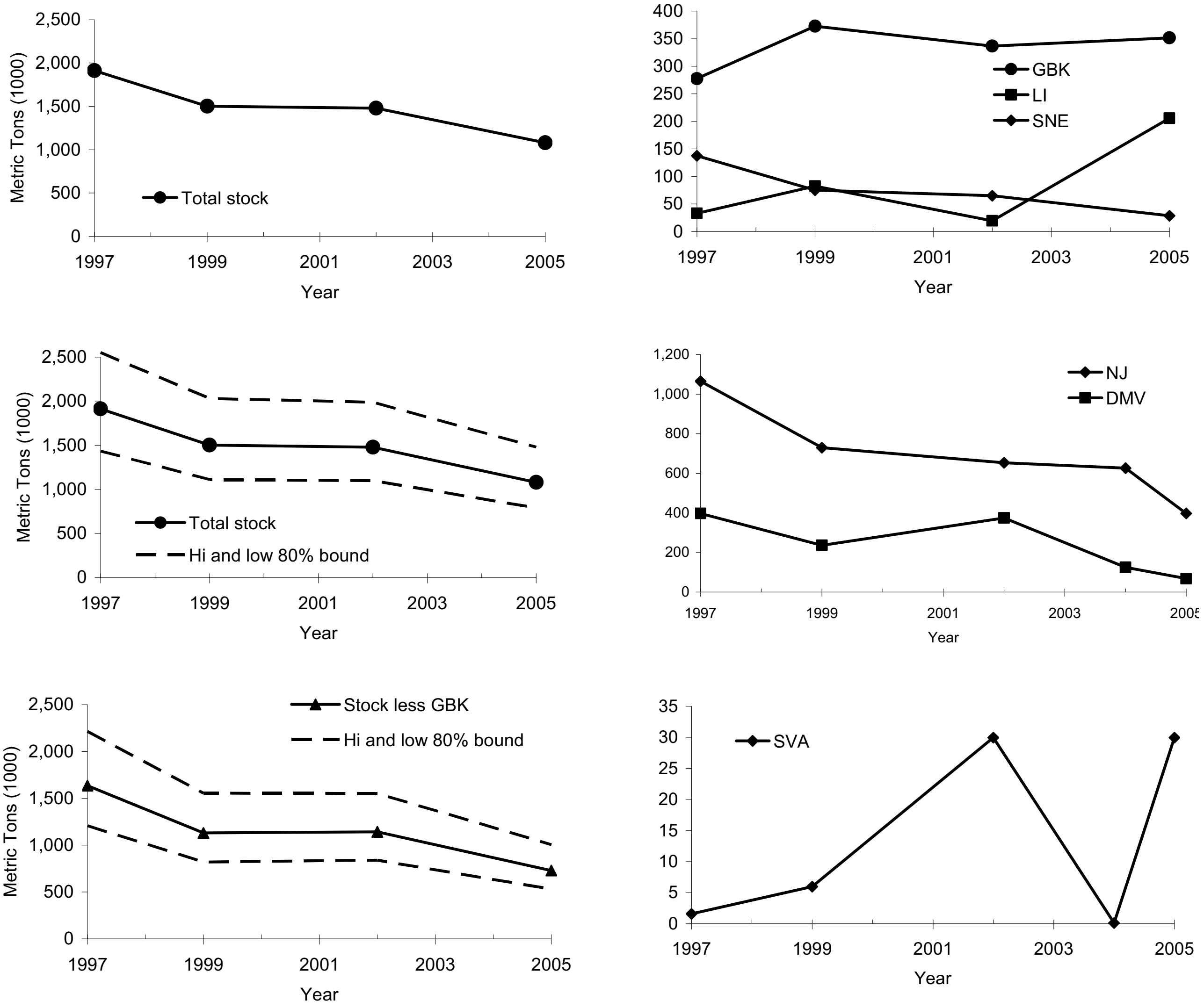


Figure C38. Efficiency corrected swept-area biomass estimates for surfclam 120+ mm SL, including estimates from the 2004 cooperative survey and NEFSC clam surveys during 1997, 1999, 2002 and 2005.

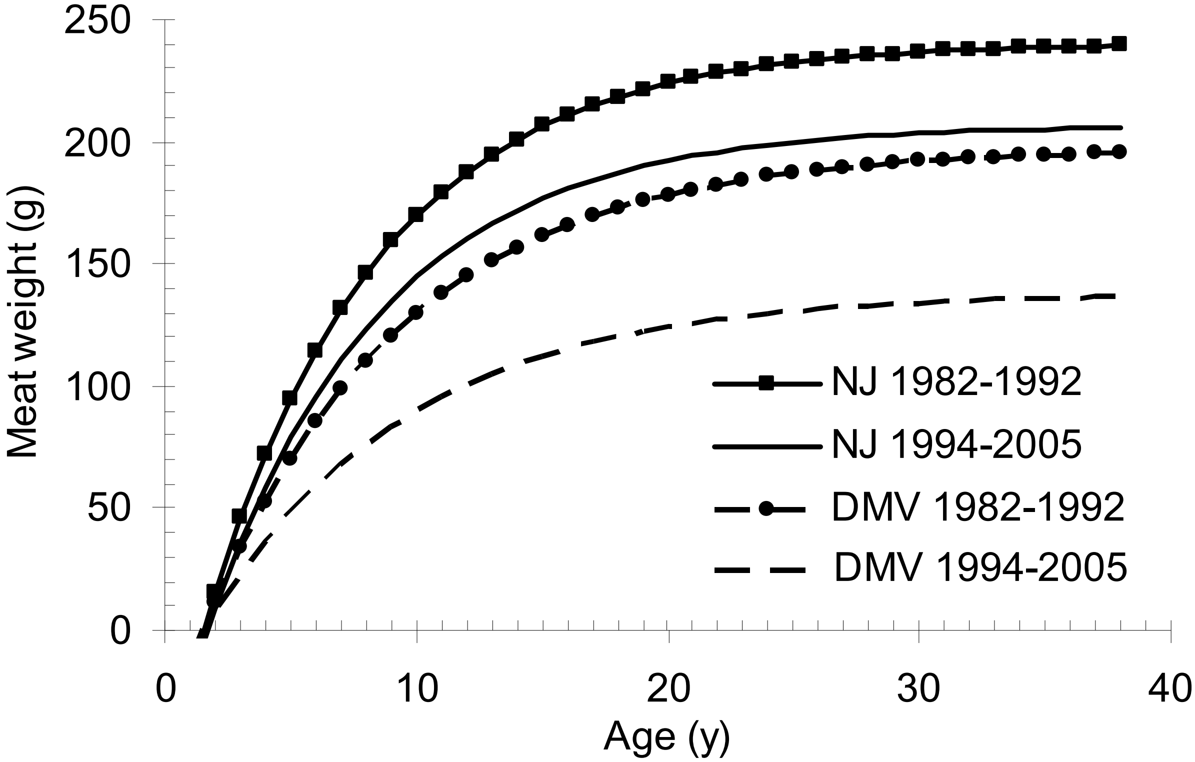
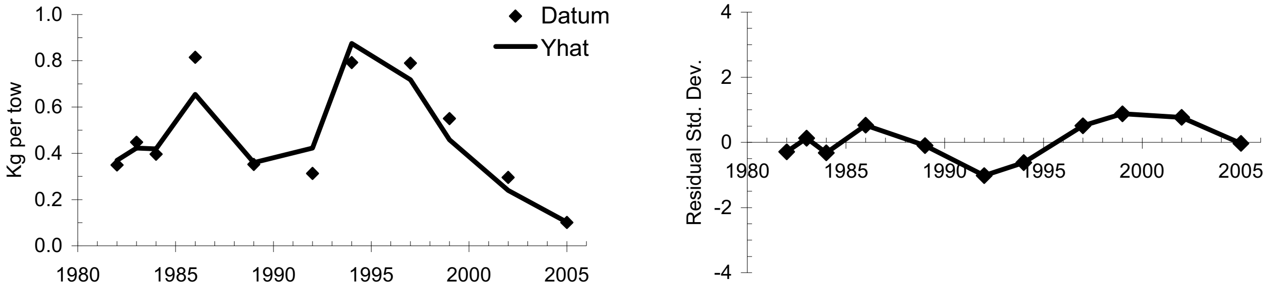


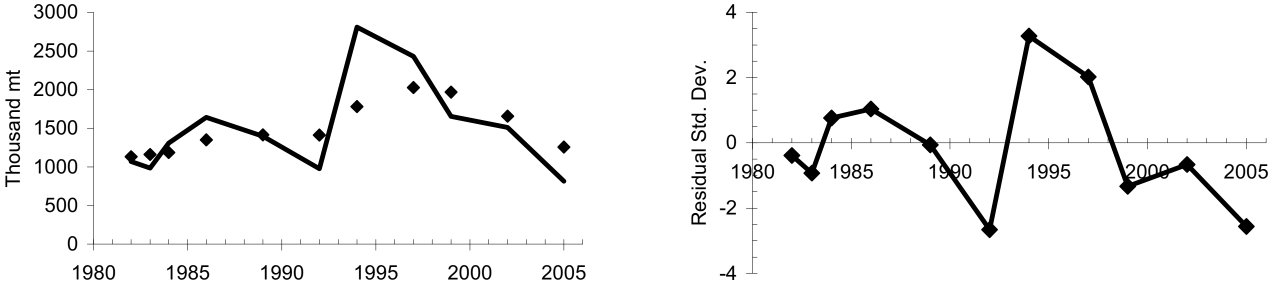
Figure C39. Von Bertlanffy curves for size (meat weight) at age of surfclam during 1982-1992 and 1994-2005 in the NNJ and DMV regions, based on NEFSC clam survey data for 1982-2005.

NEFSC.Recruit.120-129



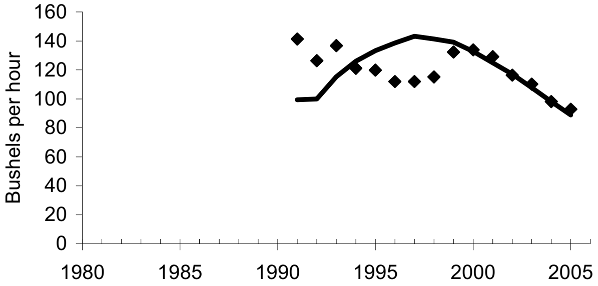
Q = 0.0037

NEFSC.120+.ScaledToBiomassUnits



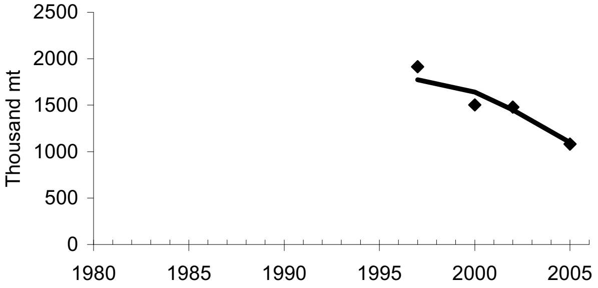
Q = 1.1415

Nominal_LPUE



Q = 0.0807

Efficiency_Corrected_Swept_Area_Biomass



Q = 0.999

Figure C40. Model diagnostics for the KLAMZ model for the entire stock of surfclam. Trends in nominal LPUE and efficiency corrected swept area biomass are shown with predicted trends from the model for comparison, but trends in these indices did not affect model estimates. Survey scaling parameter (*Q*) estimates are shown below plots for each set of data.

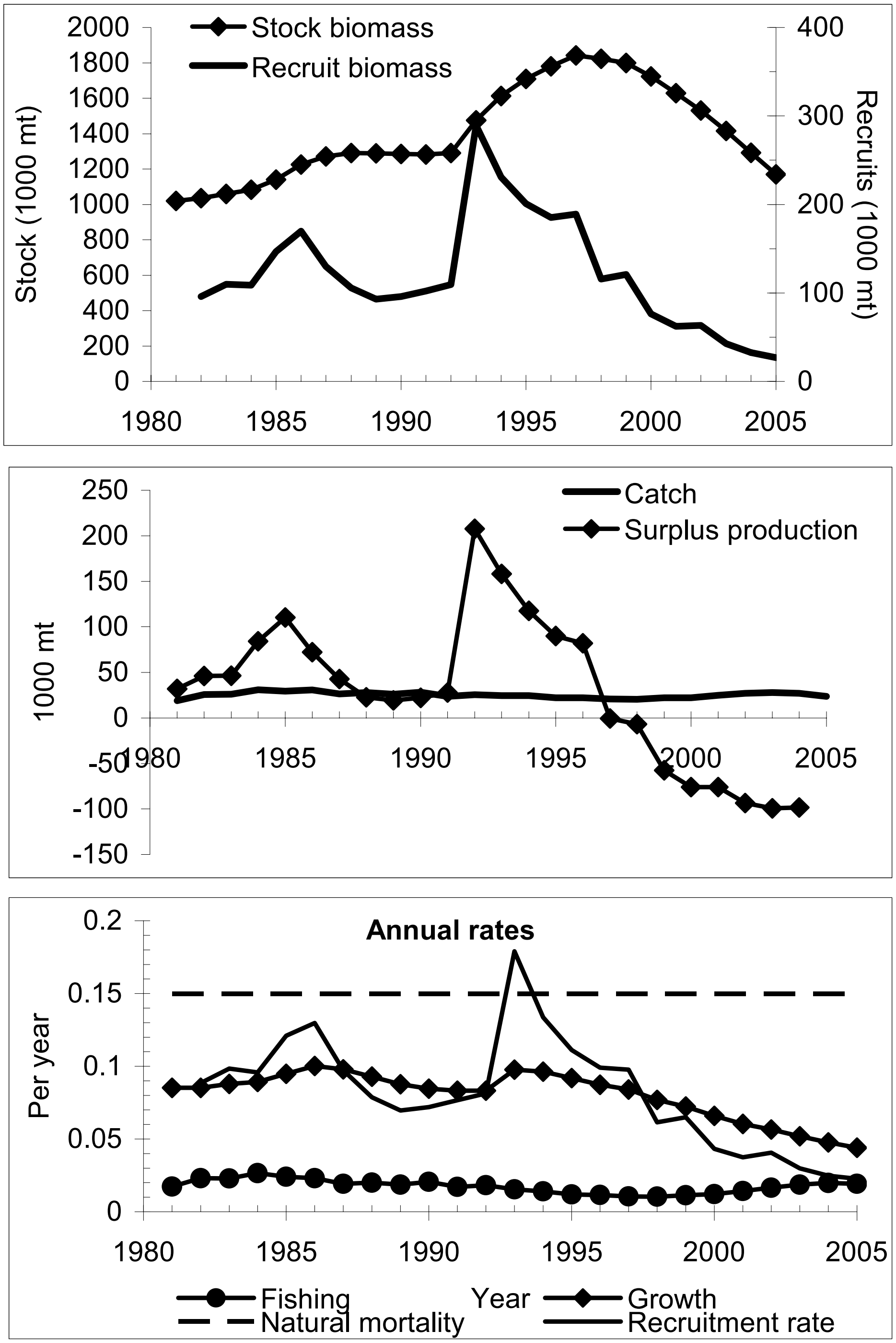


Figure C41. Population dynamics estimates from the KLAMZ model for the entire surfclam stock.

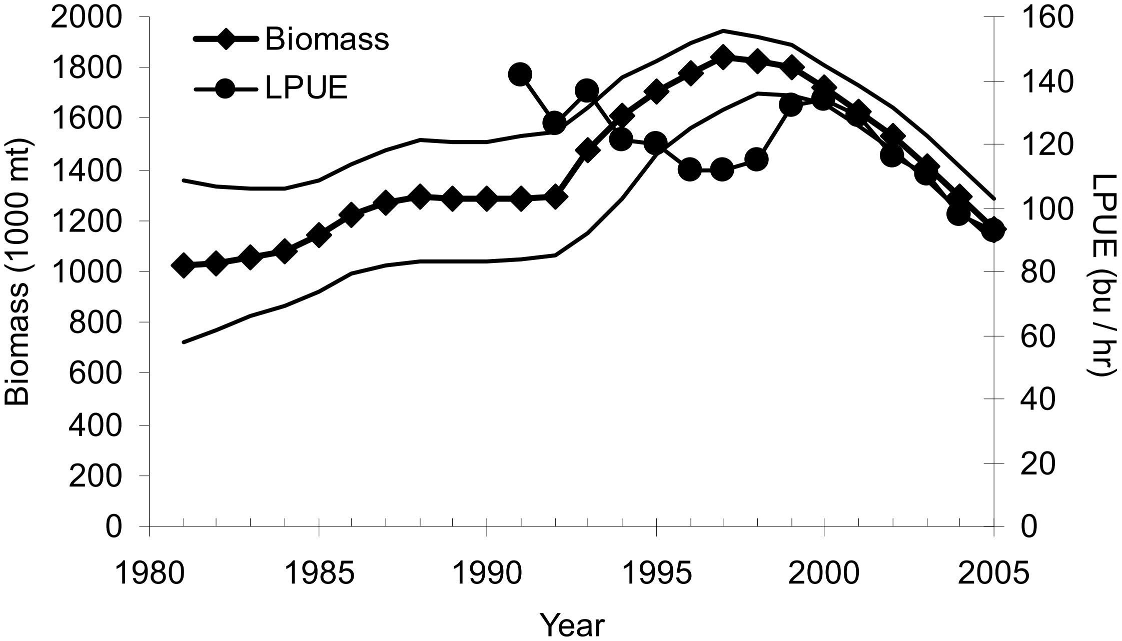


Figure C42. Fishable biomass estimates with 80% empirical confidence intervals from bootstrapping for the entire surfclam stock. Nominal LPUE from logbooks (total reported landings / total reported hours fished, all vessels and all trips) for the entire fishery is shown for comparison. LPUE data were not used in estimating biomass.

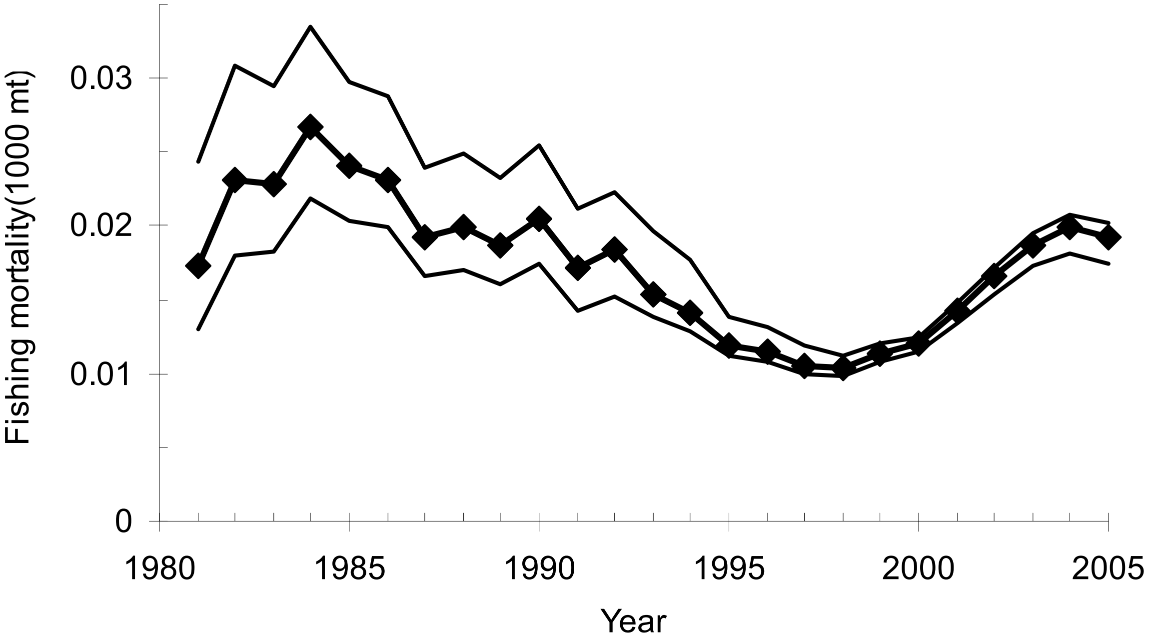


Figure C43. Fishing mortality estimates for the entire surfclam stock with 80% confidence intervals from bootstrapping.

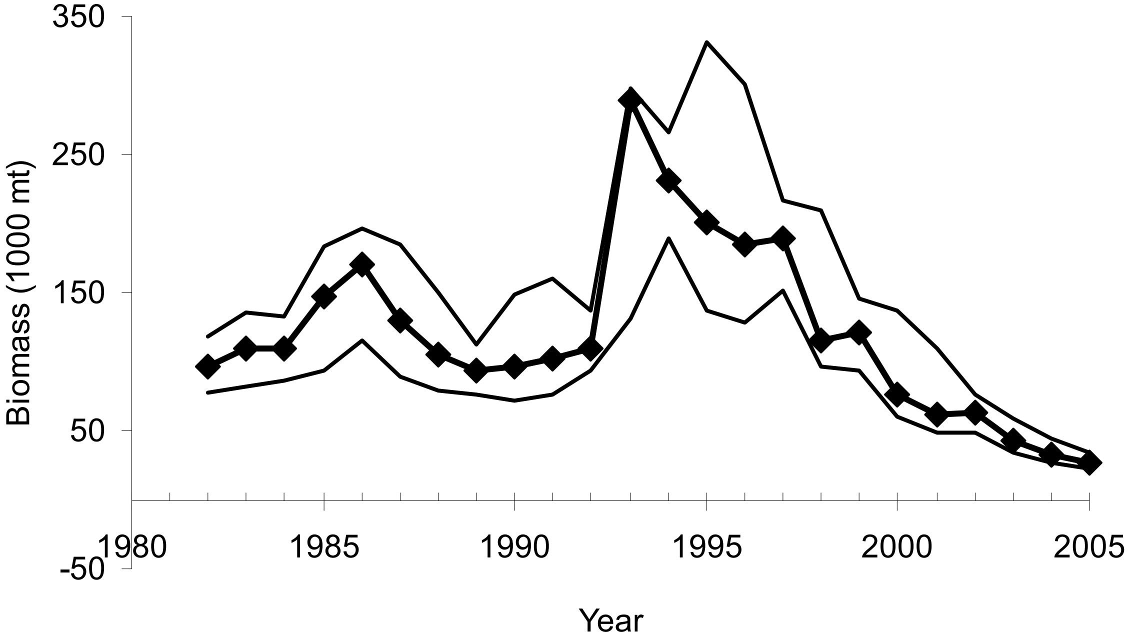
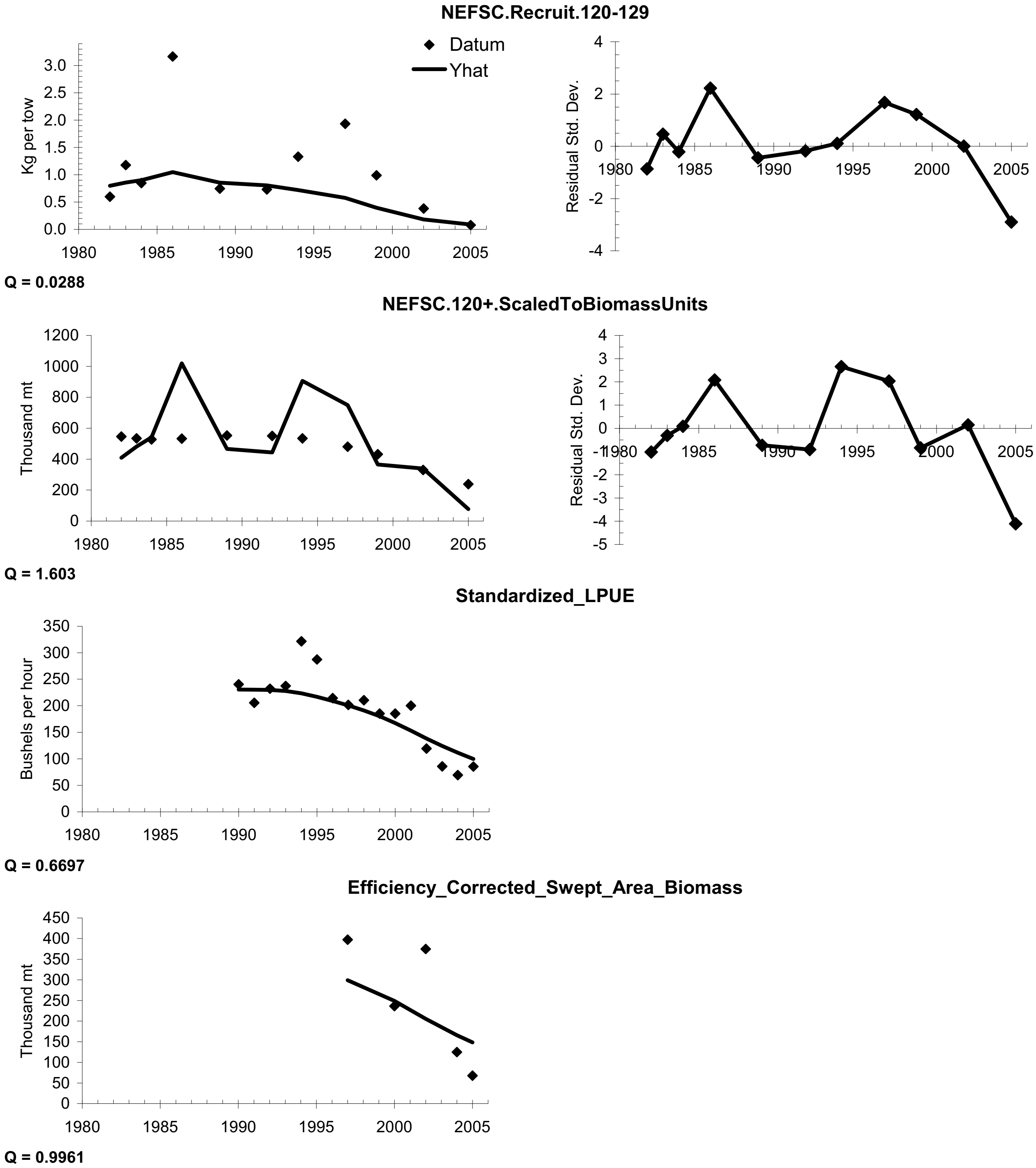


Figure C44. Recruitment for the entire surfclam stock with 80% empirical confidence intervals from bootstrapping.



NEFSC.Recruit.120-129

Q = 0.0288

NEFSC.120+.ScaledToBiomassUnits

Q = 1.603

Standardized_LPUE

Q = 0.6697

Efficiency_Corrected_Swept_Area_Biomass

Q = 0.9961

Figure C45. Model diagnostics for the KLAMZ model surfclam in DMV. Trends in nominal LPUE and efficiency corrected swept area biomass are shown with predicted trends from the model for comparison, but trends in these indices did not affect model estimates. Survey scaling parameter (*Q*) estimates are shown below plots for each set of data.

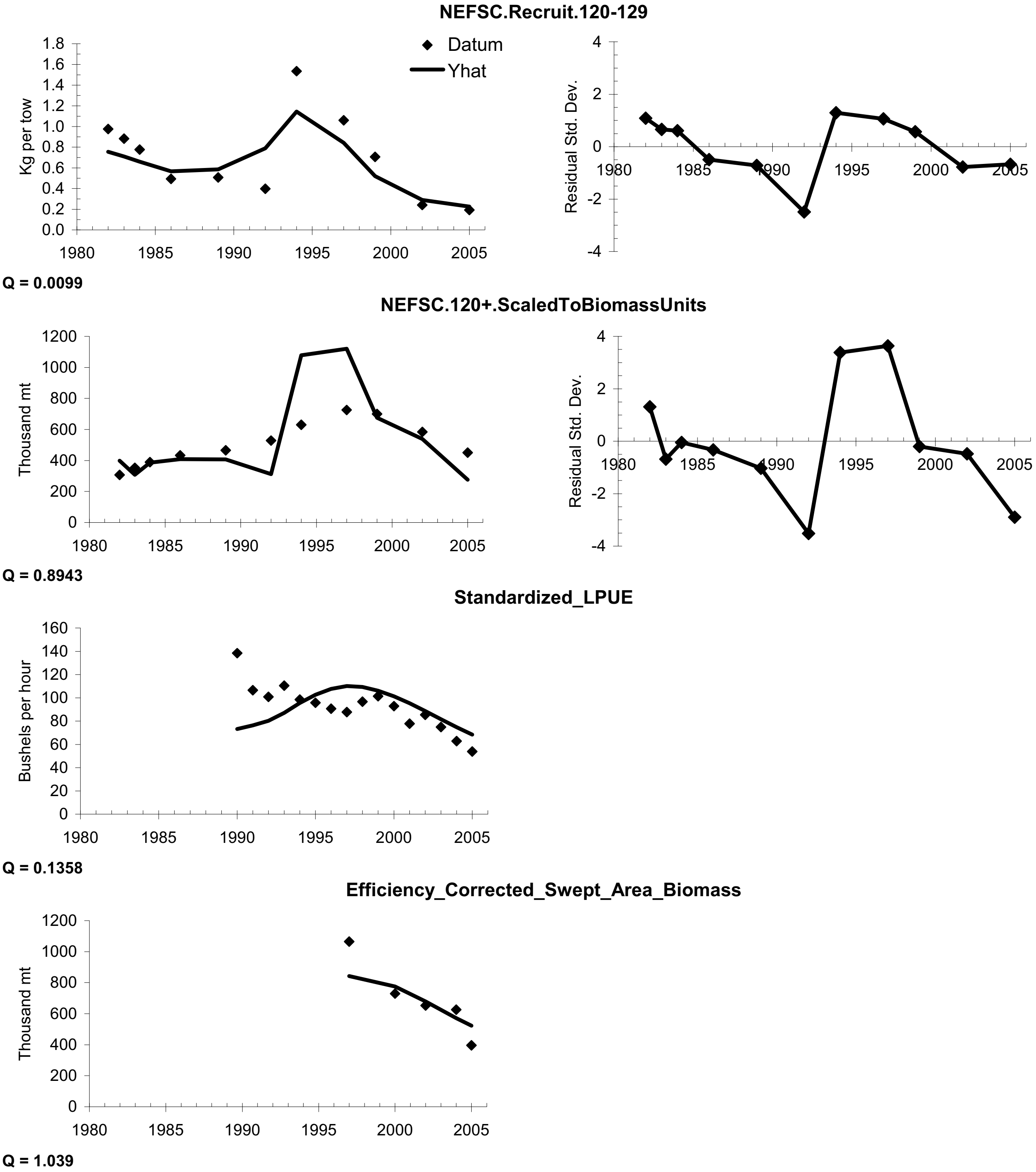


Figure C46. Model diagnostics for the KLAMZ model surfclam in NJ. Trends in nominal LPUE and efficiency corrected swept area biomass are shown with predicted trends from the model for comparison, but trends in these indices did not affect model estimates. Survey scaling parameter (*Q*) estimates are shown below plots for each set of data.

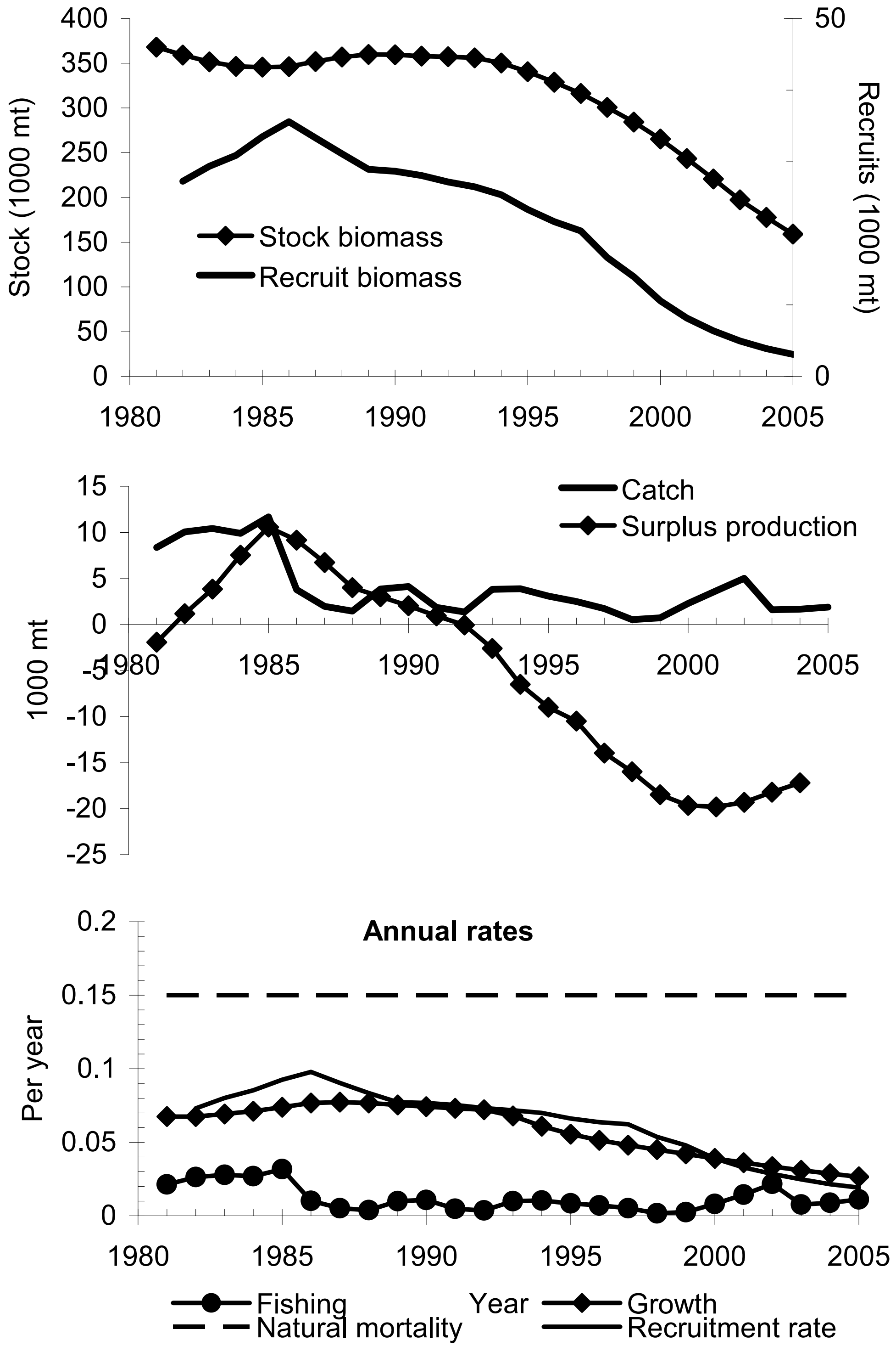


Figure C47. Population dynamics estimates from the KLAMZ model for surfclam in DMV region.

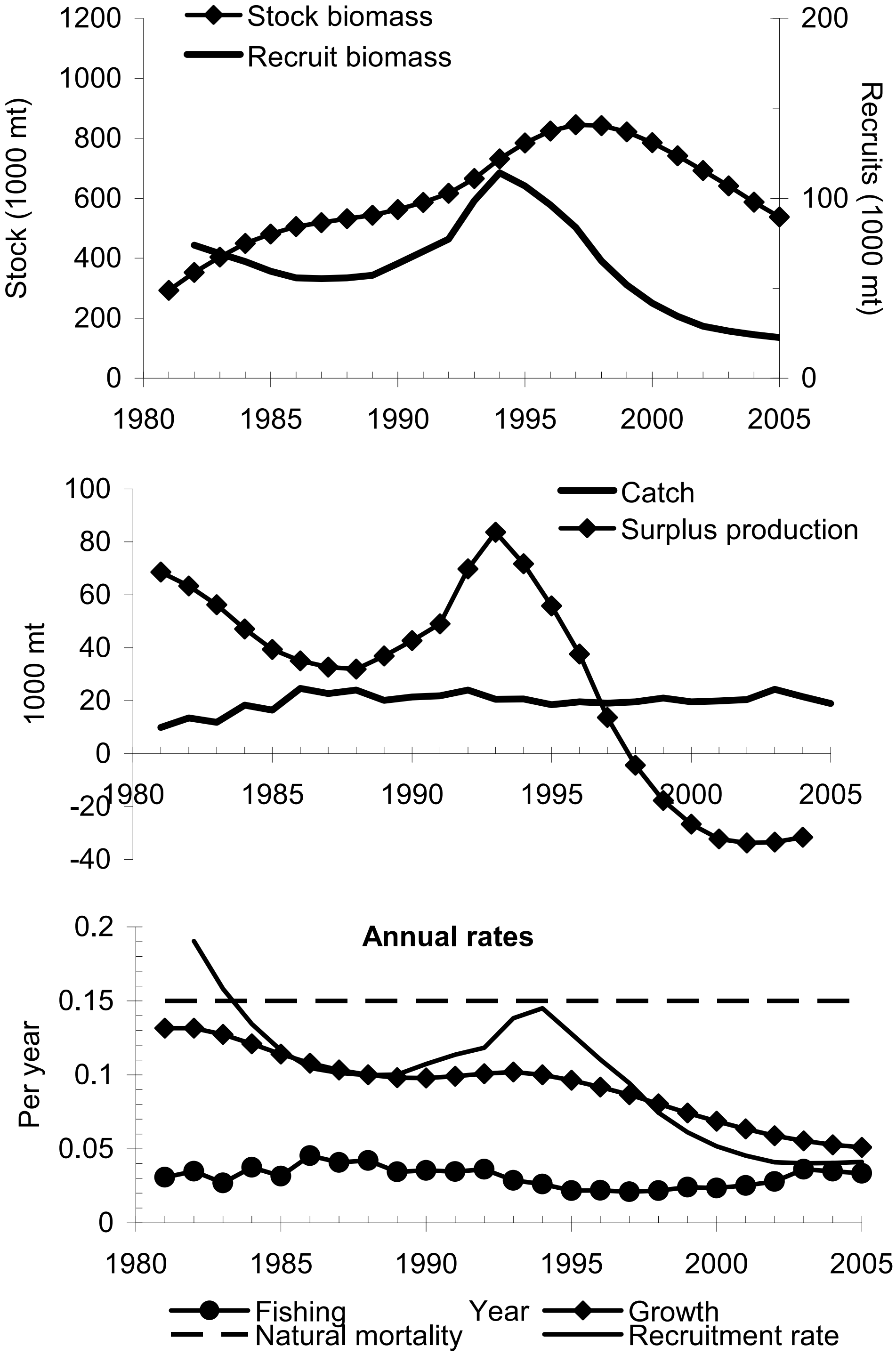


Figure C48. Population dynamics estimates from the KLAMZ model for surfclam in NJ region.

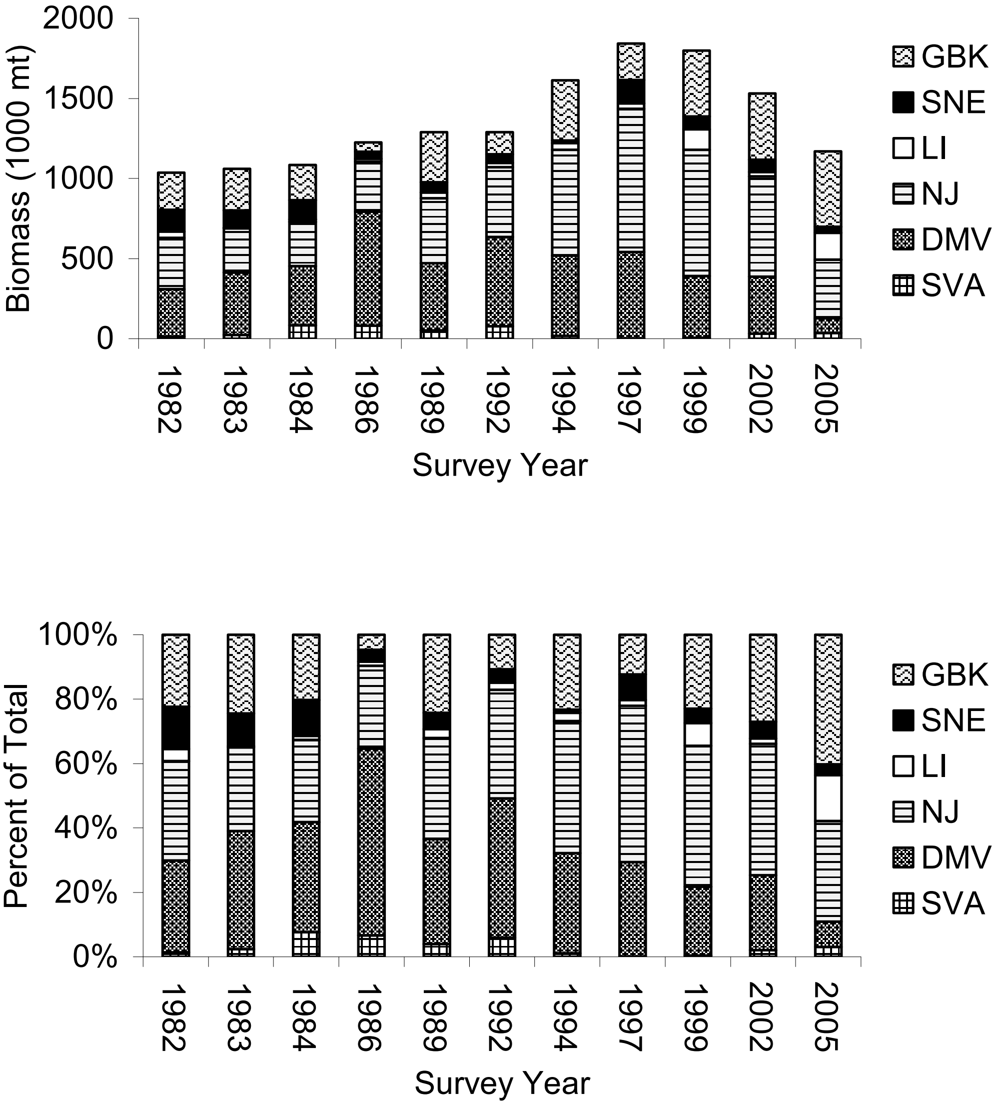


Figure C49. Surfclam biomass for the whole stock prorated into regional components based on rescaled regional survey trend data.

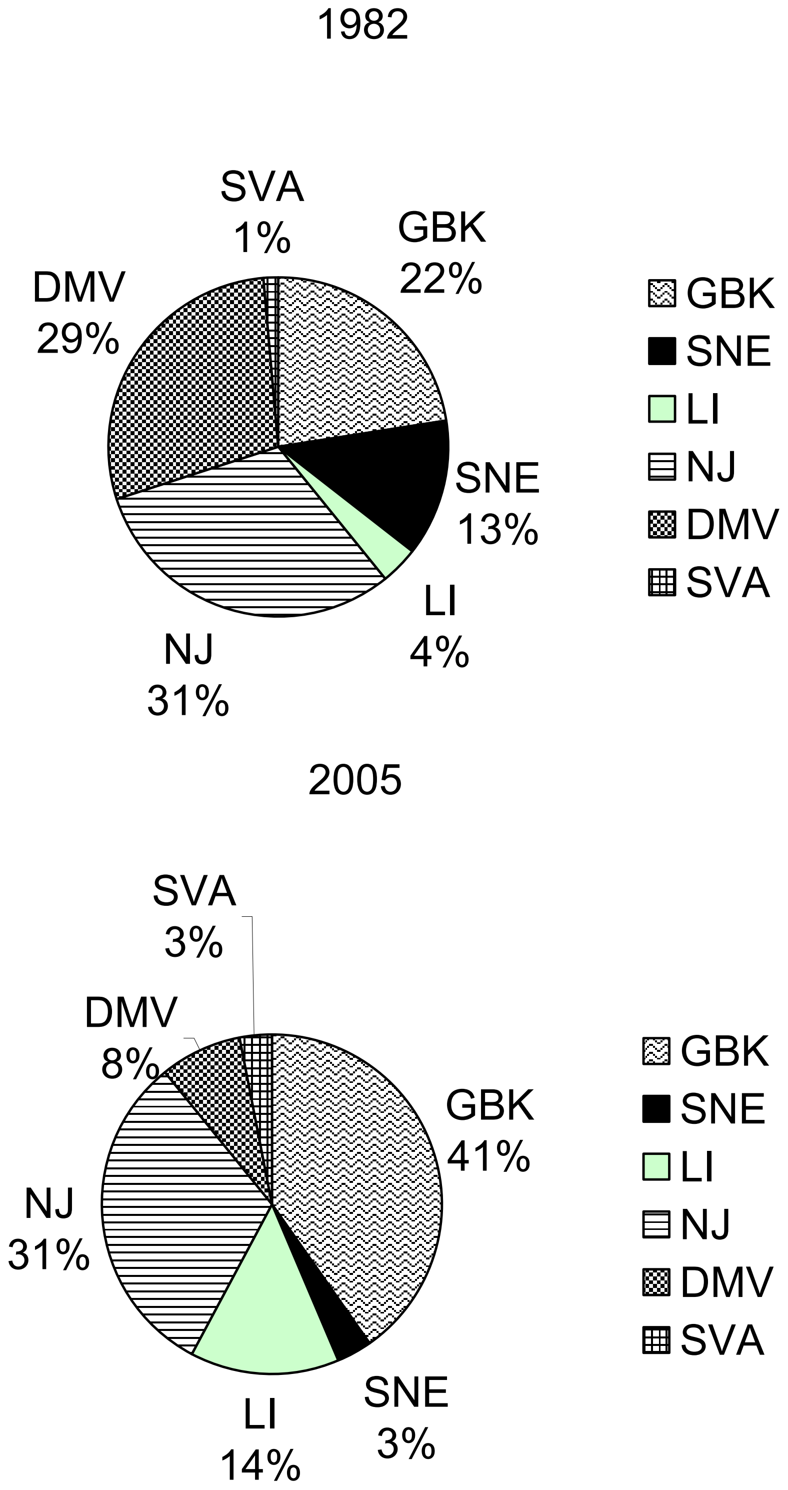


Figure C50. Proportions of total surfclam biomass by region during 1982 and 2005.

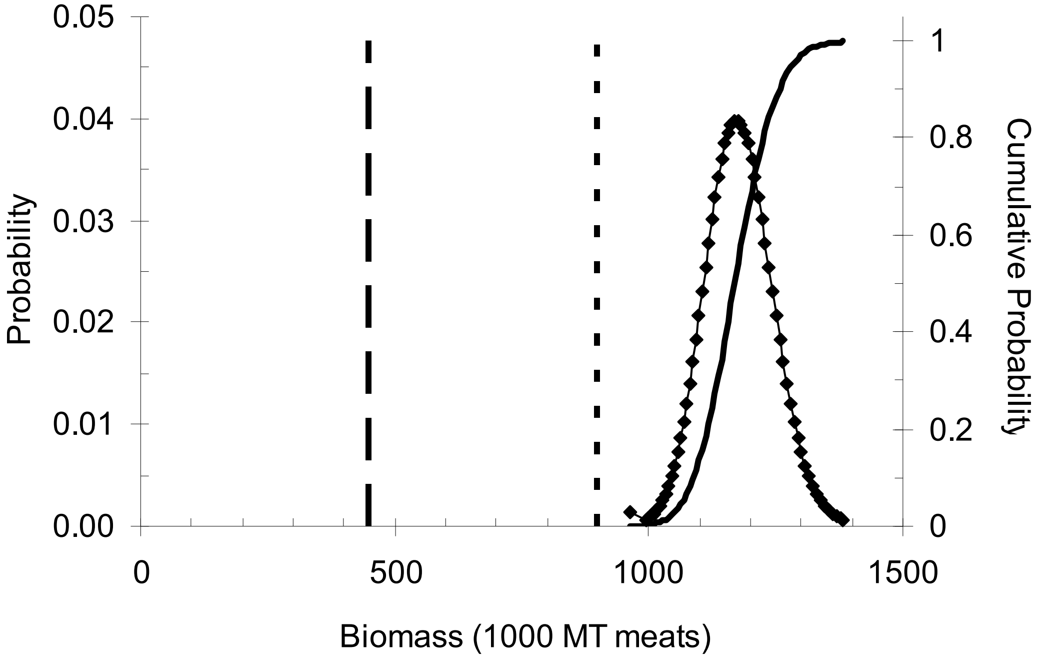


Figure C51. Fishable surfclam biomass during 2005 with probability distributions to characterize uncertainty. The long dash vertical line on the left is the biomass threshold. The short dash vertical line on the right is the biomass target.

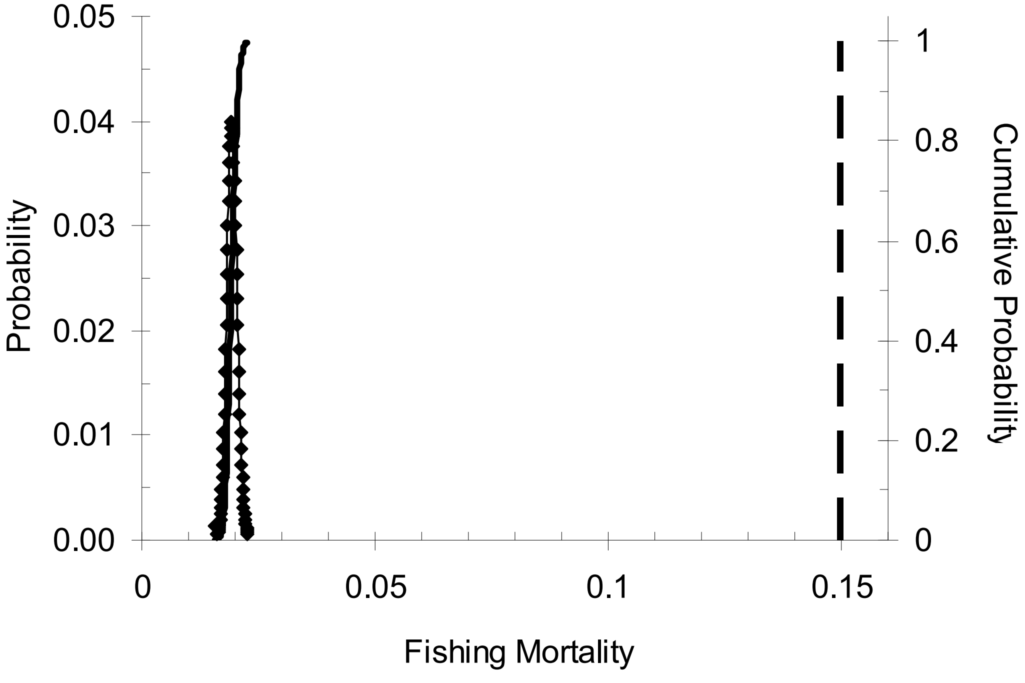


Figure C52. Fishing mortality for surfclam during 2005 with probability distributions to characterize uncertainty. The dash vertical line on the right is the fishing mortality threshold reference point.

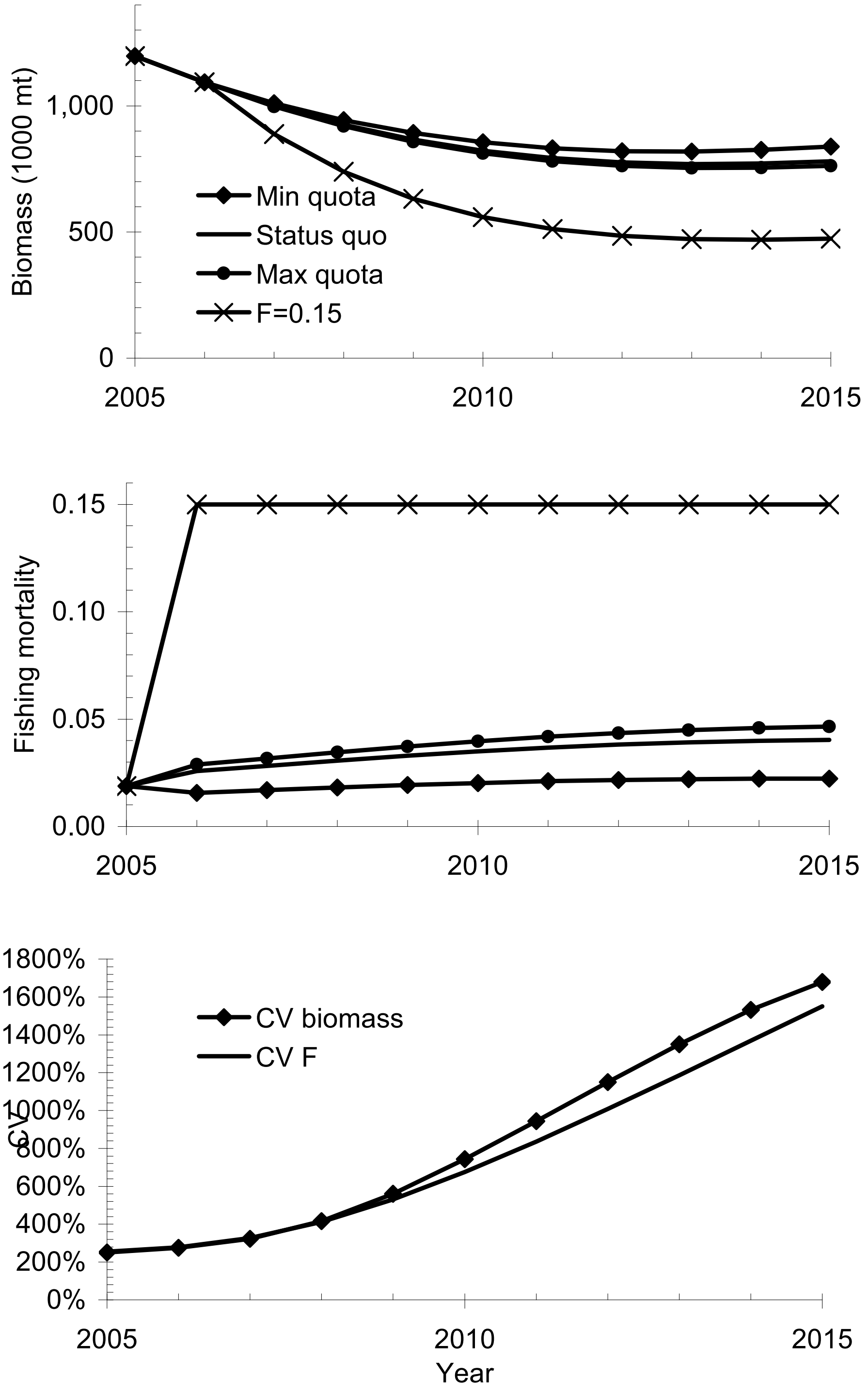


Figure C53. Average biomass and fishing mortality during 2005-2015 based on stochastic projection analysis under four assumed scenarios for constant landings of constant fishing mortality. CVs are for the variability between simulation runs in the same scenario.

APPENDIX C1. Invertebrate Subcommittee

Persons who attended Invertebrate Subcommittee meetings (September 25-26, October 16-17, and October 30-November 1, 2006) and contributed to this report are:

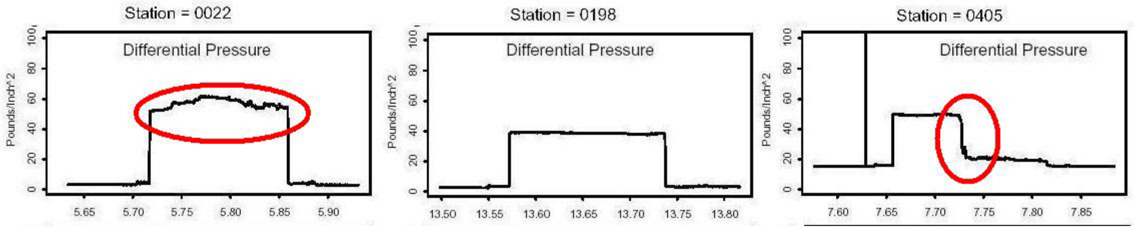
T. Alspach (Sea Watch International, Ltd.)
M. Bell (Invited external participant, Lowestoft, Suffolk, UK)
A. Chute (NEFSC)
H. Dobby (Invited external participant, FRS Marine Laboratory, Aberdeen, Scotland)
C. Heaton (Mid-Atlantic Fishery Management Council, MAFMC)
J. Heifitz (Invited external participant, NMFS, AKFSC)
T. Hoff (MAFMC)
L. Jacobson (Northeast Fisheries Science Center, NEFSC) – assessment lead
C. Pickett (NEFSC)
E. Powell (Haskin Shellfish Laboratory, Rutgers University)
D. Wallace (Wallace & Associates, Inc.)
J. Womack (Wallace & Associates, Inc.)
R. Mayo (NEFSC) – Subcommittee Chair
J. Weinberg (NEFSC)

APPENDIX C2. Analyses of tows with poor dredge performance in the 2002 NEFSC clam survey.

The review of the Survey Sensor Pack (SSP) data from the 2005 clam survey showed a significant number survey tows with anomalies that would likely affect the performance of the survey dredge. These anomalies in 2005 were mostly with problems in the manifold pressure in addition to several tows that had erratic towing angles. The number of 2005 survey tows deemed to have poor dredge performance by the proposed evaluation criteria (see Appendix C3) was approximately 8% of the total number of survey stations reviewed.

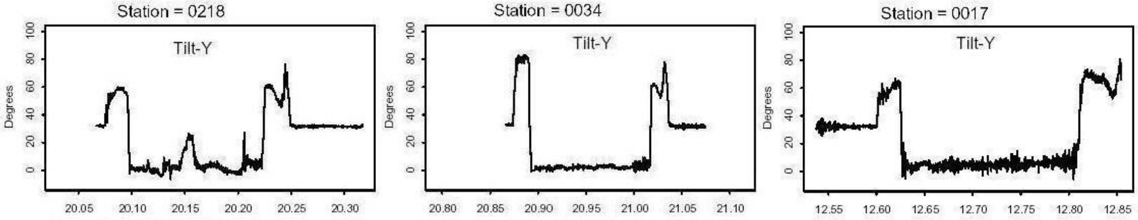
To see if the anomalies present in the 2005 survey were a unique situation or a continuation of an inherit inconsistency with the NMFS survey dredge, a review of the SSP data from the 2002 clam survey was undertaken. Because of time constraints and the limited number of survey station data plots available, this review was limited to a visual inspection of the data plots. The visual criteria used to judge a tow to have either "good" or "poor" dredge performance is the same as was used to perform a preliminary grading of the 2005 SSP data. In general the manifold pressure and fore/aft tilt angle plots were the parameters reviewed for significant deviations from normal values. Sample plots are shown below.

Manifold Pressure Visual Inspection Criteria Samples



Poor Manifold Blocked Good Normal Poor Intake Blocked

Dredge Angle Visual Inspection Criteria Samples



Poor High Spikes Good Normal Poor Erratic Over Tow

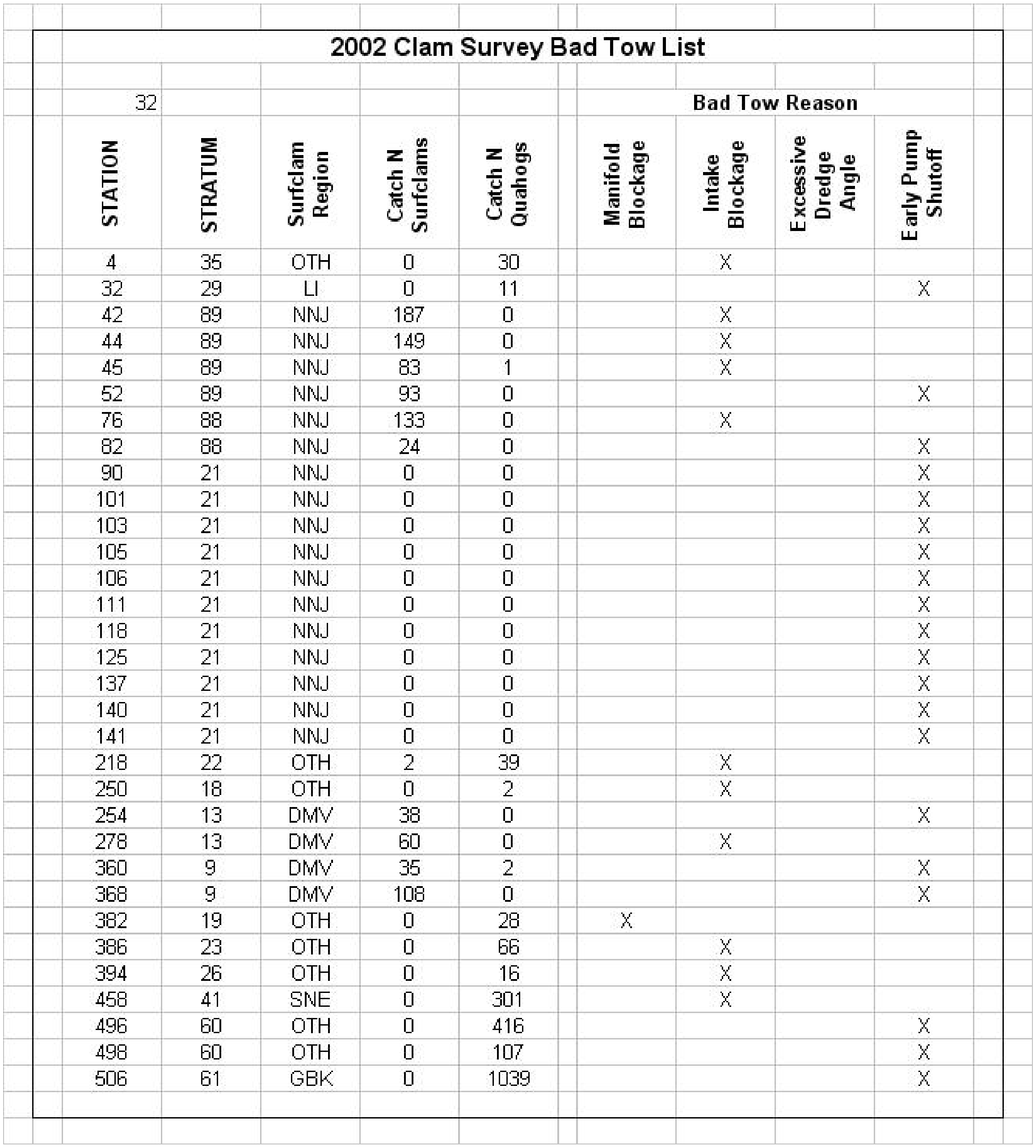
Summary of Results (for APPENDIX C2.)

The review of 2002 survey SSP data showed that similar anomalies found in 2005 survey were also found in the 2002 survey in addition to a problem with early shutoff of the dredge pump before the completion of the tow. The summary of the anomalies is shown below for both the 2002 and 2005 surveys.

Description	2002 Survey	2005 Survey
Total # of DE2 Survey Stations	556	433
Total # of Stations Tows Reviewed	213	399
Total # of Stations Labeled Good	181	366
% of Total Stations Reviewed	85.0%	91.7%
Total # of Stations Labeled Poor for Any Reason	32	33
% of Total Stations Reviewed	15.0%	8.3%
Total # of Stations Labeled for Intake Blockage	11	22
% of total Stations Reviewed	5.2%	5.5%
Total # of Stations Labeled Poor for Manifold Blockage	1	10
% of total Stations Reviewed	0.5%	2.5%
Total # of Stations Labeled Poor for Dredge Angle	0	2
% of total Stations Reviewed	0.0%	0.5%
Total # of Stations Labeled Poor for Early Pump Shutoff	20	0
% of total Stations Reviewed	9.4%	0.0%

In general the results show that the NMFS survey dredge is likely to experience a significant number of poor tows during any given survey from a number of possible reasons that affect either manifold pressure or fore and aft dredge running angle. From survey to survey, however, the predominate reason for a poor tow can vary. For example, the 2005 survey had a high number of poor tows due to manifold blockage compared to the 2002 survey. This was from an intake screen failure in 2005 on the dredge pump which allowed small stones to lodge in the manifold nozzles. In 2002, the predominate problem was the dredge pump being shutoff early which did not happen in 2005.

The list of poor tows for the 2002 tows from the tows reviewed is below. As pointed out elsewhere, many of the tows with poor gear performance would have been omitted from use in the stock assessment due to standard haul or gear condition criteria or were nonrandom tows used for special purposes.



2002 Clam Survey Bad Tow List

32

					Bad Tow Reason			
STATION	STRATUM	Surfclam Region	Catch N Surfclams	Catch N Quahogs	Manifold Blockage	Intake Blockage	Excessive Dredge Angle	Early Pump Shutoff
4	35	OTH	0	30		X		
32	29	LI	0	11				X
42	89	NNJ	187	0		X		
44	89	NNJ	149	0		X		
45	89	NNJ	83	1		X		
52	89	NNJ	93	0				X
76	88	NNJ	133	0		X		
82	88	NNJ	24	0				X
90	21	NNJ	0	0				X
101	21	NNJ	0	0				X
103	21	NNJ	0	0				X
105	21	NNJ	0	0				X
106	21	NNJ	0	0				X
111	21	NNJ	0	0				X
118	21	NNJ	0	0				X
125	21	NNJ	0	0				X
137	21	NNJ	0	0				X
140	21	NNJ	0	0				X
141	21	NNJ	0	0				X
218	22	OTH	2	39		X		
250	18	OTH	0	2		X		
254	13	DMV	38	0				X
278	13	DMV	60	0		X		
360	9	DMV	35	2				X
368	9	DMV	108	0				X
382	19	OTH	0	28	X			
386	23	OTH	0	66		X		
394	26	OTH	0	16		X		
458	41	SNE	0	301		X		
496	60	OTH	0	416				X
498	60	OTH	0	107				X
506	61	GBK	0	1039				X

APPENDIX C3. Comparison of surfclam and ocean quahog catches in tows with poor dredge performance during the 2002 and 2005 NEFSC clam surveys and 2002 cooperative survey tows (prepared by John Womack, Wallace and Associates, Ltd.)

<u>2002 Stock Assessment Survey Results</u>

- Total # of DE2 Survey Stations = 556
- Total # of Stations Reviewed = 213
- Total # of Stations Labeled Good = 181
  - % of total Stations Reviewed = 85.0%
- Total # of Stations Labeled Poor = 32 (Any Reason, Visual Inspection of Plots)
  - % of total Stations Reviewed = 15.0%
  - Total # of Stations Labeled Poor = 11 (Intake Blockage)
    - % of total Stations Reviewed = 5.2%
  - Total # of Stations Labeled Poor = 1 (Manifold Blockage)
    - % of total Stations Reviewed = 0.5%
  - Total # of Stations Labeled Poor = 0 (Dredge Angle)
    - % of total Stations Reviewed = 0.0%
  - Total # of Stations Labeled Poor = 20 (Early Pump Shutoff)
    - % of total Stations Reviewed = 9.4%
- Average # of Surfclam per Good Tow - 24.2
- Average # of Surfclam per Poor Tow - 28.5
- Average # of Quahogs per Good Tow - 69.3
- Average # of Quahogs per Poor Tow - 64.3

Poor Stations, Intake Blockage - 4, 52, 76, 218, 250, 386, 394, 458
Poor Stations, Manifold Blockage - 382
Poor Stations, Early Pump Shutoff - 32, 42, 44, 45, 82, 90, 101, 103, 104, 106, 111, 118, 125, 137, 140, 141, 254, 278, 360, 368, 496, 498, 506

<u>Comments on Review of Pump Manifold Pressure (See Figure 1)</u>

For initial portion of the cruise, station 0-230, the pump voltage was about 388 VAC. During this part of the cruise the pump manifold pressure followed a similar value and decrease in pressure pattern, i.e. normal wear, as was seen in the 2005 survey.

After about station 230 the pump voltage suddenly rises to about 400 VAC till about station 300. The pump manifold pressure also showed a small increase over the first portion of the cruise from about 34 PSI to about 35-36 PSI.

After station 300 this rise can not be tracked as voltage data is lost from around station 300 till around station 400.

At around station 400 the pump voltage suddenly rises to about 417 VAC This voltage rise lasted till the survey end. The pump manifold pressure also showed a significant increase over the first portion of the cruise from about 34 PSI to about 40 PSI.

The total voltage rise from cruise start to end is about 7.5%. The power the pump was drawing also showed a similar increase from 11.87 to 12.79.

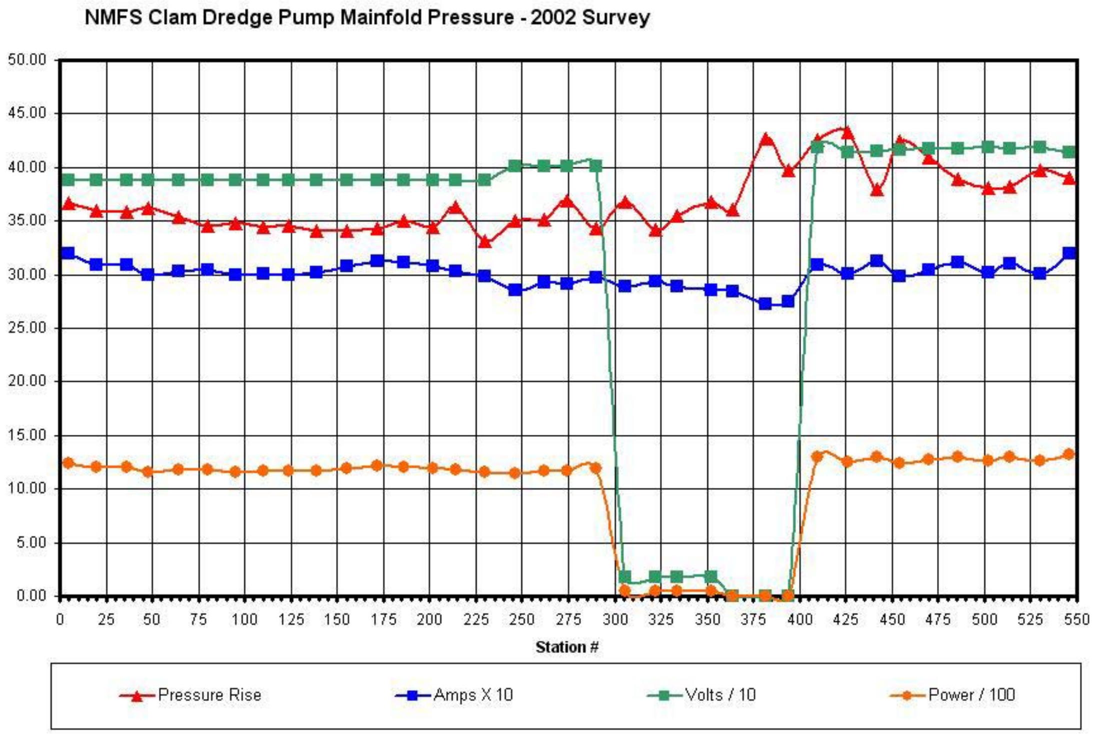


Figure 1 (Appendix C3)

Station Number	All	0-230	231-409	410-546
Avg # of Surfclam per Good Tow -	24.2	30.1	15.8	12.3
Avg # of Surfclam per Poor Tow -	28.5	33.6	30.1	0.0
Avg # of Quahogs per Good Tow -	69.3	34.3	45.0	232.5
Avg # of Quahogs per Poor Tow -	64.3	4.1	14.3	465.8
Total # Of Good Tows	181	114	37	30
Total # Of Poor Tows	32	20	8	4

For all stations and 0-230 and 231-409 groups, the NMFS dredge appears to fish surfclam better during a poor tow, generally which was a loss of manifold pressure, than a good tow. The last group, 410-546, did not show this pattern but this could be due to the fact that it appears to be primarily composed of quahog habitat stations.

The manifold may have seen some blockage in the stations around 375 to 400 as the pressure is higher but the amps draw has dropped.

For all groups as the manifold pressure rises, the surfclam catch per tow falls significantly, over 50%. See Figure 2. Caveat, limited number of stations in last two groups and last group was likely in quahog habitat.

For all groups as the manifold pressure rises, the quahog catch per tow increases significantly. See Figure 3. Caveat, limited number of stations in last two groups and last group was likely in quahog habitat.

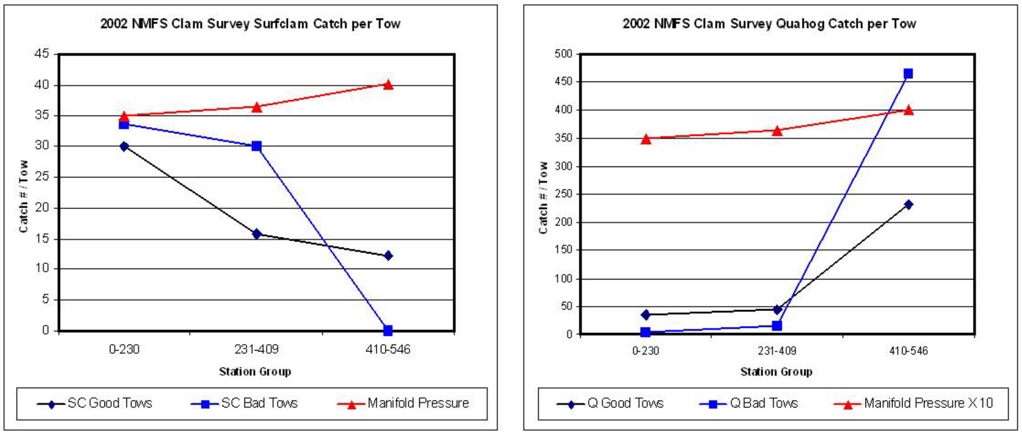


Figure 2 and Figure 3 (Appendix C3)

<u>2005 Stock Assessment Survey Results</u>

- Total # of DE2 Survey Stations = 433 82 = 556
- Total # of Stations Reviewed = 399 82 = 213
- Total # of Stations Labeled Good = 366 82 = 181
  - % of total Stations Reviewed = 91.7% 82 = 85.0%
- Total # of Stations Labeled Poor = 33 (Any Reason) 82 = 32
  - % of total Stations Reviewed = 8.3% 82 = 15.0%
  - Total # of Stations Labeled Poor = 22 (Intake Blockage) 82 = 11
    - % of total Stations Reviewed = 5.5% 82 = 5.2%
  - Total # of Stations Labeled Poor = 10 (Manifold Blockage) 82 = 1
    - % of total Stations Reviewed = 2.5% 82 = 0.5%
  - Total # of Stations Labeled Poor = 2 (Dredge Angle) 82 = 0
    - % of total Stations Reviewed = 0.5% 82 = 0.0%
  - Total # of Stations Labeled Poor = 0 (Early Pump Shutoff) 82 = 20
    - % of total Stations Reviewed = 0.0% 82 = 9.4%
- Average # of Surfclam per Good Tow - 18.20 82 = 24.2
- Average # of Surfclam per Poor Tow - 28.68 82 = 28.5
- Average # of Quahogs per Good Tow - 42.91 82 = 69.3
- Average # of Quahogs per Poor Tow - 1.19 82 = 64.3

<u>General Comments on 2002/2005 Survey Tows</u>

2002 Speed fairly smooth and consistent as opposed to 2205 survey which had more variation and steeper spikes and dips.

2002 Dredge angle relatively smooth even when pump intake was blocked or pump was shutoff early. (i.e. may have continued to fish effectively)

2002 Survey had significant changes in the dredge pump voltage and thus a significant increase in manifold pressure during the survey cruise.

NMFS Dredge fished surfclam better on poor tows then good tows for both 2002 and 2005 surveys.

2002 F/V Lisa Kim & F/V Jersey Girl Depletion Tows Review

F/V Lisa Kim Poor Tows
Station 12 - Dredge angle high. Odd as angle is about 5 degrees above normal and basically smooth throughout the tow.
Station 72 - Dredge angle very erratic varying from 0 to 25 degrees.

F/V Lisa Kim Tows with Blips, Not severe enough for a poor tow.
Station 95 - Very brief bump up in dredge angle.

F/V Jersey Girl had no Poor tows or tows with blips.