C. ATLANTIC SURFCLAM

TERMS OF REFERENCE

1. Characterize fishery performance since the last assessment based on landings, discards, fishing effort and other relevant data.
2. Analyze results of the most recent NEFSC clam survey, including population age structure, growth rates and dredge efficiency.
3. Estimate fishing mortality and stock biomass in absolute or relative terms and characterize uncertainty of estimates.
4. Evaluate stock status relative to current reference points. Update or re-estimate biological reference points based on new information if available.
5. Estimate TAC or TAL based on projected stock status and target fishing mortality rates for years 2004-2007.

EXECUTIVE SUMMARY

Surfclams in federal waters (the EEZ) are managed as a single stock; however, this assessment considered a number of smaller, stock assessment regions as well.

Abbreviation	Stock Assessment Region
SVA	Southern Virginia and North Carolina
DMV	Delmarva
SNJ	Southern New Jersey
NNJ	Northern New Jersey
LI	Long Island
SNE	Southern New England
GBK	Georges Bank

1.<u>Fishery performance.</u>

The surfclam fishery in the EEZ (beyond 3 miles from land) has been managed with a single annual commercial catch quota, which has been set since 1978. Landings from the EEZ are typically close to annual quotas. EEZ Landings rose from about 18,000 mt in 1997-1998, to about 24,000 mt in 2002. The annual quota also rose during this period.

For the last 17 years, the majority of the EEZ surfclam fishery has been concentrated off the coast of NNJ. Landings from LI and DMV have increased since 1999, but remain small relative to NNJ landings.

Commercial catch rates in the surfclam fishery are measured in units of bushels of clams per hour fishing. In NNJ, LPUE decreased gradually, but steadily, from 1031 kg/hr in 1991, to 801 kg/hr in 2002 for medium and large vessels, a -22% change. Catch rates have also declined over this period in DMV and SNJ.

Trends in LPUE were also examined on a smaller spatial scale, the ten-minute square (TNMS). Numerous TNMSs off the coast of NJ have had declining catch rates during the last decade.

Mean length of clams landed from DMV decreased steadily from 159 mm in 1982, to 123 mm in 1998. Mean length landed from DMV increased to 136 mm in 2002. Mean length of clams landed from NJ has remained relatively steady (140 – 150 mm) throughout the time series.

Surfclams begin to recuit to the fishery at about 5 years of age. However, most of the clams that were landed in 2002 from NJ and DMV were 8-12 years old. The oldest clams landed in 2002 were > 20 yr old.

2. NEFSC clam survey and dredge efficiency.

Uncertainty following the 1994 survey highlighted problems in interpretation of survey indices. To reduce this uncertainty, sensors have been used since 1997 to monitor ship and dredge performance during clam surveys.

In 2002, the *RV Delaware II* surveyed over 500 stations across a wide range of depths (10-90m). Differential pressure in the dredge manifold was usually 35 – 40 PSI, implying relatively consistent sampling.

For each random survey tow, distance sampled by the dredge was calculated as the sum of distance traveled per second, during those times when the dredge was potentially fishing. Tow distance is important in estimating biomass. Estimates of tow distance derived from the sensor data are longer than "nominal" and "Doppler" distances because sensor-based distances include any fishing that occurs when the dredge is being set out, towed for 5-min and hauled back. For the most recent three surveys (1997, 1999, 2002) the median sensor-based distances ranged from 0.20 – 0.25 nmi. In contrast, the nominal distance is 0.125 nmi.

Field studies were carried out in 2002 to estimate efficiency of the NMFS clam dredge. Four types of data were collected: 1) the survey vessel Delaware II (DE-II) resampled fixed stations, in unfished areas, from its earlier surveys, 2) a calibration ("depletion") experiment was conducted by the DE-II, 3) three calibration experiments by a commercial clam vessel were analyzed in conjunction with catches from setup tows made earlier by the DE-II, and 4) stations sampled by the DE-II in 2002 were repeated by a commercial vessel a couple of months later.

Dredge calibration experiments were analyzed using a spatial model. DE-II dredge efficiency estimates from the model for 1997, 1999, and 2002 range from 0.276 to 0.460. The value for 2002 was intermediate, 0.389. The grand mean from the 15 estimates of DE-II dredge efficiency, collected during these three years, was 0.370 (CV = 0.492).

While surfclams have occupied the same general locations since 1980, maps of the catch suggest a recent reduction in abundance of clams in relatively shallow water in DMV. Furthermore, the fraction of random stations in DMV Stratum #9 that captured zero surfclams increased from about 13% in 1997 to about 39% in 2002. This change was apparently due to higher mortality inshore, perhaps related to rising water temperature; it was not due to commercial harvesting.

Based on survey age-composition data, distinct cohorts are detectable in NJ and DMV. Populations in NJ and DMV consist of over 20 ages, and younger clams are more common than older clams. The maximum age observed in samples from 2002 was 28 yr old (born about 1978). At least some recruitment seems to occur in all years.

In NNJ, survey catch per tow of large (120+mm) clams increased from 1978 to 1997, but declined in 1999 and 2002 to an intermediate level. In DMV, survey catch per tow of large (120+mm) clams increased from 1978 to 1997, but declined in 1999 and 2002 to a relatively low level.

The most recent (1999, 2002) survey catches of 88-119 mm clams, those that will be recruiting in the near future, are near historical lows in both NNJ and DMV. Recruitment in the next few years is expected to be below average.

3. Stock biomass and fishing mortality.

Stock biomass and mortality for surfclams in each region were estimated using efficiency-corrected swept area biomass (ESB) information. In addition, the KLAMZ delay-difference stock assessment model used in the last assessment (NEFSC, 2000a) was used for surfclams in NNJ and DMV. ESB estimates are used for status determination because KLAMZ results were not available for all areas.

Total fishable biomass was fairly constant from 1997 (1,146,000 mt) to 1999 (1,460,000 mt). Total fishable biomass declined in 2002 (803,000 mt). In all three of the latest surveys, the region with the greatest fishable biomass was NNJ.

Biomass in NNJ has declined from about 486,000 mt in 1997-1999 to 315,000 mt in 2002. However, estimates are imprecise and trends are uncertain. A stronger decline in fishable biomass was detected in DMV. Estimates of total fishable biomass without GBK, where no fishing occurs, are 915,000 mt in 1997, 1,075,000 in 1999, and 566,000 mt in 2002.

Annual fishing mortality rates during 1997, 1999 and 2002 were estimated directly from the ratio of catch (landings plus an assumed incidental mortality adjustment) and ESB values for each region. The F estimates for total fishable biomass ranged from about 0.018 in 1997-1999, to 0.033 in 2002. In 2002, the 80% CI for F on total fishable biomass was (0.022, 0.049).

The greatest amount of reported landings came from NNJ. In NNJ, F was estimated to be 0.032 in 1997, 0.037 in 1999, and 0.053 in 2002. F estimates in DMV rose from about 0.009 in 1997-1999, to 0.035 in 2002. F's in SNJ have been variable, ranging from 0.011 to 0.107. In LI, F rose recently to 0.111.

In modeling and mortality estimation, fishery induced mortality was estimated based on landings plus discard plus a 12% upper bound incidental mortality adjustment. The incidental mortality adjustment is an upper bound that accounts for clams that are damaged by the dredge during fishing, but never handled on deck.

Trends in LPUE over the last decade were decreasing, while trends in survey data and estimated stock biomass were usually increasing. The commercial fishery concentrates on dense beds while the survey collects samples from random locations within strata. It is likely that declining trends in LPUE represent fishing down of dense beds. Survey trends can differ from LPUE trends because the survey samples the whole stock. However, divergent trends in LPUE and survey data are an important source of uncertainty.

For the DMV region, the ESB estimate was 317,000 mt in 1999 and 143,000 mt in 2002. Average biomass from KLAMZ during 1999-2002 was 289,000 mt. Both models show a decline in biomass in DMV from 1999 to 2002, but the decline from the KLAMZ model is more gradual.

KLAMZ model results for NNJ are shown, but the model suffered problems with residual patterns and bias. For NNJ, results from efficiency corrected swept area biomass (ESB) are probably more reliable.

4. Stock status relative to current reference points.

Target biomass (a B_{MSY} proxy) for the entire surfclam stock is (½)B_{1999} . In SARC-30 (NEFSC, 2000a), B_{1999} was estimated at 1,596 thousand mt, based on efficiency corrected swept area biomass (ESB), and at 1,268 thousand mt, based on the KLAMZ model. In the present assessment, B_{1999} was updated to be 1,460 thousand mt, based on ESB. Thus, the updated estimate of target biomass is 730 thousand mt.

Based on efficiency-corrected swept area biomass (ESB) calculations, the entire stock consisted of 803 thousand mt in 2002, with an 80% confidence interval from 542 thousand mt to 1,188 thousand mt (Table C21). Based on these estimates, the stock is not overfished. The stock is much closer to the target biomass than it was in 1999.

The fishing mortality threshold is F=M, and M was estimated at 0.15 (NEFSC, 2000a). The estimated F in 2002 for the entire stock was 0.033, with an 80% CI of 0.022 to 0.050. Based on these estimates, overfishing is not occurring.

5. Short-term projections.

Projections in this section depict potential future trends assuming catches at the quota (near status-quo) and continued low surplus production rates during 2002-2005.

It appears surfclam biomass may have declined during 1997-2002 by about -5.1% per year on average, even in the absence of fishing. Surplus production will probably continue to be low during 2002-2005 because production rates tend to be temporally autocorrelated for surfclam, and because poor recruitment is expected during 2003.

Total stock biomass may decline by about –29% to 656 thousand mt in 2006, if the entire quota is taken and surplus production remains negative during the next three years. For comparison, the target biomass (a B_{MSY} proxy) for the surfclam stock is 617 thousand mt and the biomass threshold used to identify overfished stock conditions is 309 thousand mt. Declines may range from –26% to –40% for the NNJ, SNJ and DMV regions where most of the catch is taken.

INTRODUCTION

Atlantic surfclams (*Spisula solidissima*, Dillwyn 1819) are large, fast-growing bivalves that occupy sandy substrates from the shallow subtidal zone to depths of about 50 m. Weinberg and Helser (1996) and Weinberg (1998, 1999, 2002a) describe individual growth rates, size- and age-structure, recruitment and likely effects of rising sea temperature on surfclams. Management and history of the surfclam and ocean quahog fisheries along the Atlantic coast of the United States were described by Murawski and Serchuk (1989). An individual transferable quota (ITQ) system was established in 1990.

Surfclams were assessed in 1992, 1994, 1997 and 1999 (NEFSC 1993, 1995, 1998a,b, 2000a,b), for SARC/SAW-15, -19, -26 and –30. Assessments are generally done after NMFS clam surveys, which are conducted every 2-3 years. Uncertainty in assessment results and the necessity for additional research on abundance were highlighted at SARC-22 (NEFSC 1996a,b) because 1994 survey catch rates were anomalous and the dredge efficiency estimate from a population model was unrealistic.

Due to uncertainty about survey data from 1994, a major effort has been made subsequently to improve understanding of the performance of the dredge used in NMFS clam surveys. Clams are sampled with a 3.2 ton, hydraulic dredge, similar to that used by industry. A submersible pump, mounted above the dredge, shoots water into the sea bottom just ahead of the 1.5m-wide dredge mouth. These jets of water turn the sea bottom into a fluid, which allows the clams to be captured more easily.

An underwater video camera and sensors, used for the first time in 1997, monitored the behavior of the dredge during each tow of the 1997 survey. The video and sensor data allowed for more accurate estimates of distance towed as well as estimates of water pressure at the manifold. In addition, depletion experiments were carried out in the field in 1997 to estimate the efficiency of the NMFS clam dredge. Experiments were done in collaboration with academia and the clam industry. As an additional tool, survey stations occupied during previous NMFS clam surveys in unfished areas were resampled to indicate whether there were gross changes in efficiency of the clam dredge over time.

Sensors on the dredge and ship, depletion experiments, and resampled stations were continued during the 1999 and 2002 clam surveys to monitor dredge efficiency. The new Shipboard Computing System (SCS) and, in 2002, a new Survey Sensor Package mounted on the clam dredge of the R/V DELAWARE II were used to gather continuous data on ship speed, position and dredge angle during every tow. These data allowed for a improved direct estimates of distance sampled per tow by the dredge. Additional calibration ("depletion") studies to measure survey dredge efficiency were carried out in collaboration with the clam industry and academia (see Acknowledgments). Improvements made to the clam survey in 1997, 1999 and 2002 allow for more accurate estimates of current surfclam biomass because tow distance was measured more accurately, variations in survey dredge efficiency were understood better, and dredge efficiency estimates from depletion studies were useful for estimating surfclam biomass directly.

This report summarizes analyses and major research findings. A list of research recommendations, sources of uncertainty, and SARC comments are included. This assessment used existing, improved, and new models to estimate current stock biomass, fishing mortality and annual surplus production for seven stock assessment regions that make up the surfclam stock (Figure C1). Because this fishery is highly localized and the resource is sedentary, attention was given to temporal and spatial trends in the regional commercial and survey data. The report also compares estimates of F and stock biomass to biological reference points.

Names and abbreviations for the stock assessment regions are listed (from south to north) below.

Abbreviation	**Name**
SVA	Southern Virginia and North Carolina
DMV	Delmarva
SNJ	Southern New Jersey
NNJ	Northern New Jersey
LI	Long Island
SNE	Southern New England
GBK	Georges Bank

COMMERCIAL DATA

Commercial landings and effort data from 1980 to 2002 are from mandatory vessel logbooks. It is assumed throughout this assessment that one "industry" bushel (1.88 cubic ft) of surfclams = 17 lbs = 7.711 kg of usable meats. Vessel size class categories are: Class 1 (small, 1-50 GRT), Class 2 (medium, 51-104 GRT), and Class 3 (large, 105+ GRT). Age- and length-frequencies in the commercial catch were estimated from samples collected by port agents in New Jersey and Delmarva.

Landings

The surfclam fishery in the EEZ (beyond 3 miles from land) is managed with commercial catch quotas. Landings from the EEZ are typically close to annual quotas, which have been set since 1978.

Between 1965 and 1974, total landings rose from 20,000 to 44,000 mt of meats (Table C1, Figure C2). After 1974, total landings declined steadily to 16,000 mt in 1978. A major hypoxic event off New Jersey in 1976 caused high mortality in the stock of that region. Strong recruitment of surfclams in the Mid-Atlantic region from Delmarva through New Jersey in the late 1970s resulted in increased landings throughout the early 1980s. From 1983 to 2002, annual EEZ landings were fairly constant, ranging from 18,000 - 25,000 mt. Landings from the EEZ rose from about 18,000 mt in 1997-1998, to about 24,000 mt in 2002. The annual quota also rose during this period. In the 1980s, approximately 75% of the landings were from the EEZ; other landings were from state waters. From 1990 to 2001, the percentage of landings from the EEZ ranged from 64 to 74%.

Since 1994, virtually all EEZ landings were taken from the Middle Atlantic region. Georges Bank has been closed to surfclam fishing since 1990 due to the risk of paralytic shellfish poison (PSP). For the last 17 years, the majority of the EEZ surfclam fishery has been concentrated off the coast of New Jersey in the NNJ region (Figures C4-C7) (NEFSC, 1998a, 2000a,b). During 1986-2002, 64-91% of Middle Atlantic annual landings came from the Northern New Jersey (NNJ) stock assessment region, 2-19% came from Delmarva (DMV), and 0-22% came from Southern New Jersey (SNJ) (Table C2, Figure C3). This represents a shift away from the DMV region, which was a major source of surfclams in the late 1970s and to a lesser degree in the early 1980s. Starting in 1997, a significant fraction of surfclam landings were taken from a single ten-minute square close to shore at the mouth of the Delaware Bay (NEFSC, 2000a; and Figures C4–C7), which accounts for the increased fraction of landings from the SNJ region (Table C2). There has been an increase in landings from the LI and DMV regions since 1999 (Table C2).

<u>Catch Rates and Effort</u>

Effort Trends:
In the early 1980s, consistently high levels of fishery effort (15,000 - 16000 hrs/yr) took place in Delmarva (DMV) and the Southern (SNJ) and Northern New Jersey (NNJ) regions (Figure C8). Effort subsequently declined in DMV and SNJ, but remained high in NNJ. From 1985-1990, hourly trip limits were used to manage the fishery, and effort data during this period are unreliable due to reporting problems. Fishing effort has been fairly stable since 1991, when ITQ management was imposed. Though effort in DMV remains small, relative to NNJ, effort has risen in DMV since 1998 (Figure C8).

Characteristics of Clam Vessels:
Previous assessments used vessel weight (i.e., tonclass) to assign vessels to groups for examining trends in landings per unit effort (LPUE). We used information about vessels in the 2002 clam fleet to determine if tonclass was a reasonable way to assign vessels to groups. Ton class was positively correlated with other measures of fishing power, including vessel length, engine horse power (HP), pump HP, and dredge width (Figure C9). Although there might be better ways to assign vessels to groups (a Research Recommendation) that reflect fishing power, the analysis suggests that ton class is a simple and reasonable way to make the assignment. Catch rates are presented below for 3 groups of vessels based on ton class: medium, large, and (medium + large). To maintain confidentiality, catch rates for the small ton class are not presented; they often represent a single vessel.

Landings per unit effort (*LPUE):*
Commercial catch rates in the surfclam fishery are measured in units of bushels of clams per hour fishing. Data from every trip are reported in logbooks. Trip limits of 6-hr during 1985-1990 make reported effort per trip and LPUE unreliable for those years (NEFSC 1998a). In the Mid-Atlantic region, over 95% of the annual surfclam catch is typically taken by large (105+ GRT) and medium vessels (Table C3). LPUE in the Mid-Atlantic region (Long Island to Southern Virginia) declined slightly from 1991-2002, with a small increase in the 1999 (Figure C10). A fishery for surfclams developed on Georges Bank (GBK) in the mid-1980s, but that area was closed in 1990 due to paralytic shellfish poison (PSP). The LPUE from GBK in the mid-1980s is comparable to that in the Mid-Atlantic during the 1990s, indicating that surfclams were abundant on GBK (Figure C10).

In the Northern New Jersey (NNJ) region, LPUE increased from the early 1980s to the 1990s (Figure C11). For Large + Medium vessels combined, LPUE declined in NNJ from 1991 to 1998, increased slightly in 1999-2000, and then declined in 2001-2002 (Table C3, Figure C11). LPUE decreased from 1031 kg/hr in 1991 to 801 kg/hr in 2002 for vessel class 2+3, a -22% change. Although Class 2 vessels account for only a small fraction of the NJ landings, those vessels often have a higher LPUE than Class 3 vessels.

Off Southern New Jersey, nominal LPUE for class 2+3 vessels peaked in 1993 and 1998 at almost 2000 kg/hr (Table C3, Figure C12). This represents the highest LPUE among all region/vessel class combinations. Considering data from 1991 to 2002, LPUE is presently at a relatively low value (853 kg/hr) for this region.

In the Delmarva region, LPUE has been variable since 1991, probably due to the small number of trips taken in the region (Table C3, Figure C13). Indices have tended downward for Class 2+3 vessels. Considering data from 1991 to 2002, LPUE is presently at a relatively low value (790 kg/hr) for this region.

Trends in LPUE were also examined on a smaller spatial scale, the ten minute square (TNMS; 1 minute of latitude = 1 nmile). For each TNMS, the slope of catch rate vs time was computed, for the period 1991-2002. Data for a given Year/TNMS combination were omitted whenever effort (time fishing) was < 5 hr. TNMSs with negative slopes, which indicate decreasing catch rates during the last 12 years, are coded white, while those TNMSs with positive slopes are coded black (Figure C14). Numerous TNMSs off the coast of NJ have had declining catch rates during the last decade.

General Linear Models (GLM)

GLMs were used to standardize LPUE data and estimate year effect parameters that may measure trends in surfclam biomass. GLMs were carried out, by region, on the natural log of LPUE. Year and subregion were included as explanatory variables. "Subregions" were created by splitting each region into approximate halves. Data from all medium and large vessels were included, and they were not treated as separate groups in the GLM. Other models, with ton class and month as explanatory variables, gave similar results. As described above, effort reporting problems from 1985-1990 confound interpretation of LPUE as a measure of relative resource abundance. Therefore, data from 1985-1990 were excluded from the analyses. GLM results from NNJ, SNJ and DMV are most important because the fishery is/has been active in these areas and NMFS research surveys have indicated that much of the stock biomass is within these regions.

Across regions, there is a general trend for a rise in LPUE from the early 1980s to the 1990s (Table C4, Figure C15). This is probably due to several factors including recovery of the stock biomass and age structure following the hypoxic event and heavy fishing during the 1970s, ITQ management in the 1990s, and possible changes in fleet composition and harvesting technology.

Back-transformed year coefficients from the GLMs (i.e., standardized LPUEs) follow trends in nominal LPUEs for large vessels, as well as trends in nominal LPUE for medium + large vessels, rather closely. Model results suggest that LPUE in NNJ declined by approximately 19% from 1991 to 2002. LPUE in SNJ and DMV has been highly variable, but each is currently near the minimum value for its region in the last decade (Table C4, Figure C15).

Size Composition in Landings

Length frequency distributions for surfclams landed between 1982 and 2002 are presented for the New Jersey (NJ) and Delmarva (DMV) regions in Figures C16 and C17, respectively. Sampling data are summarized in Table C5.

Mean length of clams landed from DMV decreased steadily from 159 mm in 1982 to 123 mm in 1998. Mean length increased from 1998 to 2002. Low mean length in 1994 is probably the result of low sample size, because size distributions in 1995 and 1996 were similar to those in 1991-1993.

Mean length of clams landed from the New Jersey area has remained relatively steady throughout the time series, although the percentage of small clams (90 - 110 mm) increased from 1993-1997. The proportion of clams in the 150 mm+ category increased after 1990 off NNJ, and has remained high since then.

Between 1982 and 1990, average size of clams landed from S New England (SNE) (approximately 150 mm - 160 mm) was greater than that from areas to the south (typically 120 mm - 140 mm, Table C5). No data are available from SNE and after 1990.

Age Composition of Landings

Estimates of age composition for landings involved age-length keys for each region, based on samples collected and aged from the 2002 NMFS survey, and length compostion of commercial landings, measured by port agents. Age data from commercial landings were not available.

Surfclams begin recruiting to the fishery at about 5 years of age (Figure C18). However, most of the clams that were landed in 2002 from NJ and DMV were 8-12 years old. The oldest clams landed in 2002 were > 20 yr old. In NJ and DMV the fully recruited surfclam stock in 2002 consisted of about 20 year classes.

RESEARCH SURVEYS

History of Changes Made to NMFS Clam Survey Gear

The NMFS clam survey has been conducted since 1965. Clam survey data must be used carefully because significant methodological changes have taken place over time. Table C6 summarizes changes that took place in the early years, including changes in and to research vessels, sampling in different seasons, changing dredges, mesh sizes, etc. Changes that have taken place in the last decade are listed in Table C7. Factors that changed recently include refitting the research vessel (which affected how it rides in the water), new winches which operate at different speeds and affect tow distance, and voltage on the ship powering the pump on the dredge.

Sensor data (1997, 1999, 2002)

Uncertainty following the 1994 survey highlighted problems in interpretation of survey indices. To reduce this uncertainty, changes to operational procedures at sea were implemented in 1997 and have continued to the present. Better monitoring of dredge performance was achieved via the Delaware II's Shipboard Computing System (SCS), which permits continuous monitoring of variables that are critical to operations. In addition to the SCS sensors, sensors were attached to the clam dredge. During most tows, these sensors collected data on ship's speed, ship's position, dredge angle, power to the hydraulic pump, and water pressure from the pump at depth. Depending on the sensor, the sampling interval in 1997 and 1999 varied from once per second to once per ten seconds. The smallest time unit for analysis was one second, and all sensor data collected in 2002 used this sampling frequency.

Types of sensors and the data they collect have evolved over time. In 1997 and 1999 "old" inclinometers were used to measure dredge angle. In 2002, both "old" inclinometers and a new integrated Survey Sensor Package (SSP) were used. The SSP was developed by collaborative effort between NEFSC and the clamming industry. There is consistency between readings from the "old" and new inclinometers. When the R/V DE-II was at the dock at the conclusion of the 2002 clam survey, these sensors were within 1° of each other in estimating the angle of the dredge on the ramp (33.16°- old vs. 32.3°- SSP). Furthermore, tow distances based on "old" inclinometer and new SSP angle data from 66 stations in Leg 3 were similar and highly correlated. While both old and new sensors work, in practice it is critical to calibrate them properly and to have an accurate estimate of their mounting angles relative to the dredge. The latter measurement is very difficult to make precisely with the "old" inclinometers, and is a source of uncertainty, particularly in 1997 and 1999.

Figure C19 is an example of new (SSP) sensor data collected at every station in 2002. These data were used to compute tow distance and to monitor electrical power and differential pressure from the dredge manifold. Although several pieces of equipment had to be replaced during the 2002 clam survey (Table C8), differential pressure in the manifold remained fairly stable during the entire survey (Figure C20). The survey sampled stations across a wide range of depths (10-90m). Differential pressure was usually about 35 – 40 PSI (Figure C20), implying relatively consistent sampling performance. For comparison with the NMFS clam dredge, commercial clam boats operate with much higher differential pressure, 80 – 100 PSI.

Sensors for calculation of tow distance

For each random survey tow, distance sampled by the dredge was calculated as the sum of distance traveled per second, during those times when the dredge was potentially fishing (i.e., when dredge angle was ≤5.2°) (Figure C21). Distance traveled during each second was determined from data on ship's speed, assumed to represent the movement of the dredge. This method may tend to overestimate tow distance due to this assumption. However, tow distance is grossly underestimated by nominal distance. Dredge inclinometer data had been smoothed with a 7-s moving average to eliminate high frequency shocks. Dredge angles >5.2° represented times when the dredge was probably not fishing, either because it was not near the bottom or because it had hit a large boulder and bounced up. Using the cutoff angle 5.2° for when the dredge was fishing differs from the criterion used in SARC30; the change resulted in a minor increase in average tow distance for the 1997 and 1999 surveys (ranging from 0 to 5% for tows taken at surfclam depths). The change was made for this assessment based on analysis of dredge angle data collected with both "old" and "new" sensors simultaneously in 2002, and uncertainty about mounting angle of the "old" inclinometer in 1997 and 1999. Switching to the new criterion provides a standard angle that can be applied to inclinometer data and distance calculations from all three surveys: 1997, 1999, and 2002.

In choosing which angle to pick as a cutoff, the Invertebrate Subcommittee also considered the distance from the manifold jets to the sea floor (Figure C22), and the force of water from the jets, as a function of dredge angle. New field studies to measure these relationships would be useful to get a better understanding of dredge behavior.

The use of sensor data has a major effect on estimated tow distance (Table C9; also see Weinberg et al. 2002b; West and Wallace 2000). Nominal tow distance (i.e., 0.125 nmi) is a hypothetical calculation that assumes towing for exactly 5-min at 1.5 knots. Median doppler estimates for each survey of the distance traveled by the ship during the 5-min tow (0.124 – 0.130 nmi) are similar to the nominal distance. Doppler distances are close to nominal distances because the former measures distance of the ship over ground only during the 5-min, timed tow. Both measures underestimate total distance sampled. Estimates of tow distance derived from the sensor data are longer, and for the three surveys the median distances ranged from 0.20 – 0.25 nmi. Sensor-based distances are longer because they include any fishing that occurs when the dredge is being set out, towed for 5-min and hauled back. The higher value in 1997 was due to use of a slower winch on the *R/V DE-II* in that year. Confidence intervals for the median tow distance of each survey, based on sensors, are given in the bottom of Table C9.

Surfclam mortality caused by clam dredges

The effects of hydraulic clam dredges on clams and the environment have been described in several studies (Table C10). After a dredge passes through an area, some of the clams are run over or blown out of the tow track and not captured. These clams are often injured and may die or get attacked by predators before they reburrow. This is referred to as “indirect” mortality.

Surfclams that are brought to the surface often die when they are discarded, because the shell may be cracked or because the high pressure water from the dredge can cause internal injury. Surfclams are unable to close their shells completely, and dredging forces sand into the gills and mantle cavity. In the 1980s, discarding was common, but reported levels of discarding have been low in recent years.

Efficiency of the Clam Dredge on the R/V *Delaware II*

Field studies were carried out in 1997, 1999 and 2002 to estimate efficiency of the clam dredge. This is an important parameter because it is used in the calculation of stock biomass, and because efficiency may vary between surveys, affecting abundance trend estimates. Four types of data were collected for this purpose: 1) the survey vessel Delaware II resampled fixed stations, in unfished areas, from its earlier surveys, 2) a calibration (“depletion”) experiment was conducted by the DE-II, 3) three calibration experiments by a commercial clam vessel analyzed in conjunction with catches from setup tows made earlier by the DE-II, and 4) stations were sampled by the DE-II in 2002 and repeated by the commercial vessel a couple of months later.

DE-II Resampled Stations from its Earlier Surveys

Approximately 20 fixed stations in the DMV region have been resampled in each survey since 1997 to indicate whether dredge efficiency changed radically between surveys. Commercial fishing was uncommon in these areas. In theory, changes in catch rates between surveys, with adjustments for growth and natural mortality, indicated changes in dredge efficiency. Data collected from resampled stations in 2002 could not be used to check for changes in dredge efficiency because the number of surfclams per tow in 2002 was unexpectedly low, due probably to higher natural mortality associated with elevated water temperatures in the last few years. Fishing mortality was not a factor because reported catches were very low.

Calibration Experiments – Analytical Models

Early studies of clam dredge efficiency (Meyer et al., 1981; Smolovitz and Nulk , 1982), did not obtain reliable estimates of dredge efficiency or for the habitat where the clam survey is carried out. Thus, it has been necessary to carry out new studies in 1997, 1999 and 2002. Results from 1997 and 1999 are described in detail in NEFSC (1998a,c; 1999; 2000a,c).

Calibration or "depletion" field experiments were used to estimate efficiency of the survey dredge. At the most basic level, a depletion study repeatedly samples a closed population in a small area and uses the rate of decline in catch per unit effort to measure population abundance. The total population is estimated from the rate of decline in catch over successive samples and the total quantity caught.

Dr. Paul Rago (NEFSC) extended the model used to estimate surfclam dredge efficiency in 1997 to explicitly consider spatial overlap of tows as a depletion experiment progresses. The extended negative binomial "patch" model (described in NEFSC, 1999 and Rago et al., in press) was applied to the surfclam depletion experiments from 2002. A summary of the fieldwork and final results are given below.

2002 Calibration Experiments – Results

Surfclam depletion experiments were carried out between June and August, 2002 (Figure C23, Table C11). The main purpose of the experiments was to estimate efficiency of the clam dredge on the *R/V Delaware II* (DE-II). Most depletion experiments involved the DE-II and a commercial vessel (*F/V Jersey Girl*), but the DE-II also carried out its own depletion study at a site off the coast of NJ, labeled DE-II in Figure C23. These data provided a "direct" estimate of efficiency for the DE-II. Another type of experiment involved the DE-II making 5 setup tows at a site and then having the commercial clamming vessel, perform a depletion experiment at that site. Comparison of the DE-II surfclam catch (from its set up tows) with the estimate of density and efficiency from the commercial vessel's data set was used to compute an "indirect" estimate of DE-II dredge efficiency. In 2002, three "indirect" estimates of efficiency were obtained in this manner at sites called: sc02-2, sc02-3, and sc02-4. The number of tows made by the commercial vessel at these sites was 16, 20, and 18, respectively.

For each experiment, tracks of the DE-II and commercial vessel are shown (Figures C24-C27). In general, the DE-II setup tows and FV Jersey Girl depletion tows were done at the same general area, as intended (Figures C25-C27).

Because dredge efficiency probably varies with bottom type, bottom characteristics were measured. Two independent sediment samples, from the top 4 cm, were collected from two VanVeen grab samples at each depletion site (Figure C28, Table C11). The most common particle sizes in the samples were 0.25 – 0.5 mm. Some larger particles, >4mm, were also present in some samples.

To analyze the depletion experiments, it was necessary to compare clam density estimates from the two vessels at each site, restricting the calculation to clams fully recruited to both the survey and commercial dredges. Thus, it was necessary to determine the selectivity of the *FV Jersey Girl* relative to *RV DE-II* with respect to surfclam shell length. Data used to examine relative selectivity came from measurements of surfclams from the DE-II setup tows and from every 5th tow of each of the three Jersey Girl depletion experiments. Two additional data sources came from the 9 stations sampled by both vessels in NJ, and the 9 stations sampled by both in DMV. The cumulative size distributions of clams were compared between vessels (Figure C29), and a relative selectivity function was estimated for each site using the model shown in Figure C30. The DE-II was more likely to retain smaller individuals.

Because the goal was to find the size where the vessels had similar selectivity, without eliminating too many of the clams that were measured, we chose as a cutoff the clam size where the relative selectivity of the Jersey Girl was 0.75 that of the DE-II. From the data we obtained 4 estimates of the "0.75 point", and the median of those estimates was 130 mm (Table C12A). All subsequent analyses that were related to gear efficiency and involved data from the FV Jersey Girl excluded clams smaller than 130 mm in length. The fraction of clams ≥130 mm is listed by dataset (Table C12B). Compared with samples from NJ, those from DMV had more small clams.

Rago's model was used to analyze each of the 4 depletion experiments from 2002. The cell size used in the model was twice the width of the dredge, and no indirect losses (clams lost but not counted as part of the catch) were assumed. Model estimates for dredge efficiency and density are listed in Table C13, and profile likelihood confidence intervals for these parameters are shown in Figures C31-C34.

Table C14 demonstrates how model results from the commercial depletions were used along with data from the DE-II setup tows to estimate DE-II efficiency. Efficiency of the Jersey Girl was variable across sites (0.45 – 0.95). The DE-II was never more efficient than the Jersey Girl, but at site sc02-3, both vessels had a dredge efficiency near 45%. The mean of the 3 "indirect" estimates of DE-II efficiency was 0.406. The "direct" estimate of DE-II dredge efficiency was 0.695.

DE-II Stations Resampled by the Jersey Girl, all in 2002
Other information about DE-II dredge efficiency came from comparing the catches at the stations sampled by both vessels in 2002 (Table C15). The 9 stations in DMV were each sampled once by both vessels. The 9 stations in NJ were sampled 3 times by the DE-II (once on each leg of the cruise) and one time by the Jersey Girl. The relative efficiency of the DE-II to the Jersey Girl could be computed from the ratio of the average density (i.e., number of surfclams per square foot) using data on surfclam catch and tow distance from each vessel. It was also possible to compute an absolute efficiency for the DE-II, by assuming that the efficiency of the Jersey Girl at these stations was 0.9. The 90% efficiency applied to the Jersey Girl is the best estimate for the efficiency of that vessel (i.e., calculated as the median of efficiency estimates for that vessel from depletion studies based on data collected since 1997). From this approach, the estimate of DE-II dredge efficiency was 0.187 and 0.236 in DMV and NJ (Table C16).

DE-II Dredge Efficiency Summary
DE-II dredge efficiency estimates for 1997, 1999, and 2002 are listed in Table C17. The annual values range from 0.276 to 0.460. The value for 2002 was intermediate, 0.389. The grand mean from the 15 estimates of DE-II dredge efficiency, collected during these three years, was 0.370 (CV = 0.492).

Survey Results

Description of Surveys
A series of 23 research vessel survey cruises were conducted between 1965 and 2002 to evaluate the distribution, relative abundance and size composition of surf clam and ocean quahog populations in the Middle Atlantic, Southern New England and Georges Bank (Figure C1).

Assessment regions were defined by groups of strata which remain fixed through time (Figure C1). Surveys are performed using a stratified random sampling design, allocating a pre-determined number of tows to each stratum. One tow is collected per station, and nominal tow duration and speed are 5 minutes and 1.5 knots, respectively. Catch in meat weight per tow is computed by applying length-weight equations to numbers caught in each 1 mm size category. Surfclams were measured and weighed during several DE-II clam surveys to determine the shell length meat weight relationship for important regions (see Table C18 for parameter estimates). Values used in the 1999 surfclam stock assessment were an average of fitted curves from the 1997 survey and the earlier relationships reported by Serchuk and Murawski (1980) and Gledhill (1984). Although new data were collected during the 2002 survey (Table C18), due to seasonal and annual variability that is possible in surfclam length-weight, and for consistency, we have assumed the same length/weight relationship as in the previous assessment (NEFSC, 2000a,b).

By computing simple unweighted averages from all tows within a stratum, size frequency distributions per tow were computed by stratum. Size frequency distributions and mean number of clams per tow were computed for each region by averaging over strata, weighted by stratum area.

In surveys conducted prior to 1997, doppler distance was used to standardize every tow's catch to a common tow distance (0.15 n. mi). As described in previous sections, tow distances in the 1997, 1999 and 2002 surveys were standardized by calculating tow distance from ship's velocity (measured by GPS) and contact by the dredge on the bottom as measured by the inclinometer. For the purpose of computing swept area biomass, distance-standardized catches per tow from 1997 - 2002 were computed by multiplying catch at each station by the ratio of (0.15/sensor tow distance). For analysis of trend, catches were standardized by the ratio 0.15/Doppler distance.

Locations of random stations in the 2002 clam survey are shown in Figure C35. Sampling intensity was greater in some areas (e.g. NNJ) because estimation of population abundance via area-swept methods was anticipated (Table C21). Samples were not collected in 2002 from the lower part of the S. Virginia - N. Carolina region, the Great S. Channel just to the west of Georges Bank, or from the NW corner of Georges Bank (Strata 67, 72). This was necessary to allocate enough cruise time for dredge calibration experiments.

In 1999, a new sampling policy was adopted regarding randomly chosen stations with rocky bottom that could not be sampled with the clam dredge without a high risk of severe gear damage. If the bottom was too rocky, pilots were told to search for towable bottom within 0.5 nmi of the station. If the search was unsuccessful, the log sheet for that station was filled out with a special code (SHG = 151), and the vessel moved on to the next random station. In previous surveys, pilots may have searched for good bottom and then taken a tow, even if it was a considerable distance from the original station location, without keeping a record. This procedural change in 1999 is important in providing a better estimate of the area of clam habitat on Georges Bank (NEFSC 1998a,c). In the current assessment, nominal individual stratum areas on Georges Bank were reduced in proportion to the fraction of tows from GBK that had been assigned code 151 (Table C21). The effect of this was to reduce the biomass estimate.

Spatial Distribution of Survey Catches

Clam abundance per tow data from the 2002 survey were partitioned into three size classes: small (1-87 mm), medium (88-119 mm), and large (≥ 120 mm). Detailed distribution data by size class are plotted in Figures C36 - C41. These catches were standardized to a tow distance of

0.15nmi (using tow distances from the SSP sensor and a 5.2° critical dredge angle). On a large spatial scale, surfclams were found primarily on shallow or inshore locations (typically ≤25 fathoms, or 45 m) on Georges Bank, S. New England, New Jersey and Delmarva. The largest patch of surfclams occurred off NJ. "Submergence" (i.e., species distribution shifted to deeper, cooler water) is evident at the southern extreme of the range (Figure C36).

Another series of maps shows the unadjusted catch per tow in number of surfclams (≥88mm) over time, from 1982 to 2002 (Figures C42 - C47). The purpose of these maps is to show trends in surfclam distribution. While surfclams have occupied the same general locations throughout the entire period, there appears to have been a reduction in clam abundance in shallow water in DMV, close to 37° N (Figure C44). This conclusion is supported by Table 20, which summarizes a presence/absence analysis of survey data from Stratum #9 (Figure C1), historically a primary surfclam stratum in DMV. The fraction of random stations in Stratum #9 that captured zero surfclams increased from about 13% in 1997 to about 39% in 2002 (Table C20).

Age-Structure based on Survey Data

During clam surveys, surfclam shells of live individuals are saved from every station for aging. Age estimation in the laboratory is based on annual lines in the shell. The data are used to compute age-length keys for each year/region combination. Keys were applied to survey length frequency distributions to infer age-structure in the population (Figure C48). Distinct cohorts are detectable in the figure for two regions (NJ, DMV) which have similar patterns. To interpret the data, note that the youngest age that is retained consistently by the NMFS survey dredge is about age 4 yr. A cohort of 5-yr olds is evident in data from 1997; another new cohort of 3-4 yr olds is evident in the data from 2002. Populations in NJ and DMV both consist of over 20 cohorts, and younger clams are more common than older clams. The maximum age observed in samples from 2002 was 28 yr old (born about 1978).

Trends in Numbers and Biomass, based on Survey Data

Numbers and biomass of surfclams per tow, standardized to a distance of 0.15 nmi using Doppler distances, are shown from 1978 – 2002 (Figures C49-C55). The data have been separated into two size groups and by region. The "88-119 mm" group can loosely be considered as clams that will recruit to the fishery in the coming year or two. The "120+mm" group can be considered as fully-recruited to the fishery.

These plots are useful for examining trends over time and for noting which regions have the most surfclams. Note that the data collected before 1980 must be interpreted cautiously because the sampling gear changed (Table C6). Also, the data from 1994 were collected using a higher voltage to the pump (Table C7), which probably increased differential pressure, dredge efficiency and catch in that year (NEFSC, 2000a,c).

In NNJ (Figure C52), catch per tow of 120+mm clams increased from 1978 to 1997, but has since declined in 1999 and 2002 to an intermediate level for the time series. The number and weight of 88-119 mm clams had peaks in the early 1980s and perhaps (see cautions above regarding 1994 data) the mid-1990s. The most recent values (1999, 2002) for the 88-119 mm clams are near the historical low for this time series. Therefore, recruitment in the next few years is expected to be below average in NNJ.

In DMV (Figure C50) catch per tow of 120+mm clams increased from 1978 to 1997, but has since declined in 1999 and 2002 to a relatively low level for the time series. The number and weight of 88-119 mm clams had peaks in the early 1980s and perhaps (see cautions above regarding 1994 data) the mid-1990s. The most recent values (1999, 2002) for the 88-119 mm clams are near the historical lows for this time series. Therefore, recruitment in the next few years is expected to be below average in DMV.

In both SNJ (Figure C51) and GBK (Figure C55), abundance of 120+mm clams appears to have increased over time.

MODELS TO ESTIMATE BIOMASS AND MORTALITY

Following NEFSC (2000a), stock biomass and mortality for surfclams in each region were estimated using efficiency-corrected swept area biomass (ESB) information. As in NEFSC (2000a,b), the KLAMZ delay-difference stock assessment model (Appendix A) was also used for surfclams in several stock assessment areas. ESB estimates are used for status determination. KLAMZ estimates show historical trends for two of the most important stock assessment regions. ESB and KLAMZ estimates for recent years tend to agree because ESB information is used in tuning the KLAMZ model. The natural mortality rate used in all calculations was 0.15 y^{-1}.

Efficiency-corrected swept area biomass (ESB)

Efficiency corrected swept-area biomass estimates (Table C21) for surfclams (120+ mm in SNJ and NNJ; 100+ mm in other areas) were calculated:

$$B = \frac{\overline{C}A'}{ae} * 10^{-6}$$

where e is the best estimate of survey-specific dredge efficiency for surfclams in the region (Table C17), C is mean catch per standard tow (kg tow^{-1}, see below for standardization details), A' is habitat area (nm^2), a= 0.0008225d_n nm^2 tow^{-1} is the area covered by the 5' wide survey dredge during a standard tow of nominal distance (d_n =0.15 nm), and the factor 10^{-6} converts kilograms to thousand metric tons. Port samples from commercial catches show that surfclams begin recruiting to the commercial fishery at about 120 mm in length in NNJ and SNJ, and at about 100 mm in other areas (Figures C16 and C17). Thus ESB estimates for clam sizes ≥120 or ≥100 mm are crude estimates of the fishable stock.

Habitat area for surfclams in the region was estimated:

$$A' = Au$$

where $\underline{u}$ is the proportion of random tows in the region not precluded by rocky or rough ground (surfclams occupy smooth sandy habitats, NEFSC 2000a), and A is the total area computed by summing GIS area estimates for each survey stratum in the region. Mean catch per standard tow ($\overline{C}$) is the stratified mean catch in individual tows (C_i), after adjustment to nominal tow distance based on an estimate of the actual tow distance from sensor data (d_s):

$$C_i = \frac{c_i d_n}{d_s}$$

where c_i is the original, unadjusted catch in tow i. In the cases where sensor data were absent, the median tow distance from that survey/stratum combination was assumed.

ESB for the entire surfclam stock (for clams 120+mm in NNJ and SNJ and 100+mm in other areas) during 1997-2002 (Table C21) was computed by adding estimates for individual regions. However, whole stock estimates are difficult to interpret because of unsampled strata, particularly in the GBK and SVA regions, which could not be filled by borrowing data from earlier or subsequent surveys (Table C19). In addition, dredge efficiency changed during 1997-2002 (Table C21) and borrowed records were not adjusted for changes in dredge efficiency in the database during borrowing.

For consistency in comparing the commercial catch with survey biomass, length-weight parameters used to calculate survey weight per tow for ESB calculations (Table C21) were the same as in NEFSC (2000a). Length-weight data for the 2002 survey data indicate that average meat weights have declined in some regions (Table C18). Survey catch weights and ESB estimates were not adjusted for declines in meat weights, however, because commercial catch weight estimates could not be adjusted, and because meat weights vary between seasons and years.

Efficiency corrected swept area biomass (ESB) values and 80% confidence intervals from NMFS survey data are given for 1997, 1999, and 2002 in Table C21. The ESB estimates for 1997 and 1999 have been revised from the last assessment (NEFSC 2000a,b). Changes made in the calculation include: 1) a new algorithm to borrow data from adjacent surveys to fill holes, 2) use of more accurate estimates of stratum area, 3) a new efficiency estimate for 1997, based on updated information, and 4) revised tow distances for 1997 and 1999 based on critical dredge angle of 5.2°.

Taking into account the confidence intervals (CI) in Table C21, total fishable biomass was fairly constant from 1997 (1,146,000 mt) to 1999 (1,460,000 mt), but declined in 2002 (803,000 mt). The region with the greatest fishable biomass in all three of the latest surveys was NNJ. The point estimate for biomass in NNJ has declined from about 486,000 mt in 1997-1999 to 315,000 mt in 2002. However, the point estimate from the 2002 survey is within the 80% CIs from the two previous surveys (1997 and 1999). A stronger decline in fishable biomass was detected in DMV. Estimates of total fishable biomass without GBK are 915,000 mt in 1997, 1,075,000 in 1999, and 566,000 mt in 2002.

Annual Fishing Mortality Rates (F) based on Catch and ESB

Fishing mortality rates during 1997, 1999 and 2002 were estimated directly from the ratio of catch (landings plus an assumed incidental mortality adjustment) and ESB values for each region in each year (Table C22). The F estimates for total fishable biomass ranged from about 0.018 y^{-1} in 1997-1999, to 0.033 y^{-1} in 2002.. In 2002, the 80% CI for F on total fishable biomass was (0.022, 0.049). In NNJ, which accounts for the greatest amount of reported landings, F was estimated to be 0.032 y^{-1} in 1997, 0.037 y^{-1} in 1999, and 0.053 y^{-1} in 2002. F estimates in DMV rose from about 0.009 y^{-1} in 1997-1999, to 0.035 y^{-1} in 2002. F's in SNJ have been variable, ranging from 0.011 to 0.107 y^{-1}. In LI, F recently rose to 0.111 y^{-1}.

Uncertainty in ESB and catch-ESB ratios

The variance of ESB estimates was important in tuning the KLAMZ model and in interpreting mortality estimates from catch and ESB data (Tables C21and C22). CV's for original survey densities (c_i) in ESB variance calculations were computed in the clam survey database using standard formulas for stratified random means. The CV for dredge efficiency (*e*) was from the mean and standard deviation of all efficiency estimates for surfclam during 1997-2002 (Table C17). For lack of better information, CVs for sensor tow distances (d_s), area swept per standard tow (*a*), total area of region (*A*), percent suitable habitat (*u*), and catch were all assumed to be 10%. The CV for area swept in a standard tow is understood to include variance due to Doppler distance measurements and variability in fishing power during the tow due, for example, to rocky or muddy ground.

Uncertainty in ESB and catch-ESB ratio estimates for each region and survey, and for the stock as a whole, was measured by CV's calculated using a formula for independent lognormal random variables in products and ratios (Demming 1960):

$$CV\left(\frac{ab}{c}\right)=\sqrt{CV^2(a)+CV^2(b)+CV^2(c)}$$

The accuracy of Demming's formula for ESB estimates was checked by parametric bootstrap analysis (8000 iterations) that assumed all variables in ESB calculations were from independent lognormal distributions. CV's by the two methods were similar as long as variables were assumed to follow a lognormal distribution. However, the skewed and apparently lognormal distribution of parametric bootstrap estimates was useful in gauging shape of uncertainty about ESB biomass estimates and catch-ESB fishing mortality estimates (Figure C56).

Survey data used in KLAMZ modeling

Survey trend indices for surfclam (Table C23) used in the KLAMZ model were mean meat weights (kg) per tow during 1978-2002 adjusted to an arbitrary standard tow distance of 0.15 nm (see below). Data for surveys prior to 1980 require care in interpretation (see below) because early surveys used different survey gear or were carried out during the winter (Table C6). Trend indices used data for random and nearly random "fill" tows (database RANDLIKE code 1 or 2, Table C24). Data for surveys beginning in 1982 were for tows with database codes 1 ≤ HAUL ≤ 3 and 1 ≤ STATYPE ≤ 6. Survey data for 1978-1981 did not use these criteria because HAULTYPE and STATYPE data were not recorded (Table C24).

Following NEFSC (2000a), survey data for 1994 were omitted from modeling because of anomalously high catches, probably due to the voltage used to power the submersible pump on the dredge (480 v instead of 460 v). As described in NEFSC (2000a), survey data for 1979 were not used in modeling and survey data in modeling for 1978 and 1980 were averages for two surveys during each year. As described below, the influence of survey data for 1978 and 1980 on stock biomass estimates was minimized in modeling through use of survey covariates. The main purpose of including data for 1978 and 1980 was to estimate changes in gear efficiency that may have occurred as the current survey gear was phased in.

Survey trend information used in the KLAMZ model were for "prerecruits" (ages k-1 to k, where k is the age at recruitment), "new recruits" (ages k to k+1) and "old recruits" (ages k+1 and older). In modeling, the pre-recruit index was shifted forward one year and used as an additional recruitment index. For example, the pre-recruit index for 1986 was used as an index of recruitment in 1987, when no survey was actually conducted.

For each area, the age at recruitment (k) was estimated based on fishery length composition data and von Bertalanffy growth curves in NEFSC (2000a). Taking k as the age at either 100 or 120 mm, growth curves in NEFSC (2000a) were used to calculate lengths at ages k-1, k and k+1 (Table C25). The predicted lengths for each region define upper and lower length bounds for pre-, new- and old recruits and were used to aggregate survey data for use in the KLAMZ model. For example, the prerecruit index for NNJ and SNJ was for clams 107-119 mm, the recruit index was for clams 120-129 mm and the old recruit index was for clams 130+ mm (Tables C24 and C25).

Doppler tow distance measurements were used to adjust survey data to a nominal distance of 0.15 nm for trend calculations (Table C24) using $D=C*N/d_d$ where D is the standardized catch for one tow, C is the unadjusted meat weight for the tow, n is the nominal tow distance, and d_d was the tow distance estimated by Doppler measurements. For a few tows with no Doppler data, the nominal tow distance was used instead.

Length-weight parameters used by NEFSC (2000a) for swept area biomass calculations were used in this assessment for swept area biomass and to calculate trends in weight per tow from numbers at length (database code REV_DATE_FOR_LW= 1999, Table C24). NEFSC (2000a) used an older set of length weight parameters for trends based on frozen, rather than fresh, samples (REV_DATE_FOR_LW = 0). However, choice of length weight parameters has little effect on estimated trends.

Where possible, "holes" in the survey data (strata not sampled during a survey, Table C19) were filled by borrowing (using data from the previous and or subsequent survey). Borrowing was in both directions. Adjacent holes (same strata during adjacent surveys) and holes in the first or most recent surveys, for example, could not be filled in both directions. In addition, holes in the middle of a string of three or more holes could not be filled.

"Zeros" can be used in stock assessment models (e.g. Butler et al. 2003) but the KLAMZ model has not yet been programmed to accommodate them. Therefore, a few zero values in survey trend data for surfclam were omitted.

Survey trend data in this assessment were extracted from a database that was not available for the previous surfclam assessment. The new database (also used for ocean quahog in NEFSC 2000c), was tested extensively by independent calculations and by comparison to results for surfclam in the last assessment (Table C24).

In the absence of a flexible database, NEFSC (2000a) used survey data for surfclam aggregated by predefined 10 mm size groups and it was necessary to use survey trend data for both numbers and weight per tow in tuning the KLAMZ biomass dynamic model. In particular, NEFSC (2000a) used survey data for pre-recruits (mean numbers per tow for surfclam 80-99 or 100-119 mm), recruits (mean numbers per tow for surfclam 100-109 or 120-129 mm) and all size groups (mean kg per tow for all size groups) rather than the more precisely defined groups used in this assessment. Holes in the survey trend data used by NEFSC (2000a) were not filled. These factors, and other small differences in calculation of survey indices, result in survey data and KLAMZ model biomass that have different values and trends than in the last assessment (see below).

Somatic growth in modeling

The KLAMZ model assumes von Bertalanffy growth in weight for biomass dynamic calculations. In the model, the growth parameter $\rho=e^K$ (where K is the von Bertalanffy growth parameter for weight) is constant but the growth parameters $J_t= w_{k-1}/w_k$, (where w_j is predicted weight at age j) can vary over time. Growth parameters used in this assessment were the same as in NEFSC (2000a). J_t values varied over time for the NNJ, SNJ and DMV areas (Table C26).

Catch and LPUE in the KLAMZ model

Total catch for surfclam in modeling included landings plus discards for 1982-1992 (Table D4 in NEFSC 1995). Discards were probably close to zero after 1992.

In modeling and mortality estimation, fishery induced mortality was estimated based on landings plus discard plus a 12% upper bound incidental mortality adjustment. The incidental mortality adjustment accounts for clams that are damaged by clam dredge during fishing, but never handled on deck. NEFSC (2000a) used an incidental mortality adjustment of 20%. The adjustment used in this assessment (12%) is a new upper bound estimate based on information about commercial dredge efficiency and published mortality studies. The average efficiency of commercial clam dredges in fourteen depletion studies carried out during 1997- 2002 was 75%. Based on published indirect and discard mortality estimates (Table C10) indirect mortality due to contact with a clam dredge is in the range 5-20% with 50% as an extreme upper bound. Using this information, the upper bound incidental mortality adjustment was estimated as 0.5*(1-0.75)=0.12.

Tuning and likelihood calculations in the KLAMZ model

CV's for survey index data were used in calculating goodness of fit to trend data in the KLAMZ model. The alternative internal weighting approach based on residual variance (Appendix B) was not used because CVs likely measure relative precision of indices derived from the same survey.

ESB data were used in the KLAMZ model to estimate scale (absolute biomass level) but not trend. ESB data were not used to estimate trend because other survey data in the model contain nearly the same information. Tuning the KLAMZ model to scale information in ESB data assumed that estimates of the survey scaling parameter for ESB data (Q_{ESB}) were from a prior distribution (Appendix A) assumed to be lognormal with arithmetic mean equal one and arithmetic CV=49%. The arithmetic CV was converted to a lognormal standard deviation using $\sigma^2 = \ln\left(CV^2 + 1\right)$.

Catch data were assumed to be accurate in KLAMZ model runs for surfclam. This means that the fishing mortality rates and biomass levels estimated in the model produce catch levels exactly equal to the catch data.

In contrast to NEFSC (2000a), standardized LPUE data were not used to tune the KLAMZ model. Trends in LPUE over the last decade were decreasing, while trends in survey data and estimated stock biomass were ususually increasing. For NNJ, it was not possible to reconcile the divergent trends in the KLAMZ model for this assessment, even assuming a nonlinear relationship between LPUE and stock biomass. The commercial fishery concentrates on dense beds whereas the survey collects samples from random locations within strata. It is likely that declining trends in LPUE represent fishing down of dense beds, whereas the survey is measuring stock as a whole. Future stock assessment models for surfclam should include the ability to model fishing down of large surfclam in dense beds so that LPUE data can be incorporated in the assessment model. Trends in LPUE are important information, even though they were not used to tune the KLAMZ model.

Instantaneous growth rates

An assumed level of variance in instantaneous rates of somatic growth (IGR) for age groups in the old recruit category is used in the KLAMZ model to estimate the initial age structure of the stock in the first model year and estimates of escapement biomass and recruitment for the early years (Appendix A). For surfclam, IGR values during 1978-1979 were constrained using a lognormal distribution with arithmetic mean equal to the estimated IGR for 1980 (G_{1980}^{Old}) and an arithmetic CV for years 1981-2002 estimated in a preliminary run. Assumptions about IGR levels in early years affect biomass and recruitment estimates for the earliest years primarily.

<u>Recruitment modeling in KLAMZ</u>

Following NEFSC 2000, surfclam recruitments were estimated assuming a "random walk" recruitment process (Appendix A). In effect, the random walk recruitment approach keeps the recruitment estimate in year *t*, the same as in year *t*-1, unless there is good reason, in terms of goodness of fit, to change it. Random walk recruitment estimates tend to be relatively smooth with runs of consecutive recruitments that are higher or lower than average and with at least some recruitment in every year. The random walk recruitment assumption might be perfectly appropriate for a stock with reproductive success that is similar from year to year (autocorrelated) or for a stock that recruits to the fishery over a wide range of ages (so that recruitment to the fishery is a smooth weighted average of yearclasses from many years). For surfclam, however, the random walk recruitment approach was used primarily to fill gaps with no survey data, to avoid excessive variance in recruitment estimates, and ensuring that some recruitment was estimated to occur in all years. Highly variable random recruitment patterns with almost no recruitment in some years often result when survey data are limited (Jacobson et al. 1994) but seemed unreasonable because survey age composition indicated that surfclam recruitment levels are not highly variable from year to year.

Quantifying the variability in recruitment around the underlying recruitment model was an issue in modeling for surfclam. In this context, the "*random walk recruitment variance*" σ_r^2 is the variance in sequential log scale steps in the random walk recruitment process (Appendix A). For example, if the recruitment estimates were $\{R_1, R_2, R_3, R_4\}$, then the random walk recruitment variance would be the variance of $\{\ln(R_1/R_2), \ln(R_2/R_3), \ln(R_4/R_3)\}$. In contrast, the "*variance of log scale recruitments*" would be the variance of $\{\ln(R_1), \ln(R_2), \ln(R_3)$ and $\ln(R_4)\}$. The random walk recruitment variance and variance of log scale recruitments are both measures of recruitment variability and can both be computed for any set of recruitment estimates, although the former will generally be smaller than the latter. The two types of variances are similar to the extent that smaller values for either imply smoother time series of estimate recruitment. In particular, as random walk recruitment variance increases, recruitment estimates tend to become noisy (random). As random walk recruitment variance approaches zero, recruitment estimates approach a constant value.

Variability in recruitment estimates affects estimates of *F*, biomass, etc. from the KLAMZ model. Preliminary results from this assessment (not shown) indicate that model results may be biased if an inappropriate fixed level of recruitment variability is assumed. Ideally, recruitment variance is not fixed but instead estimated along with other parameters as the model is fit to all of the available data. However, it may be necessary to assume a fixed level of recruitment variability when data are limited. For example, NEFSC (2000a) assumed that the random walk recruitment variance was σ_r^2=0.2^2=0.04 for surfclam in all regions because survey index data for prerecruits and new recruits were not available for many years and noisy. Based on residual patterns, NEFSC (2000a) commented that a higher level or random walk recruitment variance might have been used instead to achieve better fit to survey data for the late 1970s and early 1980s. In this assessment, survey data for early years are treated differently (with survey covariates, see above) so than a higher level of random walk recruitment variance may not be necessary. In NEFSC (2000a), assumptions about recruitment variance had relatively little effect on recent biomass or fishing mortality estimates, but effects on estimates for other years were not evaluated.

Based on NEFSC (2000a), we estimated the random walk recruitment variance based on a log normal prior (Appendix A). In preliminary runs, the mean for the log normal prior was $\ln(\sigma_r^2)$=ln(0.2^2) and the standard deviation was 1. Decisions about the level of recruitment variability (fixed or estimated) in final runs were based on goodness of fit, patterns in time series of recruitment estimates and bootstrap estimates of model bias.

DMV (KLAMZ model results)

Based on preliminary runs, the CV for old recruit IGR was about 41%. Variance for the random walk recruitment model was estimated internally around a lognormal prior with mean $\ln(0.2^2)$ and log scale standard deviation equal 1.

There were no pathological patterns in residual plots (Figure C57). As in runs for all other areas (not shown), changes in survey scaling parameters (*Q*) between 1980 and 1981 were larger for pre- and new recruits, than for old recruits (Figure C57). The scaling parameter estimate for ESB data was 0.84, suggesting that ESB data were about 16% too low. Mean CVs for survey data and CV for surveys based on goodness of fit were similar for old recruits and new recruits, but not for prerecruits suggesting that the model did include enough process error for prerecruits (see below). Bootstrap runs showed that biomass estimates for DMV surfclam were reasonably precise and not biased (Table C27 and Figure C58).

Run summary	DMV		
Q_{ESB}	0.84	Mean 1999-2002 Biomass	289
		Mean 1999-2002 F	0.01
Survey CVs	Prerecruits	New Recruits	Old Recruits
Mean data CV	0.48	0.50	0.28
Goodness of fit CV	1.07	0.41	0.31

(dmvfinal1.out)

As described above, there were a number of changes to survey and ESB data (Figure C62) for surfclam used in this assessment and to the assessment model (e.g. changes in treatment of the 1978-1980 survey data). In DMV surfclam, these changes resulted in different trends in estimated recruitment and biomass (Figure C62). Changes were due primarily to using survey covariates to break the NEFSC clam survey time series into two parts between 1980 and 1981 (see above). Estimated trends changed because the model did not have to scale survey data for 1978-1980 to biomass in the same way as survey data for 1981-2002. This result, which was more pronounced in results (not shown) for other regions, highlights uncertainty in long term trends and the importance of ESB data, which measure biomass directly, in surfclam stock assessments.

DMV Sensitivity analyses

There was no evidence of retrospective bias in KLAMZ estimates for surfclam in DMV (Figure C59). However, time series of biomass, recruitment and F estimates were somewhat sensitive to omitting ESB estimates in 1997, 1999 and 2002. In addition, biomass estimates because implausibly high when 1996 was the terminal year and all ESB estimates were omitted. The time series of survey and catch data for surfclam in DMV do not contain enough information to estimate biomass in the absence of ESB estimates.

A series of sensitivity runs were used to determine the sensitivity of model results to the prior for random walk recruitment variance. Model runs for DMV surfclam with priors for random walk recruitment variance ranging from $\sigma_r^2=0.1^2$ to 0.5^2 and standard deviation equal 1 showed that model estimates were very robust to choice of mean for the prior because biomass estimates were almost unchanged (Figure C60). In contrast to models for most other regions (not shown), data for surfclam in DMV seem to contain information about variability in recruitment.

The variance of log scale recruitments was 0.19 in the basecase run with random walk recruitment variance $\sigma_r^2=0.2^2$. Sensitivity to the assumption of a random walk recruitment model instead of an uncorrelated random recruitment model was evaluated in a sensitivity run using random uncorrelated recruitment and a lognormal prior for the variance of log scale recruitments with mean 0.19 and standard deviation 1 (Appendix B). Results showed that biomass estimates were not sensitive to choice of the underlying recruitment model (Figure C60). However, as expected estimated recruitment time series were smoother and less variable using the random walk recruitment assumption (Figure C61).

NNJ (KLAMZ model results)

KLAMZ model results shown for NNJ are for documentation only because KLAMZ model estimates were not reliable enough for use by managers. In the absence of model results, ESB estimates provide the best available information about recent biomass and fishing mortality in NNJ.

Problems with model estimates for NNJ were not as severe as for SNJ and LI (see below) but were probably due to the same general problems. The first general problem was a tendency for pathological patterns in survey residual plots due to incompatible trends in indices for pre- and new recruits, relative to trends for old recruits. In particular, peaks in pre- and new recruit survey data during the 1980s are not reflected in trends for old recruits during subsequent years. (Figure C63) The second general problem was bias in model estimates demonstrated by bootstrap results. Experience suggests that the bias was probably due to lack of fit to survey data. Lack of fit to survey data might be due to noise in surveys, substantial changes in survey selectivity or scaling parameters over time, higher fishing or natural mortality on young surfclams during the 1980s (so that they didn't survive to be old recruits), or to other problems.

Preliminary results for NNJ (Figure C64) indicated a CV for old recruit IGR of about 24%. The standard deviation for recruitment variability (σ_r) in the final run for NNJ was estimated internally around a lognormal prior with mean $\ln(0.2^2)$ and log scale standard deviation of 1. Changes in survey scaling parameters (Q) between 1980 and 1981 were larger for pre- and new recruits, than for old recruits (Figure C64). Mean CVs for survey data and CV for surveys based on goodness of fit were similar for old recruits (see below) suggesting that the model's estimates of process error relative to measurement error in the old recruit survey data were about right. For pre- and new recruits, however, goodness of fit CVs were larger, suggesting that the model did not include enough process error.

Run summary	NNJ		
Q_{ESB}	1.20	Mean 1999-2002 Biomass	343
		Mean 1999-2002 F	0.05
Survey CVs	Prerecruits	New Recruits	Old Recruits
Mean data CV	0.39	0.34	0.23
Goodness of fit CV	0.74	0.52	0.23

SNJ, LI, SNE, GBK and SVA regions (KLAMZ model)

A large number of model configurations were tried for surfclam in the SNJ and LI areas, but KLAMZ model results were not sufficiently reliable for use by managers. Problems were similar to problems described above for NNJ and seemed to stem from incompatible trends in survey data for pre- and new recruits, in comparison to survey data for old recruits. The KLAMZ model was not used for surfclam in the SNE area due to lack of time. Survey data for the GBK and SVA areas (Table C19) were too incomplete, even after filling holes (Table C23). In the absence of model estimates, the best available information about biomass is efficiency corrected swept area biomass (ESB) for recent years.

STOCK STATUS RELATIVE TO CURRENT REFERENCE POINTS

Target biomass (a B_{MSY} proxy) for the entire surfclam stock is (½)B_{1999} . In SARC-30 (NEFSC, 2000a), B_{1999} was estimated at 1,596 thousand mt, based on efficiency corrected swept area biomass (ESB), and at 1,268 thousand mt, based on the KLAMZ model. In the present assessment, B_{1999} was updated to be 1,460 thousand mt, based on ESB. Thus, the updated estimate of target biomass is 730 thousand mt.

Based on efficiency-corrected swept area biomass (ESB) calculations, the entire stock consisted of 803 thousand mt in 2002, with an 80% confidence interval from 542 thousand mt to 1,188 thousand mt (Table C21). Based on these estimates, the stock is not overfished. The stock is much closer to the target biomass than it was in 1999.

The fishing mortality threshold is F=M, and M was estimated at 0.15 (NEFSC, 2000a). The estimated F in 2002 for the entire stock was 0.033, with an 80% CI of 0.022 to 0.050 (Table C22). Based on these estimates, overfishing is not occurring.

SHORT-TERM STOCK PROJECTIONS

Projections in this section depict potential trends assuming maximum (near status-quo) catch and consistently low surplus production rates during 2002-2005. Results are feasible, but possibly pessimistic, because surplus production rates may increase during 2002-2005. Low surplus production rates during recent years (1997-2002) were due to low recruitment (indicated by recent survey data, Table C23) and high natural mortality (indicated by loss of surfclam from traditional DMV shallow water habitats). In addition, recent surplus production was further reduced by low meat weights (Table C18), although this was not included in projection analysis.

The future is uncertain, but surplus production may be low during 2002-2005 because surplus production rates tend to be autocorrelated for surfclam with runs of positive or negative values lasting 5-10 years (Figures C57 and C64) and because prerecruit clam survey data (Table C23 and Figures C49 – C52) indicate that recruitment will be poor during 2003. Years with negative surplus production are natural events that occur more frequently in lightly or unfished stocks like surfclam (otherwise unfished stocks would grow indefinitely), and the frequency of years with negative surplus production varies by stock and species (Jacobson et al. 2001). NEFSC (2000a,b) concluded that the surfclam stock was at a relatively high biomass level during 1997-1999 so declines should probably have been expected.

Traditional projection calculations were not feasible for surfclam because biomass, recruitment and F estimates for recent years were not available for most regions. Instead, efficiency corrected swept area biomass (ESB) estimates, annual instantaneous rates for fishing mortality (F_t) and surplus production (ρ_t) were used in the simple biomass dynamic model:

$$B_{t+1} = B_t e^{\rho - F_t}$$

Based on this model, projected catch for a specified level of F_t can be calculated using a modified catch equation:

$$C_t = -\frac{F_t\left(1 - e^{\rho - F_t}\right)B_t}{\rho - F_t}$$

If catch is known, then the modified catch equation can be solved numerically for F_t.

A regression line (Figure C65) fit to efficiency corrected swept area biomass estimates to smooth the data and reduce measurement errors (Table C21), indicates that stock biomass (all areas) was about 921 thousand mt during 2002, averaged about 1,136 thousand mt during 1997-2002 and declined, on average, by 81 thousand mt per year during the same period. During the same period, catch (landings plus a 12% maximum adjustment for incidental mortality) averaged 24 thousand mt per year. These figures imply that surplus production for the stock as a whole was negative during 1997-2002 and averaged about P_t = -81 + 24= -57 thousand mt y^{-1}. The average instantaneous surplus production rate for the whole stock was $\rho = \ln\left[\left(B_t + P_t\right)/B_t\right] = \ln\left[\left(1136 - 57\right)/1136\right] = -0.051\ y^{-1}$ (Jacobson et al. 2002; Jacobson et al. 2001). Thus, recent trends are uncertain, but it appears surfclam biomass may have declined during 1997-2002 by about -5.1% per year on average in the absence of fishing.

Stock projections were used to illustrate potential effects of harvesting the entire surfclam quota (28.068 thousand mt removed based on the 25.061 thousand mt y^{-1} quota plus a 12% maximum adjustment for incidental mortality) during 2003-2005, assuming constant surplus production rates of $P_t = -0.051$ in all regions. For comparison, average catch during 2002 (landings plus 12%) was 26.294 thousand mt. Projections for each region were summed to obtain projected values for the entire stock. The sum is important because overfishing is judged for the stock as a whole. The regional values are important because most of the catch is taken from three areas (NNJ, SNJ and DMV).

Biomass in each region during 2002 for projection calculations was approximated based on average ESB estimates for 1997-2002. For example, NNJ accounted for 38% of average biomass during 1997-2002 in the whole stock (Table C28) so biomass in NNJ during 2002 for projection calculations was 0.38 x 921=348 thousand mt. Similarly, catch from NNJ averaged 69% 0f the total during 1997-2002 (Table C28) and the catch used in projections for NNJ during 2003-2005 (including the quota and a 12% maximum adjustment for incidental mortality) was 0.69 x 28.068= 19.5 thousand mt.

Results suggest that total stock biomass may decline by about –29% to 656 thousand mt in 2006 if the entire quota is taken and surplus production remains consistently negative during the next three years (Table C28). For comparison, the target biomass (a B_{MSY} proxy) for the surfclam stock is 617 thousand mt and the biomass threshold used to identify overfished stock conditions is 309 thousand mt. Declines may range from –26% to –40% for the NNJ, SNJ and DMV regions where most of the catch is taken. Based on these calculations, the relatively lightly fished surfclam stock can experience a significant drop in biomass during relatively short periods of negative surplus production due to poor recruitment, low meat weights, poor growth or increased natural mortality.

RESEARCH RECOMMENDATIONS

Modeling

- Consider using year- and region-specific or episodic natural mortality rates. The natural mortality rate of surfclams assumed in this assessment was 0.15 y^{-1}. The estimate is reasonable as an average based on age data and longevity (NEFSC 2000a). However, based on mass mortality during 1976 off New Jersey and evidence in this assessment of increased natural mortality during recent years off Delmarva, natural mortality rates probably vary over time and among areas.

- Try to develop a forward-casting age-structured numbers-based stock assessment model. A model based on numbers of clams, rather than biomass, would probably be the best approach because there are fewer restrictions on assumptions regarding growth. It would be advantageous to structure the model so that fishery and survey length composition data could be used in tuning.

- Reconcile survey trends for pre- and new-recruits, relative to trends in survey data for old recruits. Preliminary work for this assessment (not shown) showed that models with time dependent survey scaling parameters (Q), models that estimated surfclam "catches" during the 1980s (allowing for additional discard), and models that assume higher natural mortality rates during the 1980s may be useful.

- Reconcile survey data with the consistently declining trends in LPUE during the last decade. This may require a model that accommodates scenarios with the commercial fishery targeting large clams in dense beds. It may also be necessary to model productive areas with commercial concentrations of surfclam separately from areas that are less productive, support lower surfclam densities, and are seldom fished.

- Focus on analysis of declining LPUE trends and examine new approaches for describing fishing power among commercial clamming vessels.

Commercial Catch

- Collect age and length composition data on an annual basis from commercial catches to monitor and better predict recruitment and to support the age-structured stock assessment model. Survey data about recruitment are useful but tend to be noisy and are not available every year.

- Reexamine traditional coefficients used to convert commercial catches in bushels to meat weights, and determine number of clams per bushel. Collect data on meat yield and spawning condition.

Research Surveys

- Consider using a sensor that tracks dredge position for use during depletion studies. This would likely provide better estimates of dredge efficiency. Also, give additional consideration to winch speed and distance of dredge nozzles from the bottom to better estimate tow distance and dredge efficiency.

- Survey more frequently than every three years in critical areas such as off DMV, where natural mortality may have increased, and off NJ, where future recruitment is uncertain and likely to be below average. This could be accomplished via cooperative research with industry, assuming the data collected in that manner are of high quality and acceptable for stock assessment work.

- Select a new set of fixed stations in unfished areas to monitor dredge efficiency changes between surveys.

- Consider new technological methods to be used during surveys that rely less heavily on estimating dredge efficiency.

- Consider new methods to estimate variability in the spatial distribution of biomass (e.g., kriging).

Other

- Continue to bring outside experts to working meetings of the Invertebrate subcommittee (see Appendix B).

SARC COMMENTS

The SARC discussed whether apparent declines in abundance might be due to or confounded with over-estimation of dredge efficiency. There was some concern that the use of annual estimates (being the mean of estimates obtained within each year) was not justified given their estimated precision. The use of a single efficiency estimate would change the trend of the 1997, 1999, and 2002 indices but would not substantially alter the absolute estimate in 2002. The SARC accepted the efficiency estimates for 1997, 1999, and 2002. The estimates were uncertain but the uncertainty was adequately addressed in the assessment.

The projections presented in this assessment are illustrative of potential trends, if production rates are negative over the short term, and should be viewed with caution.

The SARC discussed potential causes for apparent reductions in biomass production in recent years. Some of these factors include reduced condition factors, increases in M and below average recruitment. Trends in some of these factors may be confounded with variation in survey data, and thus a series of research recommendations to evaluate such factors were proposed.

In the discussion of the KLAMZ model results it was suggested that the basis for rejecting the model results was not well founded. One of the main arguments for rejecting model results was that bootstrap estimates revealed bad estimation bias. It was pointed out that the bias was only established at a single point in the parameter space (i.e., the estimate) and that much more extensive simulations were needed to establish whether the estimator performed well or not. There was no general acceptance of this point.

SOURCES OF UNCERTAINTY

Survey and LPUE trends were dissimilar. An explanation for this has been provided (i.e., the fishing down of dense clam beds by industry vs the survey which samples randomly from all locations), but this needs further research.

The KLAMZ model for the NNJ region suffered from residual patterns and bias. The causes of this have not been resolved.

Estimates of tow distance and analyses of dredge calibration experiments require information about dredge angle, location and speed. Location and speed are presently assumed equivalent to the ship track. A sensor to monitor dredge position directly could improve efficiency estimates and make estimates of tow distance more accurate.

Accuracy and precision of the annual dredge efficiency estimates are uncertain.

LITERATURE CITED

Butler, J. L., L.D. Jacobson, J.T. Barnes, and H.G. Moser. 2003. Biology and population dynamics of cowcod (*Sebastes levis*) in the southern California Bight. Fish. Bull. 101: 260-280.

Fisheries of the United States, 2000. U.S. DOC/NOAA/NMFS. Current Fisheries Statistics No. 2000.

Gledhill, C. T. 1984. Length-weight relationships of surf clam (*Spisula solidissima*) from Georges Bank. NEFSC. Woods Hole Lab. Ref. Doc. No. 84-30. 23 pp.

Haskin, H. H. and G. Starypan. 1976. Surfclam management project for New Jersey. Progress report for the period: July 1, 1975 – March 31, 1976. Proposal SC74-1-NJ-(2)-1 Report No. 5 to NMFS from Rutgers – The State University. 13 pp + Tables,Fig.

Jacobson, L.D., J.A.A. De Oliveira, M. Barange, M.A. Cisneros-Mata, R. Felix-Uraga, J.R. Hunter, J.Y. Kim, Y. Matsuura, M. Niquen, C. Porteiro, B. Rothschild, R.P. Sanchez, R. Serra, A. Uriarte, and T. Wada. 2001. Surplus production, variability and climate change in the great sardine and anchovy fisheries. Can. J. Fish. Aquat. Sci. 58: 1891-1903.

Jacobson, L.D., S.X. Cadrin, and J.R. Weinberg. 2002. Tools for estimating surplus production and F_{MSY} in any stock assessment model. N. Am. J. Fish. Mgmt. 22:326–338

Meyer, T. L., R. A. Cooper, and K. J. Pecci. 1981. The performance and environmental effects of a hydraulic clam dredge. Marine Fisheries Rev. 43:14-22.

Murawski S. A. and F. M. Serchuk. 1989a. Mechanized shellfish harvesting and its management: the offshore clam fishery of the eastern United States. In: Caddy JF (ed.) Marine Invertebrate Fisheries: Their Assessment and Management. Wiley, New York, pp 479-506.

Murawski, S.A. and F. M. Serchuk. 1989b. Environmental effects of offshore dredge fisheries for bivalves. Internat. Counc. Explor. Sea. Shellfish Cttee. CM 1989/K:27, Ref: Fish Capture Cttee., Biol. Ocean. Cttee. 12 pp + Fig.

NEFSC (Northeast Fisheries Science Center). (1993) Report of the 15th Northeast Regional Stock Assessment Workshop (15th SAW). A. Surfclam assessment. pp 4-18. NEFSC Ref. Doc. 93-06.

NEFSC (Northeast Fisheries Science Center). (1995) Report of the 19th Northeast Regional Stock Assessment Workshop (19th SAW). D. Surfclam assessment. pp 120-176. NEFSC Ref. Doc. 95-08.

NEFSC (Northeast Fisheries Science Center). (1996a) 22nd Northeast Regional Stock Assessment Workshop (22th SAW). D. Surfclam and Ocean quahog. pp 173-242. NEFSC Ref. Doc. 96-13.

NEFSC (Northeast Fisheries Science Center). (1996b) 22nd Northeast Regional Stock Assessment Workshop (22th SAW), Public Review Workshop. D. Surfclam and Ocean Quahog Advisory Report. pp 33-37. NEFSC Ref. Doc. 96-16.

NEFSC (Northeast Fisheries Science Center). (1998a) 26th Northeast Regional Stock Assessment Workshop (26th SAW). B. Surfclams. pp 51-169. NEFSC Ref. Doc. 98-03.

NEFSC (Northeast Fisheries Science Center). (1998b) 26th Northeast Regional Stock Assessment Workshop (26th SAW), Public Review Workshop. B. Surfclam Advisory Report. pp 13-23. NEFSC Ref. Doc. 98-04.

NEFSC (Northeast Fisheries Science Center). (1998c) 27th Northeast Regional Stock Assessment Workshop (27th SAW), E. Ocean quahogs. pp 171-244. NEFSC Ref. Doc. 98-15.

NEFSC (Northeast Fisheries Science Center). (1999) 29th Northeast Regional Stock Assessment Workshop (29th SAW). B. Sea Scallops. pp 91-172. NEFSC Ref. Doc. 99-14.

NEFSC (Northeast Fisheries Science Center). (2000a) 30th Northeast Regional Stock Assessment Workshop (30th SAW), E. Surfclams. pp 311-477. NEFSC Ref. Doc. 00-03.

NEFSC (Northeast Fisheries Science Center). (2000b) 30th Northeast Regional Stock Assessment Workshop (30th SAW). Public Review Workshop. E. Surfclam Advisory Report. pp 39-44. NEFSC Ref. Doc. 00-04.

NEFSC (Northeast Fisheries Science Center). (2000c) 31st Northeast Regional Stock Assessment Workshop (31st SAW), C. Ocean quahog. pp 172-304. NEFSC Ref. Doc. 00-15.
Rago, P., J. Weinberg, and C. Weidman (in review). A spatial model to estimate gear efficiency and animal density from depletion experiments.
Serchuk F.M. and S. A. Murawski . 1980. Assessment and status of surf clam *Spisula solidissima* (Dillwyn) populations in offshore middle Atlantic waters of the United States. USDOC/NMFS. Lab Ref Doc No 80-33
Smolowitz, R. J. and V. E. Nulk. 1982. The design of an electrohydraulic dredge for clam surveys. Marine Fisheries Rev. 44(4):1-18.
Weinberg, J. R. and T. Helser. 1996. Growth of the Atlantic Surfclam, *Spisula solidissima*, from Georges Bank to the Delmarva Peninsula, USA. Mar. Biol. 126:663-674.
Weinberg, J. R. 1998. Density-dependent growth in the Atlantic Surfclam, *Spisula solidissima*, off the coast of the Delmarva Peninsula, USA. Mar. Biol. 130:621-630.
Weinberg, J. R. 1999. Age-structure, recruitment, and adult mortality in populations of the Atlantic surfclam, *Spisula solidissima*, from 1978 to 1997. Mar. Biol. 134:113-125.
Weinberg, J. R., T. G. Dahlgren, and K. M. Halanych. 2002a. Influence of rising sea temperature on commercial bivalve species of the U.S. Atlantic coast. American Fisheries Society Symposium 32: 131-140. In: Fisheries in a changing climate. N. A. McGinn, ed.
Weinberg, J. R., P. Rago, W. Wakefield, and C. Keith. 2002b. Estimation of tow distance and spatial heterogeneity using data from inclinometer sensors: an example using a clam survey dredge. Fisheries Res. 55:49-61.
West, C. W. and J. R. Wallace. 2000. Measurements of distance fished during the trawl retrieval period. ICES Ann. Sci. Conference. Bruges, Belgium, Sept. 2000. Incorporation of external factors in marine resource surveys. ICES CM 2000/K:37, 14 pp.

ACKNOWLEDGMENTS

This assessment was supported in diverse ways by many individuals and groups. We gratefully acknowledge:

Captain and crew of the *R/V Delaware II*
NEFSC Invertebrate (Clam) Working Group
Paul Rago , NEFSC/NMFS
Victor Nordahl , NEFSC/NMFS
Paul Kostovick, NEFSC/NMFS
Charles Keith , NEFSC/NMFS
Tom Azarovitz, NEFSC/NMFS
John Galbraith , NEFSC/NMFS
Russ Brown, NEFSC/NMFS
Tom Hoff, MAFMC
Lisa Hendrickson, NEFSC/NMFS
Scott McEntire, NOAA
Chris Weidman, WHOI
David Hiltz, Data Management, NEFSC/NMFS
Survey Unit, NEFSC/NMFS
Fishery Biology Investigation, NEFSC/NMFS
Blanche Jackson, NEFSC/NMFS

Contributors to research, sensor package and funding of commercial vessels:

Surf Clams:
Blount Seafood - Todd Blount
Cape May Foods - Dan LaVecchia
Doxsee Sea Clam Co. Bob Doxsee
Eastern Shore Seafood - Rick Myers
Fair Tide Shellfish - Tom Slaughter
Galilean Seafood - Jerry Montopoli
J. H. Miles - Jack Miles

Point Pleasant Packing - Dan Cohen
Surfside Seafood - Pete LaMonica
Sea Watch - Bob Brennen
Snows/Doxsee - Steve Kowalski
Capt. Joe Karsh, FV Jersey Girl
Mate Bryon Salmonn, Mate FV Jersey Girl
Bob Walton, FV Jersey Girl
Steve Kaukman, FV Jersey Girl
Barney Truex, Owner FV Jersey Girl
Barney Truex
Martin Truex
Vern Conway
Jim Meyers
Tom Alspach
John Kelleher
Dave Wallace
John Womack
Eric Powell - Rutgers Univ.
Kathryn Alcox - Rutgers Univ.
Allison Bonner - Rutgers Univ.
Bruce Muller - Rutgers Univ.
Roger Mann - VIMS

Quahogs:
Blount Seafood - Todd Blount
Cape May Foods - Dan LaVecchia
Doxsee Sea Clam Co. Bob Doxsee
Eastern Shore Seafood - Rick Myers
Fair Tide Shellfish - Tom Slaughter
Galilean Seafood - Jerry Montopoli
J. H. Miles - Jack Miles
Point Pleasant Packing - Dan Cohen
Surfside Seafood - Pete LaMonica
Sea Watch - Bob Brennen
Snows/Doxsee - Steve Kowalski
Barney Truex
Martin Truex
Vern Conway
Jim Meyers
Tom Alspach
John Kelleher
Dave Wallace
John Womack
Norman Pennypacker
Ed Plat, Capt., FV Lisa Kim
Jeff Shell, Mate, FV Lisa Kim
FV Lisa Kim 's Crew
John Kelleher, Operator, FV Lisa Kim
Rob Jarmol, Capt., FV Christy
Elwood Wilkins, Mate, FV Christy
Lesley Rohn, FV Christy
Jack Miles, Owner
Eric Powell - Rutgers Univ.
Kathryn Alcox - Rutgers Univ.
Allison Bonner - Rutgers Univ.
Bruce Muller - Rutgers Univ.
Roger Mann - VIMS
Peter Kingsley-Smith
Juliana Harding
Melissa Southworth
And any others who were left off !

Table C1. Total USA surfclam landings (metic tons of meats), total landings from the Exclusive Economic Zone (EEZ), landings from state waters, percent of total from the EEZ[1], and annual quotas. Landings not from the EEZ are from State waters.

Year	Total Landings	EEZ Landings	State Waters Landings	Percent of Total Landed from EEZ	EEZ Quota
1965	19,998	14,968	5,029	75	-
1966	20,463	14,696	5,766	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	1,126	95	-
1972	28,744	25,071	3,674	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	2,982	87	-
1977	23,149	19,490	3,660	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	3,964	81	13,882
1982	22,552	16,688	5,873	74	18,506
1983	25,373	18,592	4,887	73	18,892
1984	31,862	22,888	7,086	72	18,892
1985	32,894	22,480	9,204	68	21,205
1986	35,720	24,520	10,797	69	24,290
1987	27,553	21,744	5,406	79	24,290
1988	28,824	23,377	4,873	81	24,290
1989	30,424	21,887	8,089	72	25,184
1990	32,556	24,018	8,528	74	24,282
1991	30,037	20,615	9,399	69	21,976
1992	33,831	21,685	11,722	64	21,976
1993	33,527	21,859	11,565	65	21,976
1994	31,048	21,942	9,106	71	21,976
1995	28,733	19,627	9,429	68	19,779
1996	28,775	19,771	8,980	69	19,779
1997	26,298	18,611	7,687	71	19,779
1998	24,509	18,233	6,276	74	19,779
1999	26,685	19,567	7,118	73	19,779
2000	31,093	19,778	11,315	64	19,779
2001	31,237	22,016	9,221	70	21,976
2002	29,614	23,838	5,776	80	24,174
2003	-	-	-	-	25,061

[1] Landings through 1982 are from the U.S. Dept. Of Commerce series "Fisheries of the United States".
For 1983 - 2003, EEZ landings were computed from the logbook database, total landings were from "Fisheries of the US", and state landings were computed as (Total - EEZ landings). 1 bushel of SC is assumed = 17 lbs meat = 7.711 kg.

Table C2. Annual EEZ surfclam landings from areas of the Mid-Atlantic region, and percent of Mid-Atlantic landings by region.

Year	Long Island mt	Long Island %	Northern New Jersey mt	Northern New Jersey %	Southern New Jersey mt	Southern New Jersey %	Delmarva mt	Delmarva %	Southern Virginia North Carolina mt	Southern Virginia North Carolina %
1978	0	0	1,348	31	53	1	2,927	68	0	0
1979	0	0	1,463	38	97	3	2,268	59	0	0
1980	0	0	1,692	41	132	3	2,300	56	0	0
1981	0	0	6,462	97	114	2	95	1	0	0
1982	49	4	7,440	44	434	3	6,777	41	1,988	12
1983	212	1	5,515	34	999	6	5,772	36	3,779	24
1984	6	4	8,787	49	1,776	10	5,303	30	1,897	11
1985	0	0	8,427	50	1,077	6	6,636	39	772	5
1986	16	1	14,703	75	1,474	8	2,604	13	849	4
1987	0	0	17,238	87	749	4	1,306	7	387	2
1988	0	0	19,196	91	195	1	1,147	5	591	3
1989	0	0	16,415	82	90	<1	3,118	16	461	2
1990	0	0	16,996	74	891	4	3,546	15	1,502	7
1991	15	<1	17,623	86	1,289	6	1,634	8	0	0
1992	61	<1	18,334	85	2,064	10	1,221	6	0	0
1993	62	<1	16,338	75	2,023	9	3,418	16	0	0
1994	71	<1	17,754	81	664	3	3,454	16	35	<1
1995	0	0	15,749	82	713	4	2,752	14	5	<1
1996	26	<1	16,077	82	1,331	7	2,237	11	0	0
1997	73	<1	14,060	76	2,934	16	1,540	8	5	<1
1998	89	<1	13,142	76	3,625	21	379	2	0	0
1999	157	<1	14,432	74	4,277	22	667	3	0	0
2000	119	<1	13,658	71	3,569	18	2,008	10	0	0
2001	913	4	16,137	75	1,172	6	3,175	15	0	0
2002	1,160	5	14,939	64	2,847	12	4,450	19	79	<1

Table C3. Mid-Atlantic EEZ surfclam landings per unit effort (LPUE, kilograms per hour fishing time) & percent of total annual catch from each region, by year and vessel class (Class 3 = largest, 105 tons +) for records with catch >0 and effort >0. Data Source: Logbooks. LPUE is not shown when % is <1, when few vessels took the catch, or for 1985-1990, when LPUE was unreliable due to effort reporting problems.

Region/Year	Vessel Class 1		Vessel Class 2		Vessel Class 3		Class 2 + 3	
	LPUE	%	LPUE	%	LPUE	%	LPUE	%
Northern NJ								
1980	-	5	407	36	646	59	528	95
1981	-	4	363	36	476	60	426	96
1982	-	7	219	44	317	49	261	93
1983	-	6	353	68	372	26	358	94
1984	-	5	569	72	697	23	596	95
1985	-	5	-	57	-	38	-	95
1986	-	3	-	35	-	61	-	96
1987	-	2	-	35	-	63	-	98
1988	-	2	-	33	-	64	-	97
1989	-	3	-	35	-	62	-	97
1990	-	2	-	33	-	66	-	99
1991	-	<1	959	29	1,063	71	1,031	100
1992	-	<1	1,018	22	851	77	884	99
1993	-	<1	1,118	20	904	79	941	99
1994	-	<1	1,058	26	791	73	847	100
1995	-	<1	1,179	29	796	70	880	99
1996	-	<1	971	35	764	65	826	100
1997	-	<1	863	28	745	72	775	100
1998	-	<1	1,031	26	663	74	730	100
1999	-	<1	1,104	27	817	73	879	100
2000	-	<1	1,161	36	770	64	876	100
2001	-	<1	944	33	721	67	781	100
2002	-	<1	915	28	764	72	801	100
Southern NJ								
1980	-	4	130	35	284	62	199	98
1981	-	5	290	32	342	63	322	95
1982	-	7	182	40	289	53	230	93
1983	-	12	236	54	399	35	281	89
1984	-	10	438	31	595	59	529	90
1985	-	4	-	12	-	84	-	96
1986	-	3	-	17	-	80	-	97
1987	-	<1	-	22	-	78	-	100
1988	-	0	-	31	-	69	-	100
1989	-	3	-	47	-	50	-	97
1990	-	<1	-	37	-	62	-	99
1991	-	<1	1,454	39	1,701	61	1,595	100
1992	-	0	1,589	43	2,008	57	1,804	100
1993	-	<1	2,238	54	1,694	46	1,949	100
1994	-	1	2,072	16	1,272	83	1,355	99
1995	-	0	997	14	1,033	86	1,027	100
1996	-	4	1,042	25	866	71	905	96
1997	-	2	1,334	60	1,256	38	1,303	98
1998	-	2	2,272	44	1,803	54	1,986	98
1999	-	2	2,089	36	1,610	62	1,760	98
2000	-	0	1,572	51	1,230	48	1,385	99
2001	-	<1	913	38	820	61	853	99
2002	-	<1	969	63	706	36	853	99
Delmarva								
1980	-	2	157	21	308	77	255	98
1981	-	2	211	15	437	83	377	98
1982	-	5	197	14	309	81	285	95
1983	-	6	234	15	408	80	366	95
1984	-	5	444	15	734	80	664	95
1985	-	3	-	13	-	84	-	97
1986	-	4	-	13	-	83	-	96
1987	-	3	-	3	-	94	-	97
1988	-	2	-	10	-	88	-	98
1989	-	<1	-	13	-	87	-	100
1990	-	0	-	21	-	79	-	100
1991	-	0	1,008	20	1,406	80	1,302	100
1992	-	0	1,733	34	1,326	66	1,442	100
1993	-	0	1,361	44	1,353	56	1,356	100
1994	-	0	1,612	43	1,937	57	1,782	100
1995	-	0	1,772	40	1,756	60	1,762	100
1996	-	0	1,443	56	1,362	44	1,406	100
1997	-	<1	1,594	47	1,278	53	1,409	100
1998	-	0	1,768	81	869	19	1,472	100
1999	-	0	1,223	12	691	88	901	100
2000	-	0	1,183	53	956	47	1,065	100
2001	-	<1	1,309	51	1,048	49	1,167	100
2002	-	0	894	42	729	58	790	100

Table C4. Standardized LPUE from a general linear model (GLM) for each major surfclam region. The model included Year and Subregion. Data from "small" vessels were excluded. Coefficients from this model were highly correlated with raw catch rates, as well as with coefficients from other GLMs that included Year, Tonclass, Subregion and Month.

	DMV		NNJ		SNJ	
Year	GLM Year Coef.	Backtransf. Coeffs.	GLM Year Coef.	Backtransf. Coeffs.	GLM Year Coef.	Backtransf. Coeffs.
1980	0.000	1.000	0.000	1.000	0.000	1.000
1981	0.369	1.447	-0.240	0.787	0.615	1.850
1982	0.150	1.162	-0.776	0.460	0.238	1.268
1983	0.363	1.437	-0.346	0.707	0.389	1.476
1984	0.990	2.690	0.157	1.170	1.019	2.772
1991	1.829	6.229	0.729	2.072	2.292	9.898
1992	1.962	7.112	0.601	1.825	2.367	10.663
1993	1.902	6.696	0.670	1.954	2.533	12.585
1994	2.299	9.968	0.583	1.792	2.403	11.061
1995	2.217	9.177	0.611	1.843	2.055	7.808
1996	1.953	7.048	0.546	1.727	2.114	8.284
1997	1.967	7.148	0.491	1.634	2.265	9.628
1998	1.996	7.358	0.418	1.520	2.663	14.345
1999	1.504	4.498	0.586	1.797	2.427	11.329
2000	1.655	5.235	0.584	1.794	2.190	8.935
2001	1.744	5.720	0.455	1.576	1.644	5.177
2002	1.330	3.781	0.520	1.682	1.706	5.506

~commer/GLM_compareModels.xls 5-May-03

Table C5. Summary statistics on surf clam commercial length frequency data by region/year. Data were collected by port agents taking random samples from landings.

Region/Year	Mean Length (mm)[1]	Min L	Max L	Number of Clams Measured[2]
New Jersey				
1982[3]	140.5	75	205	7477
1983	142.5	75	205	11253
1984	142.1	45	195	12751
1985	140.4	55	195	7674
1986	136.3	105	175	5130
1987	134.4	95	185	900
1988	137.7	85	165	900
1989	139.9	105	175	919
1990	136.5	95	175	901
1991	143.0	93	188	2272
1992	141.1	64	186	1710
1993	139.8	80	170	928
1994	138.5	85	185	900
1995	141.9	85	175	510
1996	138.0	85	185	1117
1997	136.7	75	195	957
1998	147.3	95	205	690
1999	144.3	95	205	856
2000	147.0	103	195	2655
2001	145.0	107	180	1080
2002	148.0	97	184	961
Delmarva				
1982	159.0	85	205	7756
1983	151.5	45	205	5923
1984	138.8	95	195	3066
1985	132.0	95	175	1832
1986	130.0	95	155	1260
1987	131.4	105	165	730
1988	136.0	115	165	420
1989	136.6	115	175	866
1990	139.1	95	175	892
1991	125.5	20	183	1080
1992	123.5	73	198	1170
1993	122.4	77	155	1392
1994	109.2	85	135	119
1995	125.1	105	155	720
1996	124.0	95	155	1154
1997	127.1	95	175	1622
1998	122.7	95	155	1560
1999	130.4	105	205	1720
2000	131.0	75	178	1290
2001	131.0	106	159	1060
2002	136.0	90	174	360
S. New England				
1982	153.7	135	175	30
1983	150.0	125	165	30
1984	147.9	115	175	90
1985	151.6	115	175	150
1986	161.0	125	195	330
1987	160.9	115	195	569
1988	154.3	105	185	810
1989	155.8	115	185	449
1990[4]	164.1	135	185	209

[1] "Mean length" is the expected value from the length frequency distribution, using size classes of 1 cm. Length frequency distributions were derived by weighting trips by their respective landings.
[2] Total number of clams used in this assessment. Typically, 30 clams are measured per trip.
[3] Values from 1987-1990 and 1994 are from subsamples of the data. Subsamples contained data from 30 randomly selected trips, when available.
[4] "-" = no data available after 1990

Table C6. List of research clam surveys and gear changes from 1965-1981, and 1997-2002. Column entries are shifted to accentuate changes. Changes in the gear and survey season did not occur from August, 1980 to 1992. Sources of information for 1978 - 1981 are Smolovitz and Nulk 1982 and NEFSC Cruise Reports. Sources of information for 1965 - 1977 are NEFSC 1995a and NEFSC Survey Reports. "Sensors Used" : refers to the velocity, tilt and pump pressure sensors, used in computing tow distance and pump performance. These were used for the first time in 1997. "-" : undetermined.

Cruise	Date	Vessel	Season	Purpose	Pump Type	Dredge Width(cm)	Mesh Size (cm)	Doppler Measured	Sensors Used
65-	5/65	Undaunted	Spring	Survey	Surface	76	5.1	-	No
65-10	10/65	Undaunted	Fall	Survey	Surface	76	5.1	-	No
66-6,11	8/66	Albatross IV	Summer	Survey	Surface	76	5.1	-	No
69-1,7	6/69	Albatross IV	Summer	Survey	Surface	76	5.1	-	No
70-6	8/70	Delaware	Summer	Survey	Surface	122	3	-	No
SM742	6/74	Delaware	Summer	Survey	Surface	76	5.1	-	No
76-1	4/76	Delaware	Spring	Survey	Surface	122	3	-	No
77-2	1/77	Delaware	Winter	Survey	Surface	122	3	-	No
7801	1/78	Delaware	Winter	Survey	Surface	122	1.91	No	No
7807	12/78	Delaware	Winter	Survey	Surface	122	1.91	Yes	No
7901	1/79	Delaware	Winter	Survey	Submerse	152	2.54	Yes	No
7908	8/79	Delaware	Summer	Gear test	Submerse	152	2.54 & 5.08	Yes	No
8001	1/80	Delaware	Winter	Survey	Submerse	152	5.08	Yes	No
8006	8/80	Delaware	Summer	Survey	Submerse	152	5.08	Yes	No
8105	8/81	Delaware	Summer	Survey	Submerse	152	5.08	Yes	No
9704	7/97	Delaware	Summer	Survey	Submerse	152	5.08	Yes	Yes[1]
9903	7/99	Delaware	Summer	Survey	Submerse	152	5.08	Yes	Yes[2]
200206	6/02	Delaware	Summer	Survey	Submerse	152	5.08	Yes	Yes[3]

1. Individual sensors were used.
2. A protoptype integrated sensor package was used for the first 2/3 of the cruise. After that, individuals sensors were used.
3. First use of Survey Sensor Package (SSP) from Woods Hole Group. Used for entire cruise. Individ. sensors used as backup.

H:\sarc\sarc37sc\tables\gearchange.wpd

Table C7. Recent gear changes related to the NMFS Clam Survey, 1992-2002. Column entries were shifted to accentuate changes. Changes in the gear and survey season did not occur from August, 1980 to 1992, or from 1999 to 2002. Sources of information are NEFSC Cruise Meetings. "-" : undetermined.

Cruise	Date	Vessel	Ship Modified	Winch Changed	Winch Speed Out (met/min)	Winch Speed In (met/min)	Voltage to Pump
pre-92		Delaware II			60	60	460
9203	6/92	Delaware II		--	--	80	460
9404	8/94	Delaware II			Free spool	80	480
9704	7/97	Delaware II	1/97	1/97	20	20	460
9903	7/99	Delaware II		5/99	50-60	50-60	460
200206	7/02	Delaware II		5/99	50-60	50-60	460

Table C8. Equipment replaced during the 2002 Delaware II clam shakedown and survey legs.

Gear Changes , by Leg :

	Shakedown	Leg 1	Leg 2	Leg 3
Cruise	200205	200206	200206	200206
Stations	1-~40	1-235	236-401	402-552
Dates	5/17-5/31	6/3-6/14	6/17-6/28	7/1-7/12
Electrical Cable	#1A	#1A	#2	#1B
Pump	P1	P1	P1	P2

Gear Descriptions:

Elec. Cables		
	#1A	= New, purchased for 2002 clam survey, black, flexible, loose mesh wrap insulation, 1200'
	#1B	= twin of #1A
	#2	= Old cable used in 2nd half of 1999 clam survey. White, stiffer, tight insulation like fire hose. When loaded on, some metal pieces in this cable too (from previous use).
Pumps		
	P1	= Used in 1999 and first 2/3 of 2002
	P2	= Spare pump; May have been used pre-1999.

Table C9. Nominal and computed tow distances and CIs for Delaware II clam surveys. Distances computed from "Sensors" use actual data on dredge bottom contact and vessel speed. "Nominal" distance assumes speed of 1.5 knot for 5-min. Only good tows that captured surfclams were used to compute median lengths, with cutoff dredge angle 5.15 deg. The longer computed tow length in 1997 was caused by use of a slower winch than in 1999 and 2002.

Method	Year	DredgeWidth (inches)	(nmi)	Length (nmi)	Tow Area (nmi^2)	Comments/Conditions
Nominal		60	0.00082289	**0.125**	0.000102862	Not based on data. (1.5kn, 5 min)
Doppler	**1997**	60	0.00082289	**0.130**	0.000106976	Median Doppler (5-min only).
	1999	60	0.00082289	**0.130**	0.000106976	"
	2002	60	0.00082289	**0.124**	0.000102039	"
Sensors	**1997**	60	0.00082289	**0.2528**	0.000208028	Median from sensors
	1999	60	0.00082289	**0.2135**	0.000175688	"
	2002	60	0.00082289	**0.2086**	0.000171656	"

CI for Tow Length (nmi), for Stations w/ Surfclams (based on Sensors).

		0.05	**0.1**	**median L**	**0.9**	**0.95**
Sensors	**1997**	0.1833	0.2067	**0.2528**	0.3146	0.3405
	1999	0.1616	0.1701	**0.2135**	0.2739	0.2984
	2002	0.1729	0.1769	**0.2086**	0.2355	0.2424

Source of Mortality	Species	Magnitude of Mortality	Reference	Comments
Indirect	Surfclam	20%	Meyer, et al. 1981	NMFS dredge used; % of large clams (90-130 mm) on bottom w/ broken shells; Diver observations in windrow area.
	Ocean quahog	"significant" (greater than for sea scallop, which was <5%)	Murawski and Serchuk, 1989b	Commercial vessel and dredge used. Observations from submersible.
Discard	Surfclam	>50%	Murawski and Serchuk, 1989b	Observed reburrowing of marked clams from submersible.
		33%-50%	Haskin and Starypan, 1976	Replanting experiments with divers.
	Ocean quahog	<10%	Murawski and Serchuk, 1989b	Observations from submersible; Details of dredge and dredging not given.

Table C10 .
Summary of mortality studies on surfclams and ocean quahogs. " **Indirect**" mortality is death in those clams that encountered the dredge, but they were not captured (i.e., they remained on the ocean floor). "**Discard**" mortality is death in clams that were captured, had intact shells, and died after being returned to the ocean floor.

SITE	LATITUDE (dd)	LONGITUDE (dd)
DEII	39.272609	73.782036
SC02-1	40.109080	73.844233
SC02-2	39.269225	73.781163
SC02-3	38.857905	74.408881
SC02-4	36.771116	75.049794
OQ02-1	40.727620	71.737299
OQ02-2	40.103116	73.191079
OQ02-3	38.814912	73.813348
OQ02-4	37.887552	74.644855
OQ02-5	40.730020	70.118408
OQ02-6	40.896190	71.213913

Table C11. Locations of NMFS clam dredge calibration experiments and sediment samples during the 2002 Delaware-II clam survey.

A.

Code	Location	Length (mm)	
1	NJ - Repeats	137	
2	DMV - Repeats	122	
3	SC-02	132	
4	SC-03	129	
5	SC-04	--	Bimodal, Not Used
	Median	**130**	

B.

Code:	1	2	3	4	5	1	2	3	4	5
Vessel	DE-2	DE-2	DE-2	DE-2	DE-2	JG	JG	JG	JG	JG
Region	NJ	DMV	NNJ	SNJ	DMV	NJ	DMV	NNJ	SNJ	DMV
Purpose	Random	Random	SC02-2 setups	SC02-3 setups	SC02-4 setups	Repeat DE-II	Repeat DE-II	SC02-2	SC02-3	SC02-4
Fraction	0.866	0.303	0.868	0.921	0.359	0.971	0.459	0.940	0.996	0.528

Table C12 .
A. Shell length , for each data set (code), at which the relative selectivity of the FV Jersey Girl to the RV Delaware II was 0.75.

B. Fraction of surfclams >= 130 mm collected at locations that were sampled by the FV Jersey Girl and RV Delaware II. 130 mm was the shell size where the selectivity of the Jersey Girl was about 75% that of the Delaware. The Delaware had higher selectivity of smaller clams.

Table C13. Likelihood profile results for estimated dredge efficiency and density (N/ft^2) from the Patch model for surfclams in 2002 depletion studies based on data from depletion studies carried out by the R/V Delaware II (experiment DE02) and the F/V Jersey Girl (experiments JG02-2 to JG02-4). All estimates assume no indirect effects (clams lost but not caught). Results from JG01-JG03 are for surflcams 130+ mm. Results from DE02 are for all size groups captured.

CI for Efficiency

Experiment	Best Estimate	Lo 50%	Hi 50%	Lo 90%	Hi 90%	Comments
DE02	0.695	0.61	0.78	0.46	0.93	
JG02-2	0.934	0.87	0.99	0.75	NA	a
JG02-3	0.457	0.35	0.57	0.23	0.71	
JG02-4	0.950	0.84	NA	0.57	NA	c

CI for Density

Experiment	Best Estimate	Lo 50%	Hi 50%	Lo 90%	Hi 90%	
DE02	0.054	0.048	0.061	0.044	0.077	
JG02-2	0.058	0.056	0.060	0.051	0.065	
JG02-3	0.011	0.010	0.012	0.008	NA	b
JG02-4	0.044	0.037	0.051	0.032	0.061	

a) Efficiency estimate near upper bound (e=1); profile hit upper bound on efficiency before hitting upper 90% bound.

b) Profile hit lower bound on efficiency (e=0) before hitting upper 90% bound on density.

c) Efficiency estimate near upper bound (e=1); profile hit upper bound bound on efficiency (e=1) before hitting upper 50% or 90% confidence interval bounds.

Table C14. Summary of *Delaware-II* dredge efficiency for surfclams in 2002 (Cruise 200206), inferred by comparing catches in DE-II Setup Tows with Patch Model Estimates, assuming no indirect losses, from data collected with commercial clam vessel *F/V Jersey Girl*.

Formula used to compute DEL-II dredge efficiency (EFF) in experiments with the Jersey Girl (JG):

EFF(DEL) = [EFF(JG)*Density(DEL)] / Density(JG)

Experiment	Region	Jersey Girl Density (#/ft^2)	Jersey Girl Efficiency	Delaware Station #	Delaware Density (#/ft^2) Setup Tows	Delaware Density (#/ft^2) Setup Tows	Delaware vs Jersey Girl Relative Efficiency	Delaware Efficiency (from formula)
SC02-2	NJ, offshore			87	0.0280			
				88	0.0073			
				89	0.0077			
				90	0.0119			
				91	0.0169			
		0.0575	0.934		Average:	0.0143	0.249	**0.233**
					SD of samples:	0.0085		
SC02-3	SNJ			202	0.0153			
				203	0.0029			
				204	0.0344			
				205	0.0004			
				206	0.0000			
		0.0108	0.457		Average:	0.0106	0.982	**0.449**
					SD of samples:	0.0147		
SC02-4	DMV			335	0.0194			
				336	0.0364			
				337	0.0574			
				338	0.0043			
				339	0.0063			
		0.0439	0.949		Average:	0.0248	0.564	**0.536**
					SD of samples:	0.0223		
					Grand Mean			**0.406**
					SD of 3 averages:			**0.156**
					N			**3**

Region:	DMV		NJ		NJ		NJ	
Vessel:	DE-II (Leg 2) # SC / tow	F/V JG # SC / tow	DE-II (Leg 1) # SC / tow	F/V JG # SC / tow	DE-II (Leg 2) # SC / tow	F/V JG # SC / tow	DE-II (Leg 3) # SC / tow	F/V JG # SC / tow
	9	90	213	523	82	523	59	523
	90	237	74	848	22	848	41	848
	44	97	86	738	42	738	43	738
	7	458	122	1101	17	1101	45	1101
	1	36	42	390	12	390	59	390
	5	42	41	384	22	384	84	384
	14	13	139	561	65	561	170	561
	1	39	23	280	25	280	5	280
	30	1044	64	191	5	191	22	191
Aver. catch	**22.33**	**228.41**	**89.33**	**557.43**	**32.44**	**557.43**	**58.67**	**557.43**
SD catch	29.15	336.88	59.89	292.19	25.72	292.19	47.44	292.19
CV of catch (%)	130.54	147.49	67.04	52.42	79.26	52.42	80.87	52.42
Aver. area (ft^2) / tow	**6,289.3**	**13,398.1**	**6,044.9**	**15,187.4**	**6,087.6**	**15,187.4**	**6,600.7**	**15,187.4**
SD (area)	453.80	1995.41	551.83	2017.26	407.51	2017.26	378.98	2017.26
CV of area (%)	7.22	14.89	9.13	13.28	6.69	13.28	5.74	13.28
Density (no./ft^2)	0.00355	0.01705	0.01478	0.03670	0.00533	0.03670	0.00889	0.03670

Table C15.
Estimates of relative efficiency between the Delaware II and FV Jersey Girl (JG) in Delmarva and New Jersey, 2002. Estimates are based on the ratio, between vessels, of the average density (SC catch per area towed) from 9 stations in each region, sampled by both vessels. For each vessel/region combination, average distance towed was computed from sensor data. To achieve similar clam size-selectivity between vessels, surfclams <130 mm were excluded.

	DMV Stations	NJ Stations
DE-II catch (# per tow)	22.33	180.44
DE-II area (ft^2 per tow)	6289	18731
DE-II ratio (= density)	0.003551	0.009633
JG catch	228.41	557.43
JG area	13398	15187
JG ratio (raw)	0.017048	0.036704
JG ratio (adjusted)	0.018942	0.040783
Adjustment	0.9	0.9
Efficiency of DEII (no/adj)	0.208	0.262
Efficiency of DEII (w/adj)	**0.187**	**0.236**

Table C16.
Analysis of Delaware II surfclam stations Repeated by the F/VJersey Girl. (9 stations in Delmarva and 9 in New Jersey. Assumed Jersey Girl (JG) efficiency is 0.9.

Data Source	Year 1997	Data Source	Year 1999	Data Source	Year 2002	All years combined
DE depl (patch)	0.727	DE depl patch	0.148	DE depl patch	0.695	
PP1A (patch)	0.277	Median of five experiments from SARC 30	0.246	SC02-2 patch	0.233	
AC2 (patch)	0.290	Christy Cross Check	0.243	SC02-3 patch	0.449	
AC1 (patch)	0.544	Repeated stations	0.389	SC02-4 patch	0.536	
		99-97 ratio random stations	0.353	JG Repeats, DMV	0.187	
				JG Repeats, NJ	0.236	
average	**0.460**		**0.276**		**0.389**	**0.370**
var	0.0469		0.0093		0.0414	0.0331
sd	0.2166		0.0963		0.2035	0.1820
CV	0.471		0.349		0.523	0.492
n	4		5		6	15

Table C17.
Efficiency estimates for the Delaware II (DE) survey dredge catching Atlantic surfclams in 1997, 1999, 2002 and for all years combined. Values for 1997 and 1999 are from SARC31, Table C10, p 222. "Patch" = Rago Patch model with cell size set at 2 dredge widths. Revised 17 May 2003.

REGION	ALPHA	BETA	Year Data Collected or Source of Data
SVA	-7.05830	2.30330	Murawski
DMV	-9.10630	2.76750	Serchuk and Murawski (1980)
NJ	-9.20610	2.82510	Serchuk and Murawski (1980)
LI	-7.98370	2.58020	Murawski
SNE	-7.98370	2.58020	Murawski
GBK	-7.99670	2.57720	Gledhill (1984)
DMV	-9.92060	2.96190	1997 Survey
SNJ	-9.41160	2.89970	1997 Survey
NNJ	-9.41160	2.89970	1997 Survey
GBK	-8.55830	2.73070	1997 Survey
DMV	-10.83117	3.13644	2002 Survey
SNJ	-9.68603	2.93156	2002 Survey
NNJ	-9.68603	2.93156	2002 Survey
GBK	-10.27049	3.06418	2002 Survey
SVA	-7.05830	2.30330	Values used in SARC-30 (NEFSC 2000a)
DMV	-9.489134	2.860176	“
NNJ and SNJ	-9.312103	2.863716	“
LI	-7.98370	2.58020	“
SNE	-7.98370	2.58020	“
GBK	-8.274427	2.654215	“

Table C18.
Parameter estimates for the relationship between drained meat weight (gr) and shell length (mm) in surfclams, by region and time. Samples collected in 1997 and 2002 include all tissue minus shell, weighed fresh at sea. Weight = (e^alpha) *(L^beta).

Table C19. Number of NEFSC clam survey tows during 1982-2002 (random and nearly random "fill" tows) by survey, region and stratum. "Holes" (strata with zero tows) are highlighted.

		Cruise									
Stratum	Region	8204	8305	8403	8604	8903	9203	9404	9704	9903	200206
9	DMV	30	26	35	29	37	37	39	39	38	39
10	DMV	2	2	3	3	3	3	3	3	3	3
13	DMV	19	18	25	20	20	20	21	22	19	20
14	DMV	2	2	3	3	3	3	5	3	3	3
82	DMV	1	1	1	1	1	1	1	1	2	2
83	DMV	2	2	2	2	2	2	2	2	2	2
84	DMV	4	3	3	4	4	4	4	4	3	4
85	DMV	6	5	4	5	5	5	5	5	5	5
86	DMV	2	2	3	3	3	2	3	2	3	3
54	GBK			3	3		3	3	3		
55	GBK	3			3	1	3	3	3	2	2
57	GBK				2	1	2	5	2	2	2
59	GBK	1	4		1	2	6	5	5	4	5
61	GBK	8	1		5		7	6	6	6	6
65	GBK				3		2	2	3		1
67	GBK			5	5	7	7	7	7		
68	GBK	1		7	3	6	6	5	5		
69	GBK	2	5		6	6	6	7	6	7	
70	GBK	1	2		4		4	4	4	3	2
71	GBK			2	3	1	2	3	3	1	2
72	GBK	2		8	1	8	8	8	8	6	
73	GBK	1	1		3	6	6	6	6	5	6
74	GBK	3		1	3		4	4	4	3	3
29	LI	11	10		10	10	10	10	10	11	10
30	LI	7	8		6	6	6	6	6	7	6
33	LI	4	4		4	4	4	5	4	4	4
34	LI	2	2		2	2	2	5	2	2	2
91	LI	3	2	4	4	3	3	3	3	3	3
92	LI	2	2	3	2	2	2	2	2	2	2
93	LI	1	1	2	1	1	1	1	1	1	2
21	NNJ	18	18	22	19	20	20	23	26	39	29
25	NNJ	9	9	13	8	9	9	9	12	8	9
88	NNJ	15	15	24	17	20	20	20	21	22	20
89	NNJ	15	15	21	15	18	17	17	19	18	18
90	NNJ	2	2	3	2	2	2	2	2	2	2
37	SNE	7	4		3		3	5	4	4	3
38	SNE	3	2		3	3	3	5	3	3	3
41	SNE	6	5	7	5	6	6	6	6	5	6
45	SNE	3	7	9	4	4	4	4	4	4	3
46	SNE	2	5	5	3	2	3	5	3	3	2
47	SNE	4	3	4	2	2	4	5	4	3	1
94	SNE	1	2				1	2	2		2
95	SNE	4	14	11	4	4	4	4	4	4	4
96	SNE		12		1	1	3	2	4		
17	SNJ	11	11	18	12	12	12	12	14	12	12
87	SNJ	8	7	10	9	9	9	9	9	9	16
1	SVA		10	14	7	10	10	11	10		
2	SVA					1	2	1	1		
5	SVA	4	9	13	8	8	8	8	8		8
6	SVA	1	1	1	1	1	1	1	1		2
80	SVA		6	9	3	7	7	8	7		
81	SVA		4	7	3	5	5	5	5		5
Total		233	264	305	273	288	324	347	343	283	284

NMFS Survey	1982	1983	1984	1986	1989	1992	1994	1997	1999	2002
Total # of Station in Strata 9	30	26	35	29	37	37	39	39	37	38
# of Stations w/one or more clams	24	18	26	25	27	29	35	34	26	23
# of Stations w/zero clams	6	8	9	4	10	8	4	5	11	15
p= Proportion of Zeros	**0.20**	**0.31**	**0.26**	**0.14**	**0.27**	**0.22**	**0.10**	**0.13**	**0.30**	**0.39**
Var(p)	0.0053	0.0082	0.0055	0.0041	0.0053	0.0046	0.0024	0.0029	0.0056	0.0063

Table C20. Trends in percentage of random stations in Stratum # 9, off DMV, that captured no surfclams. Var(p)=pq/n.

Table C21. Efficiency corrected swept-area biomass estimates (1000 mt) by stock assessment area and CVs for surfclam during 1997, 2000 and 2002.

	Estimate	CV
INPUT: Nominal tow distance (d_n, *nm*) and CV for Doppler tow distance	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

Northern New Jersey (NNJ)	3,284	10%
Southern New Jersey (SNJ)	1,059	10%
Delmarva (DMV)	4,660	10%
S. Virginia and N. Carolina (SVA)	3,119	10%
Long Island (LI)	2,917	10%
Southern New England (SNE)	4,321	10%
Georges Bank (GBK)	5,772	10%
Total	25,132	

INPUT: Fraction suitable habitat (*u*)

Northern New Jersey (NNJ)	100%	10%
Southern New Jersey (SNJ)	100%	10%
Delmarva (DMV)	100%	10%
S. Virginia and N. Carolina (SVA)	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)

Northern New Jersey (NNJ)	3,284	14%
Southern New Jersey (SNJ)	1,059	14%
Delmarva (DMV)	4,660	14%
S. Virginia and N. Carolina (SVA)	3,119	14%
Long Island (LI)	2,917	14%
Southern New England (SNE)	4,321	14%
Georges Bank (GBK)	5,079	14%

INPUT: Original survey mean survey catch (kg/tow, for tows adjusted to nominal tow distance using sensors)	**Estimates for 1997**	**CV**	**Estimates for 1999**	**CV**	**Estimates for 2002**	**CV**
Northern New Jersey (NNJ) 120+ mm	8.3896	12%	5.0454	12%	4.6001	18%
Southern New Jersey (SNJ) 120+ mm	1.9938	38%	3.7458	73%	1.9190	44%
Delmarva (DMV) 100+ mm	3.5577	21%	2.3135	21%	1.4707	17%
S. Virginia and N. Carolina (SVA) 100+ mm	0.1065	50%	0.1045	35%	0.2826	54%
Long Island (LI) 100+ mm	0.3514	66%	0.9832	57%	0.1918	63%
Southern New England (SNE) 100+ mm	1.0006	34%	0.4854	64%	0.4046	23%
Georges Bank (GBK) 100+ mm	2.5842	26%	2.5836	32%	2.2333	44%
INPUT: Survey dredge efficiency (e)	0.460	49%	0.276	49%	0.389	49%
Efficiency adjusted swept area biomass (B, 1000 mt)						
Northern New Jersey (NNJ) 120+ mm	485	53%	487	53%	315	55%
Southern New Jersey (SNJ) 120+ mm	37	64%	116	90%	42	68%
Delmarva (DMV) 100+ mm	292	56%	317	56%	143	55%
S. Virginia and N. Carolina (SVA) 100+ mm	6	72%	10	62%	18	75%
Long Island (LI) 100+ mm	18	84%	84	77%	12	82%
Southern New England (SNE) 100+ mm	76	62%	62	82%	36	57%
Georges Bank (GBK) 100+ mm	231	58%	385	61%	236	68%
Total fishable biomass less GBK (100+ and 120+ mm)	915	34%	1,075	32%	566	34%
Total fishable biomass (100+ and 120+ mm)	1,146	30%	1,460	28%	803	31%

Lower bound for 80% confidence intervals on biomass (1000 mt, for lognormal distribution with no bias correction)	**Estimates for 1997**	**Estimates for 1999**	**Estimates for 2002**
Northern New Jersey (NNJ) 120+ mm	256	256	163
Southern New Jersey (SNJ) 120+ mm	18	44	19
Delmarva (DMV) 100+ mm	150	162	74
S. Virginia and N. Carolina (SVA) 100+ mm	3	5	8
Long Island (LI) 100+ mm	7	35	5
Southern New England (SNE) 100+ mm	37	25	18
Georges Bank (GBK) 100+ mm	116	188	107
Total fishable biomass less GBK (100+ and 120+ mm)	599	723	370
Total fishable biomass (100+ and 120+ mm)	791	1,022	542
Upperbound for 80% confidence intervals on biomass (1000 mt, for lognormal distribution with no bias correction)			
Northern New Jersey (NNJ) 120+ mm	922	924	607
Southern New Jersey (SNJ) 120+ mm	79	311	93
Delmarva (DMV) 100+ mm	570	618	275
S. Virginia and N. Carolina (SVA) 100+ mm	13	20	43
Long Island (LI) 100+ mm	46	202	29
Southern New England (SNE) 100+ mm	158	155	72
Georges Bank (GBK) 100+ mm	462	792	521
Total fishable biomass less GBK (100+ and 120+ mm)	1,398	1,599	867
Total fishable biomass (100+ and 120+ mm)	1,661	2,086	1,188

Table C22. Fishing mortality rates (F yr^{-1}) during 1997, 1999 and 2002 with CVs from catch and efficiency corrected swept-area biomass estimates.

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**
Northern New Jersey (NNJ)	14.060	14.432	14.939
Southern New Jersey (SNJ)	2.934	4.277	2.847
Delmarva (DMV)	1.540	0.667	4.450
S. Virginia and N. Carolina (SVA)	0.005	0.000	0.079
Long Island (LI)	0.073	0.157	1.160
Southern New England (SNE)	0.000	0.016	0.124
Georges Bank (GBK)	0.000	0.000	0.000
Total	18.611	19.548	23.600

Catch (1000 mt, landings + upper bound incidental mortality allowance)			
Northern New Jersey (NNJ)	15.747	16.163	16.732
Southern New Jersey (SNJ)	3.286	4.790	3.189
Delmarva (DMV)	1.725	0.747	4.984
S. Virginia and N. Carolina (SVA)	0.005	0.000	0.088
Long Island (LI)	0.081	0.175	1.300
Southern New England (SNE)	0.000	0.018	0.139
Georges Bank (GBK)	0.000	0.000	0.000
Total	20.844	21.894	26.432

INPUT: Efficiency Corrected Swept Area Biomass (1000 mt)	**Estimates for 1997**	**CV**	**Estimates for 1999**	**CV**	**Estimates for 2002**	**CV**
Northern New Jersey (NNJ) 120+ mm	485	53%	487	53%	315	55%
Southern New Jersey (SNJ) 120+ mm	37	64%	116	90%	42	68%
Delmarva (DMV) 100+ mm	292	56%	317	56%	143	55%
S. Virginia and N. Carolina (SVA) 100+ mm	6	72%	10	62%	18	75%
Long Island (LI) 100+ mm	18	84%	84	77%	12	82%
Southern New England (SNE) 100+ mm	76	62%	62	82%	36	57%
Georges Bank (GBK) 100+ mm	231	58%	385	61%	236	68%
Total fishable biomass less GBK (100+ and 120+ mm)	915	34%	1,075	32%	566	34%
Total fishable biomass (100+ and 120+ mm)	1,146	30%	1,460	28%	803	31%

Fishing mortality (y^{-1})						
Northern New Jersey (NNJ) 120+ mm	0.032	54%	0.033	54%	0.053	56%
Southern New Jersey (SNJ) 120+ mm	0.088	65%	0.041	90%	0.075	69%
Delmarva (DMV) 100+ mm	0.006	57%	0.002	57%	0.035	56%
S. Virginia and N. Carolina (SVA) 100+ mm	0.001	NA	0.000	NA	0.005	75%
Long Island (LI) 100+ mm	0.004	84%	0.002	78%	0.111	82%
Southern New England (SNE) 100+ mm	0.000	63%	0.000	83%	0.004	58%
Georges Bank (GBK) 100+ mm	0.000	NA	0.000	NA	0.000	NA
Total fishable biomass less GBK (100+ and 120+ mm)	0.023	35%	0.020	33%	0.047	36%
Total fishable biomass (100+ and 120+ mm)	0.018	31%	0.015	30%	0.033	33%

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**
Northern New Jersey (NNJ) 120+ mm	0.017	0.017	0.027
Southern New Jersey (SNJ) 120+ mm	0.041	0.015	0.034
Delmarva (DMV) 100+ mm	0.003	0.001	0.018
S. Virginia and N. Carolina (SVA) 100+ mm	NA	NA	0.002
Long Island (LI) 100+ mm	0.002	0.001	0.044
Southern New England (SNE) 100+ mm	NA	0.000	0.002
Georges Bank (GBK) 100+ mm	NA	NA	NA
Total fishable biomass less GBK (100+ and 120+ mm)	0.015	0.013	0.030
Total fishable biomass (100+ and 120+ mm)	0.012	0.010	0.022

Upper bound for 80% confidence intervals for fishing mortality (y^{-1}, for lognormal distribution with no bias correction)			
Northern New Jersey (NNJ) 120+ mm	0.062	0.064	0.104
Southern New Jersey (SNJ) 120+ mm	0.189	0.110	0.167
Delmarva (DMV) 100+ mm	0.012	0.005	0.068
S. Virginia and N. Carolina (SVA) 100+ mm	NA	NA	0.011
Long Island (LI) 100+ mm	0.011	0.005	0.280
Southern New England (SNE) 100+ mm	NA	0.001	NA
Georges Bank (GBK) 100+ mm	NA	NA	NA
Total fishable biomass less GBK (100+ and 120+ mm)	0.035	0.031	0.073
Total fishable biomass (100+ and 120+ mm)	0.027	0.022	0.050

Table C23 (1 of 7). Survey trend data used in the KLAMZ model for surfclam.

Region	Cruise	Length Bin	Group Name	N/Tow	CV	Kg/Tow	CV	Number Tows	Number PositiveTows	Number Strata Sampled
SVA	7801	83-99	Prerecruits	0.1639	0.76	0.0049	0.76	40	2	5
SVA	7807	83-99	Prerecruits	0.1639	0.76	0.0049	0.76	40	2	5
SVA	*78 Mean*	*83-99*	*Prerecruits*	*0.1639*	*0.76*	*0.0049*	*0.76*	*80*	*4*	*NA*
SVA	7901	83-99	Prerecruits	9.8913	1.00	0.2985	1.00	16	2	4
SVA	8001	83-99	Prerecruits	9.8063	1.00	0.2959	1.00	21	2	5
SVA	8006	83-99	Prerecruits	9.8913	1.00	0.2985	1.00	16	2	4
SVA	*80 Mean*	*83-99*	*Prerecruits*	*9.8488*	*1.00*	*0.2972*	*1.00*	*37*	*4*	*NA*
SVA	8105	83-99	Prerecruits	0.0000	.	0.0000	.	5	0	2
SVA	8204	83-99	Prerecruits	0.7931	0.68	0.0212	0.68	25	4	5
SVA	8305	83-99	Prerecruits	0.9569	0.57	0.0260	0.57	30	7	5
SVA	8403	83-99	Prerecruits	1.5296	0.43	0.0435	0.44	44	12	5
SVA	8604	83-99	Prerecruits	0.1118	0.93	0.0032	0.93	23	2	6
SVA	8903	83-99	Prerecruits	1.3304	0.80	0.0367	0.79	32	6	6
SVA	9203	83-99	Prerecruits	1.2098	0.38	0.0353	0.40	33	12	6
SVA	9404	83-99	Prerecruits	2.6695	0.36	0.0766	0.37	34	14	6
SVA	9704	83-99	Prerecruits	2.0080	0.40	0.0595	0.41	32	11	6
SVA	9903	83-99	Prerecruits	2.7725	0.41	0.0779	0.40	42	14	6
SVA	200206	83-99	Prerecruits	7.9737	0.72	0.2139	0.71	15	4	3
SVA	7801	100-112	New recruits	0.1144	1.00	0.0047	1.00	40	1	5
SVA	7807	100-112	New recruits	0.1144	1.00	0.0047	1.00	40	1	5
SVA	*78 Mean*	*100-112*	*New recruits*	*0.1144*	*1.00*	*0.0047*	*1.00*	*80*	*2*	*NA*
SVA	7901	100-112	New recruits	13.9301	1.00	0.5275	1.00	16	2	4
SVA	8001	100-112	New recruits	13.8519	1.00	0.5245	1.00	21	3	5
SVA	8006	100-112	New recruits	13.9301	1.00	0.5275	1.00	16	2	4
SVA	*80 Mean*	*100-112*	*New recruits*	*13.8910*	*1.00*	*0.5260*	*1.00*	*37*	*5*	*NA*
SVA	8105	100-112	New recruits	0.4846	1.00	0.0189	1.00	5	1	2
SVA	8204	100-112	New recruits	1.9710	0.95	0.0815	0.95	25	3	5
SVA	8305	100-112	New recruits	3.1862	0.68	0.1315	0.68	30	5	5
SVA	8403	100-112	New recruits	2.6895	0.42	0.1094	0.42	44	10	5
SVA	8604	100-112	New recruits	0.5201	0.42	0.0211	0.43	23	6	6
SVA	8903	100-112	New recruits	0.4841	0.61	0.0194	0.61	32	5	6
SVA	9203	100-112	New recruits	9.6412	0.95	0.3960	0.95	33	7	6
SVA	9404	100-112	New recruits	6.3030	0.57	0.2557	0.57	34	12	6
SVA	9704	100-112	New recruits	3.6891	0.61	0.1475	0.61	32	8	6
SVA	9903	100-112	New recruits	2.2219	0.52	0.0881	0.53	42	12	6
SVA	200206	100-112	New recruits	1.5710	0.45	0.0593	0.45	15	4	3
SVA	7801	113+	Old recruits	1.8229	0.34	0.1736	0.33	40	10	5
SVA	7807	113+	Old recruits	1.8229	0.34	0.1736	0.33	40	10	5
SVA	*78 Mean*	*113+*	*Old recruits*	*1.8229*	*0.34*	*0.1736*	*0.33*	*80*	*20*	*NA*
SVA	7901	113+	Old recruits	0.8328	0.83	0.0470	0.75	16	2	4
SVA	8001	113+	Old recruits	2.9293	0.71	0.2007	0.74	21	5	5
SVA	8006	113+	Old recruits	0.8328	0.83	0.0470	0.75	16	2	4
SVA	*80 Mean*	*113+*	*Old recruits*	*1.8810*	*0.83*	*0.1238*	*0.75*	*37*	*7*	*NA*
SVA	8105	113+	Old recruits	26.3764	0.92	1.9494	0.91	5	3	2
SVA	8204	113+	Old recruits	4.3047	0.93	0.2847	0.89	25	5	5
SVA	8305	113+	Old recruits	7.2900	0.59	0.4812	0.57	30	9	5
SVA	8403	113+	Old recruits	24.6144	0.31	1.7467	0.30	44	13	5
SVA	8604	113+	Old recruits	22.7574	0.74	1.5810	0.74	23	8	6
SVA	8903	113+	Old recruits	9.9908	0.82	0.7682	0.81	32	8	6
SVA	9203	113+	Old recruits	18.6504	0.65	1.1278	0.66	33	8	6
SVA	9404	113+	Old recruits	10.2603	0.48	0.6142	0.42	34	6	6
SVA	9704	113+	Old recruits	1.5904	0.45	0.0835	0.45	32	6	6
SVA	9903	113+	Old recruits	1.8460	0.36	0.1141	0.38	42	10	6
SVA	200206	113+	Old recruits	5.9706	0.56	0.4139	0.55	15	4	3

Table C23 (cont) (p.2 of 7)

Region	Cruise	Length Bin	Group Name	N/Tow	CV	Kg/Tow	CV	Number Tows	Number PositiveTows	Number Strata Sampled
DMV	7801	83-99	Prerecruits	1.7443	0.43	0.0544	0.44	61	9	9
DMV	7807	83-99	Prerecruits	1.9197	0.31	0.0607	0.31	58	14	9
DMV	*78 Mean*	*83-99*	*Prerecruits*	*1.8320*	*0.43*	*0.0576*	*0.44*	*119*	*23*	*NA*
DMV	7901	83-99	Prerecruits	0.5520	0.59	0.0182	0.57	49	3	9
DMV	8001	83-99	Prerecruits	31.8887	0.90	0.9399	0.90	70	27	9
DMV	8006	83-99	Prerecruits	22.1965	0.56	0.6822	0.60	51	22	9
DMV	*80 Mean*	*83-99*	*Prerecruits*	*27.0426*	*0.90*	*0.8110*	*0.90*	*121*	*49*	*NA*
DMV	8105	83-99	Prerecruits	79.3071	0.62	2.5299	0.61	47	14	9
DMV	8204	83-99	Prerecruits	56.0215	0.62	1.8850	0.62	68	25	9
DMV	8305	83-99	Prerecruits	3.4159	0.32	0.1081	0.32	61	23	9
DMV	8403	83-99	Prerecruits	63.8289	0.85	1.7656	0.82	79	26	9
DMV	8604	83-99	Prerecruits	4.9484	0.34	0.1668	0.35	70	25	9
DMV	8903	83-99	Prerecruits	2.4888	0.50	0.0837	0.53	78	25	9
DMV	9203	83-99	Prerecruits	2.6017	0.21	0.0800	0.21	77	38	9
DMV	9404	83-99	Prerecruits	11.0529	0.25	0.3408	0.25	83	57	9
DMV	9704	83-99	Prerecruits	21.4606	0.23	0.6608	0.23	81	51	9
DMV	9903	83-99	Prerecruits	2.2844	0.26	0.0745	0.27	78	31	9
DMV	200206	83-99	Prerecruits	5.2042	0.31	0.1548	0.31	81	34	9
DMV	7801	100-112	New recruits	0.6232	0.55	0.0290	0.56	61	8	9
DMV	7807	100-112	New recruits	1.8929	0.31	0.0875	0.31	58	13	9
DMV	*78 Mean*	*100-112*	*New recruits*	*1.2580*	*0.55*	*0.0583*	*0.56*	*119*	*21*	*NA*
DMV	7901	100-112	New recruits	0.9719	0.55	0.0431	0.55	49	7	9
DMV	8001	100-112	New recruits	3.3542	0.49	0.1521	0.47	70	19	9
DMV	8006	100-112	New recruits	11.8311	0.90	0.5172	0.89	51	18	9
DMV	*80 Mean*	*100-112*	*New recruits*	*7.5926*	*0.90*	*0.3346*	*0.89*	*121*	*37*	*NA*
DMV	8105	100-112	New recruits	67.7290	0.84	3.1077	0.84	47	16	9
DMV	8204	100-112	New recruits	80.5405	0.45	3.6940	0.45	68	25	9
DMV	8305	100-112	New recruits	11.7466	0.49	0.5814	0.51	61	23	9
DMV	8403	100-112	New recruits	24.3551	0.58	1.1603	0.58	79	35	9
DMV	8604	100-112	New recruits	18.8035	0.40	0.9347	0.40	70	26	9
DMV	8903	100-112	New recruits	8.0890	0.69	0.3876	0.68	78	25	9
DMV	9203	100-112	New recruits	3.0911	0.26	0.1506	0.28	77	35	9
DMV	9404	100-112	New recruits	25.5786	0.50	1.2493	0.51	83	52	9
DMV	9704	100-112	New recruits	24.5648	0.21	1.1750	0.21	81	51	9
DMV	9903	100-112	New recruits	12.6531	0.32	0.6232	0.32	78	32	9
DMV	200206	100-112	New recruits	3.9517	0.31	0.1861	0.31	81	32	9
DMV	7801	113+	Old recruits	7.2558	0.21	1.0545	0.20	61	34	9
DMV	7807	113+	Old recruits	9.5939	0.34	1.3085	0.34	58	18	9
DMV	*78 Mean*	*113+*	*Old recruits*	*8.4248*	*0.34*	*1.1815*	*0.34*	*119*	*52*	*NA*
DMV	7901	113+	Old recruits	15.1010	0.50	2.0363	0.43	49	22	9
DMV	8001	113+	Old recruits	15.6895	0.21	2.1606	0.22	70	38	9
DMV	8006	113+	Old recruits	13.5695	0.24	1.8941	0.24	51	29	9
DMV	*80 Mean*	*113+*	*Old recruits*	*14.6295*	*0.24*	*2.0273*	*0.24*	*121*	*67*	*NA*
DMV	8105	113+	Old recruits	23.7939	0.44	2.3456	0.31	47	26	9
DMV	8204	113+	Old recruits	38.4884	0.30	3.7702	0.27	68	43	9
DMV	8305	113+	Old recruits	44.6220	0.56	3.9819	0.43	61	36	9
DMV	8403	113+	Old recruits	46.7133	0.28	4.2844	0.26	79	49	9
DMV	8604	113+	Old recruits	107.2927	0.43	8.6805	0.37	70	44	9
DMV	8903	113+	Old recruits	37.3597	0.24	3.4548	0.23	78	48	9
DMV	9203	113+	Old recruits	33.7532	0.33	3.2207	0.26	77	47	9
DMV	9404	113+	Old recruits	77.7309	0.23	6.9976	0.20	83	55	9
DMV	9704	113+	Old recruits	76.8682	0.24	6.2856	0.22	81	52	9
DMV	9903	113+	Old recruits	39.9086	0.23	3.2314	0.21	78	45	9
DMV	200206	113+	Old recruits	23.6741	0.21	2.4152	0.19	81	48	9

Table C23 (cont) (p.3 of 7)

Region	Cruise	Length Bin	Group Name	N/Tow	CV	Kg/Tow	CV	Number Tows	Number PositiveTows	Number Strata Sampled
SNJ	7801	107-119	Prerecruits	0.7375	0.58	0.0508	0.59	26	4	2
SNJ	7807	107-119	Prerecruits	0.3893	0.76	0.0245	0.77	11	2	2
SNJ	*78 Mean*	*107-119*	*Prerecruits*	*0.5634*	*0.76*	*0.0377*	*0.77*	*37*	*6*	*NA*
SNJ	7901	107-119	Prerecruits	0.0000	.	0.0000	.	10	0	2
SNJ	8001	107-119	Prerecruits	0.5680	0.34	0.0405	0.34	18	5	2
SNJ	8006	107-119	Prerecruits	0.3603	0.61	0.0247	0.62	18	3	2
SNJ	*80 Mean*	*107-119*	*Prerecruits*	*0.4642*	*0.61*	*0.0326*	*0.62*	*36*	*8*	*NA*
SNJ	8105	107-119	Prerecruits	0.2101	1.00	0.0158	1.00	16	1	2
SNJ	8204	107-119	Prerecruits	13.0322	0.98	0.9156	0.98	19	5	2
SNJ	8305	107-119	Prerecruits	0.5427	0.46	0.0364	0.48	18	5	2
SNJ	8403	107-119	Prerecruits	0.0461	1.00	0.0032	1.00	28	1	2
SNJ	8604	107-119	Prerecruits	0.4665	0.66	0.0302	0.68	21	4	2
SNJ	8903	107-119	Prerecruits	0.4315	0.68	0.0300	0.71	21	4	2
SNJ	9203	107-119	Prerecruits	1.0162	0.49	0.0696	0.49	21	5	2
SNJ	9404	107-119	Prerecruits	14.5266	0.72	0.9910	0.72	21	12	2
SNJ	9704	107-119	Prerecruits	1.4060	0.36	0.0993	0.37	23	10	2
SNJ	9903	107-119	Prerecruits	6.1756	0.99	0.4561	0.99	21	2	2
SNJ	200206	107-119	Prerecruits	1.1262	0.22	0.0754	0.22	28	15	2
SNJ	7801	120-129	New recruits	0.5585	0.59	0.0501	0.59	26	3	2
SNJ	7807	120-129	New recruits	0.5053	1.00	0.0421	1.00	11	1	2
SNJ	*78 Mean*	*120-129*	*New recruits*	*0.5319*	*1.00*	*0.0461*	*1.00*	*37*	*4*	*NA*
SNJ	7901	120-129	New recruits	0.0000	.	0.0000	.	10	0	2
SNJ	8001	120-129	New recruits	0.9737	0.46	0.0879	0.47	18	6	2
SNJ	8006	120-129	New recruits	0.4426	0.70	0.0388	0.70	18	2	2
SNJ	*80 Mean*	*120-129*	*New recruits*	*0.7081*	*0.70*	*0.0633*	*0.70*	*36*	*8*	*NA*
SNJ	8105	120-129	New recruits	0.0000	.	0.0000	.	16	0	2
SNJ	8204	120-129	New recruits	4.9934	0.84	0.4353	0.84	19	7	2
SNJ	8305	120-129	New recruits	0.3868	0.49	0.0347	0.49	18	4	2
SNJ	8403	120-129	New recruits	0.2450	0.58	0.0229	0.58	28	4	2
SNJ	8604	120-129	New recruits	0.1397	0.57	0.0131	0.57	21	3	2
SNJ	8903	120-129	New recruits	0.3229	0.57	0.0287	0.57	21	4	2
SNJ	9203	120-129	New recruits	0.6666	0.44	0.0599	0.43	21	6	2
SNJ	9404	120-129	New recruits	14.3583	0.72	1.2528	0.71	21	12	2
SNJ	9704	120-129	New recruits	3.6370	0.54	0.3320	0.54	23	8	2
SNJ	9903	120-129	New recruits	23.5977	1.00	2.1528	1.00	21	3	2
SNJ	200206	120-129	New recruits	1.8377	0.43	0.1711	0.44	28	9	2
SNJ	7801	130+	Old recruits	12.7466	0.28	2.4382	0.27	26	14	2
SNJ	7807	130+	Old recruits	4.2720	0.33	0.7629	0.33	11	6	2
SNJ	*78 Mean*	*130+*	*Old recruits*	*8.5093*	*0.33*	*1.6006*	*0.33*	*37*	*20*	*NA*
SNJ	7901	130+	Old recruits	4.1451	0.31	0.8564	0.39	10	6	2
SNJ	8001	130+	Old recruits	10.2916	0.29	2.0474	0.28	18	10	2
SNJ	8006	130+	Old recruits	12.3756	0.37	2.6891	0.39	18	13	2
SNJ	*80 Mean*	*130+*	*Old recruits*	*11.3336*	*0.37*	*2.3682*	*0.39*	*36*	*23*	*NA*
SNJ	8105	130+	Old recruits	12.2688	0.38	2.8345	0.39	16	10	2
SNJ	8204	130+	Old recruits	20.0771	0.34	4.1156	0.33	19	13	2
SNJ	8305	130+	Old recruits	11.6226	0.34	2.5251	0.35	18	10	2
SNJ	8403	130+	Old recruits	10.9630	0.29	2.2941	0.28	28	16	2
SNJ	8604	130+	Old recruits	19.2820	0.50	4.1915	0.52	21	13	2
SNJ	8903	130+	Old recruits	10.5571	0.31	2.0856	0.30	21	11	2
SNJ	9203	130+	Old recruits	6.8826	0.42	1.4120	0.43	21	8	2
SNJ	9404	130+	Old recruits	58.5203	0.68	9.0087	0.66	21	14	2
SNJ	9704	130+	Old recruits	21.0333	0.36	3.0911	0.34	23	14	2
SNJ	9903	130+	Old recruits	31.3131	0.71	4.1551	0.62	21	12	2
SNJ	200206	130+	Old recruits	16.5809	0.44	2.8528	0.48	28	20	2

Table C23 (cont) (p.4 of 7)

Region	Cruise	Length Bin	Group Name	N/Tow	CV	Kg/Tow	CV	Number Tows	Number PositiveTows	Number Strata Sampled
NNJ	7801	107-119	Prerecruits	0.2529	0.43	0.0171	0.43	67	6	5
NNJ	7807	107-119	Prerecruits	1.3798	0.46	0.0912	0.46	40	6	5
NNJ	*78 Mean*	*107-119*	*Prerecruits*	*0.8164*	*0.46*	*0.0541*	*0.46*	*107*	*12*	*NA*
NNJ	7901	107-119	Prerecruits	0.4291	0.57	0.0279	0.55	36	4	5
NNJ	8001	107-119	Prerecruits	5.5509	0.43	0.3646	0.43	59	22	5
NNJ	8006	107-119	Prerecruits	24.5250	0.80	1.6827	0.81	50	22	5
NNJ	*80 Mean*	*107-119*	*Prerecruits*	*15.0380*	*0.80*	*1.0236*	*0.81*	*109*	*44*	*NA*
NNJ	8105	107-119	Prerecruits	9.4792	0.28	0.6648	0.28	41	23	5
NNJ	8204	107-119	Prerecruits	18.9602	0.42	1.3045	0.42	59	34	5
NNJ	8305	107-119	Prerecruits	24.9287	0.57	1.7088	0.57	59	32	5
NNJ	8403	107-119	Prerecruits	8.4357	0.22	0.5861	0.22	83	50	5
NNJ	8604	107-119	Prerecruits	5.9367	0.22	0.4126	0.22	61	39	5
NNJ	8903	107-119	Prerecruits	6.6141	0.32	0.4630	0.32	69	36	5
NNJ	9203	107-119	Prerecruits	11.8811	0.58	0.8253	0.58	68	47	5
NNJ	9404	107-119	Prerecruits	25.6020	0.21	1.7717	0.21	71	59	5
NNJ	9704	107-119	Prerecruits	14.6337	0.20	1.0251	0.20	80	65	5
NNJ	9903	107-119	Prerecruits	3.6851	0.24	0.2574	0.24	89	45	5
NNJ	200206	107-119	Prerecruits	3.9985	0.19	0.2758	0.19	78	63	5
NNJ	7801	120-129	New recruits	0.0741	0.69	0.0067	0.70	67	2	5
NNJ	7807	120-129	New recruits	0.5520	0.37	0.0501	0.37	40	7	5
NNJ	*78 Mean*	*120-129*	*New recruits*	*0.3130*	*0.69*	*0.0284*	*0.70*	*107*	*9*	*NA*
NNJ	7901	120-129	New recruits	0.3336	0.84	0.0300	0.84	36	2	5
NNJ	8001	120-129	New recruits	1.0253	0.40	0.0915	0.40	59	16	5
NNJ	8006	120-129	New recruits	7.8636	0.74	0.6722	0.73	50	19	5
NNJ	*80 Mean*	*120-129*	*New recruits*	*4.4445*	*0.74*	*0.3819*	*0.73*	*109*	*35*	*NA*
NNJ	8105	120-129	New recruits	8.1425	0.31	0.7304	0.31	41	24	5
NNJ	8204	120-129	New recruits	16.6014	0.25	1.4897	0.25	59	33	5
NNJ	8305	120-129	New recruits	16.3749	0.33	1.4629	0.33	59	32	5
NNJ	8403	120-129	New recruits	14.7170	0.27	1.3238	0.27	83	50	5
NNJ	8604	120-129	New recruits	9.6039	0.28	0.8779	0.29	61	42	5
NNJ	8903	120-129	New recruits	9.8082	0.21	0.8857	0.21	69	43	5
NNJ	9203	120-129	New recruits	7.2160	0.28	0.6432	0.28	68	45	5
NNJ	9404	120-129	New recruits	25.7885	0.22	2.3034	0.22	71	56	5
NNJ	9704	120-129	New recruits	19.8317	0.23	1.8029	0.23	80	66	5
NNJ	9903	120-129	New recruits	6.0189	0.19	0.5507	0.19	89	61	5
NNJ	200206	120-129	New recruits	4.0246	0.28	0.3638	0.28	78	58	5
NNJ	7801	130+	Old recruits	0.4969	0.37	0.0895	0.39	67	10	5
NNJ	7807	130+	Old recruits	2.3121	0.41	0.4074	0.43	40	9	5
NNJ	*78 Mean*	*130+*	*Old recruits*	*1.4045*	*0.41*	*0.2484*	*0.43*	*107*	*19*	*NA*
NNJ	7901	130+	Old recruits	1.1416	0.55	0.1820	0.59	36	5	5
NNJ	8001	130+	Old recruits	6.0932	0.32	1.0637	0.33	59	23	5
NNJ	8006	130+	Old recruits	4.6301	0.31	0.7597	0.31	50	21	5
NNJ	*80 Mean*	*130+*	*Old recruits*	*5.3617*	*0.32*	*0.9117*	*0.33*	*109*	*44*	*NA*
NNJ	8105	130+	Old recruits	20.0586	0.42	2.9222	0.40	41	28	5
NNJ	8204	130+	Old recruits	26.7880	0.28	3.4843	0.27	59	35	5
NNJ	8305	130+	Old recruits	18.9996	0.22	2.5772	0.22	59	44	5
NNJ	8403	130+	Old recruits	28.1055	0.20	3.7137	0.20	83	57	5
NNJ	8604	130+	Old recruits	30.0218	0.19	4.2175	0.18	61	46	5
NNJ	8903	130+	Old recruits	35.9347	0.15	4.9326	0.14	69	56	5
NNJ	9203	130+	Old recruits	26.2561	0.17	3.8198	0.16	68	55	5
NNJ	9404	130+	Old recruits	86.4794	0.13	12.4319	0.13	71	56	5
NNJ	9704	130+	Old recruits	101.6671	0.13	14.7857	0.12	80	71	5
NNJ	9903	130+	Old recruits	55.5655	0.13	8.2520	0.12	89	79	5
NNJ	200206	130+	Old recruits	44.2097	0.18	7.1699	0.18	78	69	5

Table C23 (cont) (p.5 of 7)

Region	Cruise	Length Bin	Group Name	N/Tow	CV	Kg/Tow	CV	Number Tows	Number PositiveTows	Number Strata Sampled
LI	7801	82-99	Prerecruits	0.0498	1.00	0.0016	1.00	46	1	7
LI	7807	82-99	Prerecruits	0.1793	1.00	0.0074	1.00	23	1	7
LI	*78 Mean*	*82-99*	*Prerecruits*	*0.1146*	*1.00*	*0.0045*	*1.00*	*69*	*2*	*NA*
LI	7901	82-99	Prerecruits	0.1583	0.71	0.0064	0.71	33	2	7
LI	8001	82-99	Prerecruits	0.1789	0.61	0.0066	0.61	28	3	7
LI	8006	82-99	Prerecruits	0.1131	0.37	0.0047	0.35	28	2	7
LI	*80 Mean*	*82-99*	*Prerecruits*	*0.1460*	*0.61*	*0.0057*	*0.61*	*56*	*5*	*NA*
LI	8105	82-99	Prerecruits	0.0516	1.00	0.0022	1.00	29	1	7
LI	8204	82-99	Prerecruits	0.0000	.	0.0000	.	30	0	7
LI	8305	82-99	Prerecruits	0.0330	1.00	0.0012	1.00	29	1	7
LI	8403	82-99	Prerecruits	0.1860	0.37	0.0070	0.36	55	7	7
LI	8604	82-99	Prerecruits	0.1878	0.60	0.0067	0.61	29	3	7
LI	8903	82-99	Prerecruits	0.3889	1.00	0.0146	1.00	28	1	7
LI	9203	82-99	Prerecruits	1.6034	0.41	0.0629	0.41	28	7	7
LI	9404	82-99	Prerecruits	1.1167	0.12	0.0441	0.11	32	10	7
LI	9704	82-99	Prerecruits	0.2297	0.38	0.0091	0.37	28	4	7
LI	9903	82-99	Prerecruits	0.1529	0.52	0.0052	0.49	30	3	7
LI	200206	82-99	Prerecruits	0.2958	0.57	0.0101	0.57	29	5	7
LI	7801	100-113	New recruits	0.0203	1.00	0.0012	1.00	46	1	7
LI	7807	100-113	New recruits	0.0768	1.00	0.0048	1.00	23	1	7
LI	*78 Mean*	*100-113*	*New recruits*	*0.0486*	*1.00*	*0.0030*	*1.00*	*69*	*2*	*NA*
LI	7901	100-113	New recruits	0.1998	0.58	0.0118	0.59	33	3	7
LI	8001	100-113	New recruits	0.0000	.	0.0000	.	28	0	7
LI	8006	100-113	New recruits	0.0419	1.00	0.0021	1.00	28	1	7
LI	*80 Mean*	*100-113*	*New recruits*	*0.0209*	*1.00*	*0.0011*	*1.00*	*56*	*1*	*NA*
LI	8105	100-113	New recruits	0.0516	1.00	0.0029	1.00	29	1	7
LI	8204	100-113	New recruits	0.0000	.	0.0000	.	30	0	7
LI	8305	100-113	New recruits	0.0000	.	0.0000	.	29	0	7
LI	8403	100-113	New recruits	0.0622	0.56	0.0038	0.59	55	2	7
LI	8604	100-113	New recruits	0.0694	0.49	0.0041	0.44	29	2	7
LI	8903	100-113	New recruits	0.6813	0.83	0.0404	0.83	28	3	7
LI	9203	100-113	New recruits	2.3791	0.56	0.1457	0.56	28	4	7
LI	9404	100-113	New recruits	1.5826	0.32	0.0939	0.32	32	6	7
LI	9704	100-113	New recruits	0.7820	0.54	0.0455	0.55	28	4	7
LI	9903	100-113	New recruits	0.0882	0.71	0.0052	0.71	30	2	7
LI	200206	100-113	New recruits	0.2034	0.41	0.0121	0.41	29	4	7
LI	7801	114+	Old recruits	2.1478	0.36	0.3382	0.39	46	12	7
LI	7807	114+	Old recruits	6.5628	0.41	1.0222	0.42	23	5	7
LI	*78 Mean*	*114+*	*Old recruits*	*4.3553*	*0.41*	*0.6802*	*0.42*	*69*	*17*	*NA*
LI	7901	114+	Old recruits	3.4717	0.30	0.5170	0.31	33	5	7
LI	8001	114+	Old recruits	1.7597	0.10	0.2656	0.13	28	5	7
LI	8006	114+	Old recruits	5.2449	0.27	0.7588	0.31	28	7	7
LI	*80 Mean*	*114+*	*Old recruits*	*3.5023*	*0.27*	*0.5122*	*0.31*	*56*	*12*	*NA*
LI	8105	114+	Old recruits	0.0913	0.71	0.0180	0.71	29	2	7
LI	8204	114+	Old recruits	4.7463	0.51	0.7540	0.52	30	5	7
LI	8305	114+	Old recruits	0.4073	0.72	0.0545	0.72	29	2	7
LI	8403	114+	Old recruits	1.7534	0.32	0.2603	0.33	55	7	7
LI	8604	114+	Old recruits	1.7845	0.58	0.2902	0.60	29	3	7
LI	8903	114+	Old recruits	3.6611	0.73	0.4882	0.74	28	4	7
LI	9203	114+	Old recruits	3.6113	0.36	0.3530	0.34	28	7	7
LI	9404	114+	Old recruits	8.2497	0.19	0.9869	0.21	32	8	7
LI	9704	114+	Old recruits	4.5178	0.63	0.5880	0.62	28	4	7
LI	9903	114+	Old recruits	10.8701	0.64	1.4445	0.60	30	5	7
LI	200206	114+	Old recruits	2.0229	0.66	0.3102	0.67	29	5	7

Table C23 (cont) (p.6 of 7)

Region	Cruise	Length Bin	Group Name	N/Tow	CV	Kg/Tow	CV	Number Tows	Number PositiveTows	Number Strata Sampled
SNE	7801	77-99	Prerecruits	1.0488	1.00	0.0323	1.00	15	1	5
SNE	7807	77-99	Prerecruits	1.2051	0.88	0.0380	0.86	17	2	5
SNE	*78 Mean*	*77-99*	*Prerecruits*	*1.1269*	*1.00*	*0.0352*	*1.00*	*32*	*3*	*NA*
SNE	7901	77-99	Prerecruits	0.9329	0.00	0.0341	0.00	9	1	4
SNE	8001	77-99	Prerecruits	0.2650	1.00	0.0069	1.00	20	1	6
SNE	8006	77-99	Prerecruits	0.2094	0.71	0.0082	0.71	14	2	5
SNE	*80 Mean*	*77-99*	*Prerecruits*	*0.2372*	*1.00*	*0.0076*	*1.00*	*34*	*3*	*NA*
SNE	8105	77-99	Prerecruits	1.4509	0.31	0.0490	0.36	27	8	8
SNE	8105	77-99	Prerecruits	2.5254	0.33	0.0883	0.38	10	6	4
SNE	8204	77-99	Prerecruits	1.2480	0.29	0.0435	0.34	42	11	9
SNE	8305	77-99	Prerecruits	0.2987	0.39	0.0111	0.39	54	15	9
SNE	8403	77-99	Prerecruits	0.1886	0.48	0.0061	0.49	63	7	9
SNE	8604	77-99	Prerecruits	0.1591	0.64	0.0047	0.66	25	3	8
SNE	8903	77-99	Prerecruits	0.7398	0.53	0.0257	0.52	23	6	8
SNE	9203	77-99	Prerecruits	0.4947	0.53	0.0172	0.52	31	7	9
SNE	9404	77-99	Prerecruits	0.4591	0.39	0.0159	0.40	38	9	9
SNE	9704	77-99	Prerecruits	1.2177	0.36	0.0441	0.38	34	10	9
SNE	9903	77-99	Prerecruits	1.2746	0.50	0.0482	0.54	34	10	9
SNE	200206	77-99	Prerecruits	0.2023	0.71	0.0080	0.75	24	3	8
SNE	7801	100-116	New recruits	1.1986	1.00	0.0729	1.00	15	1	5
SNE	7807	100-116	New recruits	1.1986	1.00	0.0729	1.00	17	1	5
SNE	*78 Mean*	*100-116*	*New recruits*	*1.1986*	*1.00*	*0.0729*	*1.00*	*32*	*2*	*NA*
SNE	7901	100-116	New recruits	0.3110	0.82	0.0175	0.84	9	2	4
SNE	8001	100-116	New recruits	0.1451	0.82	0.0082	0.84	20	2	6
SNE	8006	100-116	New recruits	0.1228	0.53	0.0074	0.54	14	3	5
SNE	*80 Mean*	*100-116*	*New recruits*	*0.1340*	*0.82*	*0.0078*	*0.84*	*34*	*5*	*NA*
SNE	8105	100-116	New recruits	0.8340	0.38	0.0488	0.34	27	2	8
SNE	8105	100-116	New recruits	1.7103	0.38	0.1001	0.34	10	2	4
SNE	8204	100-116	New recruits	0.8673	0.34	0.0504	0.31	42	5	9
SNE	8305	100-116	New recruits	0.3420	0.46	0.0206	0.46	54	13	9
SNE	8403	100-116	New recruits	0.3098	0.47	0.0179	0.46	63	8	9
SNE	8604	100-116	New recruits	0.1593	0.57	0.0088	0.58	25	4	8
SNE	8903	100-116	New recruits	0.3004	0.46	0.0176	0.47	23	5	8
SNE	9203	100-116	New recruits	0.0498	0.71	0.0028	0.71	31	2	9
SNE	9404	100-116	New recruits	0.6643	0.72	0.0409	0.72	38	4	9
SNE	9704	100-116	New recruits	1.0424	0.38	0.0627	0.38	34	8	9
SNE	9903	100-116	New recruits	0.2349	0.47	0.0136	0.48	34	5	9
SNE	200206	100-116	New recruits	0.7284	0.72	0.0464	0.72	24	4	8
SNE	7801	117+	Old recruits	26.2199	1.00	3.7305	1.00	15	1	5
SNE	7807	117+	Old recruits	26.2199	1.00	3.7305	1.00	17	1	5
SNE	*78 Mean*	*117+*	*Old recruits*	*26.2199*	*1.00*	*3.7305*	*1.00*	*32*	*2*	*NA*
SNE	7901	117+	Old recruits	12.5657	0.42	1.8324	0.42	9	4	4
SNE	8001	117+	Old recruits	5.8631	0.42	0.8550	0.42	20	4	6
SNE	8006	117+	Old recruits	1.7757	0.56	0.2617	0.57	14	4	5
SNE	*80 Mean*	*117+*	*Old recruits*	*3.8194*	*0.56*	*0.5584*	*0.57*	*34*	*8*	*NA*
SNE	8105	117+	Old recruits	10.9687	0.48	1.4624	0.48	27	9	8
SNE	8105	117+	Old recruits	16.9081	0.56	2.2296	0.57	10	4	4
SNE	8204	117+	Old recruits	12.5824	0.40	1.7896	0.41	42	11	9
SNE	8305	117+	Old recruits	8.0424	0.39	1.2844	0.39	54	20	9
SNE	8403	117+	Old recruits	10.9240	0.34	1.6826	0.34	63	18	9
SNE	8604	117+	Old recruits	4.1245	0.68	0.6436	0.69	25	7	8
SNE	8903	117+	Old recruits	5.7642	0.31	0.8650	0.31	23	7	8
SNE	9203	117+	Old recruits	2.5171	0.57	0.4011	0.58	31	3	9
SNE	9404	117+	Old recruits	1.7225	0.53	0.2674	0.54	38	6	9
SNE	9704	117+	Old recruits	12.3193	0.30	1.9161	0.30	34	9	9
SNE	9903	117+	Old recruits	4.4130	0.65	0.7338	0.65	34	7	9
SNE	200206	117+	Old recruits	3.8853	0.27	0.6039	0.22	24	7	8

Table C23 (cont) (p.7 of 7)

Region	Cruise	Length Bin	Group Name	N/Tow	CV	Kg/Tow	CV	Number Tows	Number PositiveTows	Number Strata Sampled
GBK	8001	85-99	Prerecruits	0.5911	0.00	0.0230	0.00	9	1	3
GBK	8006	85-99	Prerecruits	0.5911	0.00	0.0230	0.00	9	1	3
GBK	*80 Mean*	*85-99*	*Prerecruits*	*0.5911*	*0.00*	*0.0230*	*0.00*	*18*	*2*	*NA*
GBK	8105	85-99	Prerecruits	0.9919	0.22	0.0430	0.23	31	5	10
GBK	8105	85-99	Prerecruits	0.8700	0.25	0.0384	0.27	22	4	9
GBK	*81 Mean*	*85-99*	*Prerecruits*	*0.9310*	*0.25*	*0.0407*	*0.27*	*53*	*9*	*NA*
GBK	8204	85-99	Prerecruits	0.8700	0.25	0.0384	0.27	22	4	9
GBK	8305	85-99	Prerecruits	0.9310	0.33	0.0386	0.34	44	15	11
GBK	8403	85-99	Prerecruits	1.3811	0.31	0.0566	0.31	29	11	7
GBK	8604	85-99	Prerecruits	4.4127	0.80	0.1812	0.80	45	10	14
GBK	8903	85-99	Prerecruits	0.7516	0.28	0.0314	0.28	76	19	14
GBK	9203	85-99	Prerecruits	4.7721	0.46	0.2006	0.47	66	29	14
GBK	9404	85-99	Prerecruits	8.4210	0.36	0.3590	0.36	68	36	14
GBK	9704	85-99	Prerecruits	17.2458	0.32	0.7204	0.32	65	33	14
GBK	9903	85-99	Prerecruits	5.6447	0.49	0.2369	0.49	58	17	14
GBK	200206	85-99	Prerecruits	5.5683	0.58	0.2338	0.58	42	17	11
GBK	8001	100-111	Prerecruits	0.1478	0.00	0.0077	0.00	9	1	3
GBK	8006	100-111	Prerecruits	0.1478	0.00	0.0077	0.00	9	1	3
GBK	*80 Mean*	*100-111*	*Prerecruits*	*0.1478*	*0.00*	*0.0077*	*0.00*	*18*	*2*	*NA*
GBK	8105	100-111	Prerecruits	0.2439	0.43	0.0132	0.43	31	3	10
GBK	8105	100-111	Prerecruits	0.2132	0.51	0.0117	0.50	22	2	9
GBK	*81 Mean*	*100-111*	*Prerecruits*	*0.2286*	*0.51*	*0.0124*	*0.50*	*53*	*5*	*NA*
GBK	8204	100-111	New recruits	0.2132	0.51	0.0117	0.50	22	2	9
GBK	8305	100-111	New recruits	0.3912	0.46	0.0232	0.46	44	7	11
GBK	8403	100-111	New recruits	0.9156	0.19	0.0536	0.20	29	8	7
GBK	8604	100-111	New recruits	2.6033	0.73	0.1519	0.73	45	10	14
GBK	8903	100-111	New recruits	1.5841	0.43	0.0999	0.45	76	22	14
GBK	9203	100-111	New recruits	5.1266	0.53	0.3055	0.52	66	22	14
GBK	9404	100-111	New recruits	9.6806	0.39	0.5820	0.39	68	30	14
GBK	9704	100-111	New recruits	18.0554	0.36	1.0752	0.36	65	31	14
GBK	9903	100-111	New recruits	8.0000	0.50	0.4874	0.49	58	17	14
GBK	200206	100-111	New recruits	7.3069	0.63	0.4424	0.63	42	13	11
GBK	8001	112+	Old recruits	0.1478	0.00	0.0106	0.00	9	1	3
GBK	8006	112+	Old recruits	0.1478	0.00	0.0106	0.00	9	1	3
GBK	*80 Mean*	*112+*	*Old recruits*	*0.1478*	*0.00*	*0.0106*	*0.00*	*18*	*2*	*NA*
GBK	8105	112+	Old recruits	0.6260	0.01	0.0696	0.00	31	4	10
GBK	8105	112+	Old recruits	0.6095	0.01	0.0693	0.00	22	3	9
GBK	*81 Mean*	*112+*	*Old recruits*	*0.6177*	*0.01*	*0.0694*	*0.00*	*53*	*7*	*NA*
GBK	8204	112+	Old recruits	0.6095	0.01	0.0693	0.00	22	3	9
GBK	8305	112+	Old recruits	3.9641	0.58	0.5867	0.66	44	12	11
GBK	8403	112+	Old recruits	8.0097	0.61	1.2074	0.68	29	8	7
GBK	8604	112+	Old recruits	7.4371	0.53	0.8927	0.52	45	6	14
GBK	8903	112+	Old recruits	26.5323	0.72	3.1317	0.73	76	20	14
GBK	9203	112+	Old recruits	10.5515	0.31	1.1874	0.31	66	25	14
GBK	9404	112+	Old recruits	53.5769	0.36	6.4436	0.39	68	25	14
GBK	9704	112+	Old recruits	35.8057	0.27	3.6609	0.25	65	28	14
GBK	9903	112+	Old recruits	36.8253	0.31	3.9445	0.30	58	23	14
GBK	200206	112+	Old recruits	32.4079	0.43	3.6658	0.41	42	17	11

Table C24. Database parameters for surfclam survey data used in this assessment and for data similar to data used by NEFSC (2000). Parameters for survey trends in NNJ and SNJ are shown as examples; length boundary parameters for other areas are given in Table C25. Database extractions for swept area biomass calculations used a lower length bound of 120 mm (NNJ and SNJ) or 100 mm (all other areas). Negative parameter values are ignored in database calculations.

Database Parameter	For comparison to N/Tow for various sizegroups in SARC 30 (Table E15)	For comparison to "KG/Tow All Sizes" in SARC 30 (Table E15)	Trends in NNJ and SNJ surfclam prior to 1982	Trends in NNJ and SNJ surfclam 1982 and later	Survey data for swept area biomass calculations
DISTANCE_TYPE	TREND	TREND	TREND	TREND	SENDIST_NEG1
LENGTH_BIN_SIZE_MM	10	10000	1000	1000	1000
FIRST_LENGTH_MM	0	0	107 or 120 or 130	107 or 120 or 130	100 or 120
FIRST_BIN_IS_PLUSGROUP	-1	-1	-1	-1	-1
LAST_LENGTH_MM	250	250	119 or 129 or 250	119 or 129 or 250	250
LAST_BIN_IS_PLUSGROUP	-1	-1	-1	-1	-1
SVSPP_TO_USE	403	403	403	403	403
AREAKIND	OLD	OLD	GIS	GIS	GIS
REV_DATE_FOR_AREAS	2002	2002	2002	2002	2002
REV_DATE_FOR_LW	0	0	1999	1999	1999
FIRST_JWSTCODE	-1	-1	-1	-1	-1
LAST_JWSTCODE	-1	-1	-1	-1	-1
FIRST_RANDLIKE	1	1	1	1	1
LAST_RANDLIKE	2	2	2	2	2
FIRST_STATION	-1	-1	-1	-1	-1
LAST_STATION	-1	-1	-1	-1	-1
FIRST_HAUL	1	1	-1	1	1
LAST_HAUL	3	3	-3	3	3
FIRST_GEARCOND	6	1	-1	1	1
LAST_GEARCOND	6	6	-6	6	6
FIRST_STRATUM	1	1	1	1	1
LAST_STRATUM	96	96	96	96	96
FIRST_REGION_CODE	1	1	3	3	1
LAST_REGION_CODE	7	7	4	4	7
WRITE_TOW_DATA	1	1	-1	-1	-1
WRITE_STRATUM_DATA	1	1	-1	-1	-1
FIRST_CRUISE	-9700	-9700	-7000	-7000	9700
LAST_CRUISE	-9800	-9800	8200	-8200	-9800
NOMINAL_TOW_DISTANCE_NM	0.15	0.15	0.15	0.15	0.15
FILLHOLZ	-1	-1	1	1	1

Table C25. Surfclam growth model (length at age) parameters (Weinberg and Helser 1996) and length groups for pre-recruit, recruit and old recruit survey data.

Stock	New Jersey (NNJ and SNJ)			Delmarva and SVA			Long Island (LI)	Southern New England (SNE)	Georges Bank (GBK)
Time Period	1980	1989-1992	Average	1980	1989-1992	Average	All	All	All
L_{max} (mm)	170.8	163.7	[redacted]	171.0	164.0	[redacted]	161.8	164.7	154.1
K (y^{-1})	0.254	0.217	[redacted]	0.256	0.177	[redacted]	0.251	0.300	0.242
t_o (y)	0.010	-0.214	[redacted]	0.132	-1.125	[redacted]	-0.443	0.319	0.203
Age at recruitment (k) in years	4.8	5.9	5.3	3.6	4.2	3.9	3.4	3.4	4.5
Length at age k-1	105	109	107	79	88	83	82	77	85
Length at age k	120	120	120	100	100	100	100	100	100
Length at age k+1	131	129	130	116	110	113	114	117	112

Table C26. Growth model parameters (meat weight at age) used in the KLAMZ model for surfclam (NEFSC 2000).

Area	Years	ρ	J_t
New Jersey (NNJ and SNJ)	< 1981	0.8392	0.6841
	1981-1988	0.8392	By interpolation
	>1988	0.8392	0.7569
Delmarva	< 1981	0.8621	0.5079
	1981-1988	0.8621	By interpolation
	>1988	0.8621	0.5553
Long Island (LI)	All	0.8278	0.5232
Southern New England (SNE)	All	0.8023	0.4346
Georges Bank (GBK)	All	0.8456	0.6588

Table C27. KLAMZ model results for DMV surfclam. CV's for biomass and recruitment are from a bootstrap analysis (1000 iterations). CV's for fishing mortality rates are by the delta method.

Year	Biomass (1000 mt)	CV	Recruitment (1000 mt)	CV	Fishing Mortality (y^{-1})	CV	Surplus Production (1000 mt)	Instantaneous Surplus Production Rate (y^{-1})
1977	79	800%	NA	NA	0.042	82%	29	0.318
1978	105	160%	26	0.043846	0.031	66%	37	0.298
1979	138	105%	31	0.508006	0.018	58%	59	0.355
1980	194	71%	52	0.501089	0.013	53%	87	0.369
1981	279	46%	76	0.404296	0.000	50%	93	0.289
1982	372	33%	77	0.286368	0.027	50%	57	0.143
1983	419	26%	41	0.168609	0.021	50%	26	0.061
1984	436	24%	21	0.278116	0.019	50%	20	0.045
1985	448	24%	27	0.368931	0.021	50%	8	0.019
1986	447	23%	22	0.229895	0.007	50%	-4	-0.009
1987	440	22%	15	0.358235	0.005	50%	-12	-0.027
1988	427	21%	13	0.359718	0.003	50%	-17	-0.041
1989	408	21%	11	0.417193	0.010	50%	-22	-0.055
1990	383	20%	8	0.563822	0.011	50%	-24	-0.065
1991	355	19%	7	0.728656	0.005	50%	-25	-0.073
1992	328	19%	6	0.913564	0.004	50%	-23	-0.072
1993	304	20%	7	1.201202	0.013	50%	-16	-0.055
1994	284	20%	12	0.834815	0.014	50%	-6	-0.023
1995	274	21%	19	0.421947	0.012	50%	5	0.017
1996	276	21%	26	0.268422	0.009	50%	14	0.051
1997	288	20%	32	0.309467	0.006	50%	21	0.071
1998	307	19%	35	0.618812	0.001	50%	5	0.016
1999	312	18%	17	0.156186	0.002	50%	-7	-0.023
2000	304	18%	8	0.439081	0.008	50%	-12	-0.040
2001	290	18%	7	0.798677	0.013	51%	-15	-0.052
2002	272	19%	6	0.936476	0.019	51%	NA	NA

Table C28. Projected biomass, catch and fishing mortality for surfclam during 2002-2003. Projections are uncertain, may be overly pessimistic, and should be interpreted with care (see text for additional details).

Table PROJ-1. Projected biomass, catch and fishing mortality for surfclam during 2002-2003. Projections assume a constant instantaneous rate of surplus production during 2002-2005, use actual catches in 2002 and use catches during 2003-2005 equal to the quota + 12% incidental mortality allowance, prorated by region based on average catches during 1999-2002. Total biomass for 2002 is from a regression model used to smooth original efficiency corrected swept area biomass (ESB) estimates. The biomass in each region during 2002 was calculated by prorating the total based on average ESB in each region during 1997-2002. See text for additional details.

Surplus production rate ρ (y^{-1})	-0.051

	Northern New Jersey (NNJ)	Southern New Jersey (SNJ)	Delmarva (DMV)	S. Virginia and N. Carolina (SVA)	Long Island (LI)	Southern New England (SNE)	Georges Bank (GBK)	Total
Average ESB 1997-2002 (1000 mt)	429	65	251	11	38	58	284	1,136
% Average ESB 1997-2002	38%	6%	22%	1%	3%	5%	25%	100%
Average Catch 1997-2002 (1000 mt)	16.21	3.76	2.49	0.03	0.52	0.05	0.00	23.06
% Average Catch 1997-2002	70%	16%	11%	0%	2%	0%	0%	100%
Biomass on 1 January (1000 mt)								
2002	348	53	203	9	31	47	230	921
2003	314	47	188	9	28	45	219	849
2004	279	40	176	8	26	42	208	780
2005	246	34	164	8	24	40	198	714
2006	215	28	153	7	22	38	188	651
Percent Change in Biomass								
2002	0%	0%	0%	0%	0%	0%	0%	0%
2003	-10%	-11%	-7%	-6%	-9%	-5%	-5%	-8%
2004	-20%	-24%	-13%	-11%	-16%	-10%	-10%	-15%
2005	-29%	-36%	-19%	-16%	-22%	-15%	-14%	-23%
2006	-38%	-47%	-25%	-20%	-28%	-19%	-18%	-29%
Catch = Landings + 12% (1000 mt)								
2002	16.73	3.19	4.98	0.09	1.30	0.14	0.00	26.43
2003	19.74	4.57	3.03	0.04	0.63	0.06	0.00	28.07
2004	19.74	4.57	3.03	0.04	0.63	0.06	0.00	28.07
2005	19.74	4.57	3.03	0.04	0.63	0.06	0.00	28.07
Fishing Mortality (y^{-1})								
2002	0.051	0.064	0.026	0.010	0.044	0.003	0.000	0.030
2003	0.067	0.105	0.017	0.005	0.023	0.001	0.000	0.034
2004	0.075	0.123	0.018	0.005	0.025	0.002	0.000	0.038
2005	0.086	0.149	0.019	0.005	0.027	0.002	0.000	0.041

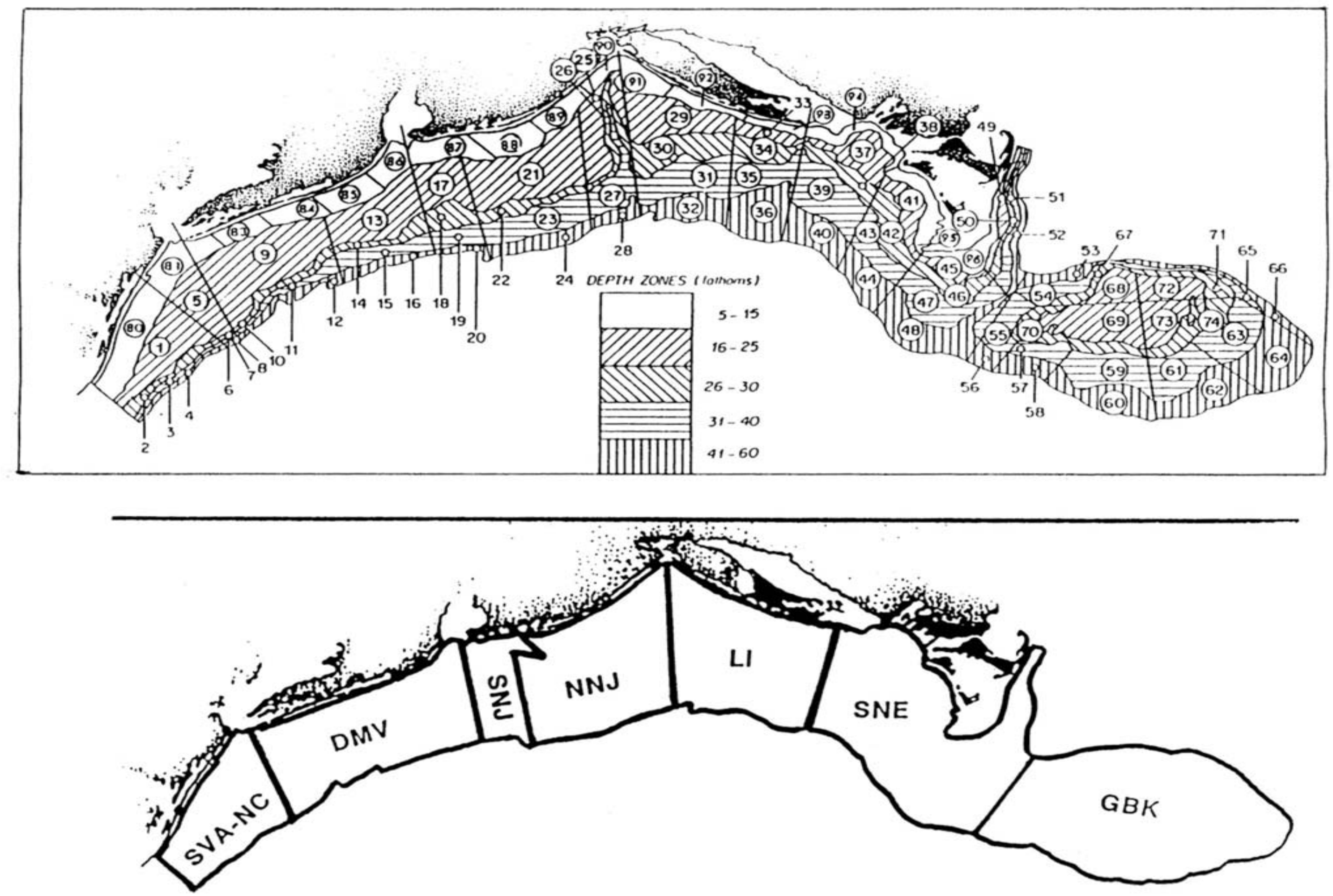


Figure C1. Clam strata and regions.

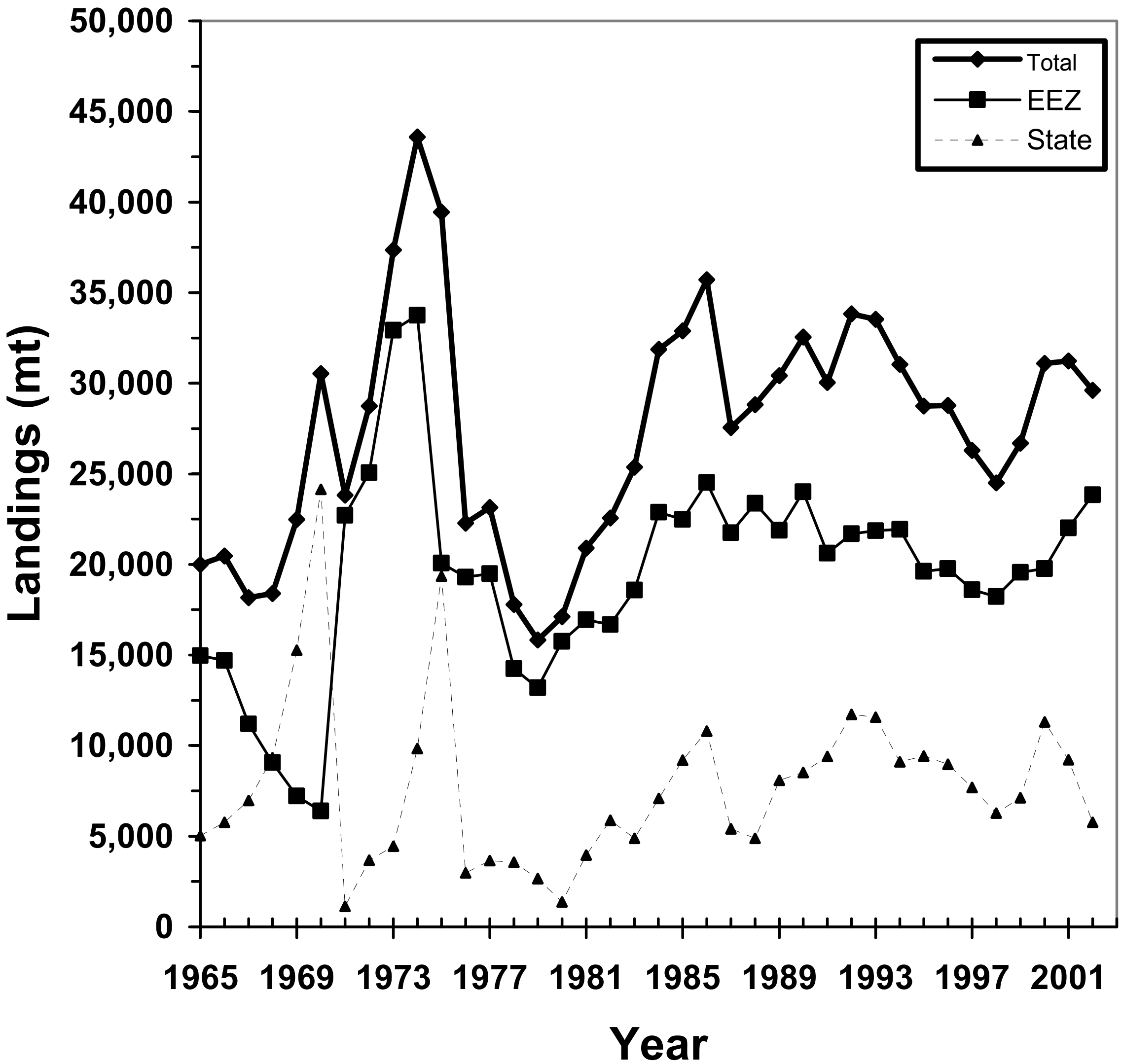


Figure C2. Landings of surfclams, 1965 - 2002. Data are for all areas (total), Exclusive Economic Zone (EEZ, 3 - 200 miles from the coast, and state (inshore) waters. EEZ data source: Logbooks.

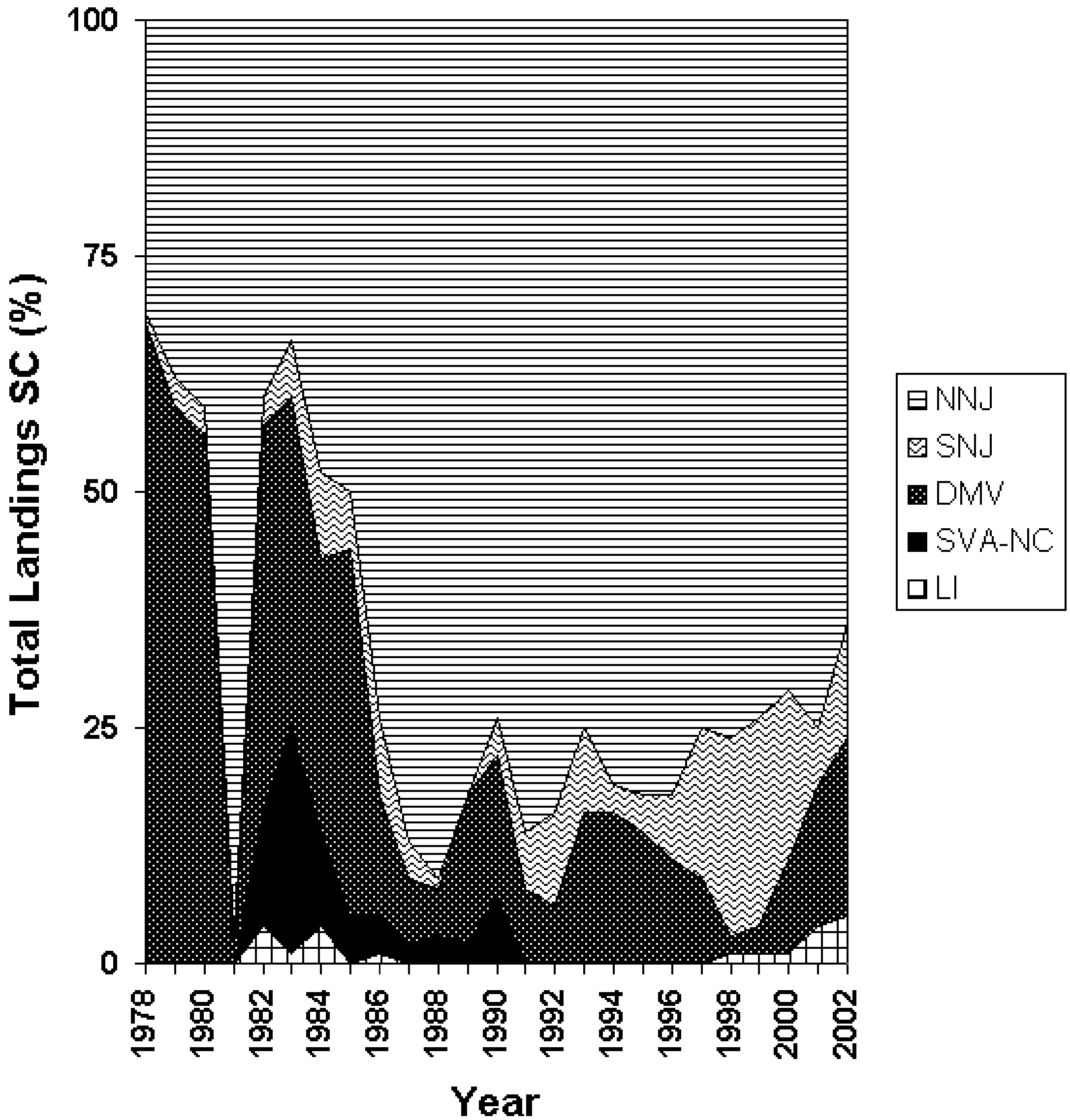


Figure C3. Proportion of surfclam landings in the Mid-Atlantic region, by area and year, 1978- 2002.

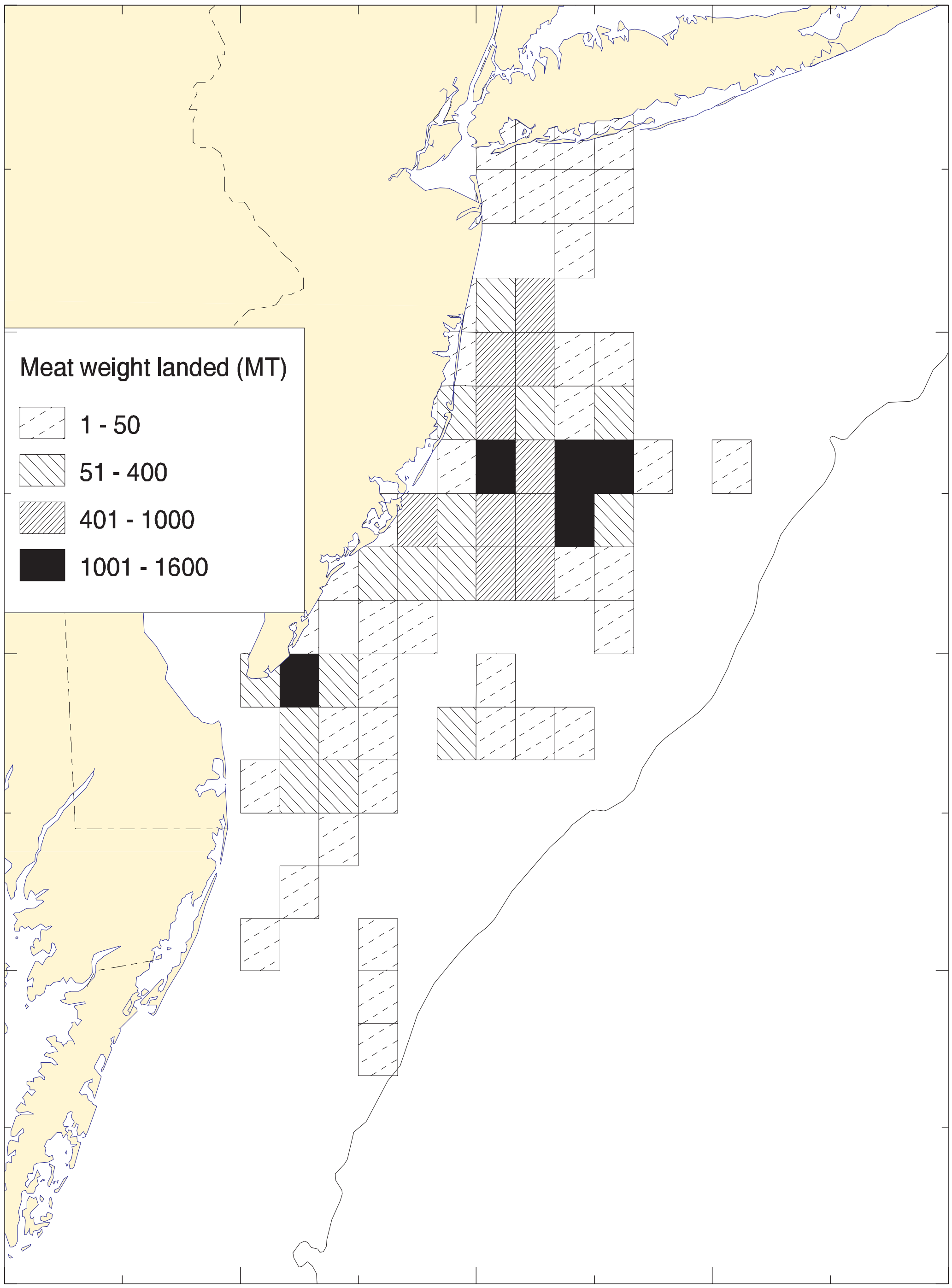


Figure C4. Distribution of surfclam landings during 1999(sclnd832002b) by ten-minute square.

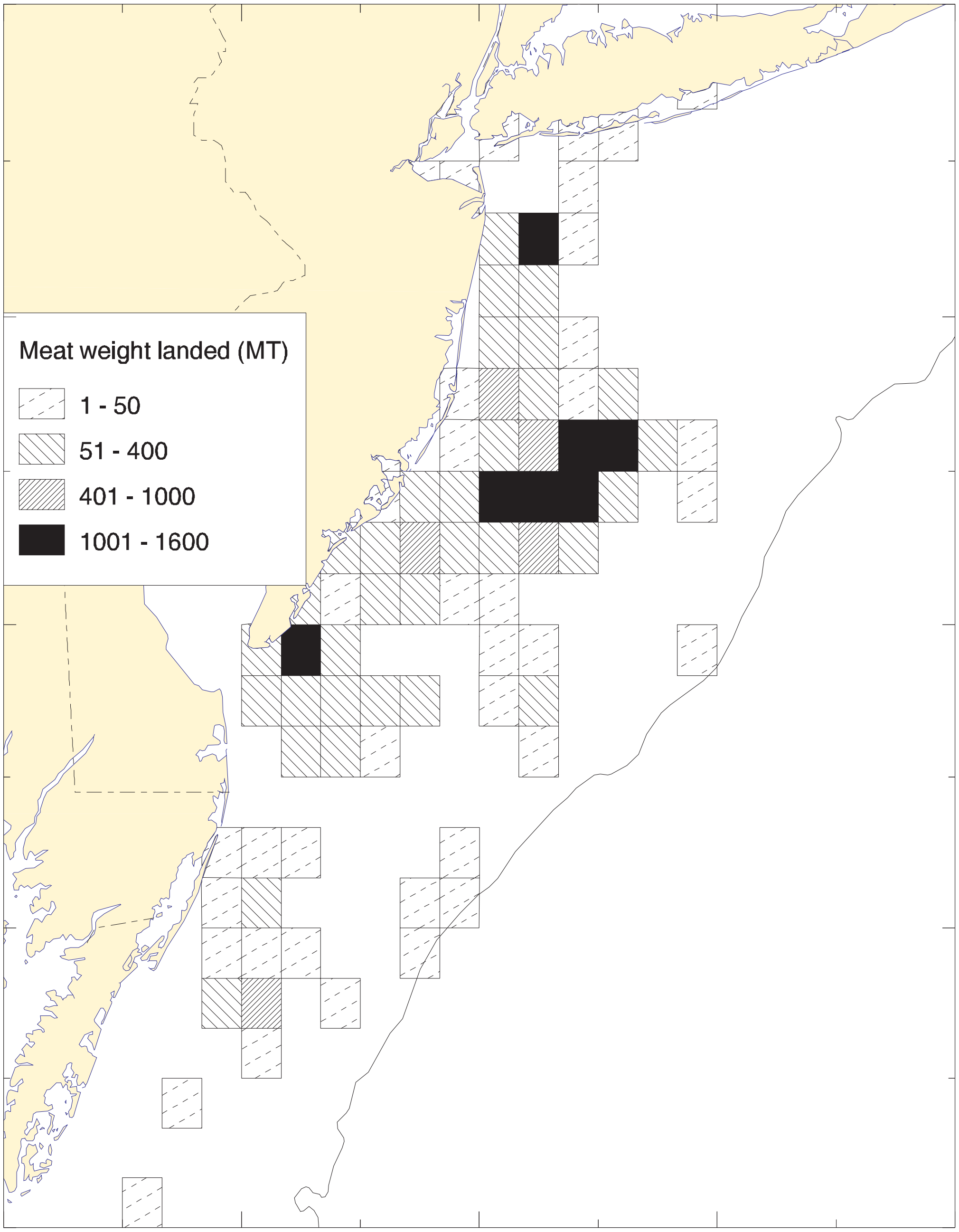


Figure C5. Distribution of surfclam landings during 2000(sclnd832002b) by ten-minute square.

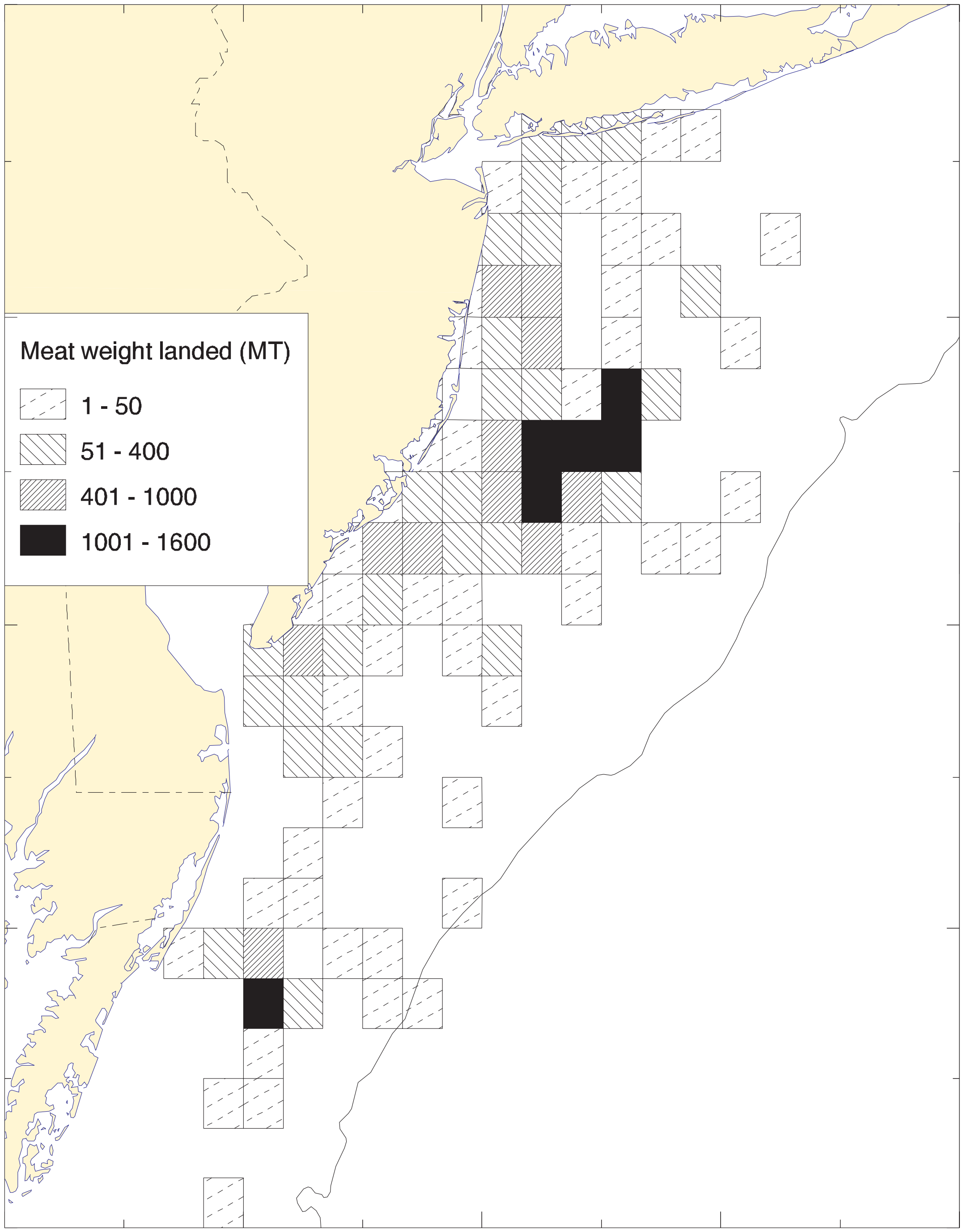


Figure C6. Distribution of surfclam landings during 2001(sclnd832002b) by ten-minute square.

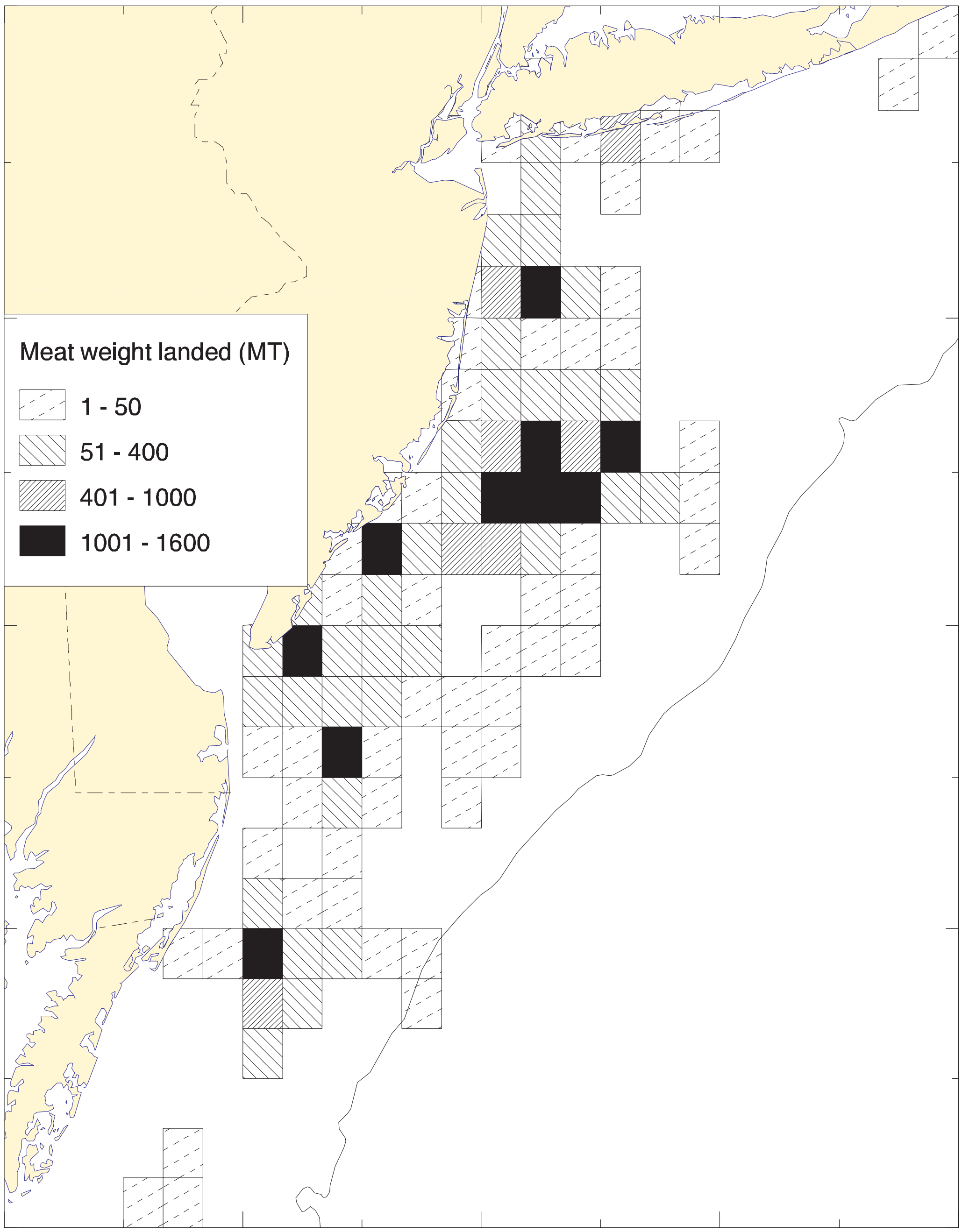


Figure C7. Distribution of surfclam landings during 2002(sclnd832002b) by ten-minute square.

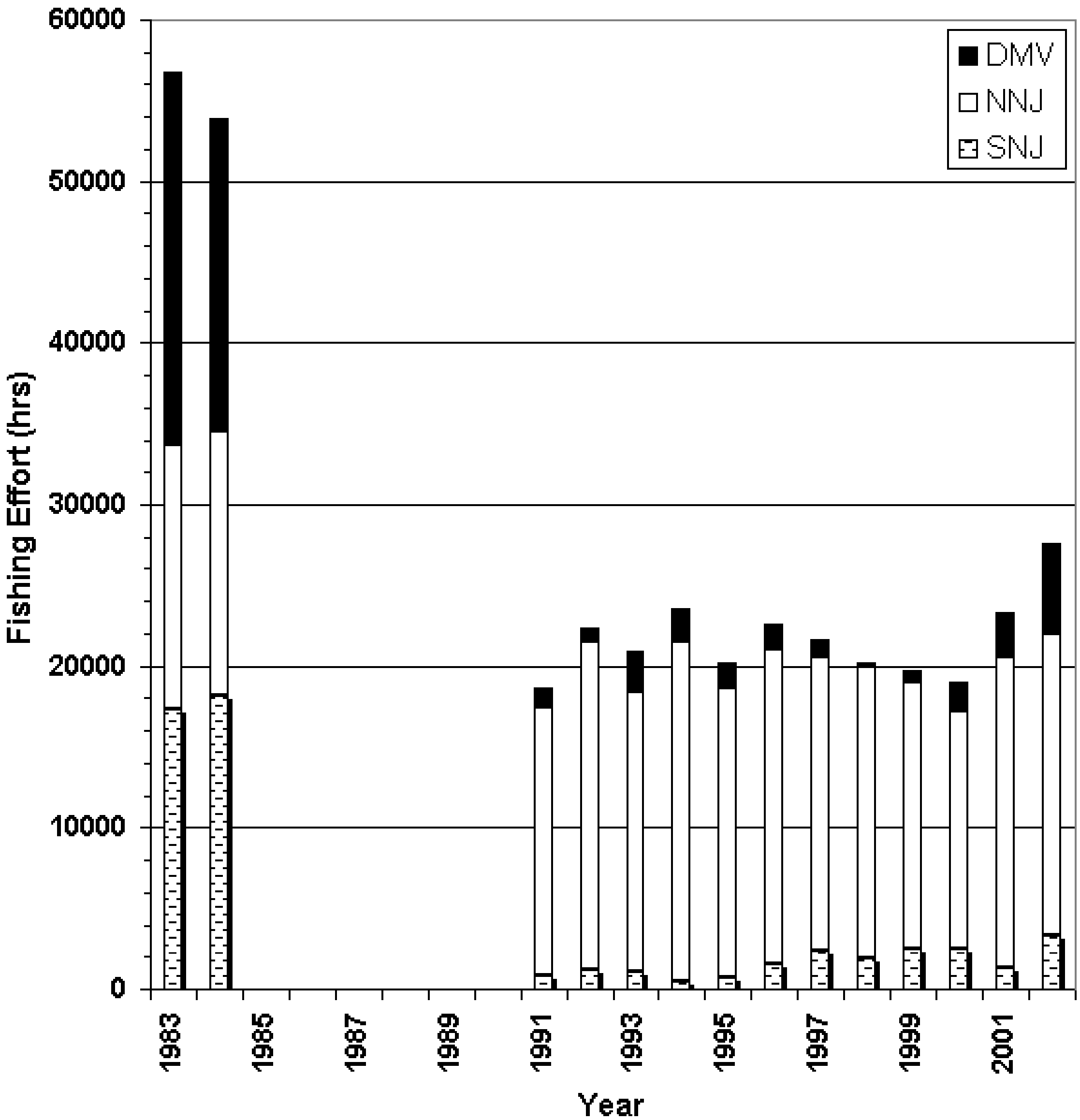
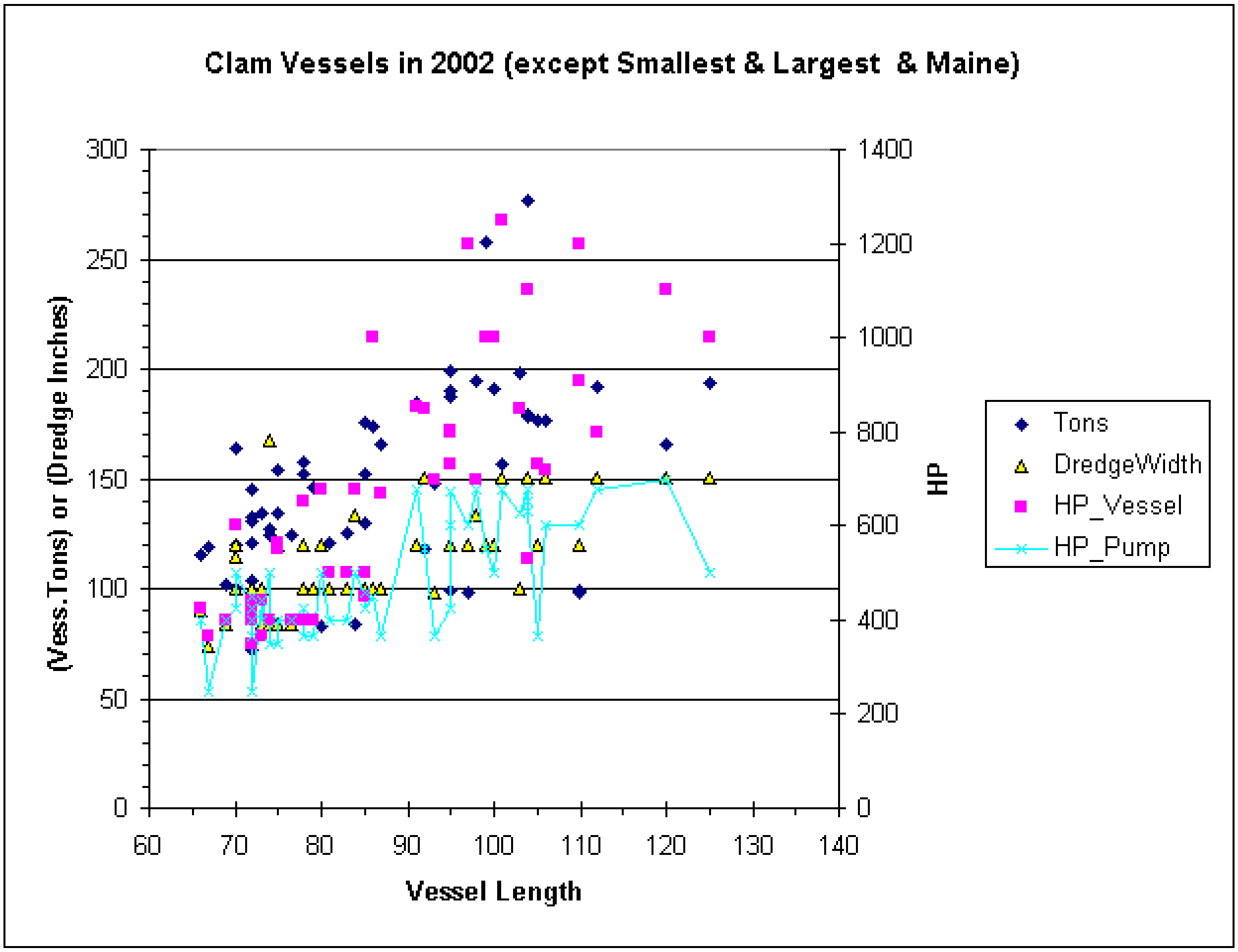


Figure C8. Total reported hours fishing during surfclam trips, by region year. Effort was not reported accurately from 1985 - 1990.



All 2002 Clam Vessels (Except from Maine) :

Var1	Var2	Corr. Coef. (r)	Significance
Length	Tons	0.718	**
HP Vessel	Tons	0.318	*
Dredge W	Tons	0.404	**
HP Pump	Tons	0.439	**

for v=n-2; n=55 :

Significance Level	Critical Value
* (p=.05)	0.26
** (p=.01)	0.34

Figure C9. Correlations between physical characteristics of commercial clam vessels.

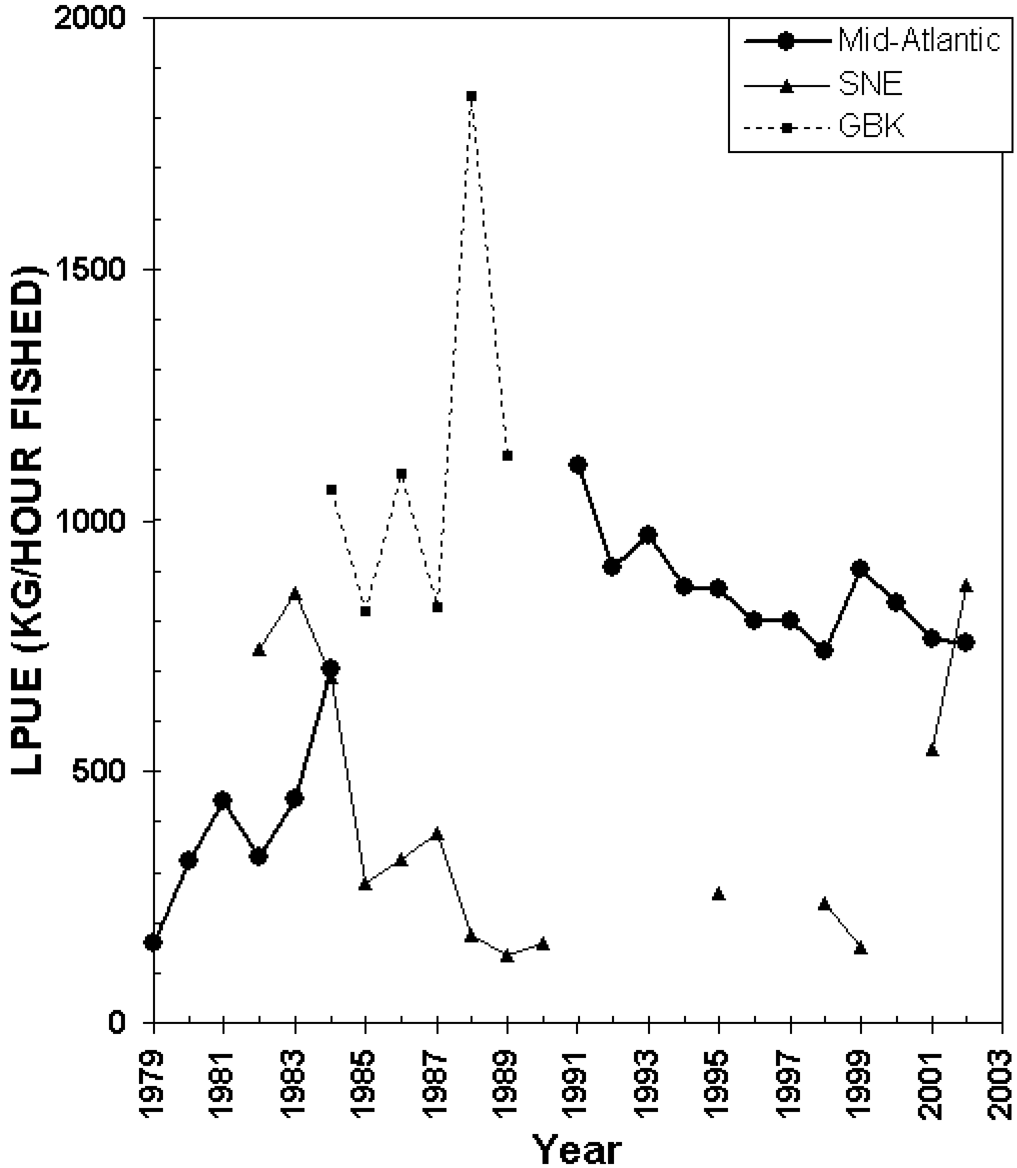


Figure C10. Landings per unit effort of surfclams by Class 3 vessels (105 + GRT) by region, 1979 - 2002. Data source: Logbooks (SfyyyVR).

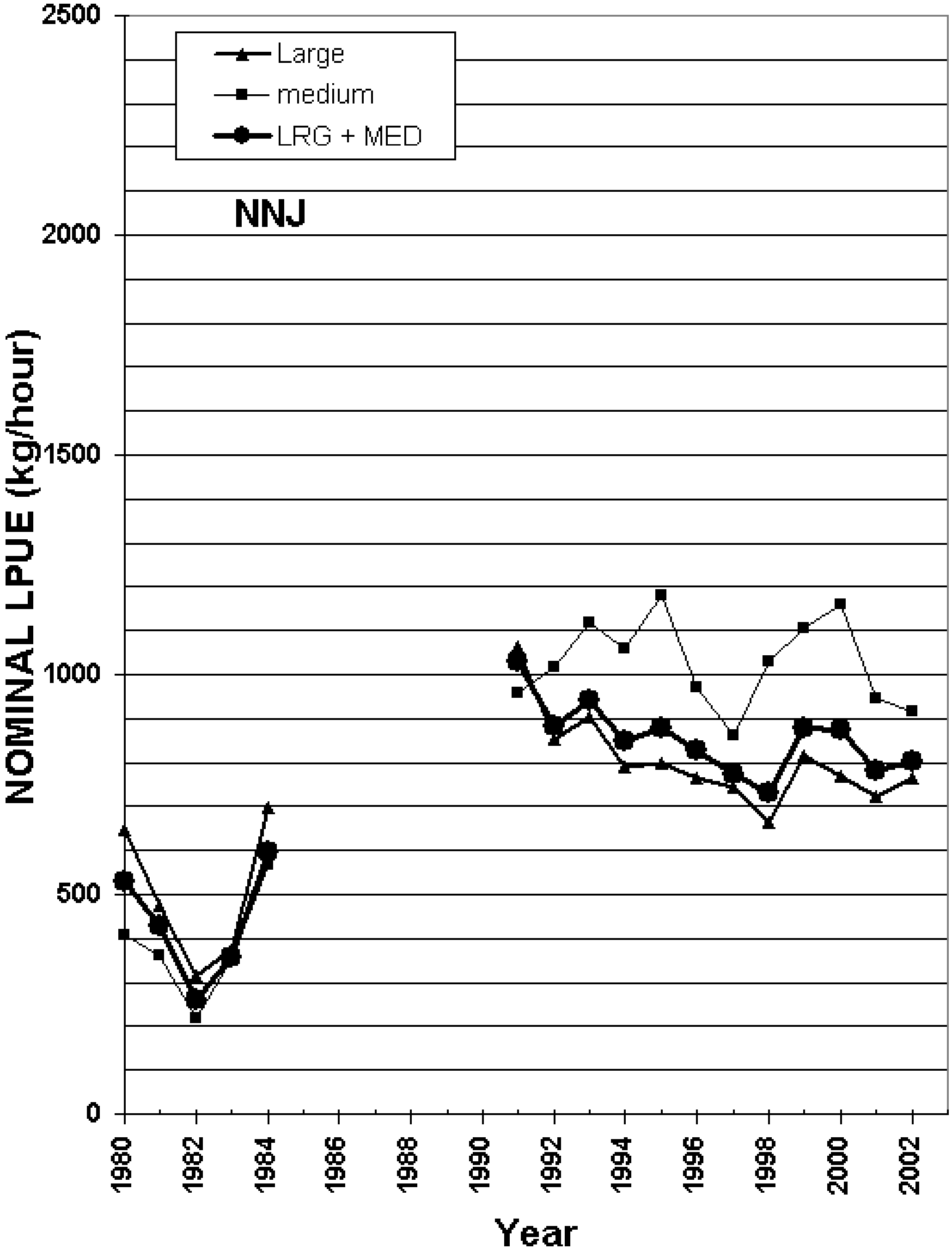


Figure C11. Nominal landings per unit effort for N. New Jersey, by vessel class (Medium: 51-104 GRT; Large: 105 GRT+).

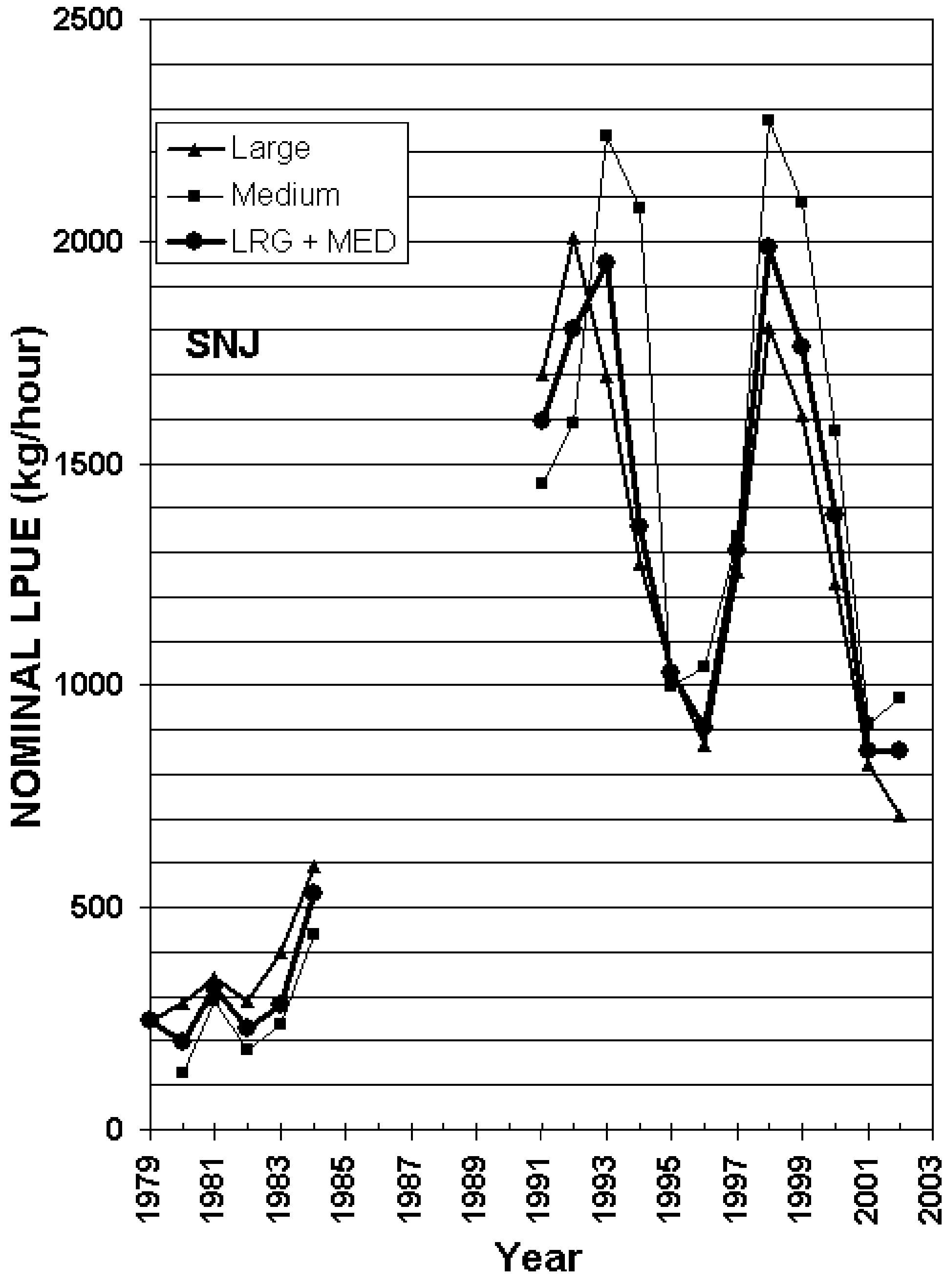


Figure C12. Nominal landings per unit effort for S. New Jersey, by vessel class (Medium: 51-104 GRT; Large: 105 GRT+).

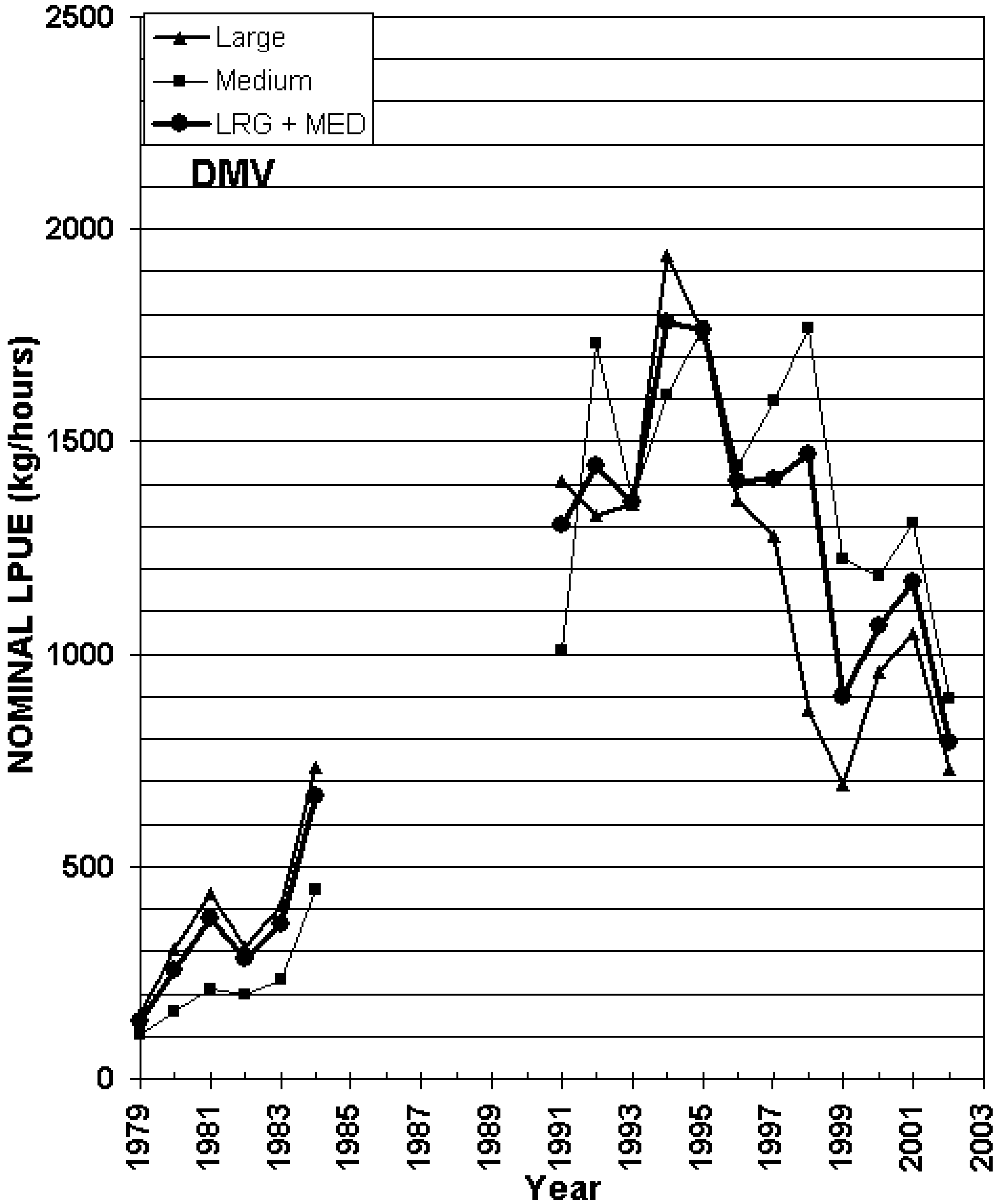


Figure C13. Nominal landings per unit effort for Delmarva, by vessel class (Medium: 51-104 GRT; Large: 105 GRT+).

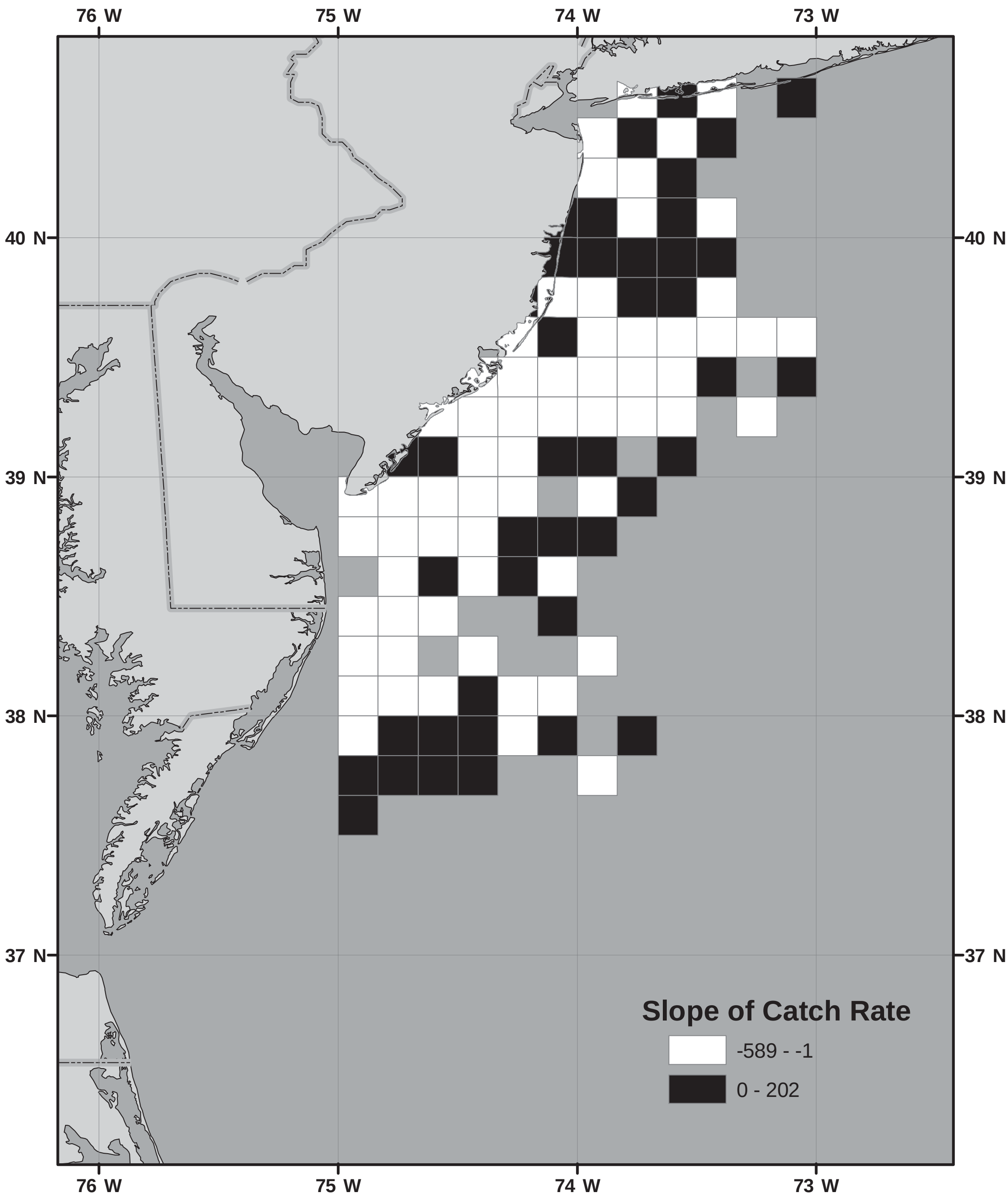


Figure C14. Spatial analysis, by ten minute square (TNMS), of trends in commercial catch rate from 1991-2002. For each TNMS, the slope of LPUE vs time was computed. If the slope was positive the TNMS was filled with black. If the slope was negative, the TNMS was filled with white.

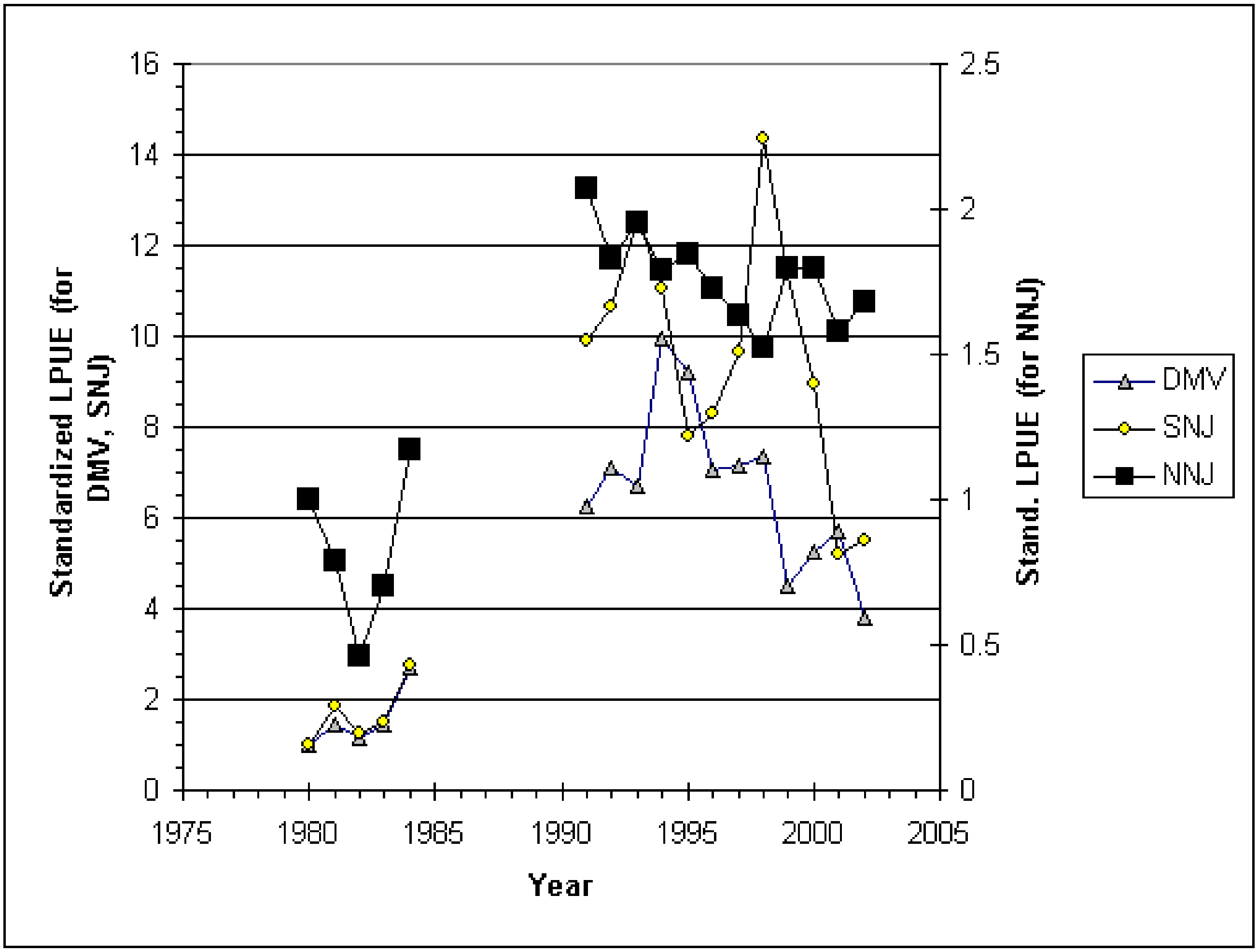


Figure C15. Standardized LPUE for surfclams, analyzed with a general linear model including Year and Subregion. A separate model was run for each region.

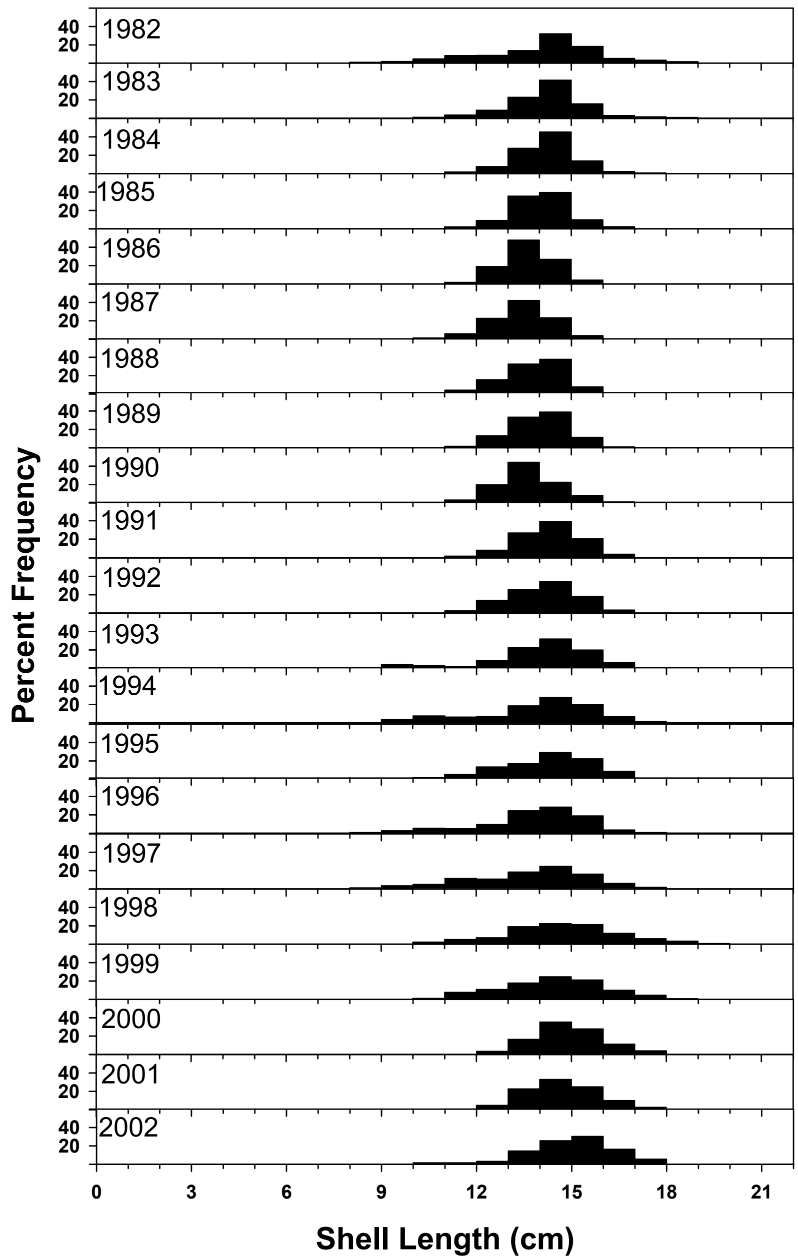


Figure C16. Surfclam commercial length frequency distributions based on port samples.
Region : **New Jersey**.

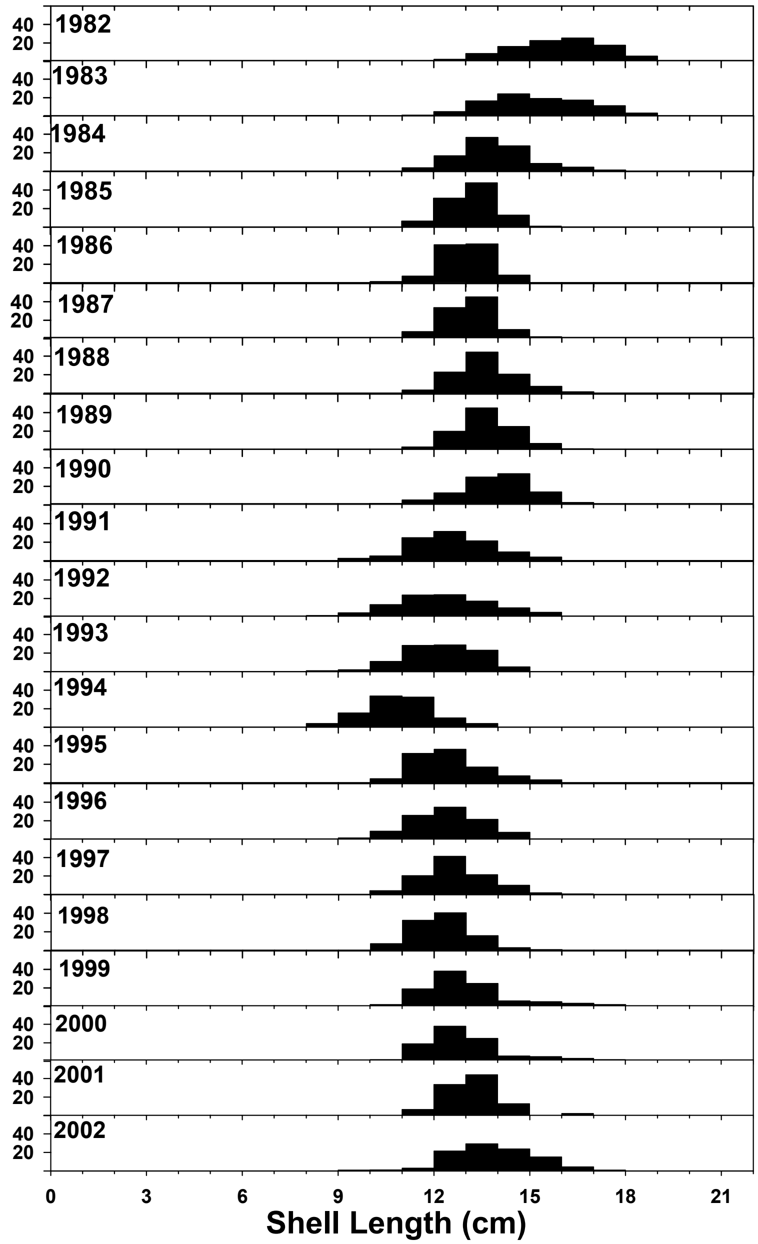
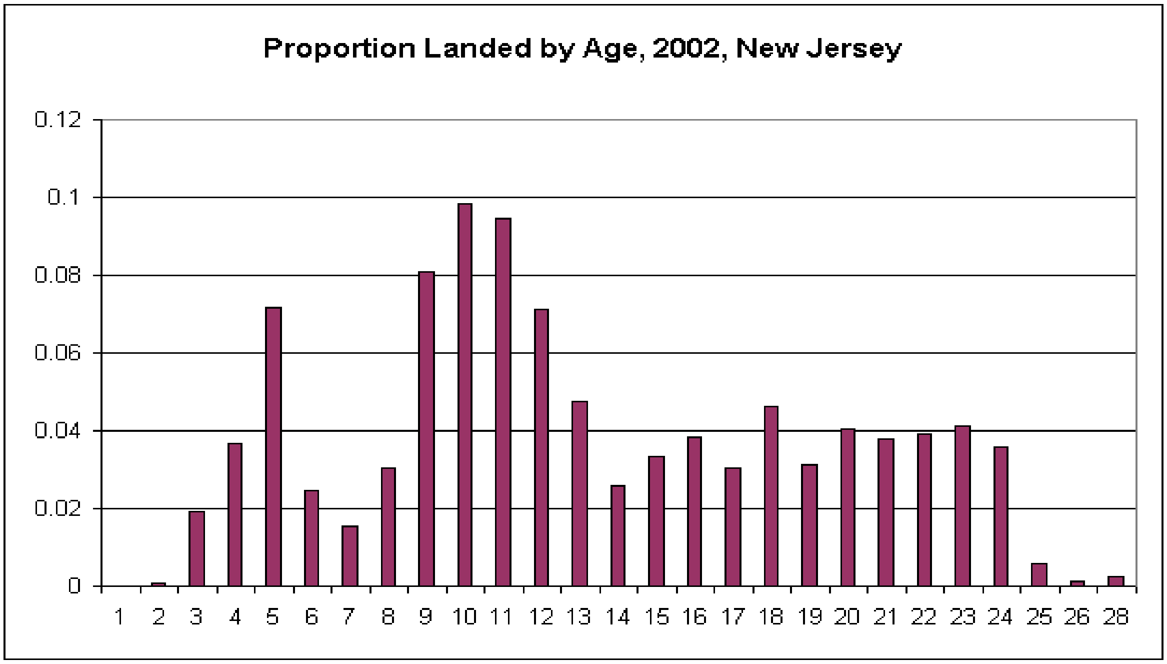


Figure C17. Surfclam commercial length frequency distributions based on port samples. Region : **Delmarva**.



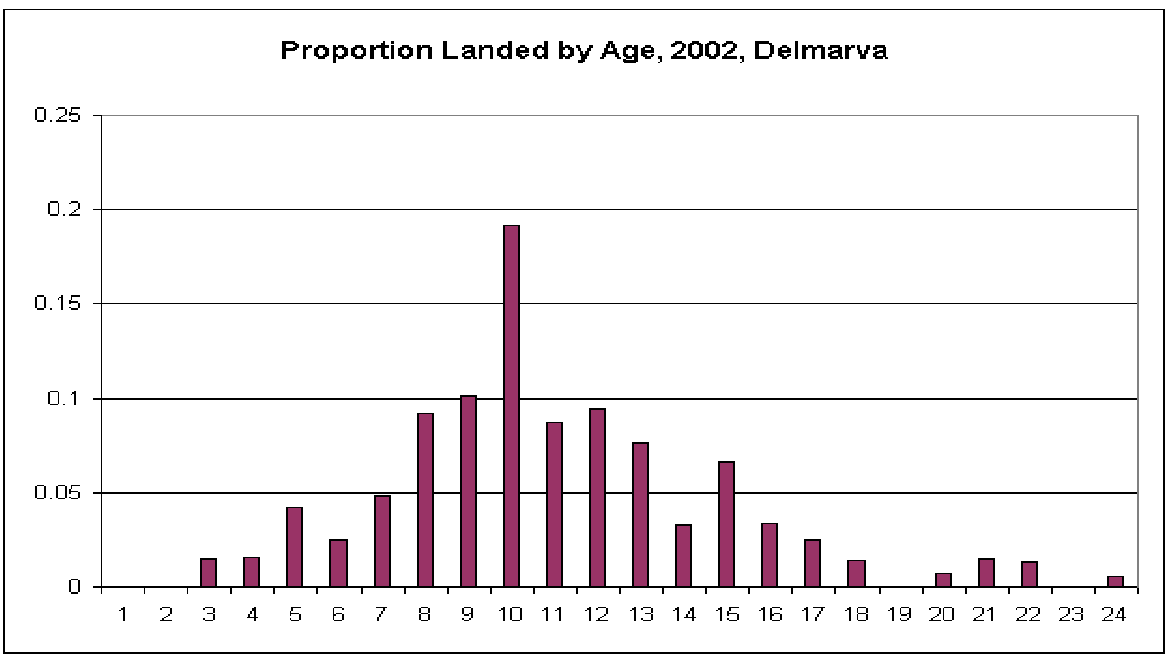


Figure C18. Proportion of surfclams landed in 2002, by region and age (years). Source data: Commer. Port samples.

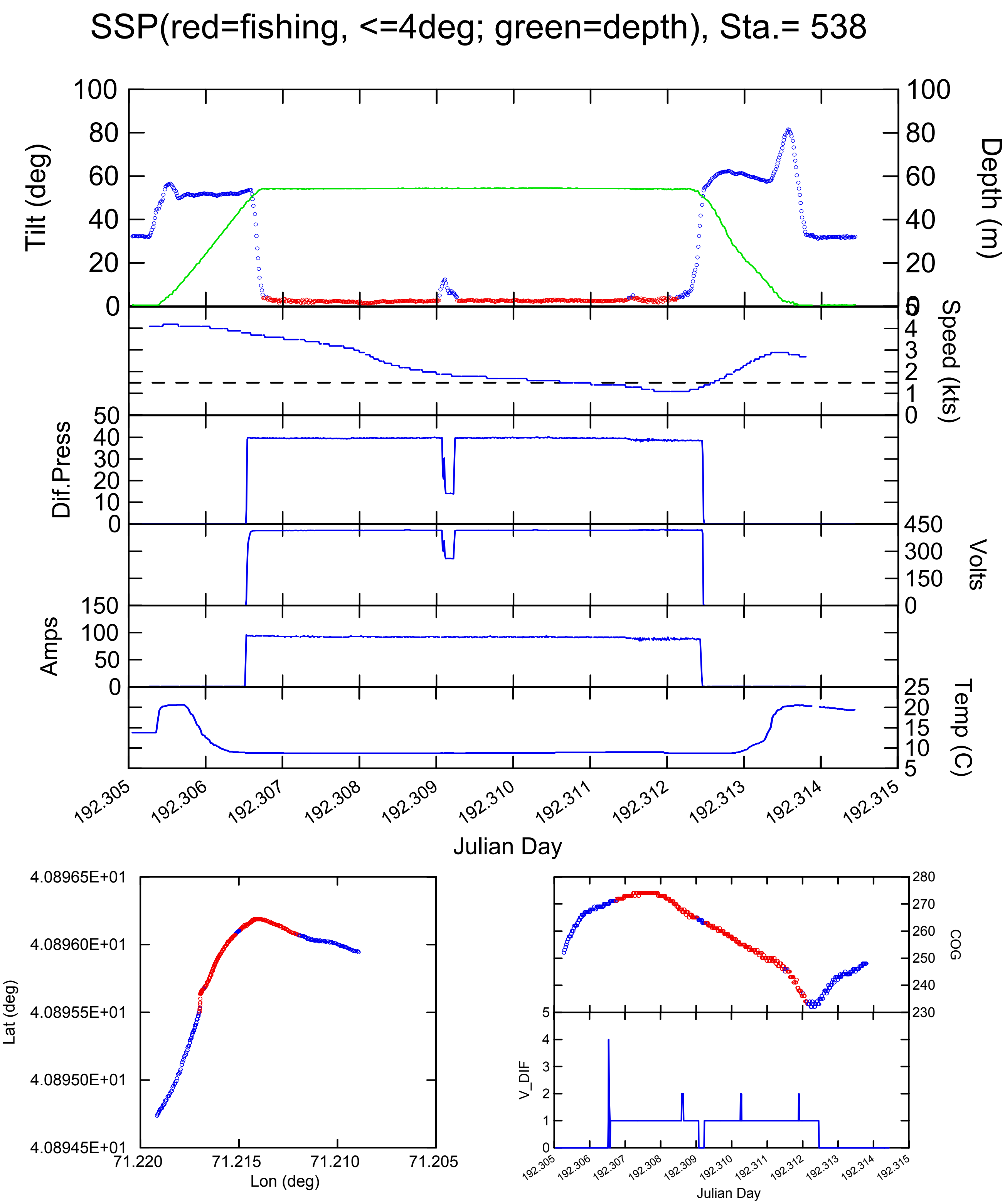


Figure C19. Example of sensor data collected at each DE-II station during the 2002 clam survey.

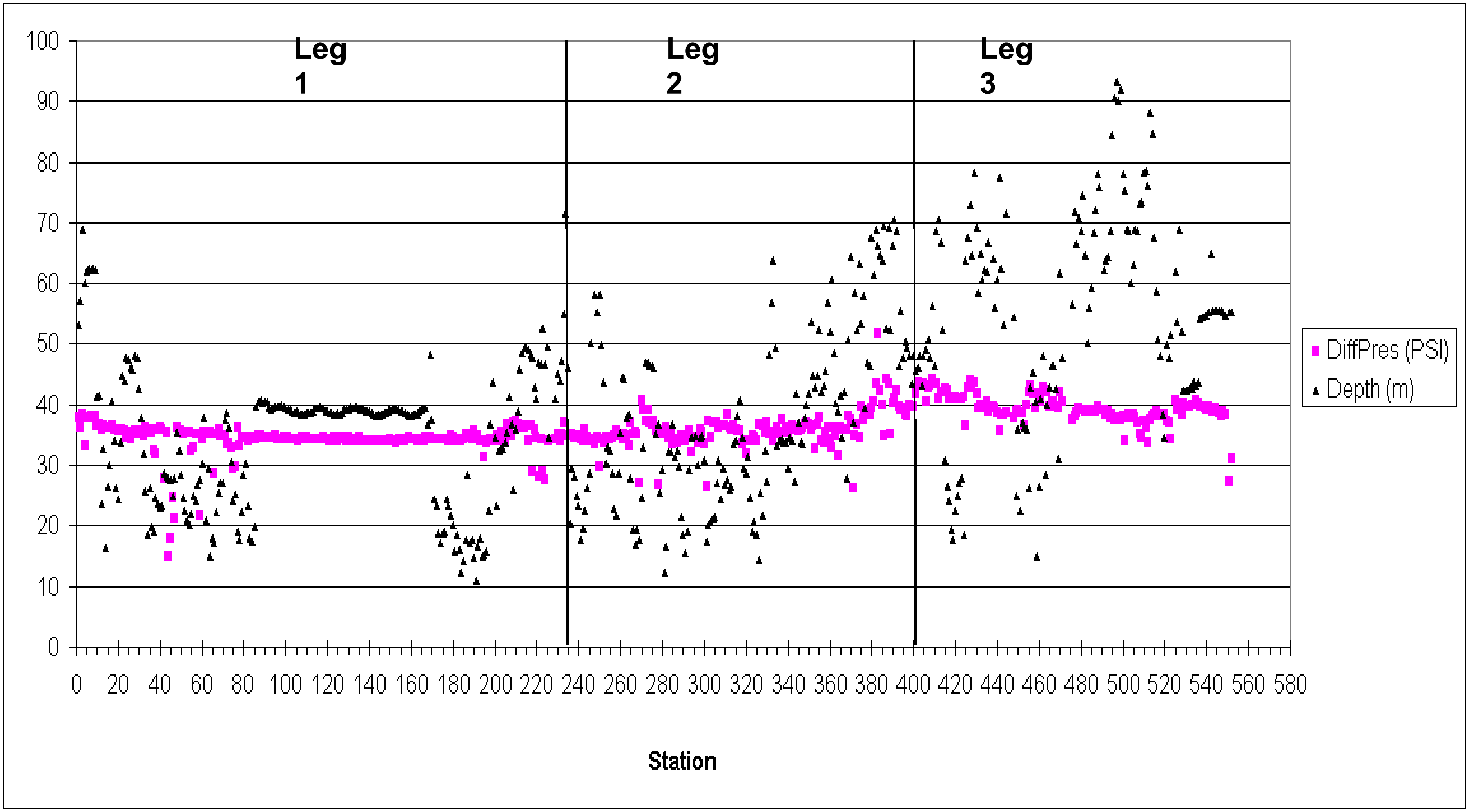
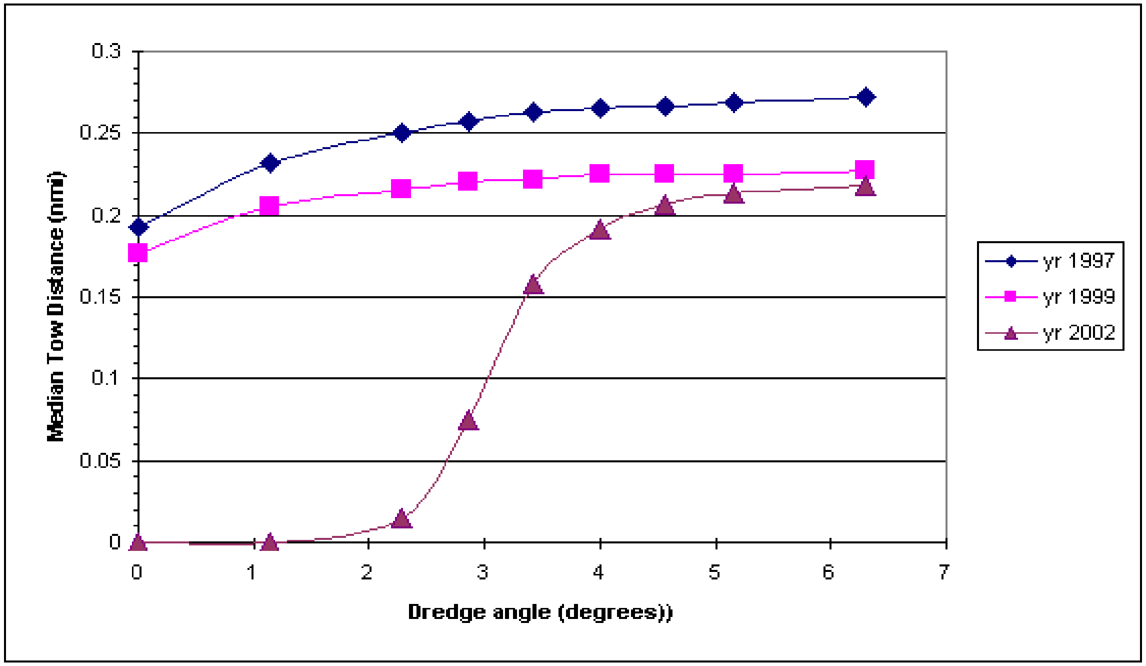


Figure C20. Delaware II differential pressure (psi) and station depth (m) measured by the Survey Sensor Package, 2002 NMFS Clam Survey, Cruise 200206.

Figure C21.
Examination of tow distance, computed from sensor data, as a function of dredge angle, in 1997, 1999, and 2002. Calculation includes all good survey tows.

	Median Tow Distance (nmi)			Fraction of Distance at Asymptote		
Dredge Angle (degrees)	yr 1997	yr 1999	yr 2002	**yr 1997**	**yr 1999**	**yr 2002**
6.3	0.272	0.227	0.218	1.000	1.000	1.000
5.2	0.269	0.225	0.213	0.989	0.991	0.977
4.6	0.267	0.225	0.206	0.982	0.991	0.945
4.0	0.265	0.225	0.191	0.974	0.991	0.876
3.4	0.263	0.222	0.158	0.967	0.978	0.725
2.9	0.257	0.22	0.075	0.945	0.969	0.344
2.3	0.25	0.216	0.015	0.919	0.952	0.069
1.1	0.232	0.205	0	0.853	0.903	0.000
0.0	0.193	0.176	0	0.710	0.775	0.000



	Used	By Drawing	Measured
Knife Pivot Fwd of Dredge End (Inches):	72	71.75	72
Knife Edge Fwd of Pivot (Inches):	32.5	32	32.5
Knife Edge Fwd of Dredge End (Inches):	104.5	103.75	
Knife Edge Below Dredge Runner (Inches):	8	8	
Manifold Center Fwd of Dredge End (Inches):	138.5	138.5	138.5
Manifold Nozzle Aft of Manifold Center (Inches):	3.1	3.1	
Manifold Nozzle Fwd of Dredge End (Inches):	135.4	135.4	
Manifold Nozzle Above Dredge Runner (Inches):	1.5	1.5	
Manifold Nozzle Angle to Runner (Degrees):	45	45	

Dredge Angle To Bottom Deg	Manifold Nozzle Vert Height Above Bottom Inches	Manifold Angle To Bottom Degrees	Water Jet Travel To Bottom Inches
6.00	15.73	51.00	20.24
5.50	14.54	50.50	18.84
5.00	13.35	50.00	17.42
4.50	12.16	49.50	15.99
4.00	10.97	49.00	14.53
3.50	9.78	48.50	13.06
3.00	8.60	48.00	11.57
2.50	7.41	47.50	10.05
2.00	6.23	47.00	8.52
1.50	5.05	46.50	6.96
1.00	3.86	46.00	5.37
0.50	2.68	45.50	3.76
0.00	1.50	45.00	2.12
	NH	NA	WL
Dredge Angle	Nozzle Abv Bttm		Water Jet Travel

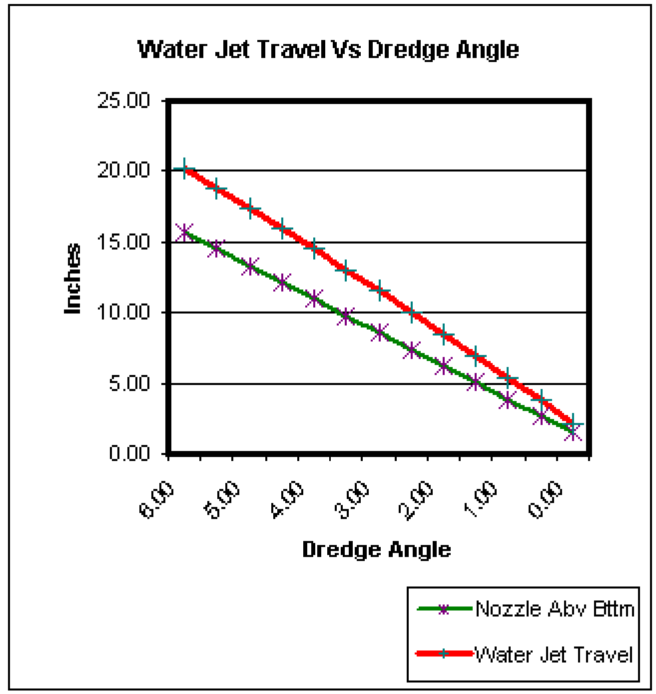


Figure C22.
Relationship between NMFS clam dredge angle and water jet travel distance to bottom. From J. Womack, 5/2003.

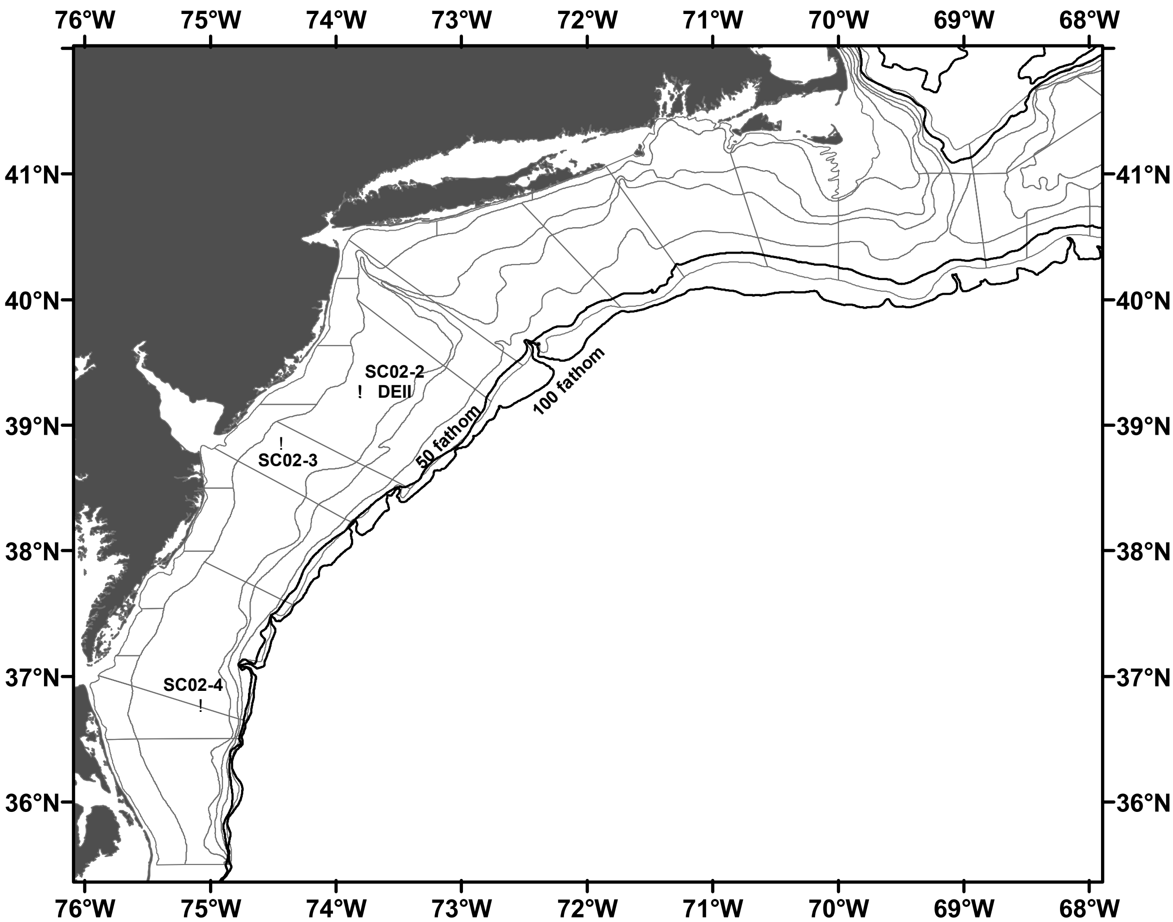


Figure C23. Locations of dredge efficiency experiments with surfclams in 2002. Vessels : R/V Delaware II and F/V Jersey Girl.

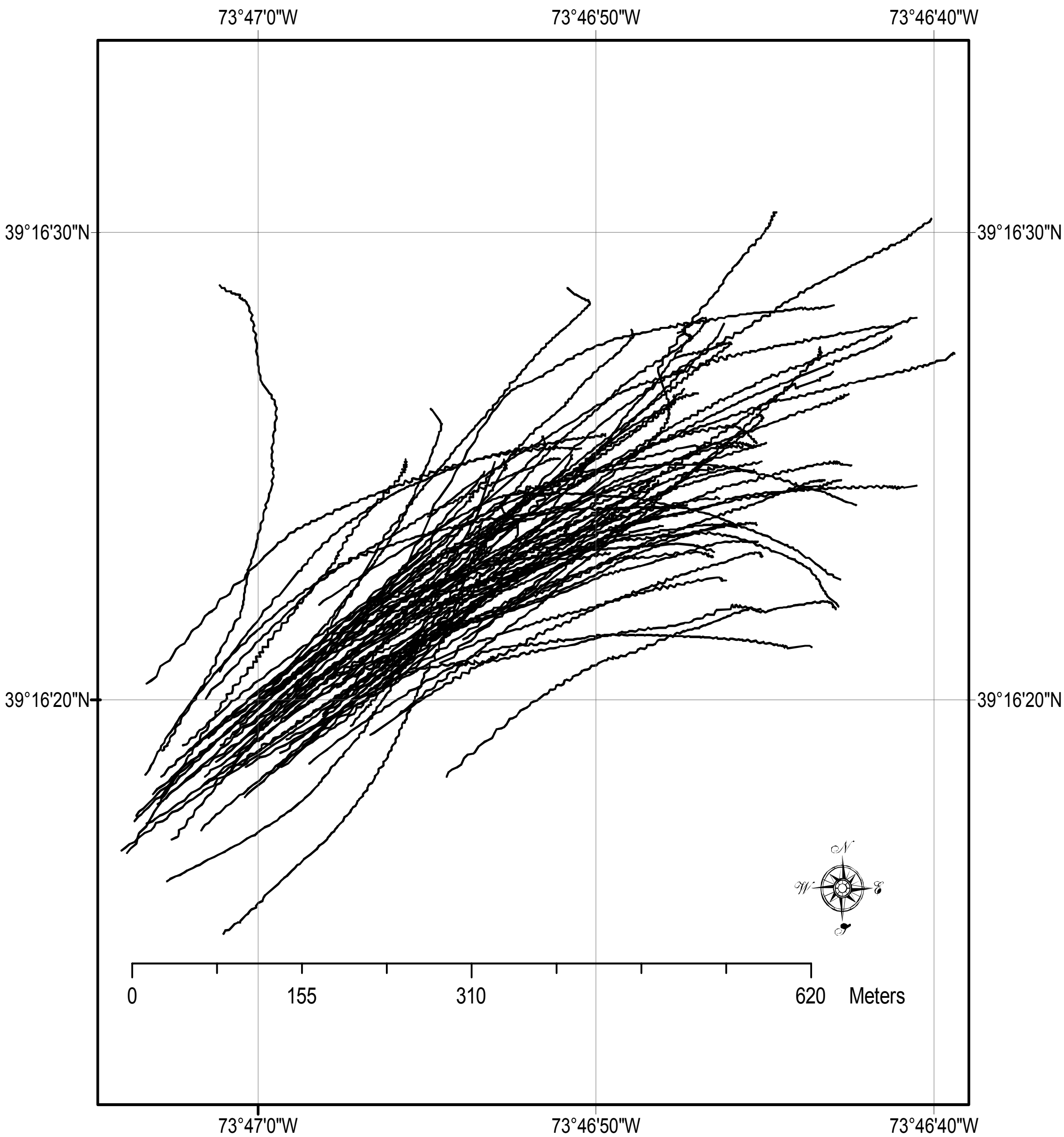


Fig. C24. *R/V Delaware-II* dredge calibration experiment on surfclams off NJ in June, 2002.

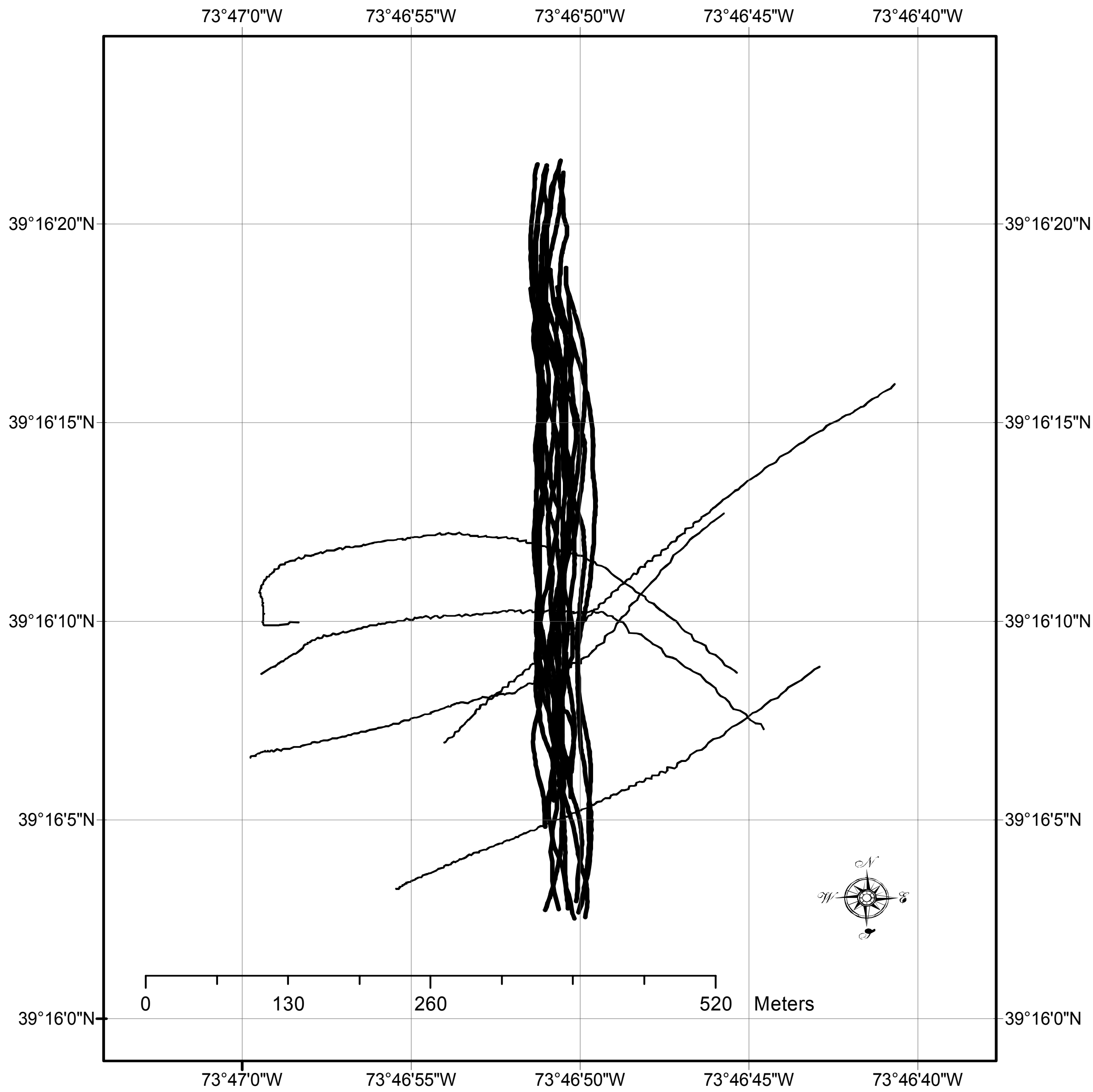


Fig. C25. Towpaths by the *R/V Delaware-II* setup tows (lighter lines) and the *F/V Jersey Girl* (darker lines), 2002, off NJ at site: sc02-2.

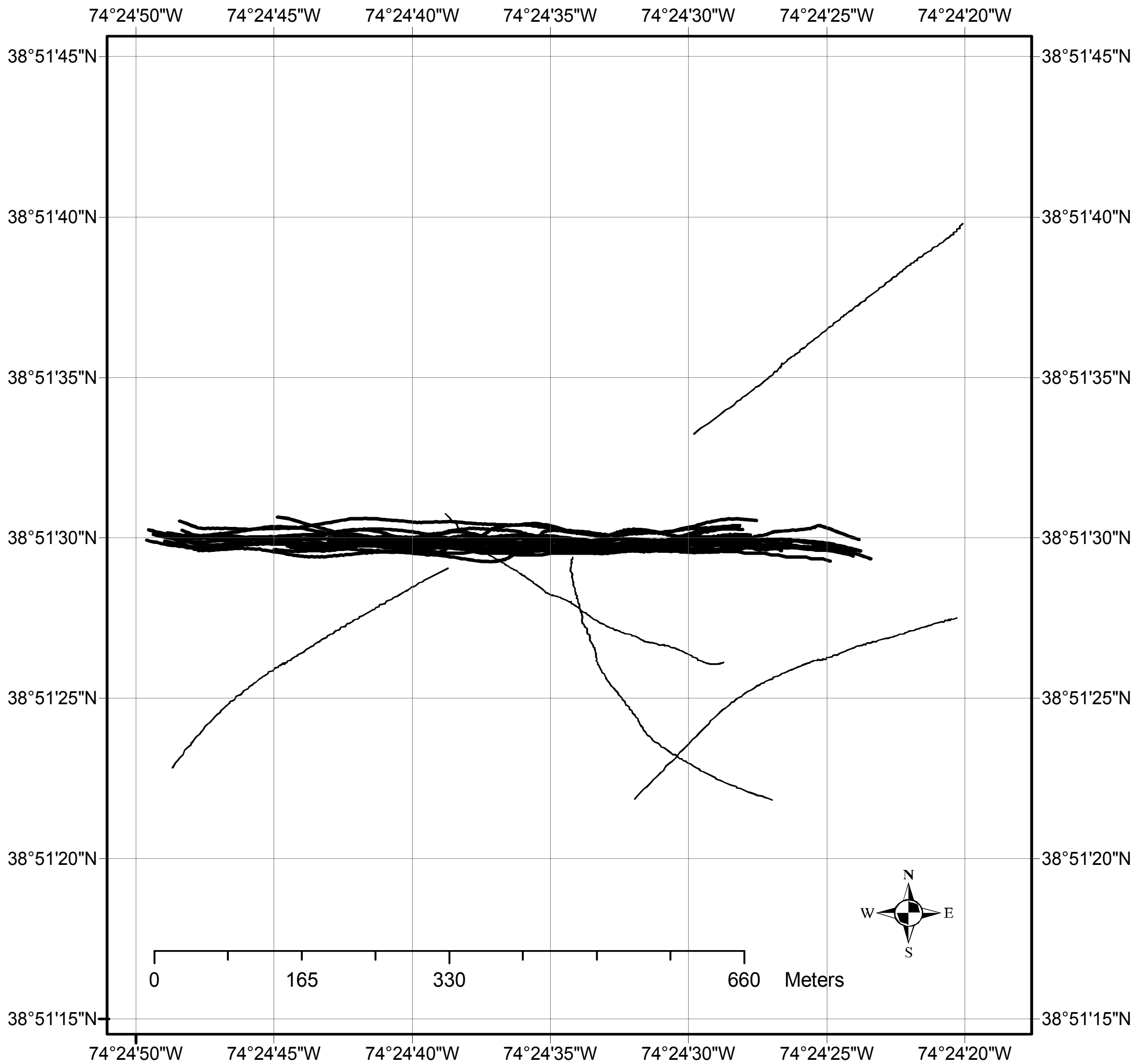


Fig. C26. Towpaths by the *R/V Delaware-II* setup tows (lighter lines) and the *F/V Jersey Girl* (darker lines), 2002, off SNJ at site: sc02-3.

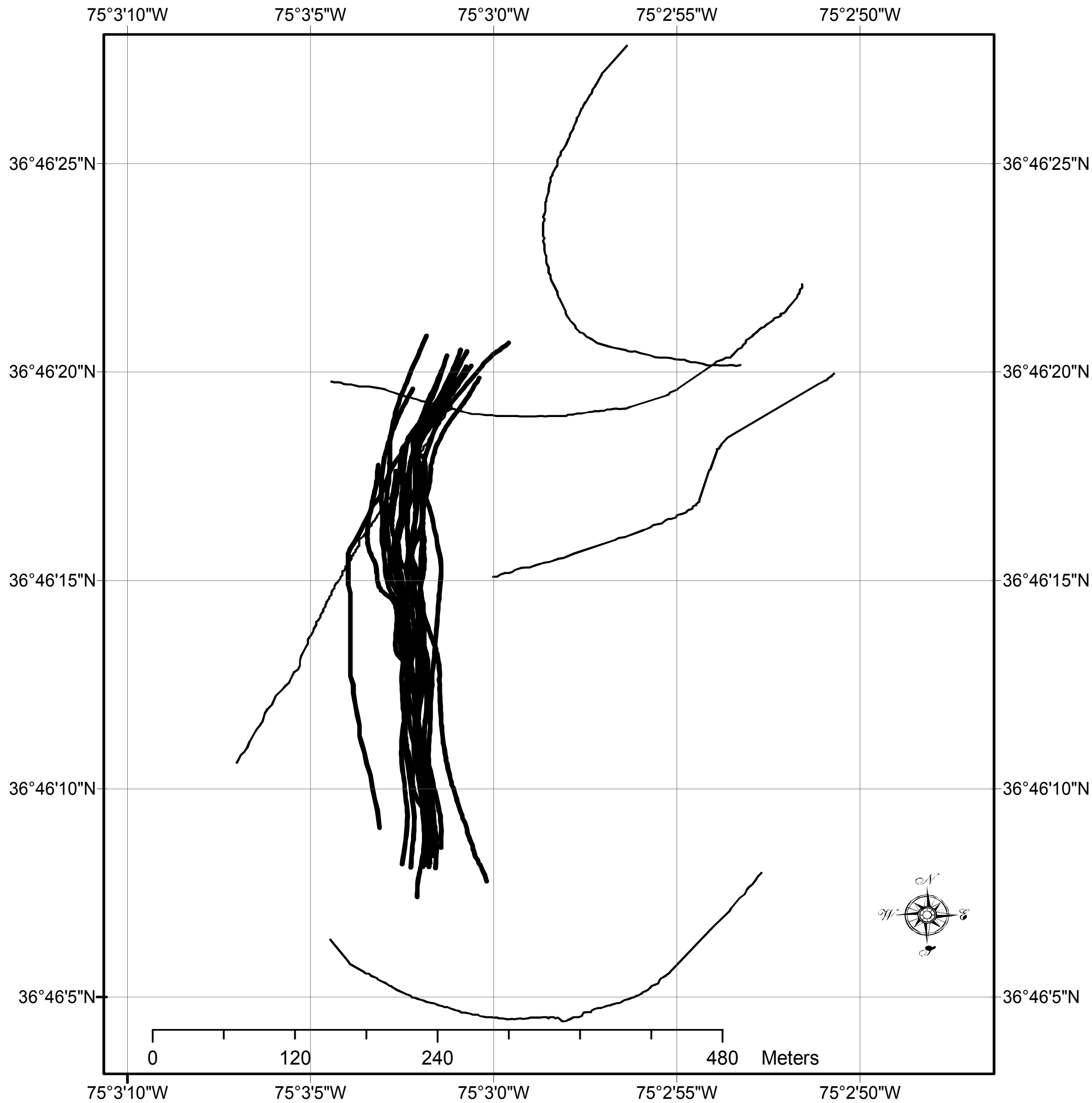
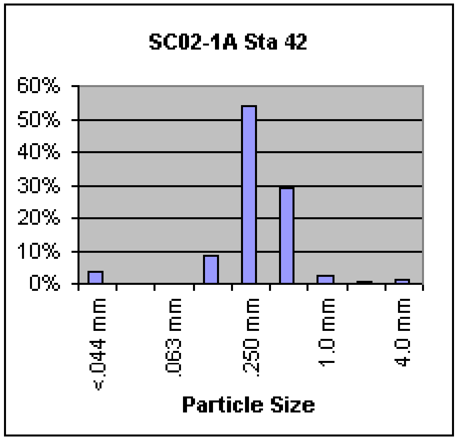
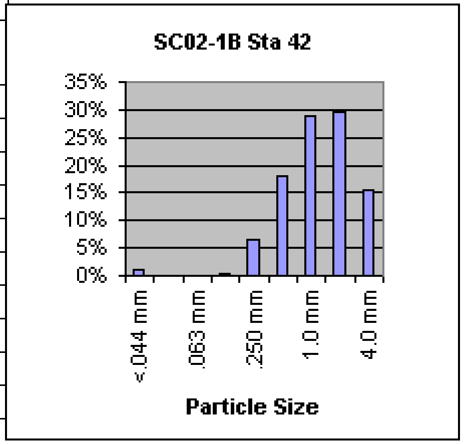


Fig. C27. Towpaths by the *R/V Delaware-II* setup tows (lighter lines) and the *F/V Jersey Girl* (darker lines), 2002, off Delmarva at site: sc02-4.

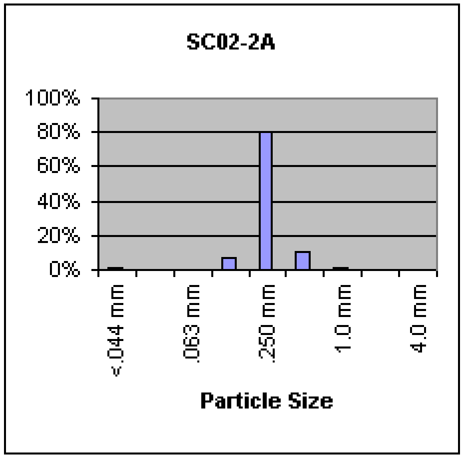
	SC02-1A Sta 42	
Particle Size	Mass	Percent
<.044 mm	18.006	3.7%
.044 mm	0.148	0.0%
.063 mm	1.275	0.3%
.125 mm	40.163	8.3%
.250 mm	262.128	54.0%
.500 mm	140.714	29.0%
1.0 mm	10.940	2.3%
2.0 mm	4.341	0.9%
4.0 mm	7.283	1.5%
Total Mass	484.998	100.0%



	SC02-1B Sta 42	
Particle Size	Mass	Percent
<.044 mm	4.576	0.9%
.044 mm	0.174	0.0%
.063 mm	0.209	0.0%
.125 mm	2.504	0.5%
.250 mm	31.274	6.4%
.500 mm	87.430	17.9%
1.0 mm	141.734	29.0%
2.0 mm	145.375	29.8%
4.0 mm	75.190	15.4%
Total Mass	488.466	100.0%



	SC02-2A	
Particle Size	Mass	Percent
<.044 mm	8.946	1.4%
.044 mm	0.209	0.0%
.063 mm	1.816	0.3%
.125 mm	44.037	6.7%
.250 mm	530.024	80.2%
.500 mm	70.101	10.6%
1.0 mm	4.004	0.6%
2.0 mm	1.611	0.2%
4.0 mm	0.229	0.0%
Total Mass	660.977	100.0%



	SC02-2B	
Particle Size	Mass	Percent
<.044 mm	15.037	2.4%
.044 mm	0.171	0.0%
.063 mm	2.495	0.4%
.125 mm	128.341	20.9%
.250 mm	434.518	70.7%
.500 mm	21.290	3.5%
1.0 mm	2.036	0.3%
2.0 mm	0.698	0.1%
4.0 mm	10.294	1.7%
Total Mass	614.880	100.0%

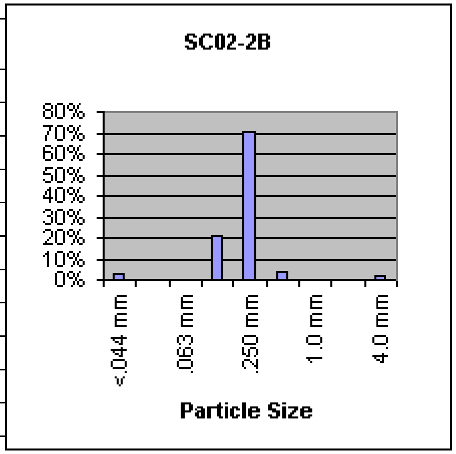
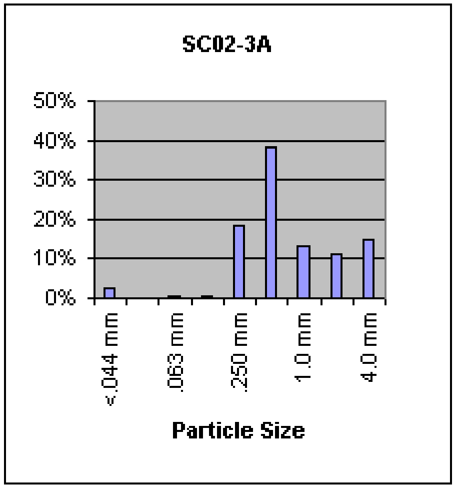


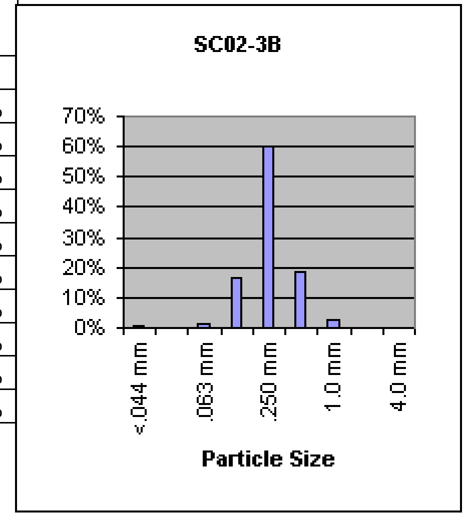
Fig. C28. (1 of 3)

Figure C28. (2 of 3)

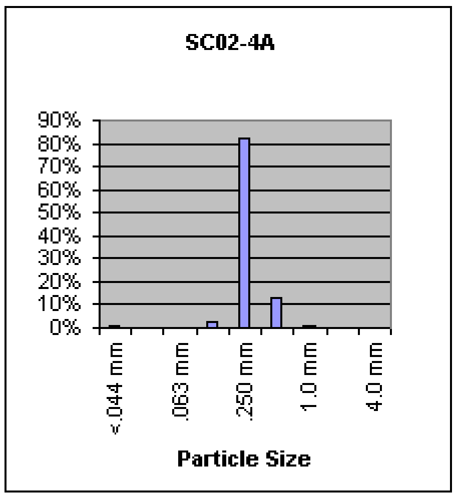
	SC02-3A	
Particle Size	Mass	Percent
<.044 mm	14.598	2.8%
.044 mm	0.201	0.0%
.063 mm	2.909	0.6%
.125 mm	2.999	0.6%
.250 mm	97.978	18.6%
.500 mm	200.921	38.2%
1.0 mm	69.133	13.1%
2.0 mm	59.626	11.3%
4.0 mm	77.995	14.8%
Total Mass	526.360	100.0%



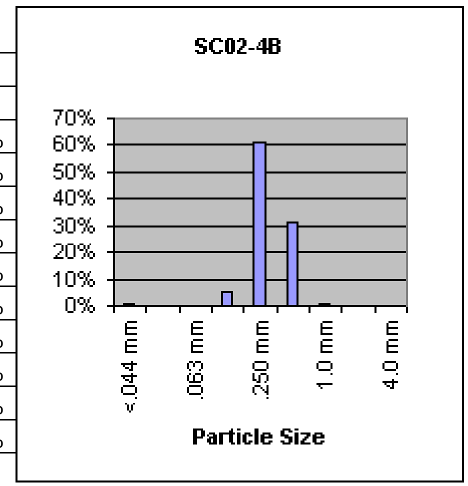
	SC02-3B	
Particle Size	Mass	Percent
<.044 mm	3.377	0.6%
.044 mm	0.239	0.0%
.063 mm	6.529	1.1%
.125 mm	92.925	16.4%
.250 mm	342.799	60.4%
.500 mm	105.890	18.6%
1.0 mm	13.707	2.4%
2.0 mm	1.568	0.3%
4.0 mm	0.937	0.2%
Total Mass	567.971	100.0%



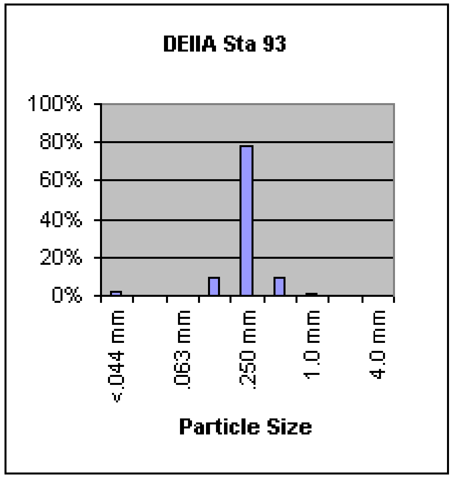
	SC02-4A	
Particle Size	Mass	Percent
<.044 mm	6.310	1.2%
.044 mm	0.203	0.0%
.063 mm	0.572	0.1%
.125 mm	14.138	2.7%
.250 mm	429.034	81.9%
.500 mm	67.660	12.9%
1.0 mm	2.962	0.6%
2.0 mm	1.149	0.2%
4.0 mm	1.653	0.3%
Total Mass	523.681	100%



	SC02-4B	
Particle Size	Mass	Percent
<.044 mm	3.273	0.8%
.044 mm	0.059	0.0%
.063 mm	0.580	0.1%
.125 mm	22.292	5.2%
.250 mm	263.903	61.4%
.500 mm	135.534	31.5%
1.0 mm	2.354	0.5%
2.0 mm	0.815	0.2%
4.0 mm	1.233	0.3%
Total Mass	430.043	100.0%



Particle Size	DE-IIA Sta 93 Mass	Percent
<.044 mm	11.636	1.9%
.044 mm	0.368	0.1%
.063 mm	1.684	0.3%
.125 mm	53.740	8.9%
.250 mm	469.458	78.1%
.500 mm	54.801	9.1%
1.0 mm	5.605	0.9%
2.0 mm	2.127	0.4%
4.0 mm	1.483	0.2%
Total Mass	600.902	100.0%



Particle Size	DE-IIB Sta 93 Mass	Percent
<.044 mm	1.522	0.3%
.044 mm	0.054	0.0%
.063 mm	1.285	0.3%
.125 mm	51.258	11.5%
.250 mm	360.867	80.8%
.500 mm	24.147	5.4%
1.0 mm	1.329	0.3%
2.0 mm	0.322	0.1%
4.0 mm	5.892	1.3%
Total Mass	446.676	100.0%

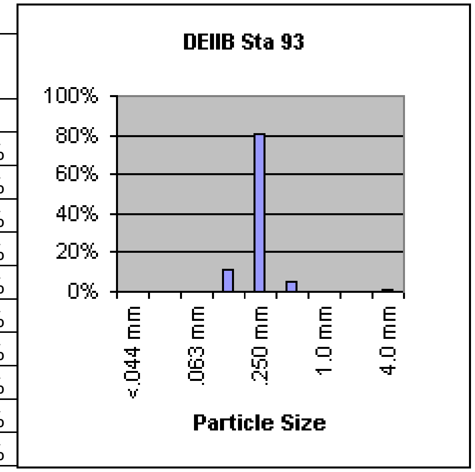


Figure C28 (3 of 3).

Figure C29. Sizes of surfclams captured at several locations by the RV Delaware II and FV Jersey Girl, summer of 2002.

NJ- Repeats

model: $S(L) = 1/(1+\exp(alpha+beta * L))$

alpha	beta	L50%ile
10.442	-0.084	124.3

FV *Jersey Girl* Relative to RV *Delaware-II*, Surfclams, Summer 2002

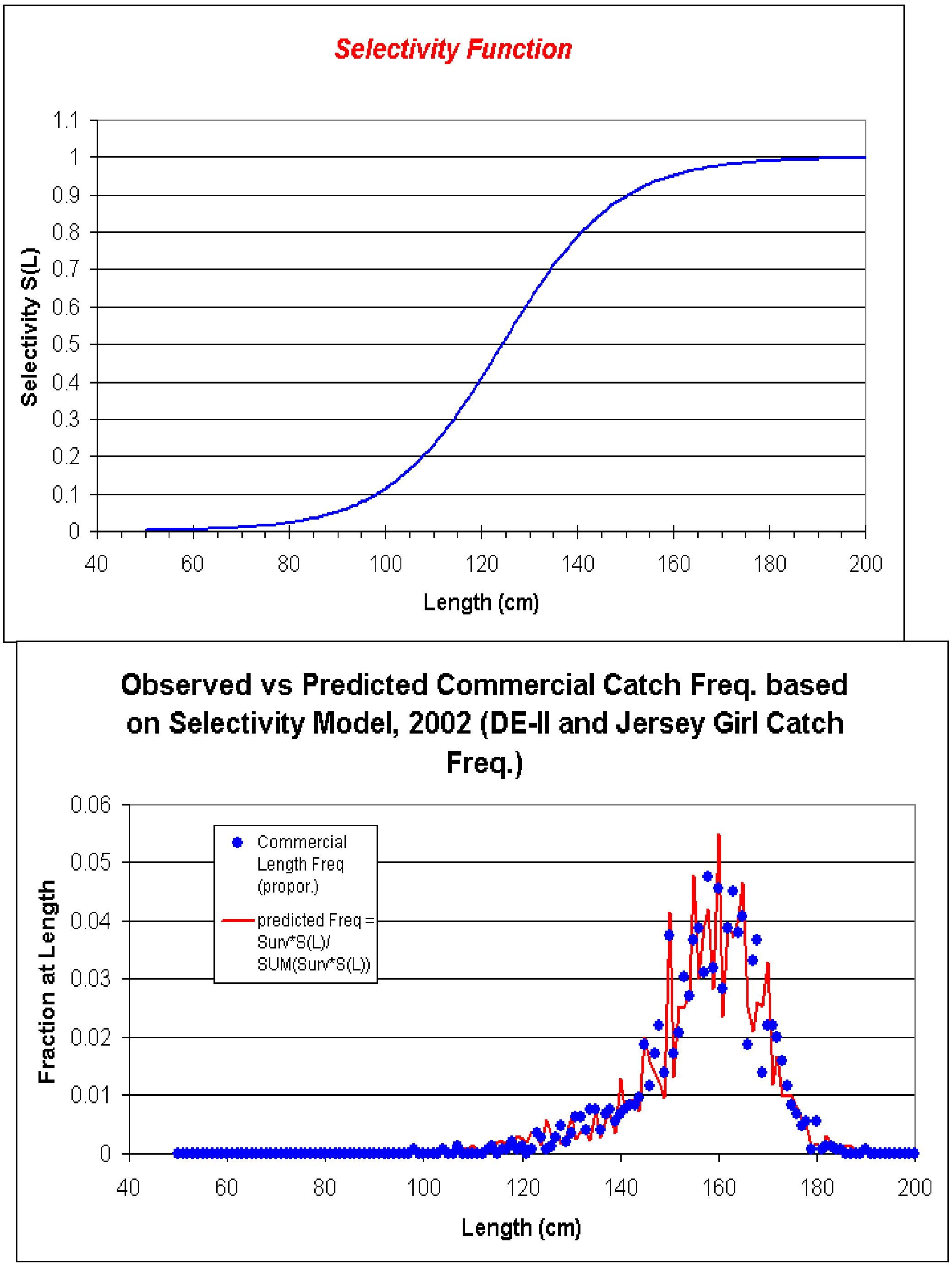


Figure C30. Example of program used to estimate relative selectivity of surfclam lengths between vessels. Data shown are from 9 "repeat" stations off New Jersey, 2002.

Figure C31. Likelihood profile analysis and asymptotic confidence intervals for dredge efficiency and initial density of surfclam in the DE02 depletion study (no indirect effects assumed, 130+ mm).

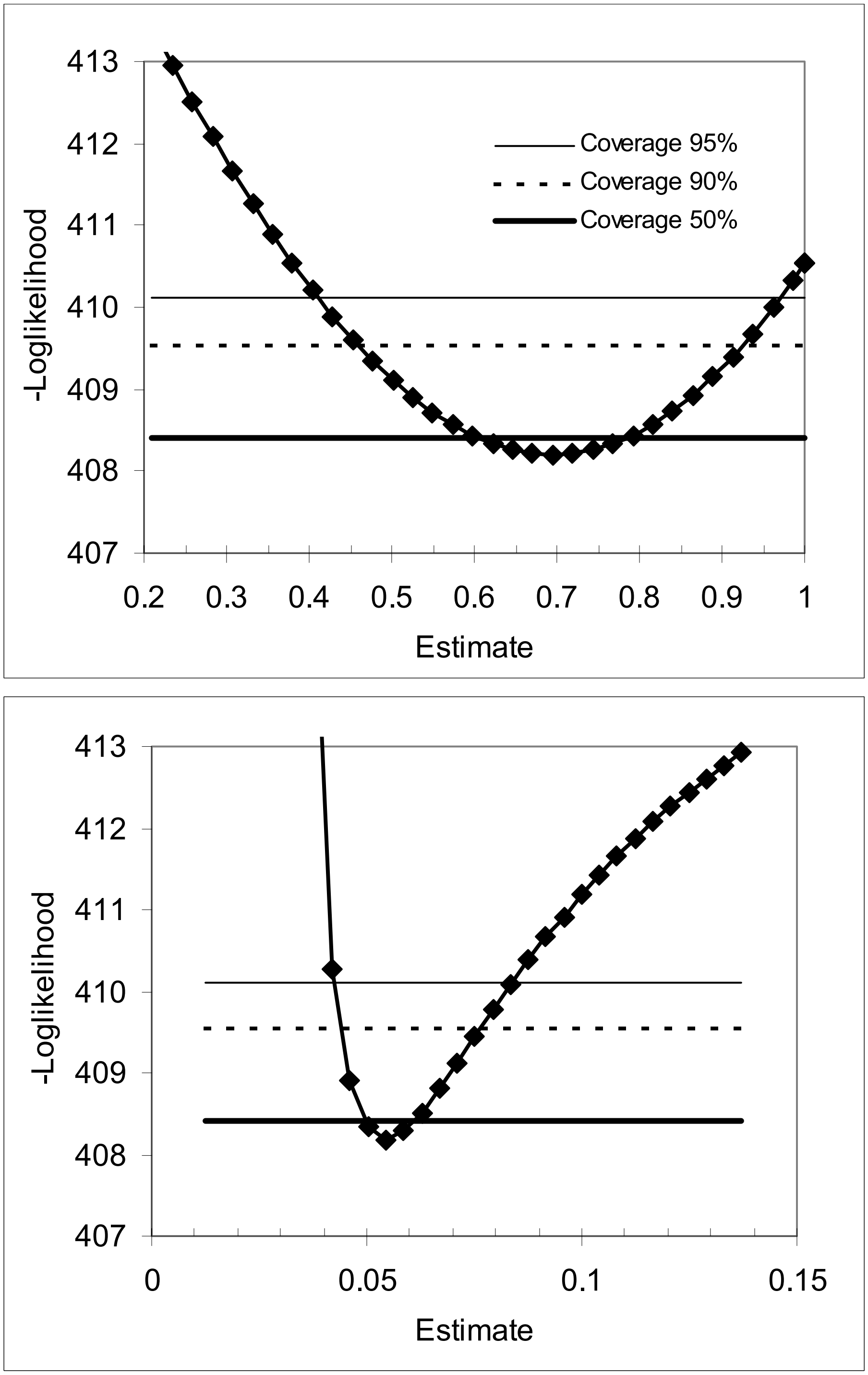
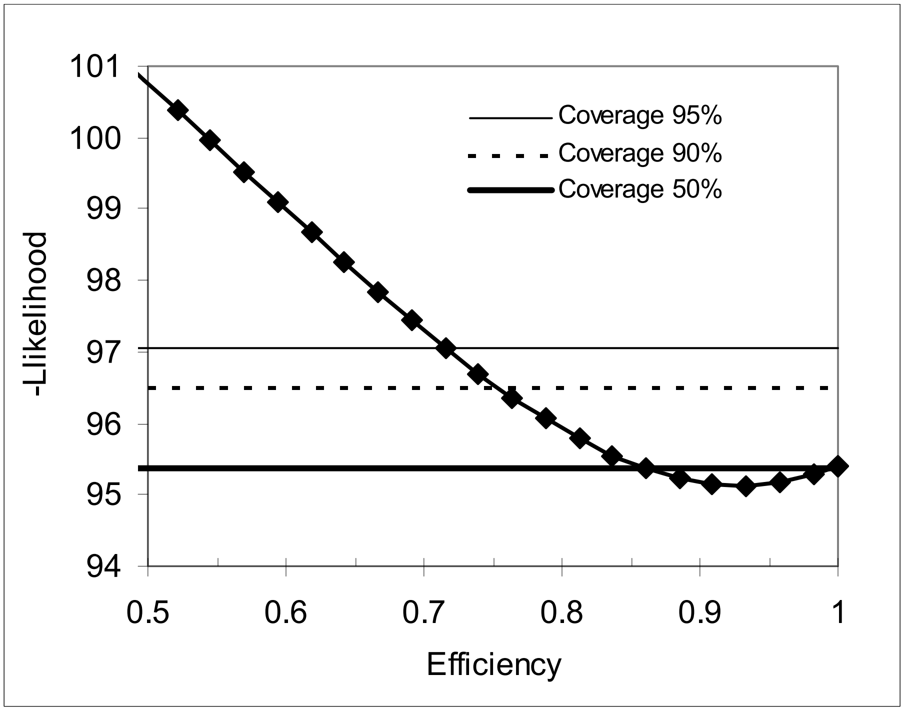


Figure C32. Likelihood profile analysis and asymptotic confidence intervals for dredge efficiency and initial density of surfclam in the JG02 depletion study (no indirect effects assumed, all sizes).



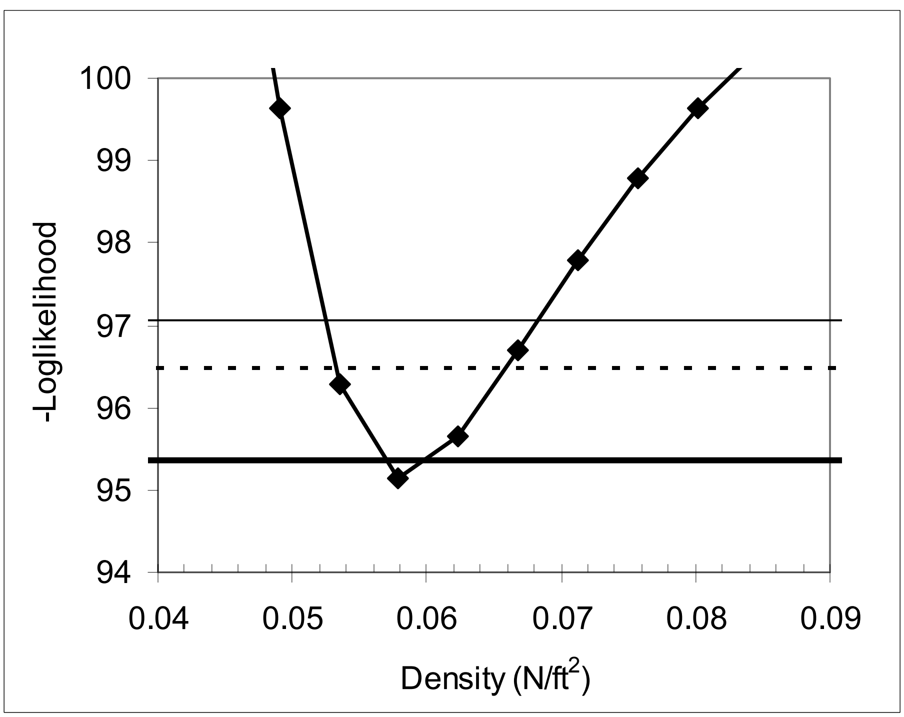
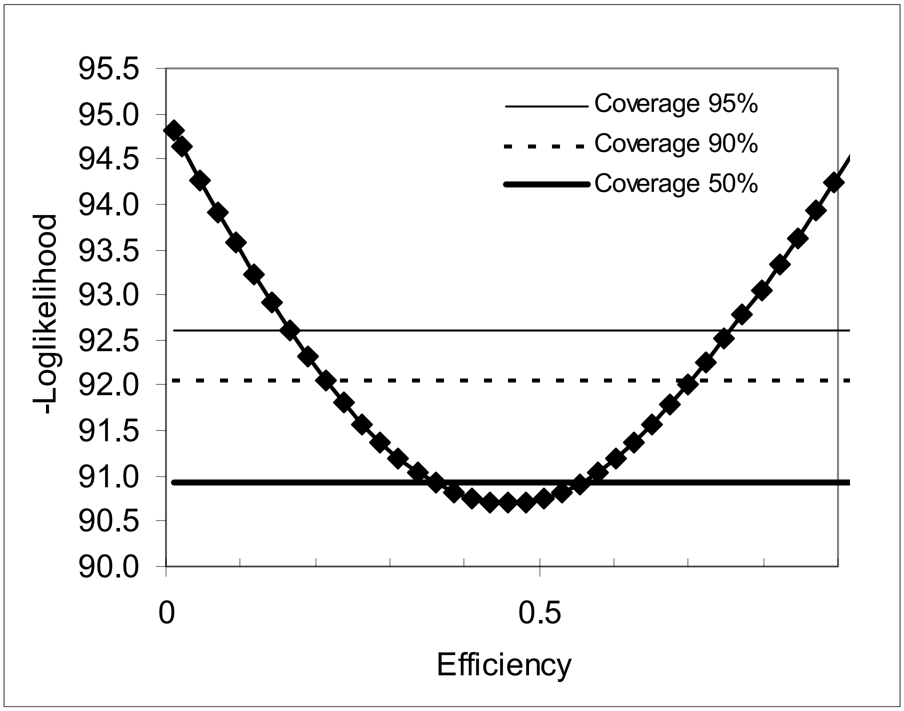


Figure C33. Likelihood profile analysis and asymptotic confidence intervals for dredge efficiency and initial density of surfclam in the JG03 depletion study (no indirect effects assumed, 130+ mm).



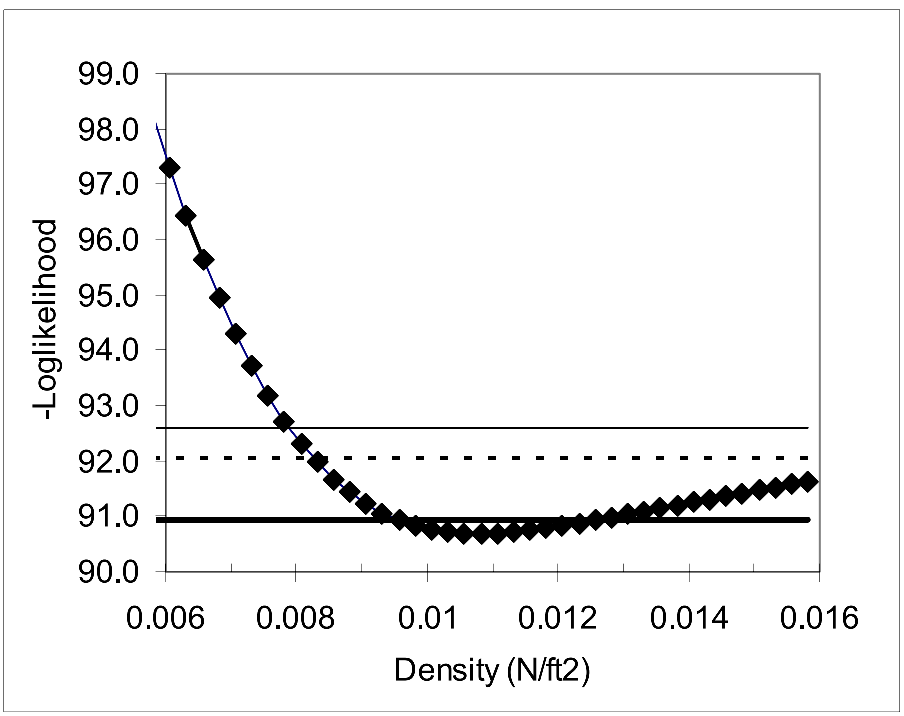
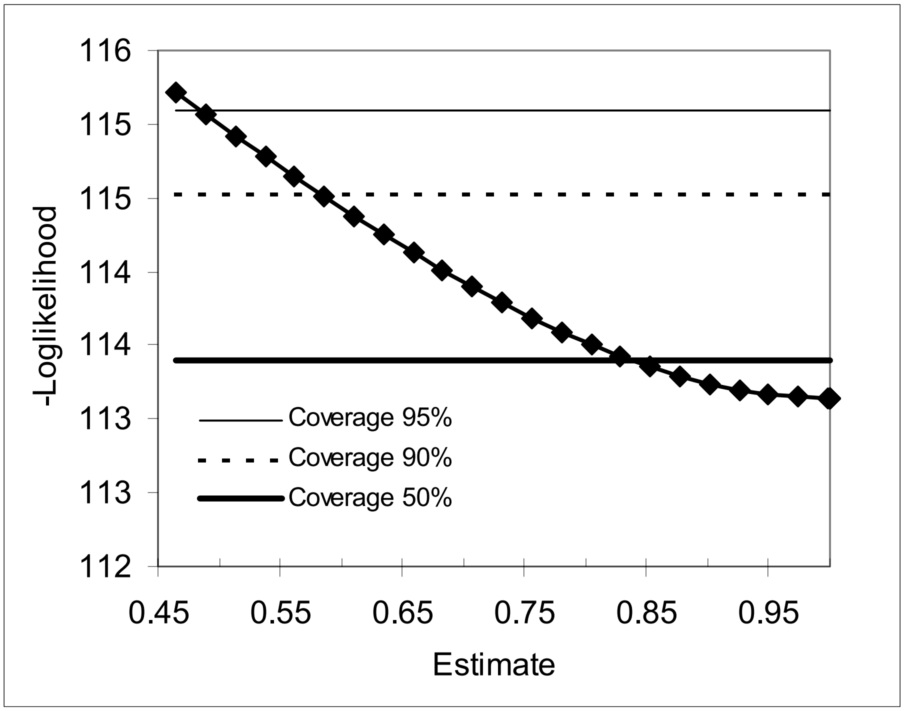
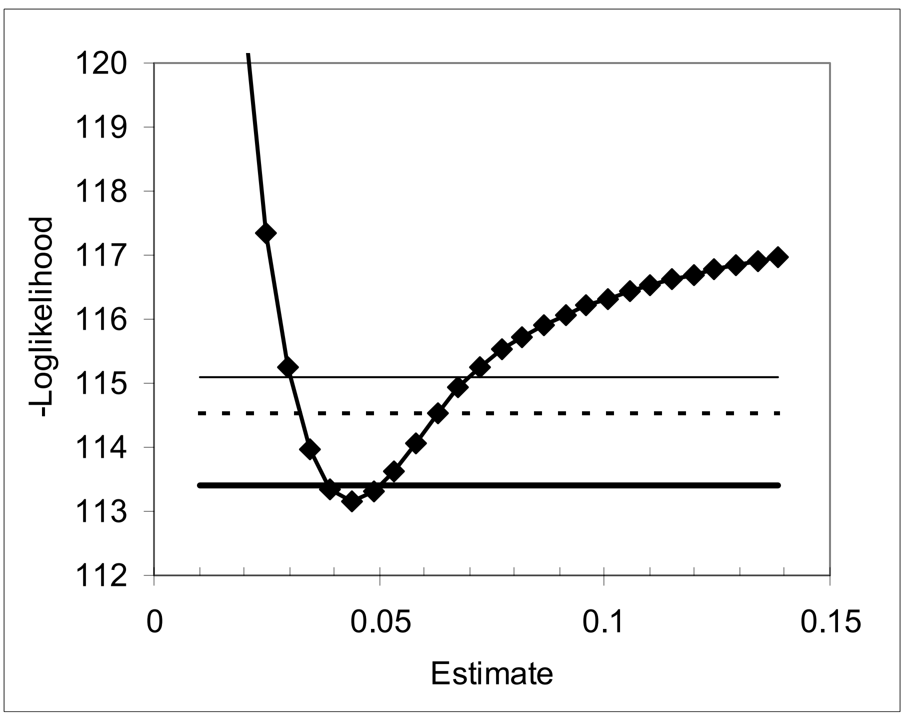


Figure C34. Likelihood profile analysis and asymptotic confidence intervals for dredge efficiency and initial density of surfclam in the JG04 depletion study (no indirect effects assumed, 130+ mm).





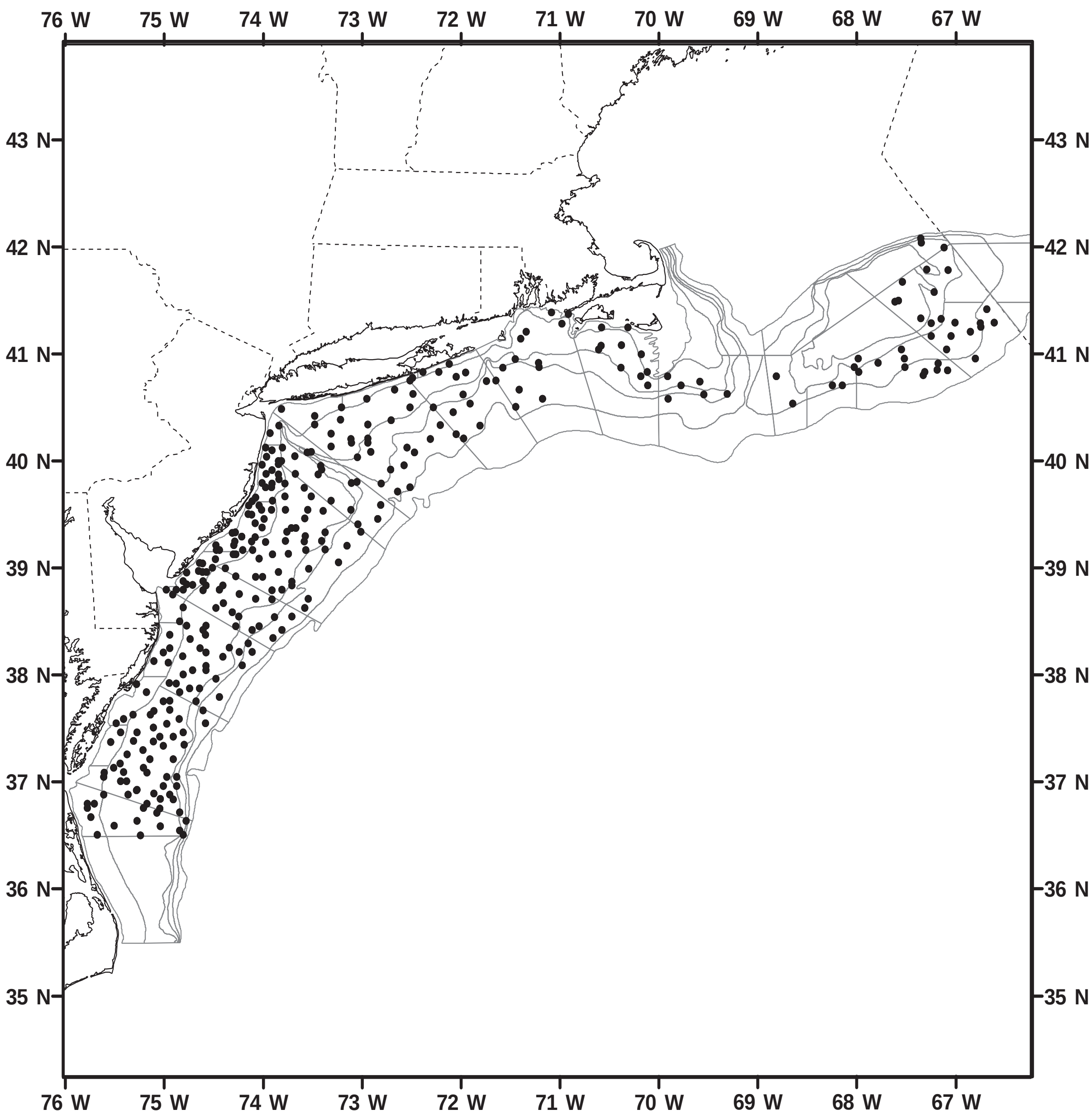


Figure C35.
Station locations from the 2002 NEFSC surfclam/ocean quahog survey.

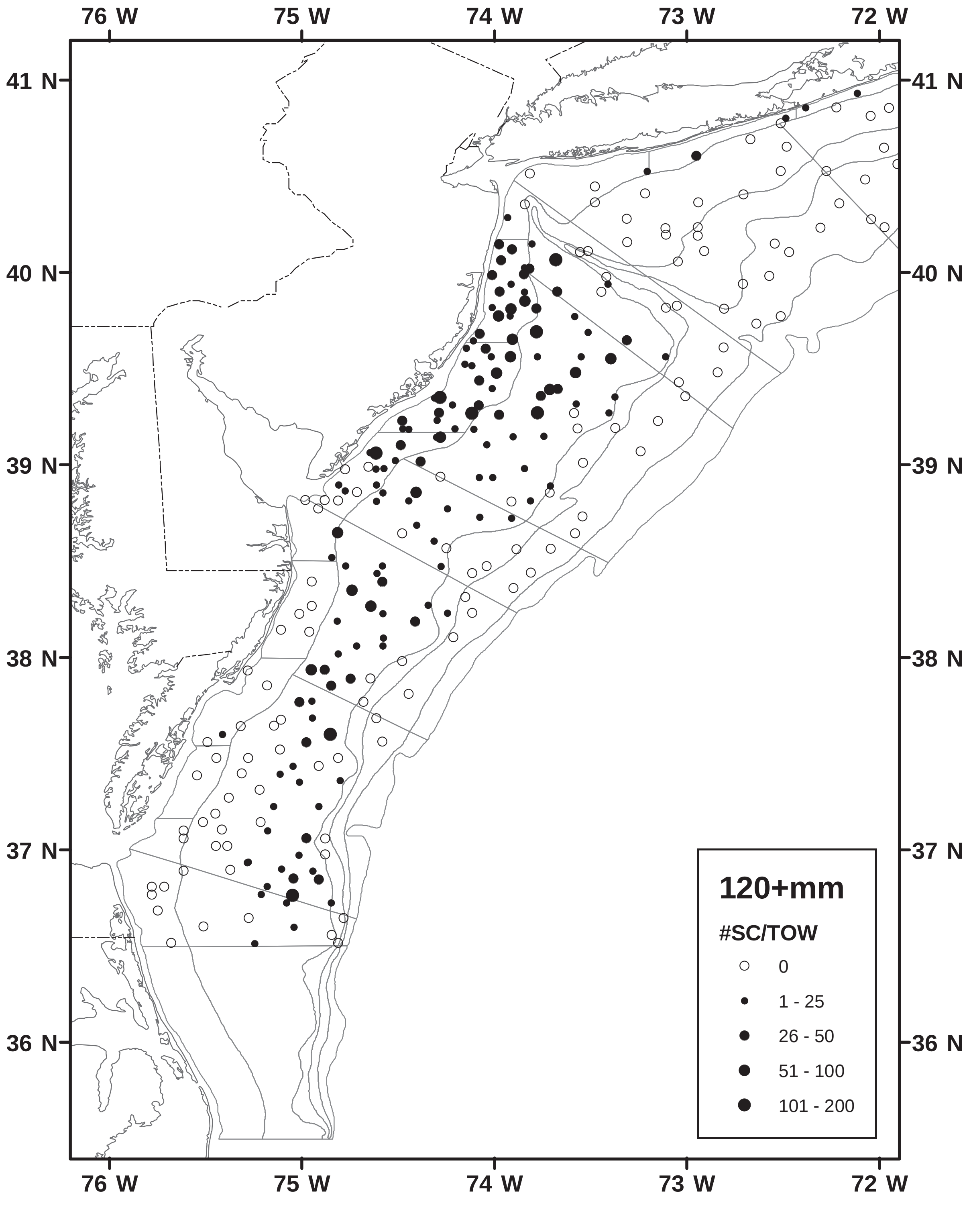


Figure C36.
Surfclam abundance per tow (>= 120mm) adjusted to 0.15 n. mi. tow distance with SSP sensor data, 2002 survey.

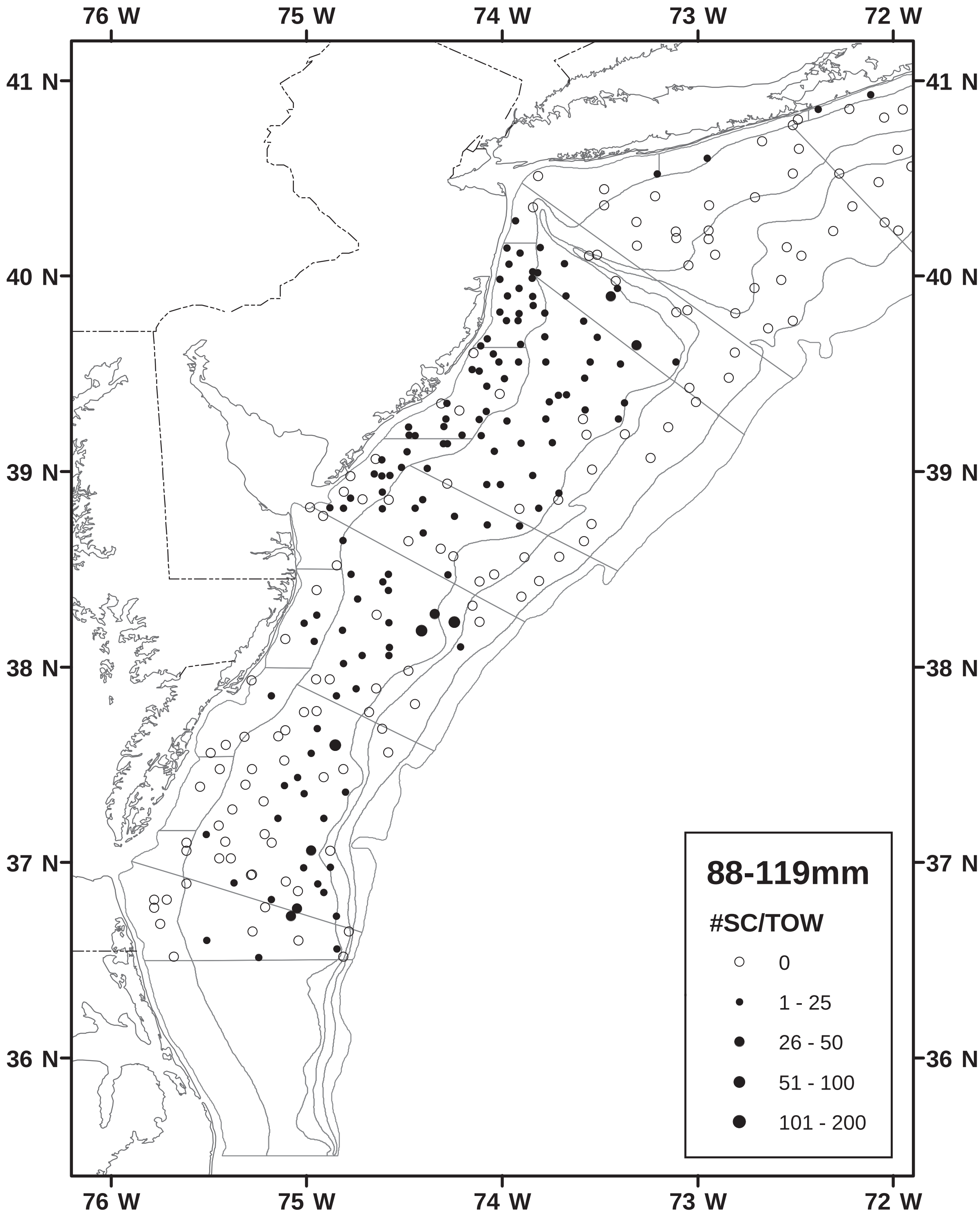


Figure C37.
Surfclam abundance per tow (88-119)mm) adjusted to 0.15 n. mi. tow distance with SSP sensor data, 2002 survey.

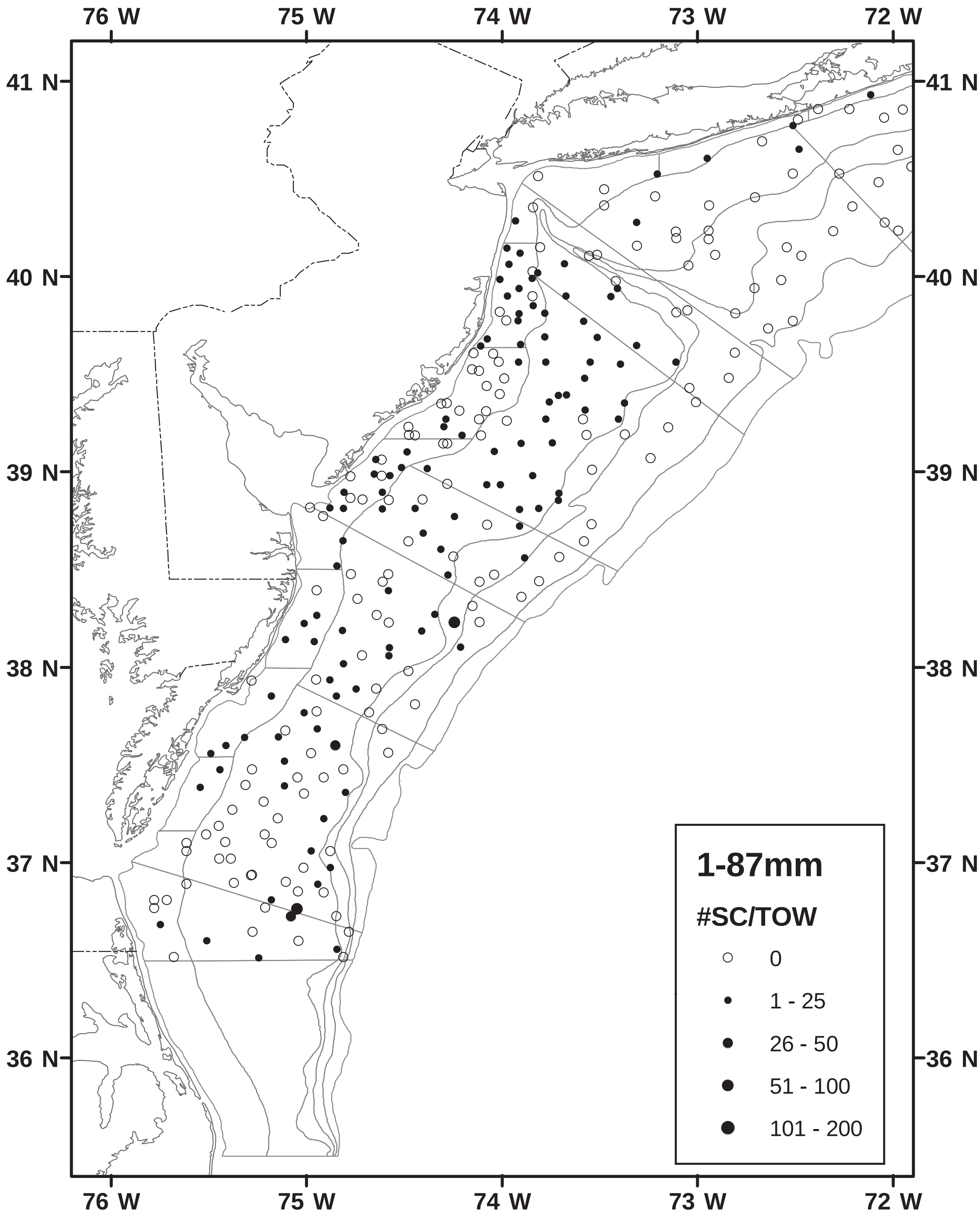


Figure C38.
Surfclam abundance per tow (1-87mm) adjusted to 0.15 n. mi. tow distance with SSP sensor data, 2002 survey.

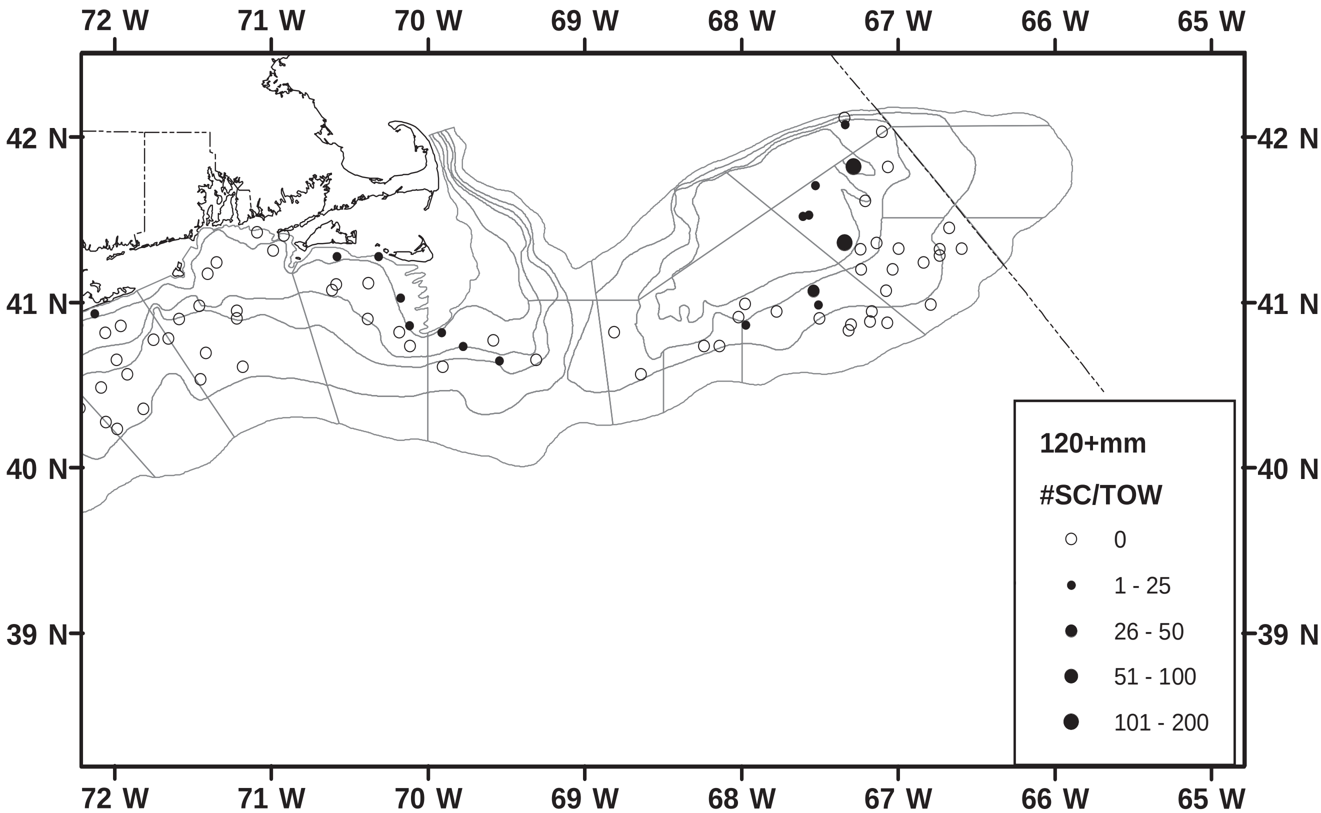


Figure C39.
Surfclam abundance per tow (>=120mm) adjusted to 0.15 n. mi. tow distance with SSP sensor data, 2002 survey.

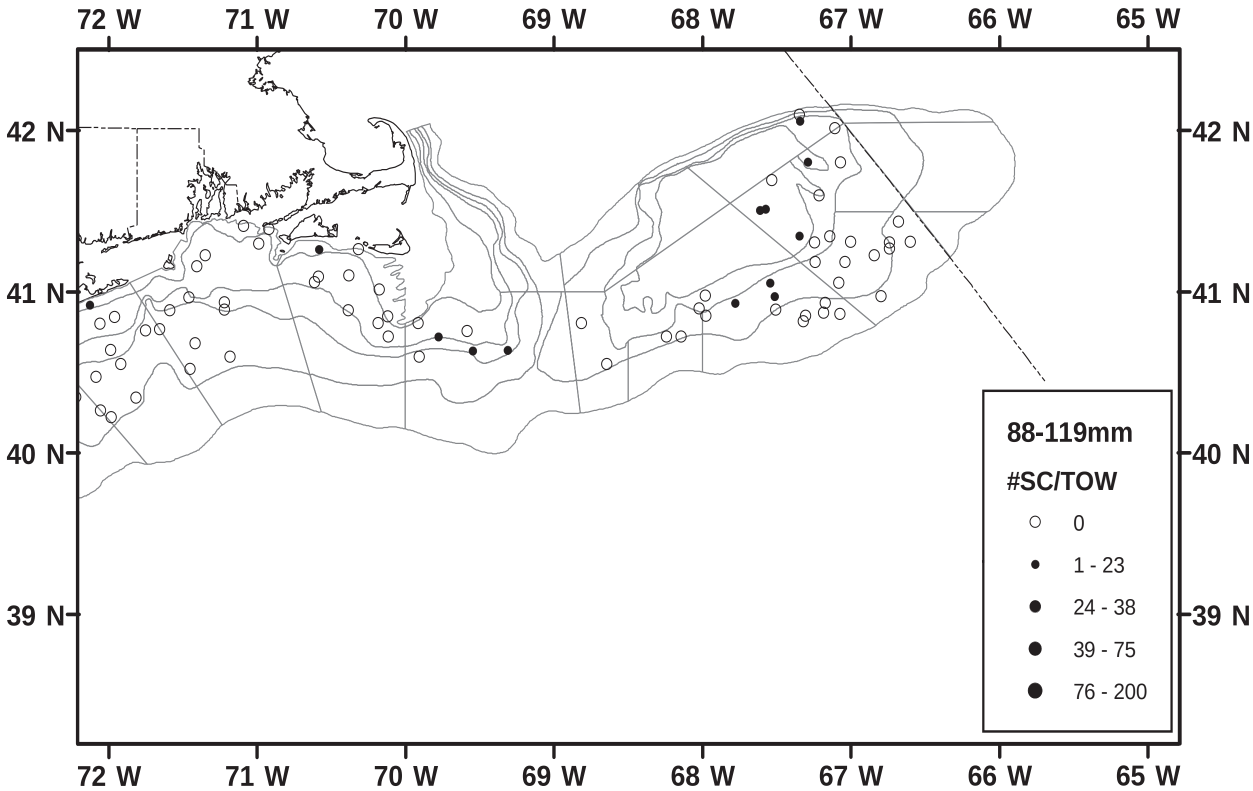


Figure C40.
Surfclam abundance per tow (88-119 mm) adjusted to 0.15 n. mi. tow distance with SSP sensor data, 2002 survey.

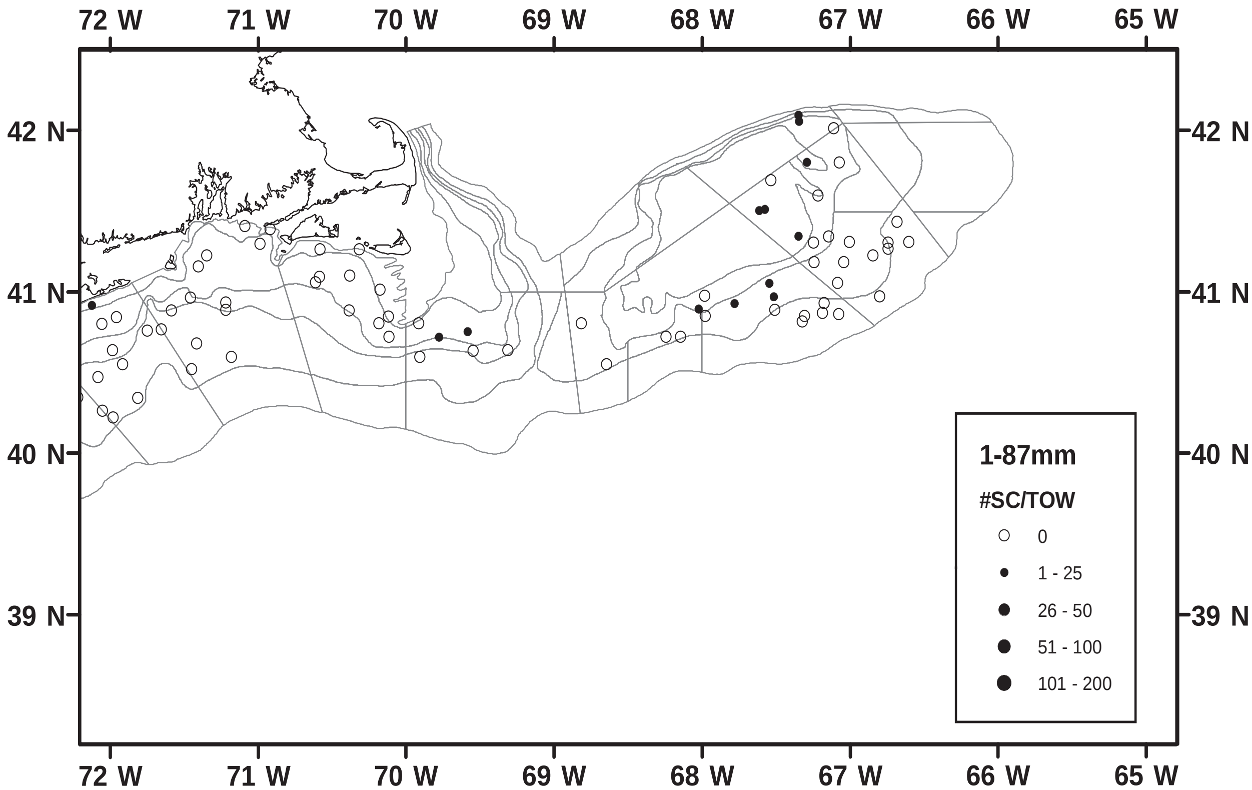


Figure C41.
Surfclam abundance per tow (1-87 mm) adjusted to 0.15 n. mi. tow distance with SSP sensor data, 2002 survey.

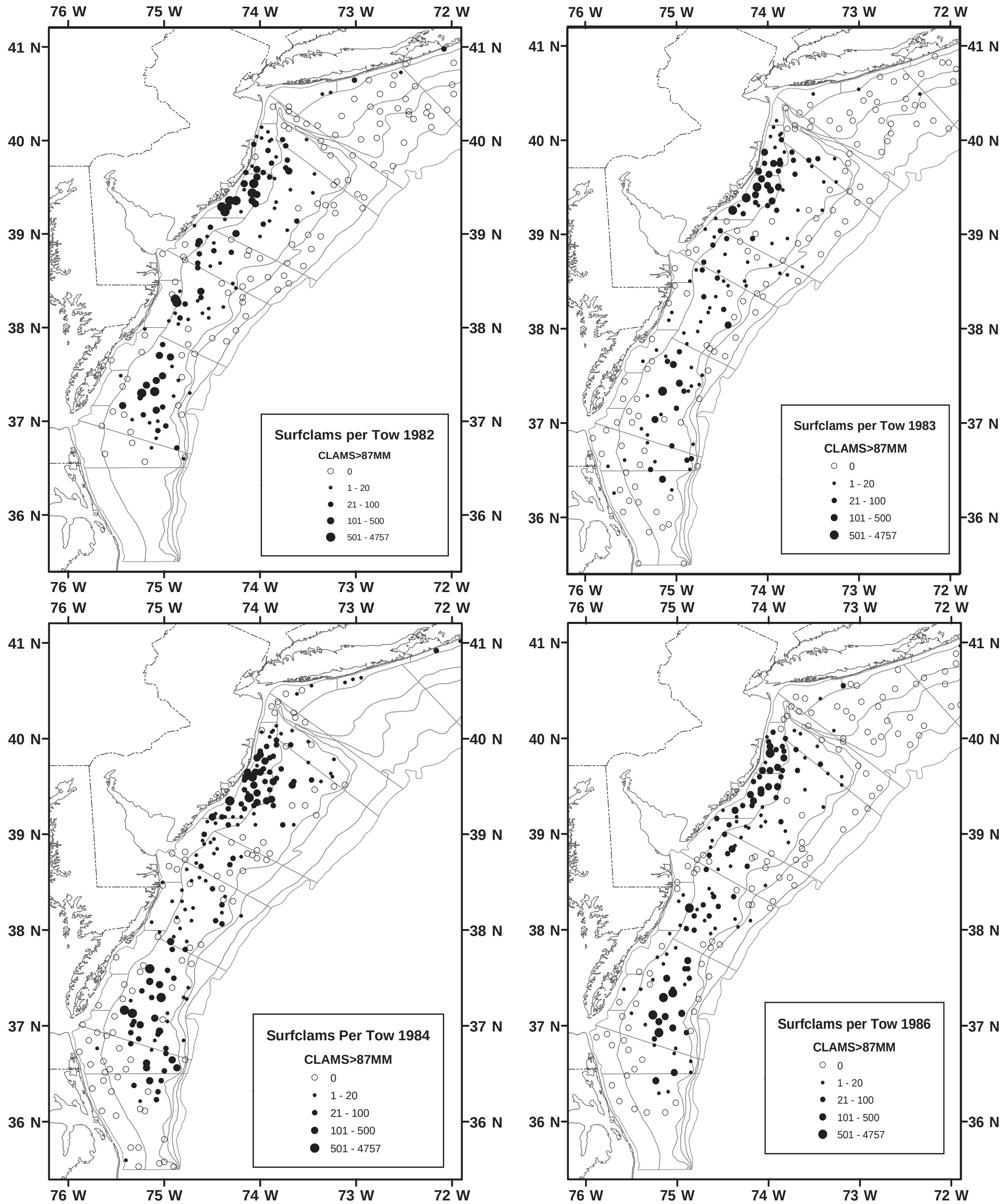


Figure C42.
Number of surfclams (88mm+), by station, in NMFS clam surveys, 1982-1986. Catch was not adjusted for distance. Only includes random stations without gear problems.

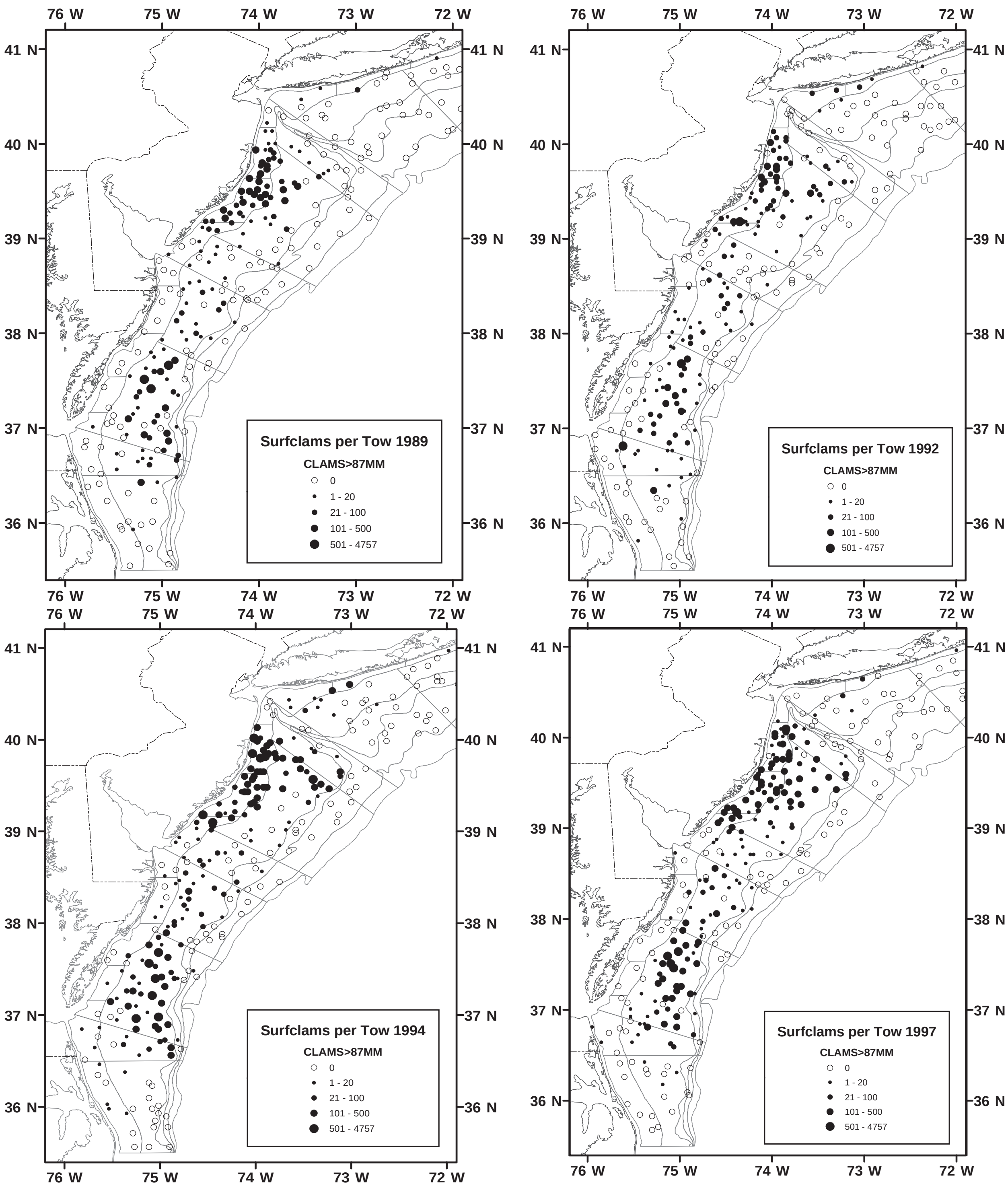
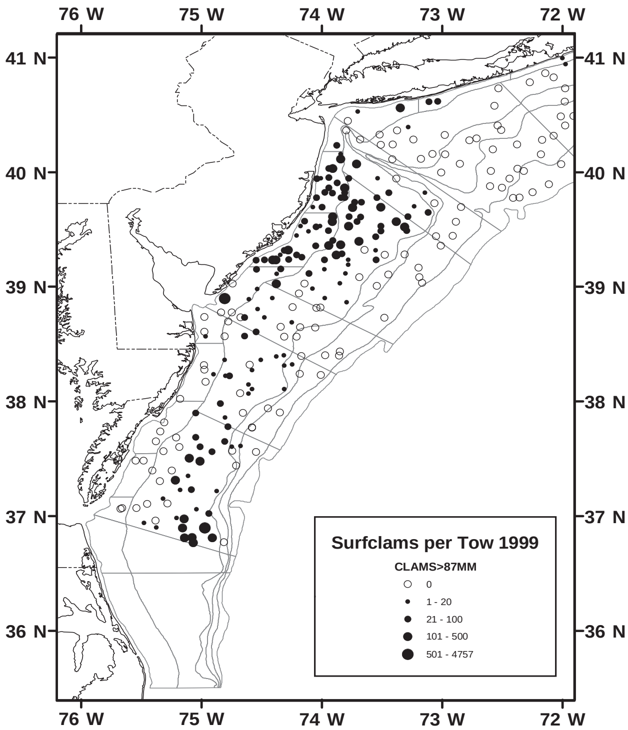


Figure C43.
Number of surfclams (88mm+), by station, in NMFS clam surveys, 1989-1997. Catch was not adjusted for distance. Only includes random stations without gear problems.



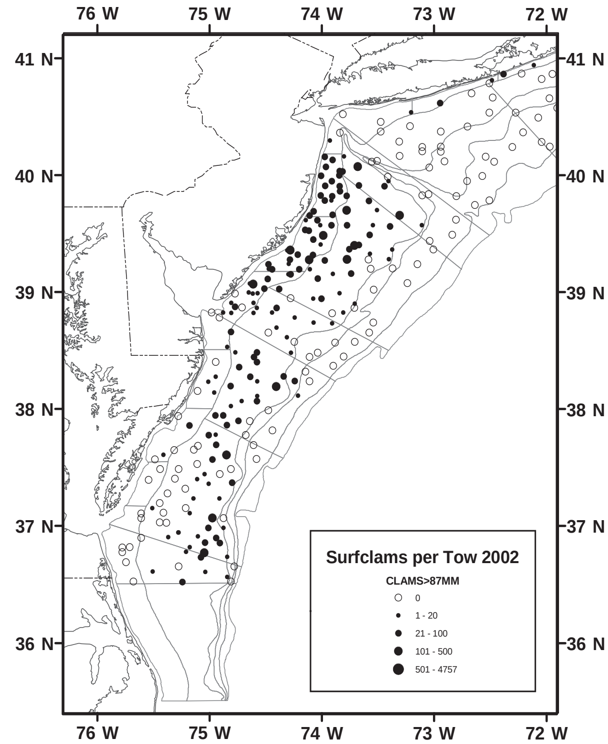


Figure C44.
Number of surfclams (88mm+), by station, in NMFS clam surveys, 1999-2002. Catch was not adjusted for distance. Only includes random stations without gear problems.

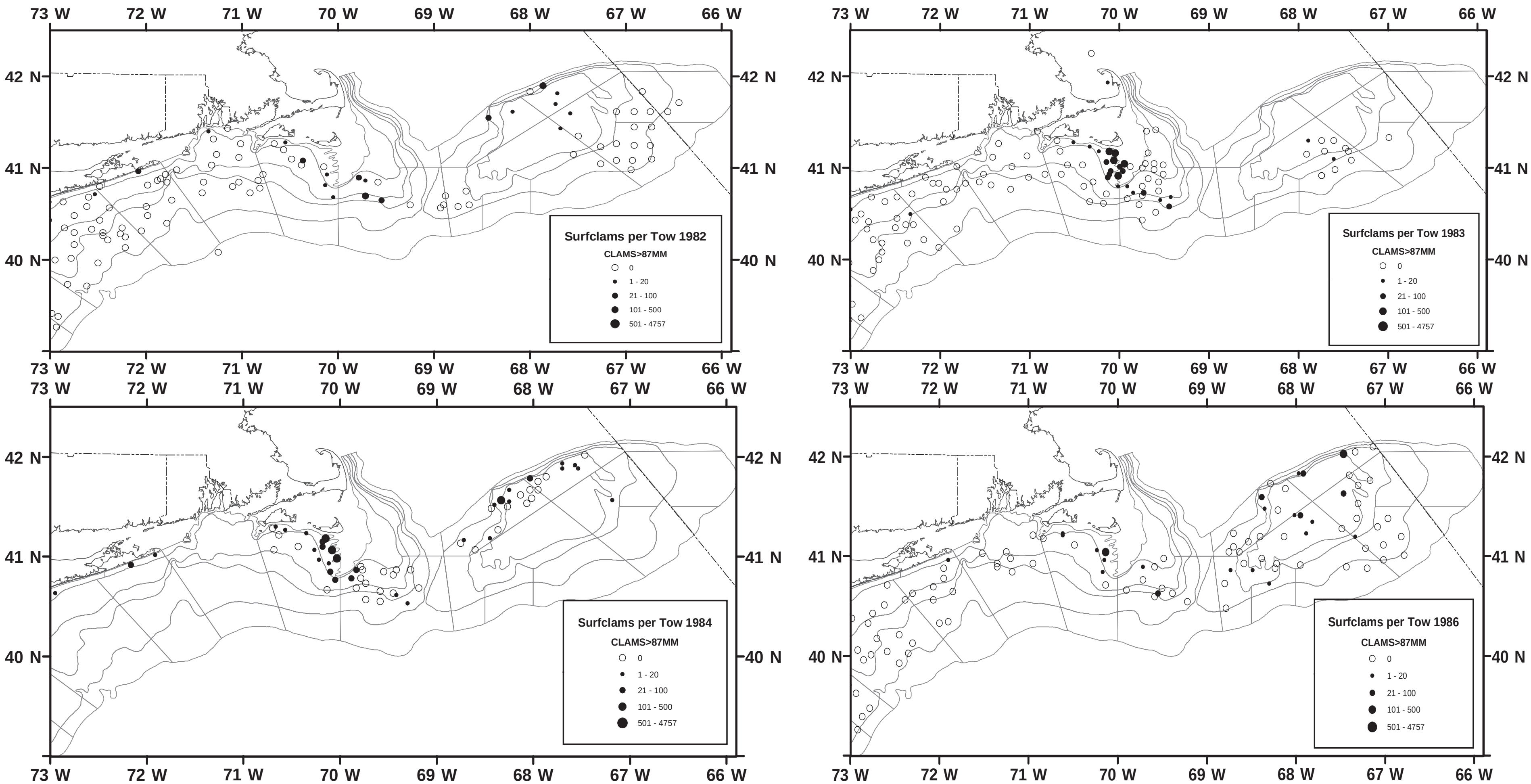


Figure C45.
Number of surfclams (88mm+), by station, in NMFS clam surveys, 1982-1986. Catch was not adjusted for distance. Only includes random stations without gear problems.

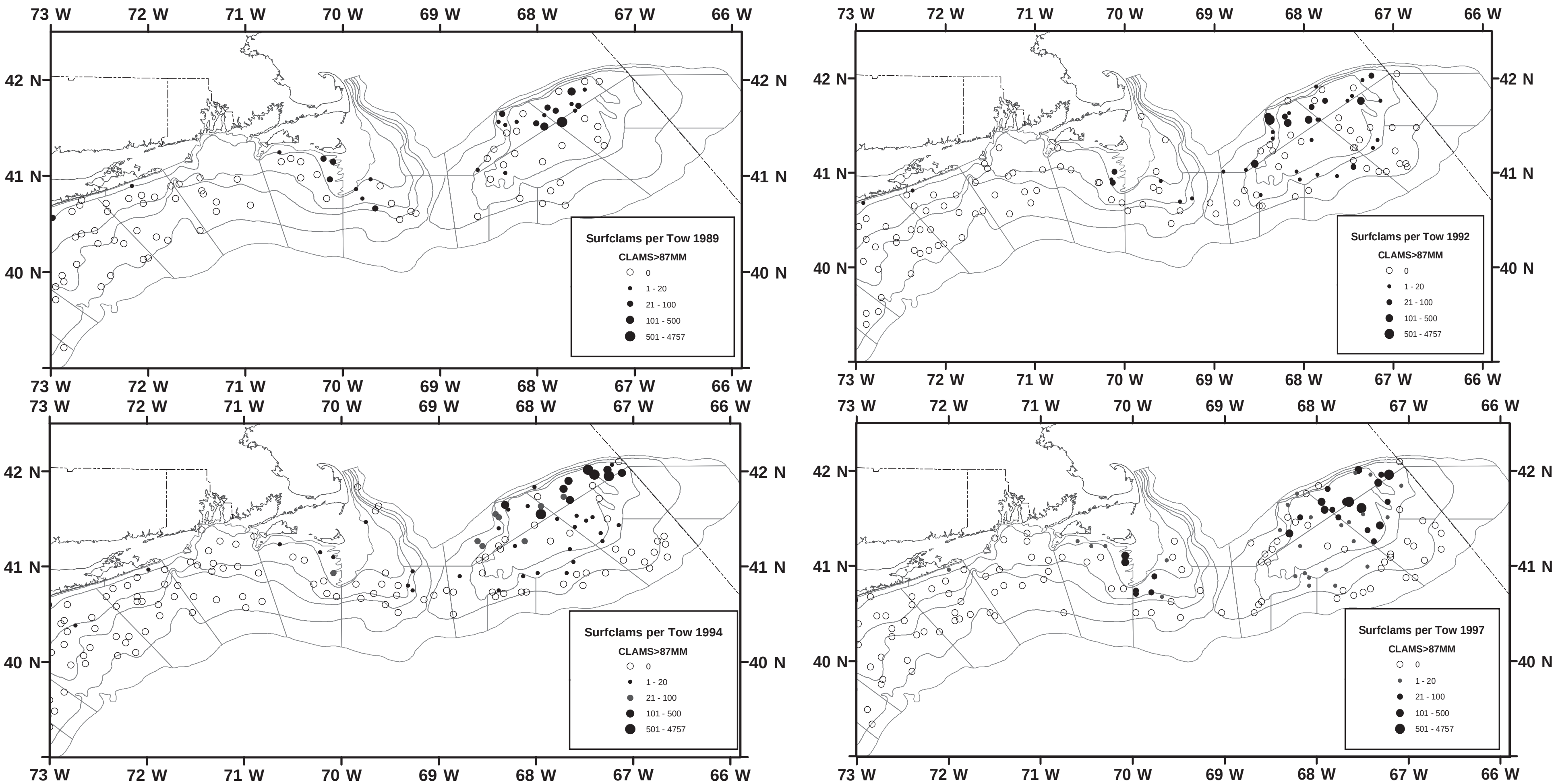


Figure C46.
Number of surfclams (88mm+), by station, in NMFS clam surveys, 1989-1997. Catch was not adjusted for distance. Only includes random stations without gear problems.

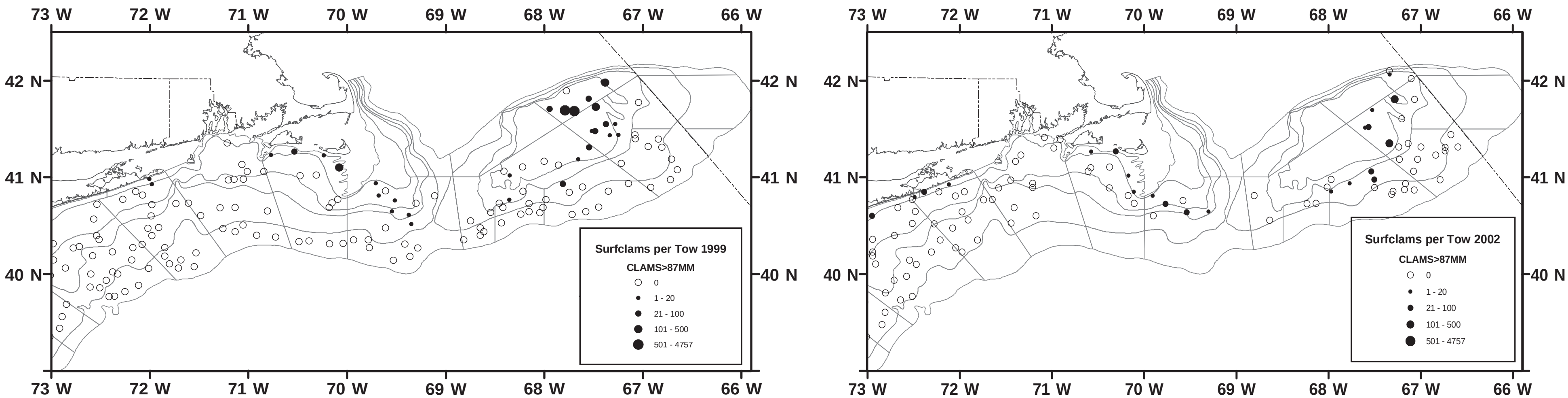


Figure C47.
Number of surfclams (88mm+), by station, in NMFS clam surveys, 1999-2002. Catch was not adjusted for distance. Only includes random stations without gear problems.

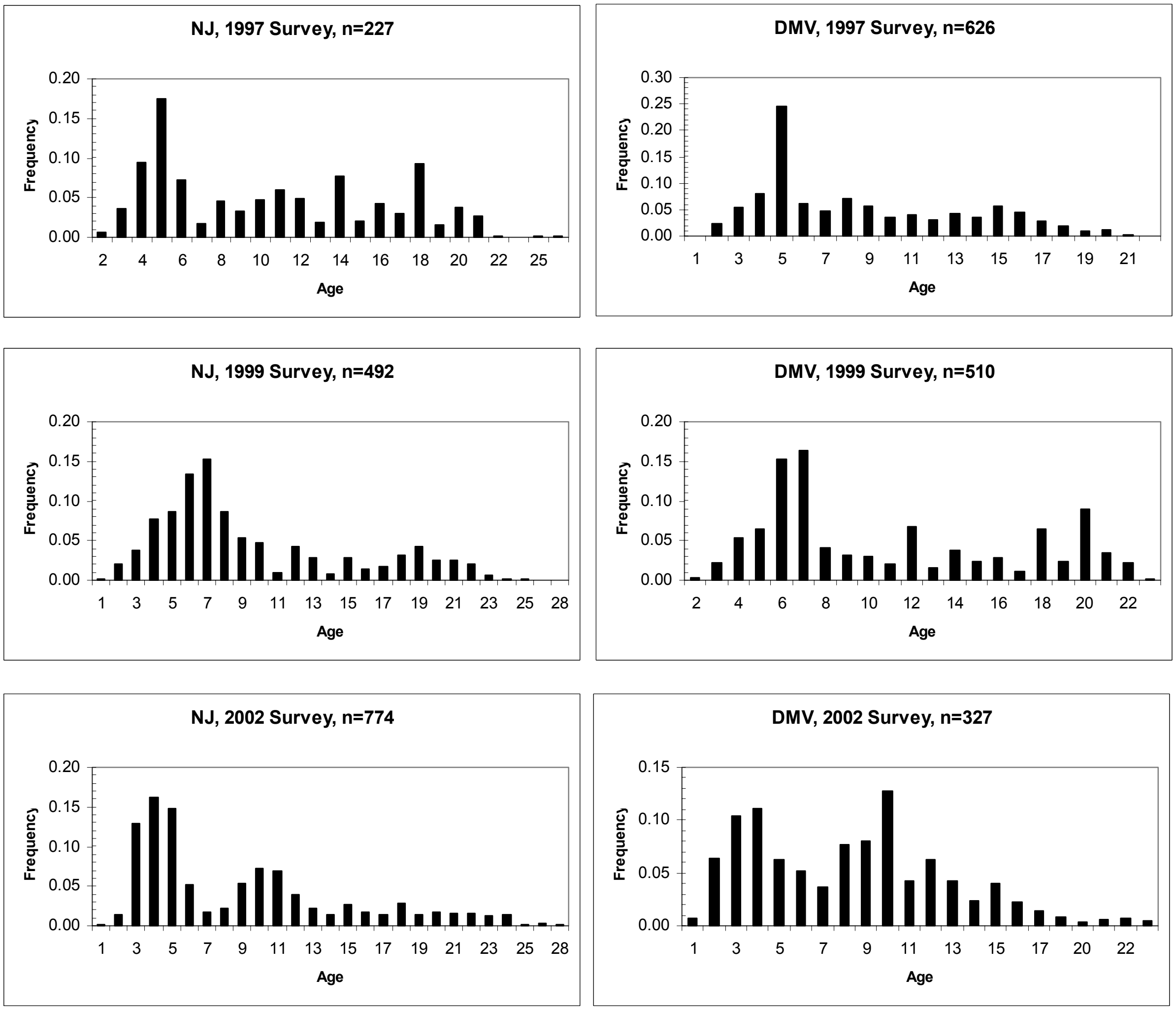
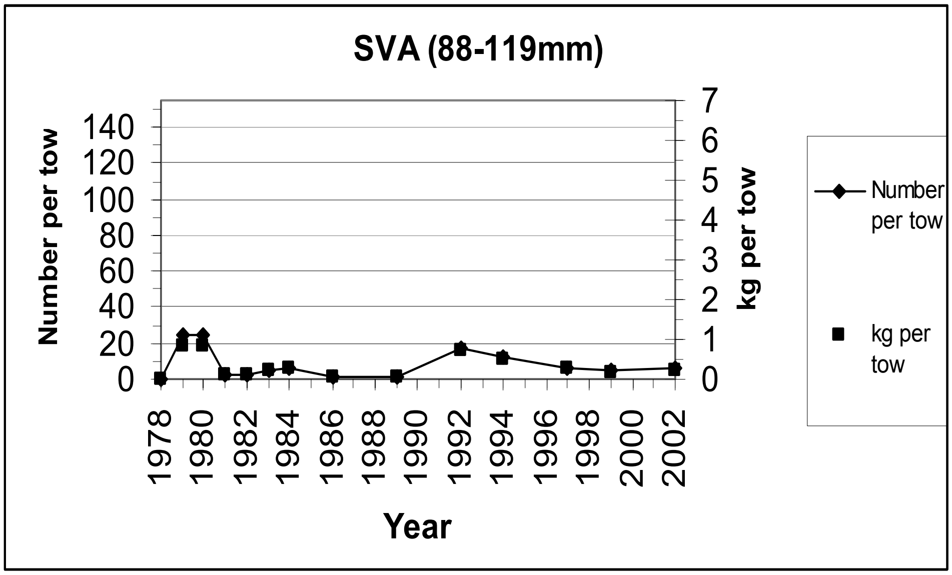


Figure C48.
Age-structure of surfclams in the New Jersey (NJ) and Delmarva (DMV) regions, by year. Results are based on NMFS survey data on surfcalm shell length and age. "n"= number of surfclams that were aged and used to estimate an age-length key.



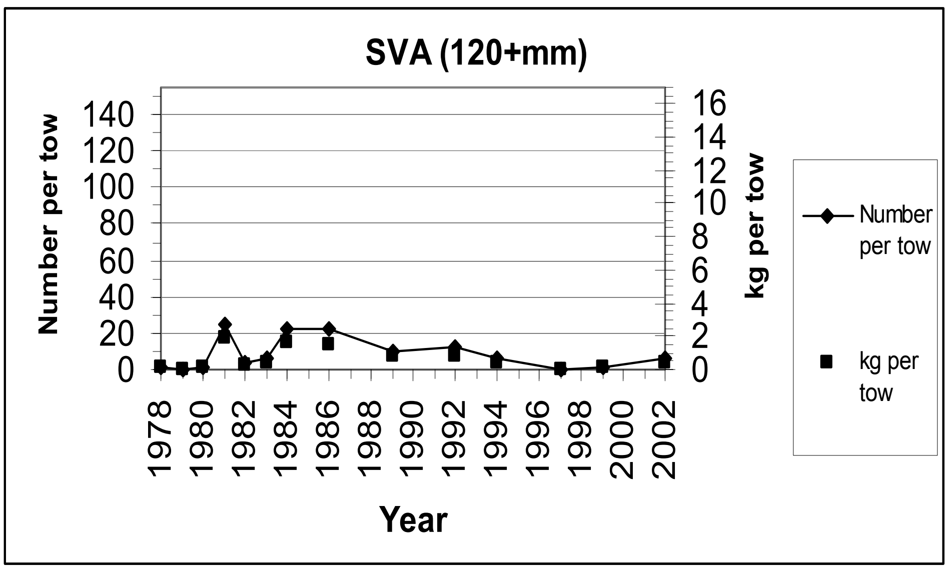
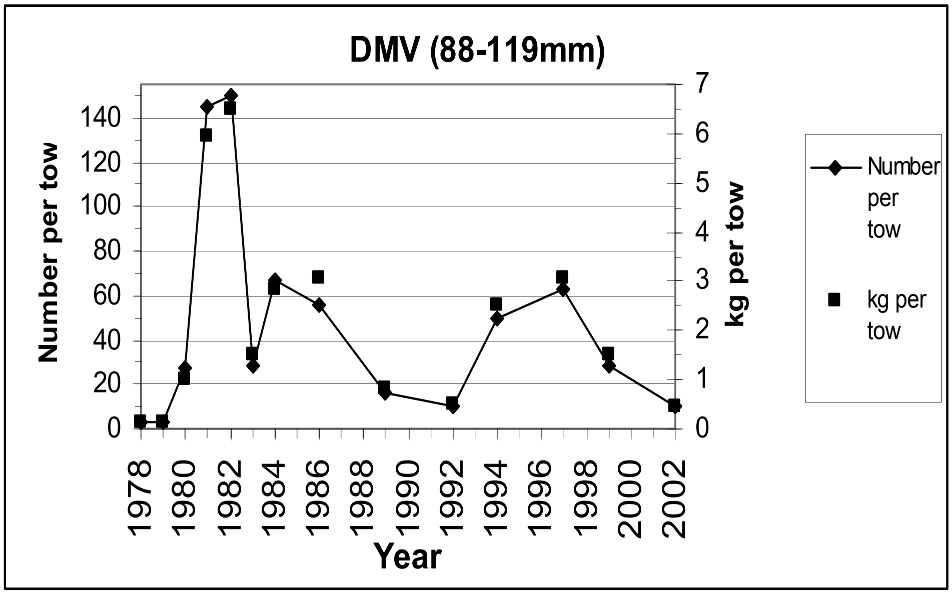


Figure C49.
Number and meat weight (kg) of surfclams per tow for NMFS surveys, 1978-2002. Data are presented for two size groups. Standardized to a tow distance of 0.15 n. mi. based on doppler distance, and assuming length/weights from Sarc-30 (NEFSC, 2000a).
Region: S. Virginia/N. Carolina (SVA).



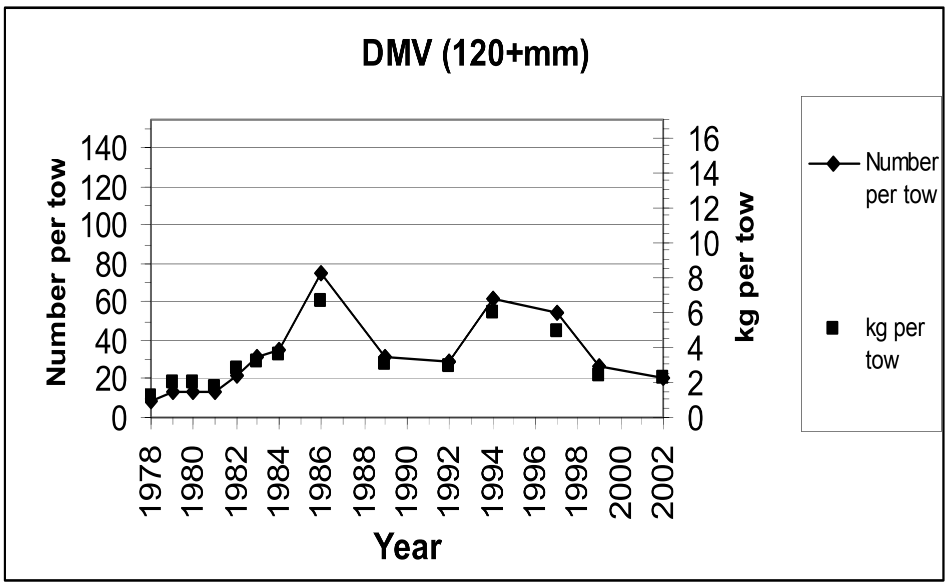
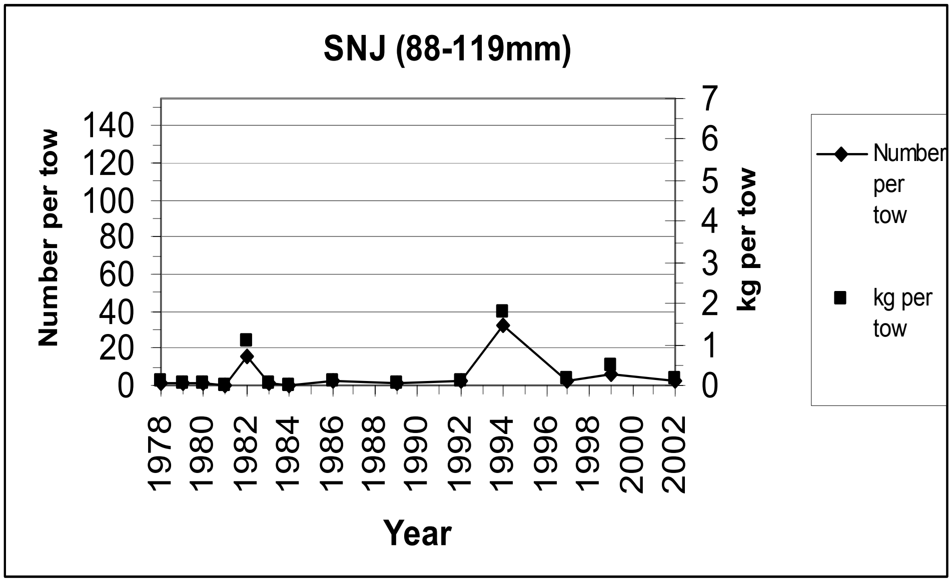


Figure C50.
Number and meat weight (kg) of surfclams per tow for NMFS surveys, 1978-2002. Data are presented for two size groups. Standardized to a tow distance of 0.15 n. mi. based on doppler distance, and assuming length/weights from Sarc-30 (NEFSC, 2000a).
Region: Delmarva (DMV).



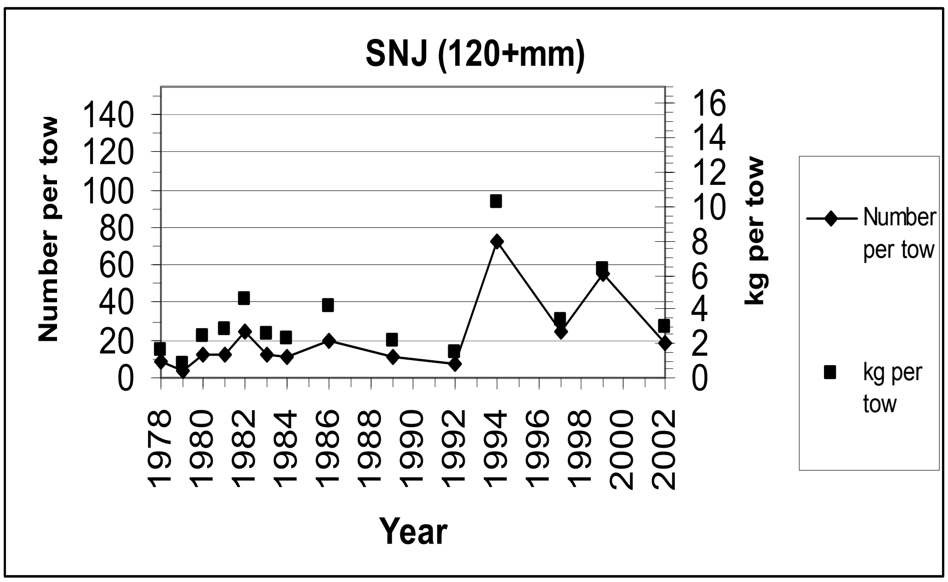


Figure C51.
Number and meat weight (kg) of surfclams per tow for NMFS surveys, 1978-2002. Data are presented for two size groups. Standardized to a tow distance of 0.15 n. mi. based on doppler distance, and assuming length/weights from Sarc-30 (NEFSC, 2000a).
Region: S. New Jersey (SNJ).

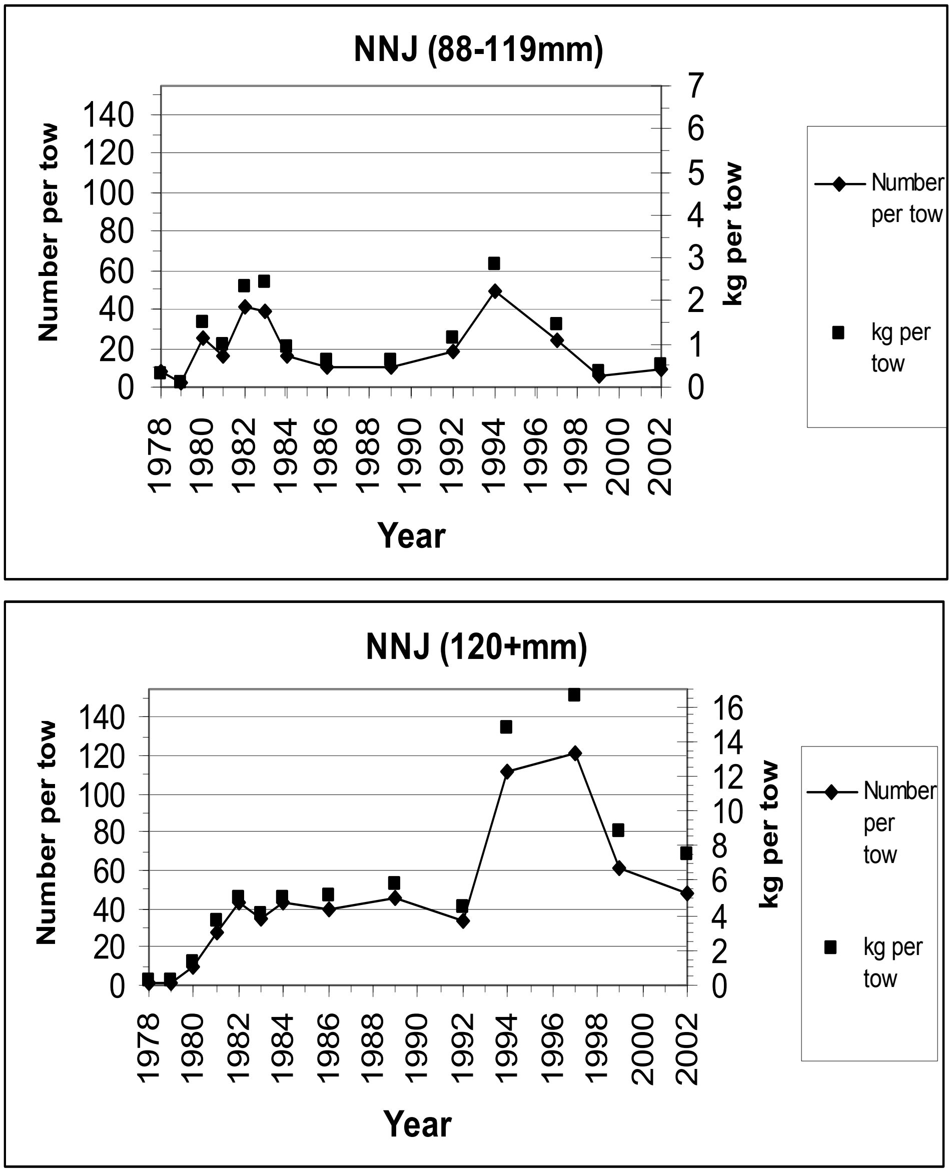
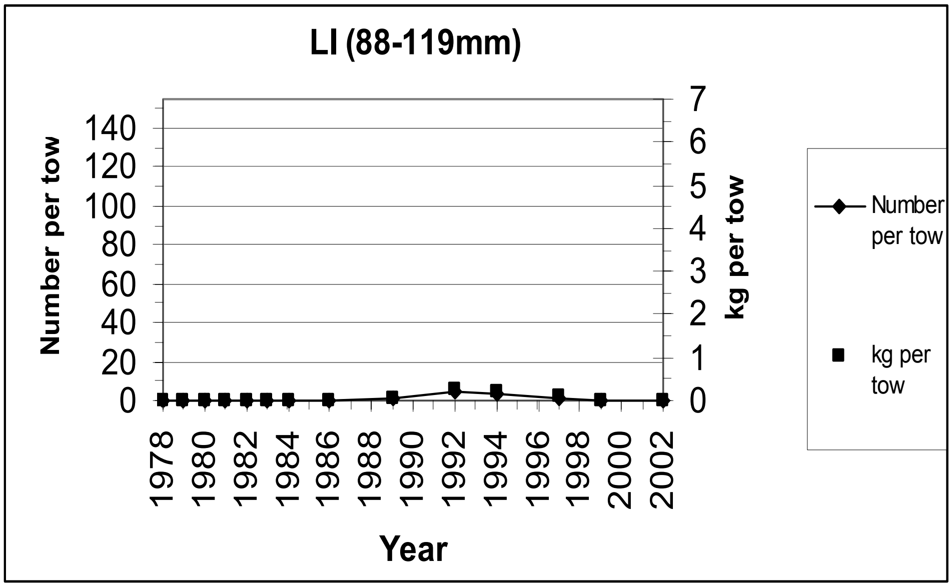


Figure C52.
Number and meat weight (kg) of surfclams per tow for NMFS surveys, 1978-2002. Data are presented for two size groups. Standardized to a tow distance of 0.15 n. mi. based on doppler distance, and assuming length/weights from Sarc-30 (NEFSC, 2000a).
Region: N. New Jersey (NNJ).



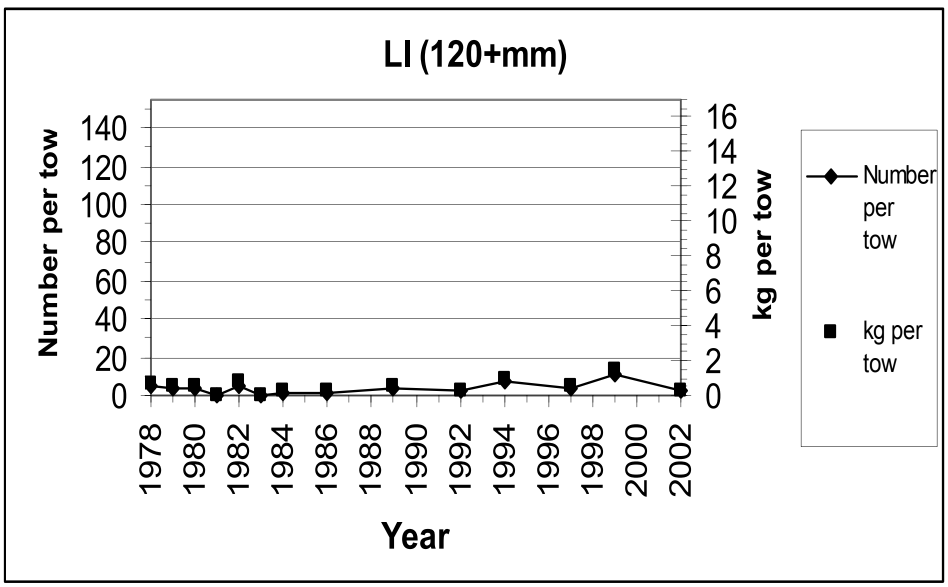
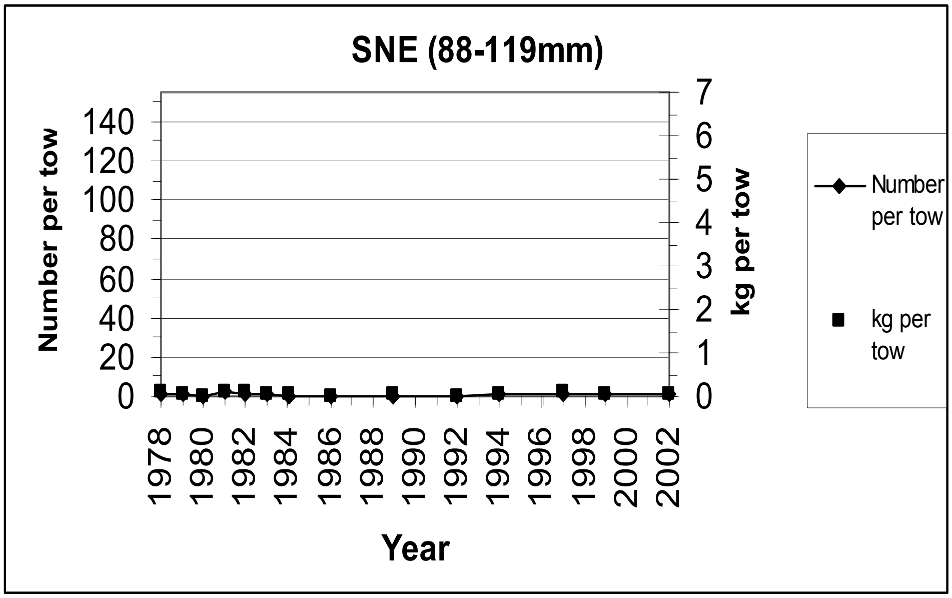


Figure C53.
Number and meat weight (kg) of surfclams per tow for NMFS surveys, 1978-2002. Data are presented for two size groups. Standardized to a tow distance of 0.15 n. mi. based on doppler distance, and assuming length/weights from Sarc-30 (NEFSC, 2000a).
Region: Long Island (LI).



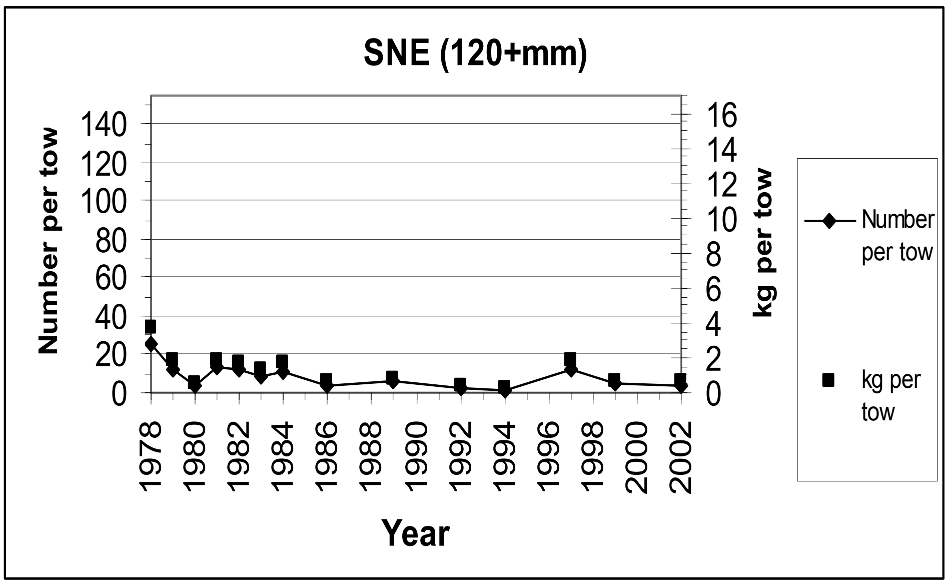
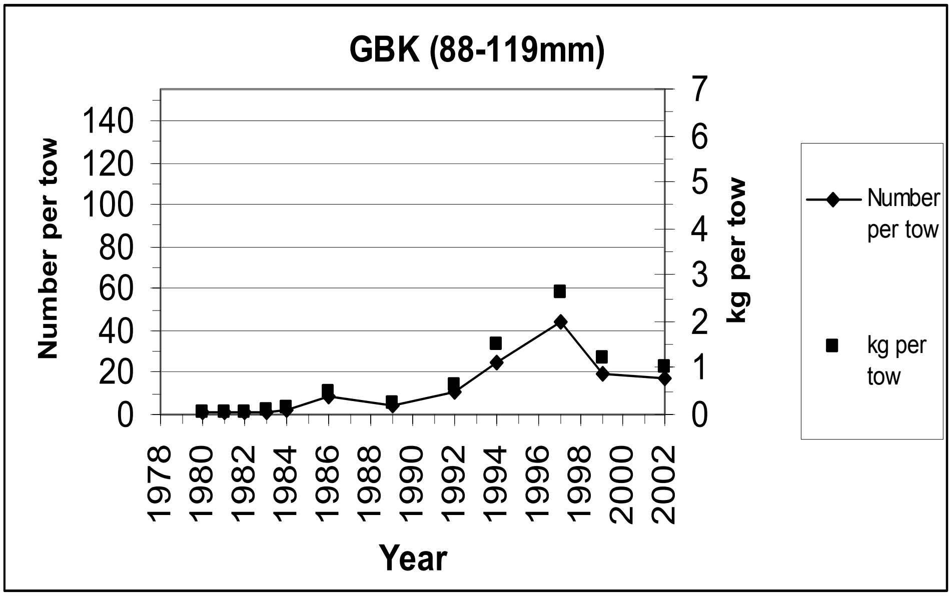


Figure C54.
Number and meat weight (kg) of surfclams per tow for NMFS surveys, 1978-2002. Data are presented for two size groups. Standardized to a tow distance of 0.15 n. mi. based on doppler distance, and assuming length/weights from Sarc-30 (NEFSC, 2000a).
Region: S. New England (SNE).



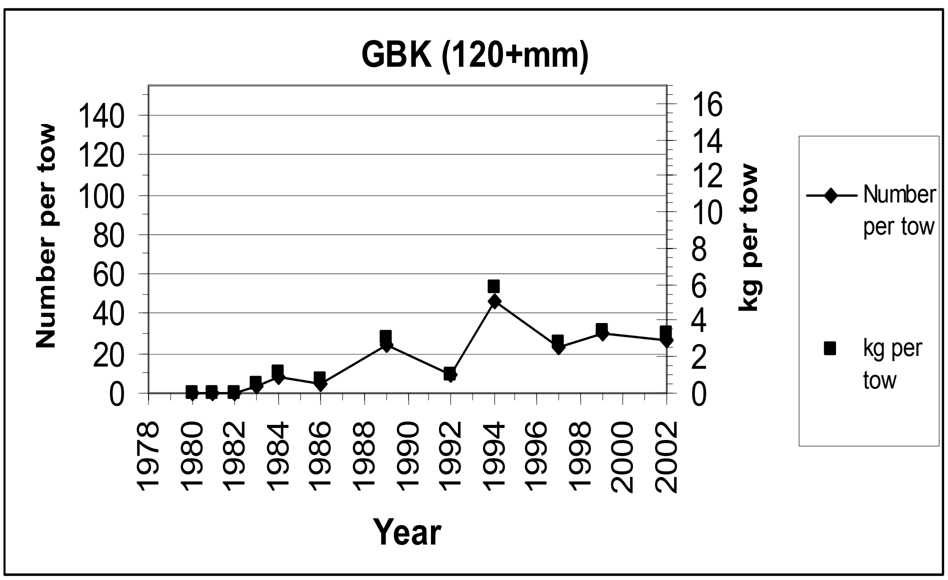


Figure C55.
Number and meat weight (kg) of surfclams per tow for NMFS surveys, 1978-2002. Data are presented for two size groups. Standardized to a tow distance of 0.15 n. mi. based on doppler distance, and assuming length/weights from Sarc-30 (NEFSC, 2000a).
Region: Georges Bank (GBK).

Figure C56. Parametric bootstrap distributions (8000 iterations) depicting uncertainty in efficiency corrected swept area biomass estimates for surfclam during 2002. Biomass (1000 mt) is for 120+ mm surfclam in NNJ and SNJ and for 100+ mm surfclam in other regions.

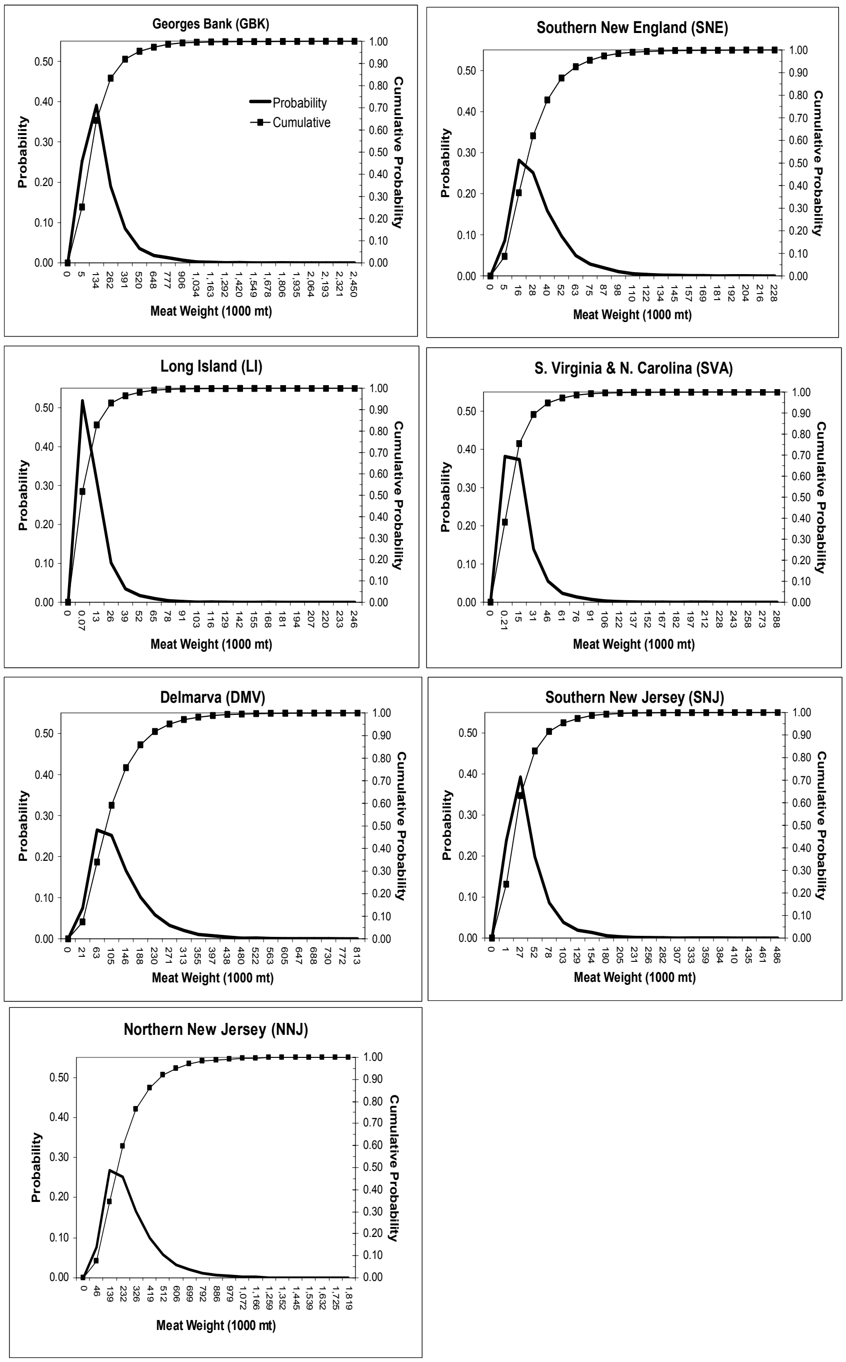


Figure C57. Summary of KLAMZ model results for DMV surfclam.

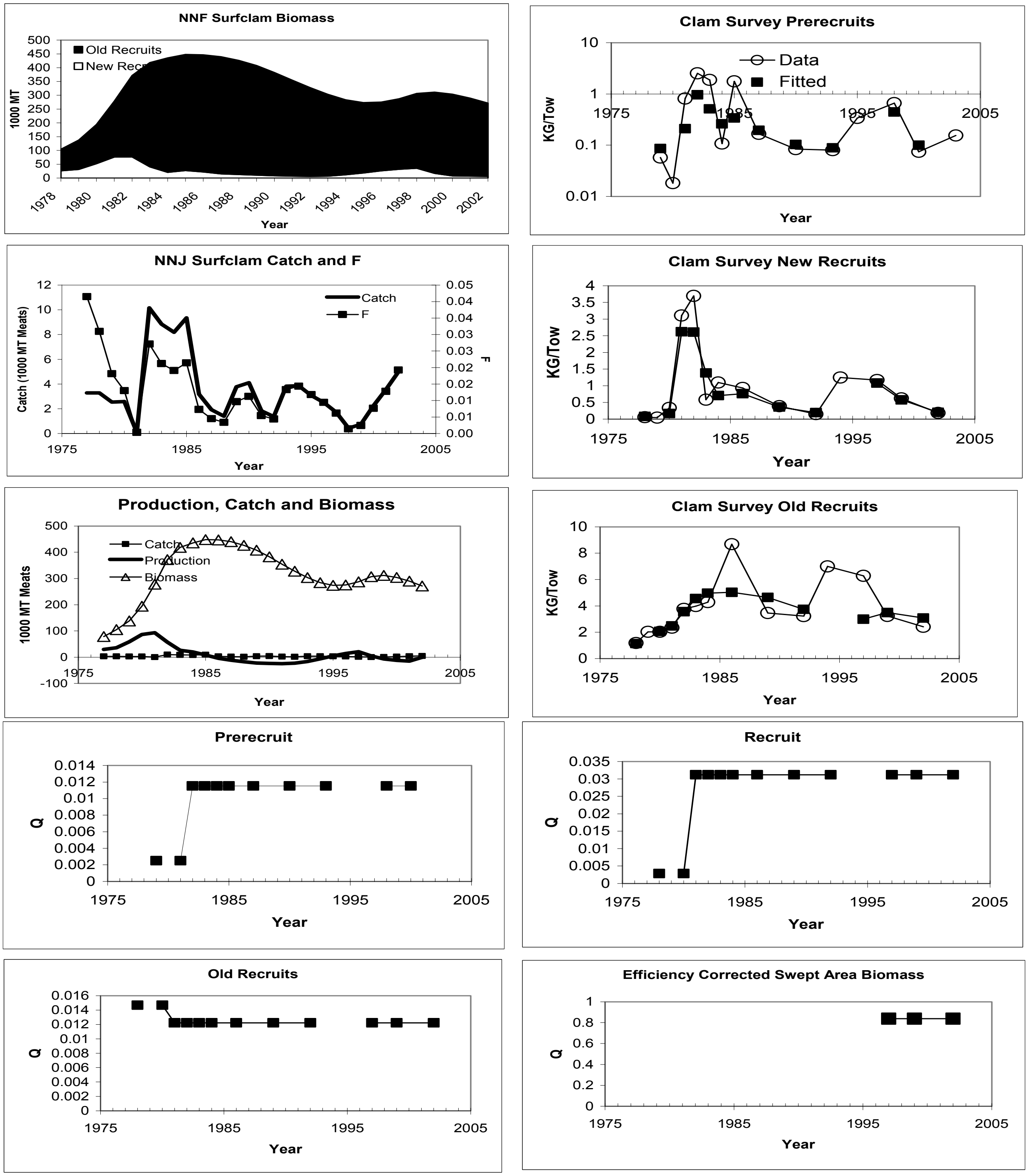


Figure C58. Biomass estimates and 80% bootstrap confidence intervals for DMV surfclam.

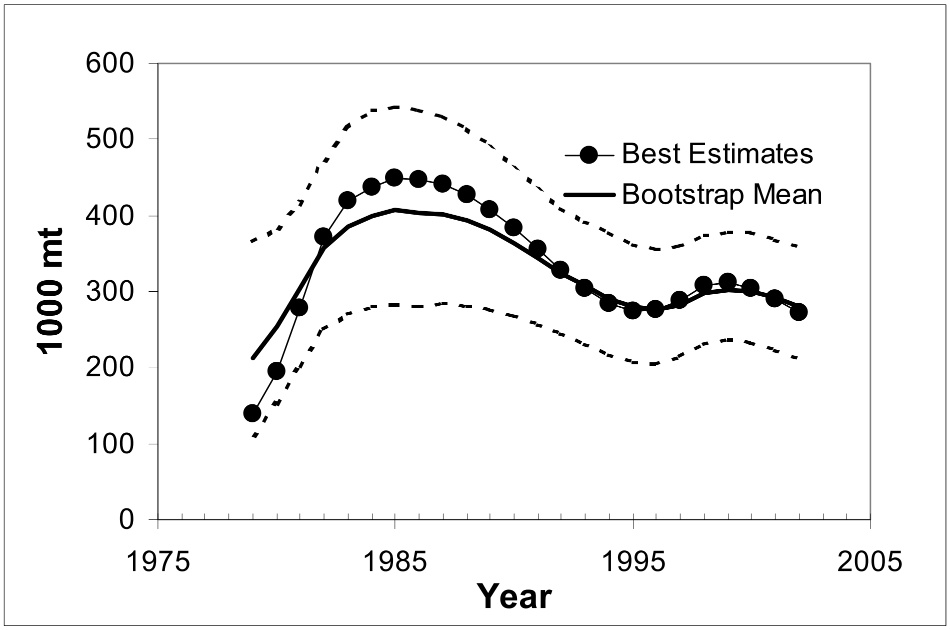


Figure C59. Retrospective analysis for DMV surfclam biomass estimates.

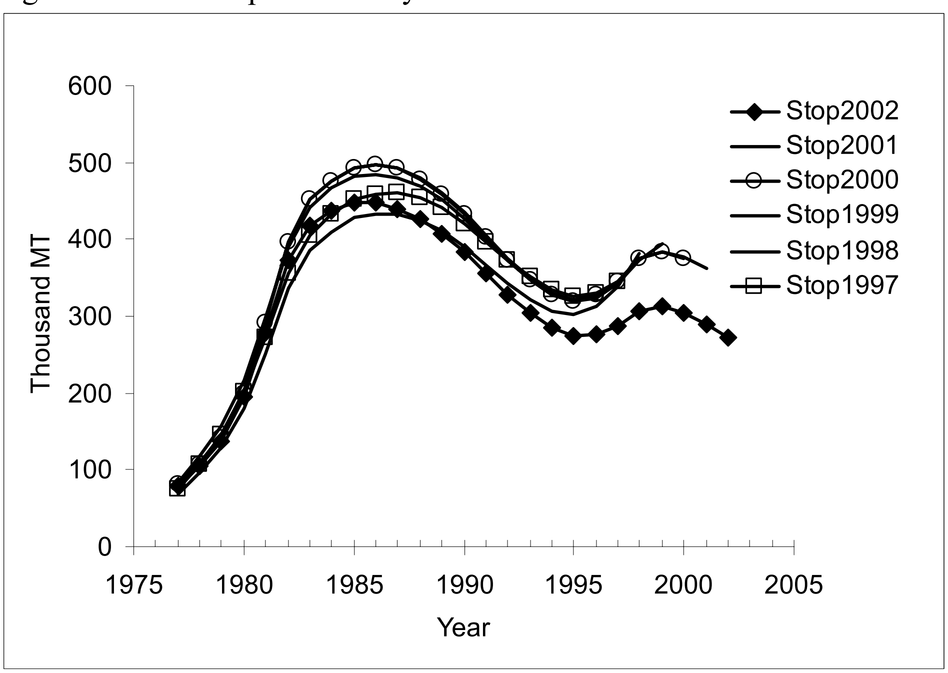


Figure C60. Sensitivity of DMV biomass estimates to recruitment assumptions.

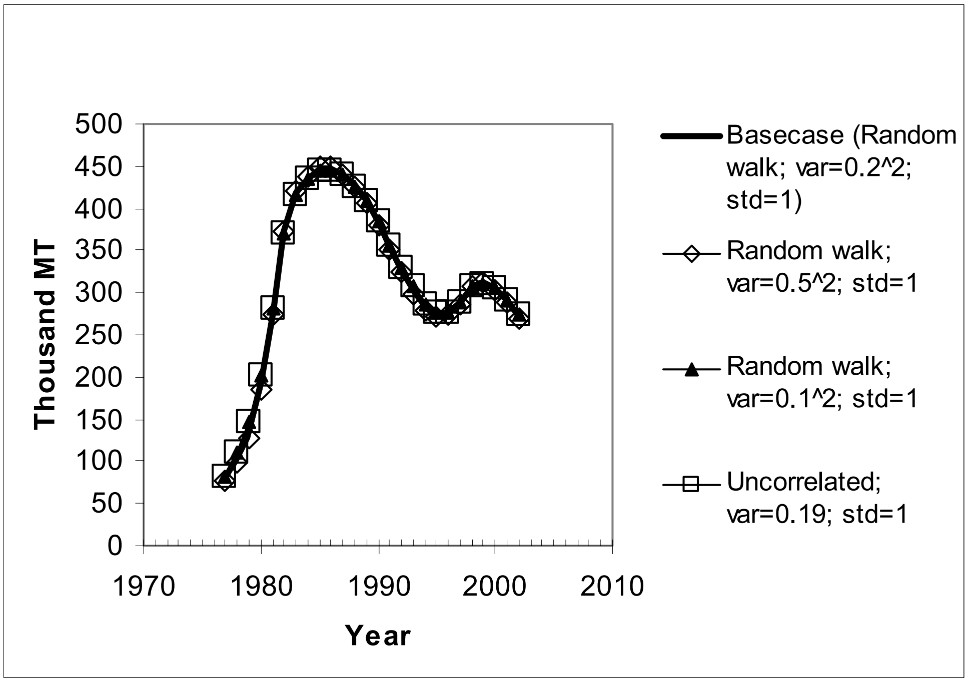


Figure C61. Sensitivity of DMV recruitment estimates to recruitment assumptions.

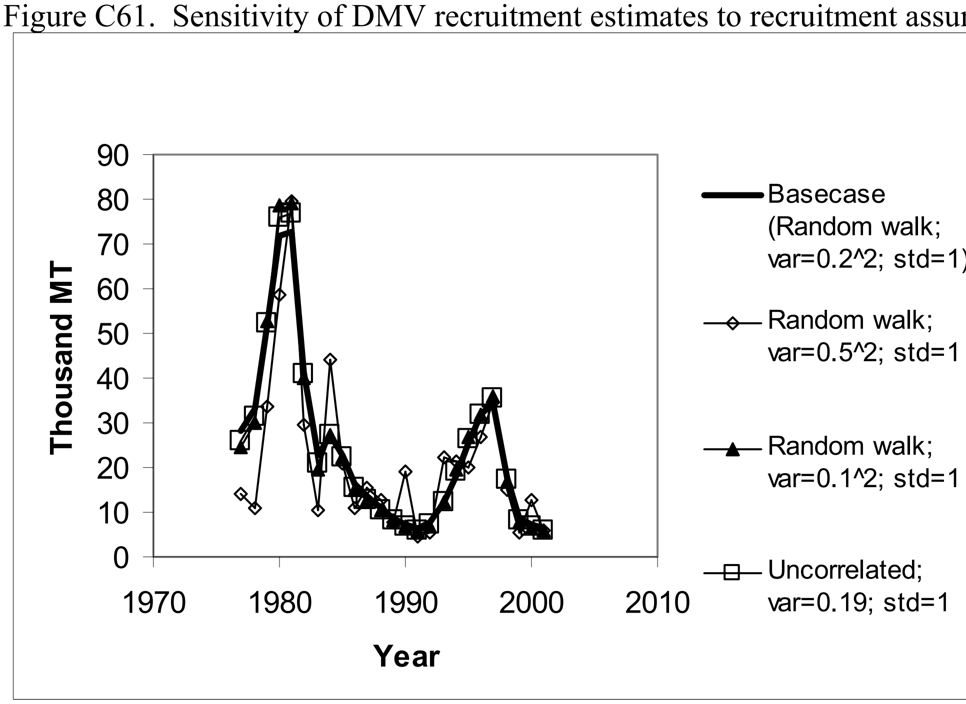


Figure C62. Survey data, efficiency corrected swept area biomass estimates used as data, biomass and recruitment estimates for Delmarva (DMV) surfclam from the KLAMZ model used in this assessment (and in the previous assessment (NEFSC 2000a). Y-axes are not labeled for pre-, new- and old recruit data because only the trends are important.

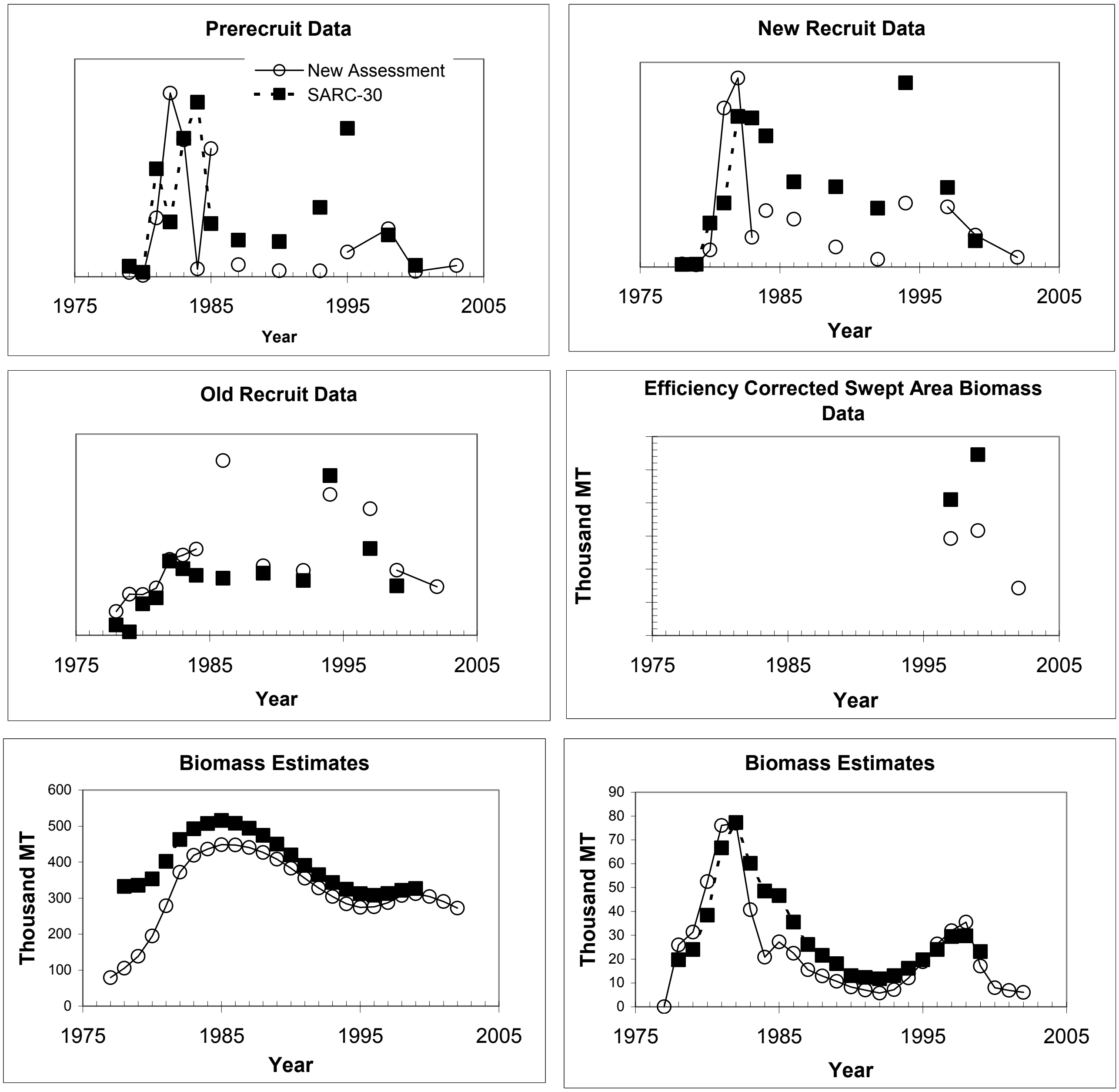


Figure C63. Residual plots for the final KLAMZ model for NNJ surfclam (not reliable enough for use by managers)

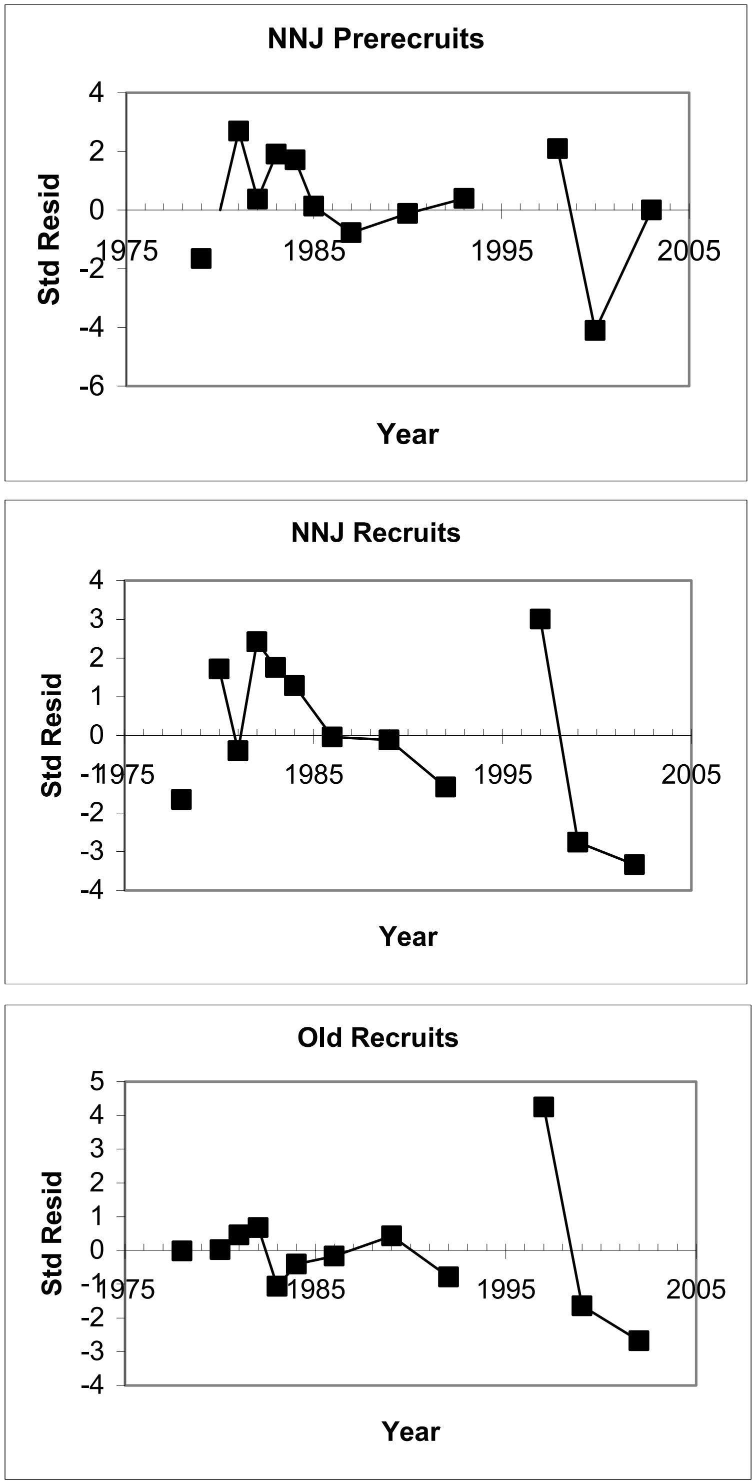


Figure C64. Summary of KLAMZ model results for NNJ surfclam (not reliable enough for use by managers).

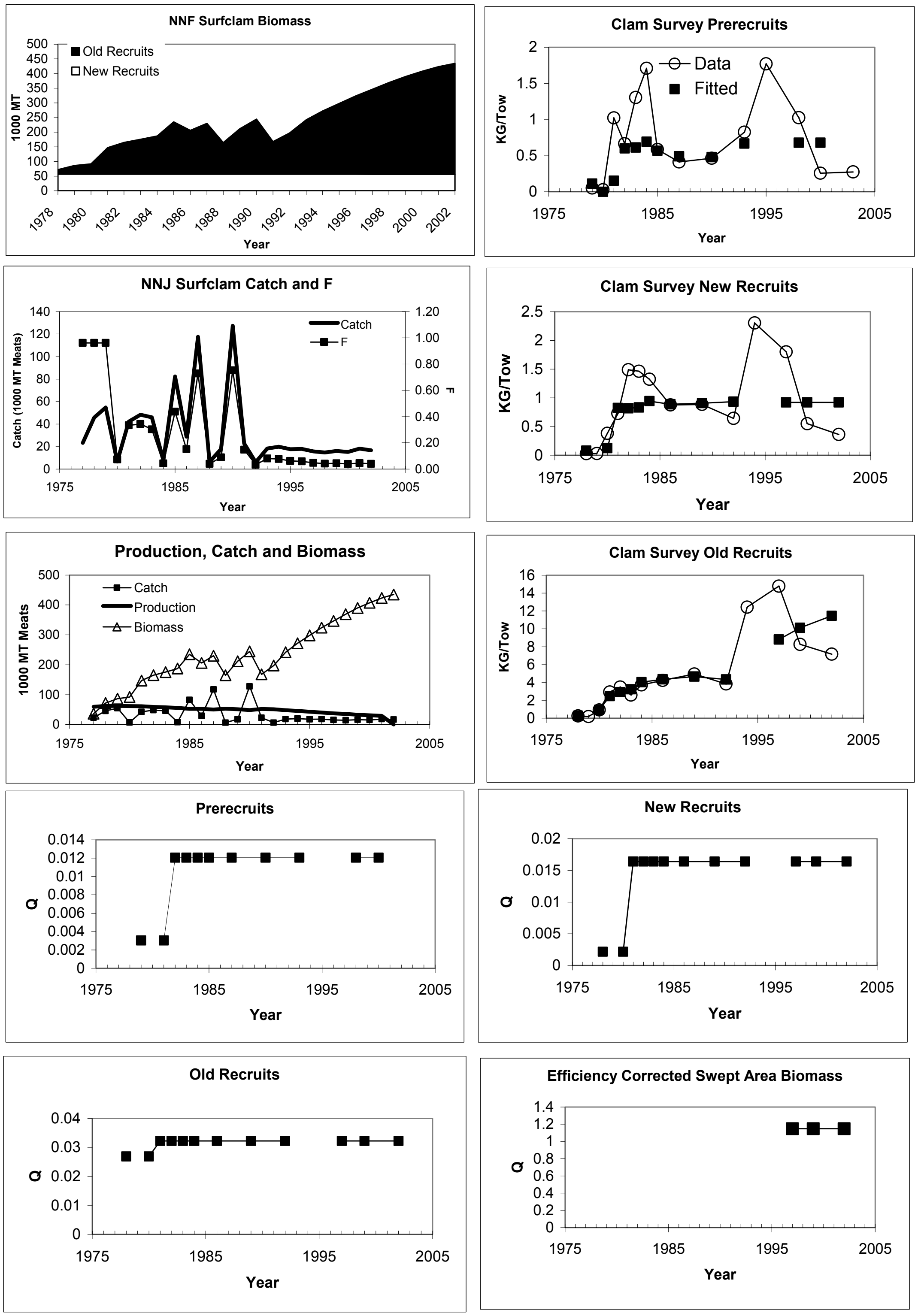
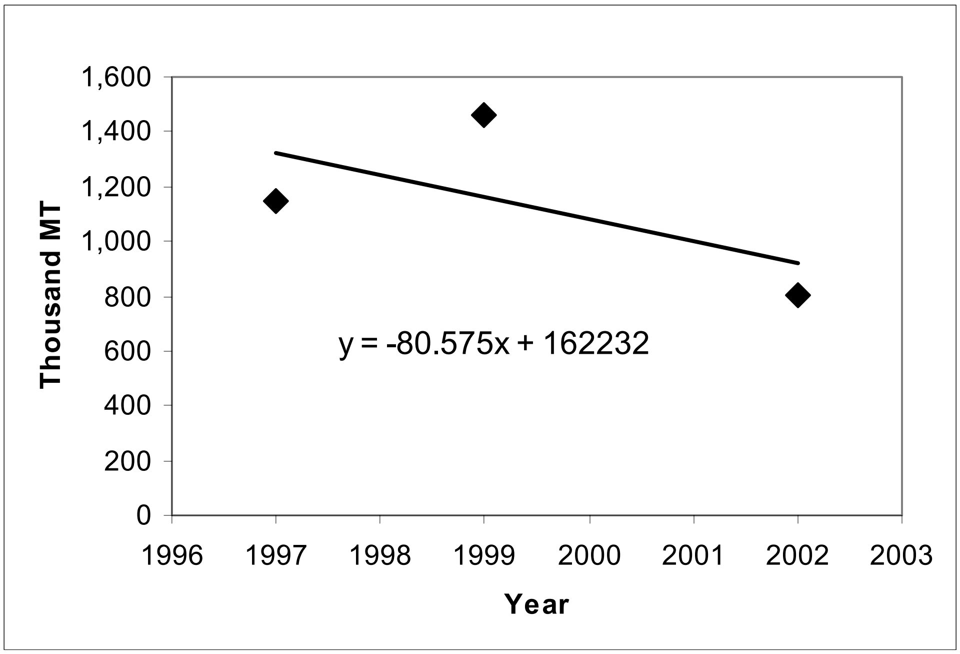


Figure C65. Efficiency corrected swept area biomass estimates for the EEZ surfclam stock.



Appendix A.
(of "C. Atlantic Surfclam" SARC-37 Report):

The KLAMZ Assessment Model

The KLAMZ assessment model (NEFSC 2000; 2001) is based on the Deriso-Schnute delay-difference equation (Deriso 1980; Schnute 1985; Quinn and Deriso 1999). The delay-difference equation is a relatively simple and implicitly age structured model that counts fish in either numerical or biomass units. It gives the same results as explicitly age-structured models (e.g. Leslie matrix model) if fishery selectivity is "knife-edged", somatic growth follows the von Bertalanffy equation, and natural mortality is the same for all age groups in each year. Knife-edge selectivity means that all individuals alive in the model during the same year experience the same fishing mortality rate.[1] Natural and fishing mortality rates, growth parameters and recruitment may change from year to year, but delay-difference calculations assume that all individuals share the same mortality and growth parameters within each year.

As in many other simple models, the delay difference equation explicitly distinguishes between two age groups. In KLAMZ, the two age groups are called "new" recruits and "old" recruits. New recruits are individuals that recruited at the beginning or during the current year. Old recruits are all older individuals in the model. As described above, KLAMZ assumes that new and old recruits are fully vulnerable to the fishery. The most important differences between the delay-difference and other simple models (e.g. Prager 1994; Conser 1995; Jacobson et al. 1994) are that von Bertalanffy growth is used to calculate biomass dynamics and that the delay-difference model captures transient age structure effects due to variation in recruitment, growth and mortality exactly. Transient effects on population dynamics are captured exactly because, as described above, the delay-difference equation is algebraically equivalent to an explicitly age-structured model with von Bertalanffy growth. As described above, delay-difference calculations can be carried out in units of biomass or numerical abundance. The KLAMZ model includes simple numerical models as special cases (e.g. Conser 1995) because growth can be turned off so that all calculations are in numerical units (see below).

The KLAMZ model incorporates a few extensions to Schnute's (1985) revision of Deriso's (1980) original delay difference model. Most of the extensions facilitate tuning to a wider variety of data that anticipated in Schnute (1985). The KLAMZ model was programmed in both Excel and in C++ using AD Model Builder libraries[2]. The AD

---

[1] In applications, assumptions about knife-edge selectivity can be relaxed by assuming the model tracks "fishable", rather that total, biomass (NEFSC 2000a; 2000b). An analogous approach assigns pseudo-ages based on recruitment to the fishery so that new recruits in the model are all pseudo-age *k*. The synthetic cohort of fish pseudo-age *k* may consist of more than one biological cohort. The first pseudo-age (*k*) can be the predicted age at first, 50% or full recruitment based a von Bertalanffy curve and size composition data (Butler et al. 2002). The "incomplete recruitment" approach (Deriso 1980) calculates recruitment to the model in each year R_t as the weighted sum of contributions from two or more cohorts due to spawning in successive years (i.e. $R_t = \sum_{a=1}^{k} r_a \Pi_{t-a}$ where k is the age at full recruitment to the fishery, r_a is the contribution of fish age *k-a* to the fishable stock, and $_{t-a}$ is the number or biomass of fish age *k-a* during year *t*).

[2] Otter Research Ltd., Box 2040, Sydney, BC, V8L 3S3 (otter@otter-rsch.com).

Model Builder version is faster, more reliable and probably better for producing "official" stock assessment results. The Excel version is slower but useful in developing prototype assessment models, teaching and for checking calculations.

Population dynamics

The assumed birth date and first day of the year are assumed the same in derivation of the delay-difference equation. It is therefore natural (but not strictly necessary) to tabulate catch and other data using annual accounting periods that start on the assumed biological birthday of cohorts.

Schnute's (1985) delay-difference equation in the KLAMZ model is:

$$B_{t+1} = (1+\rho)\,\tau_t\, B_t - \rho\,\tau_t\,\tau_{t-1}\, B_{t-1} + R_{t+1} - \rho\,\tau_t\, J_t\, R_t$$

where B_t is total biomass of individuals at the beginning of year t; ρ is Ford's growth coefficient (see below); $\tau_t=exp(-Z_t)=exp[-(F_t+M)]$ is the fraction of the stock that survived in year t, Z_t, F_t, and M are instantaneous rates for total, fishing and natural mortality; and R_t is the biomass of new recruits (at age k) at the beginning of the year. The natural mortality rate M_t may vary or be constant over time. Instantaneous mortality rates in KLAMZ model calculations are biomass-weighted averages if von Bertalanffy growth is turned on in the model. However, biomass-weighted mortality estimates in KLAMZ are the same as rates for numerical calculations because all individuals are fully recruited. The growth parameter $J_t = w_{t-1,k-1} / w_{t,k}$ is the ratio of mean weight one year before recruitment (age k-1 in year t-1) and mean weight at recruitment (age k in year t).

It is not necessary to specify body weights at and prior to recruitment in the KLAMZ model (parameters v_{t-1} and V_t in Schnute 1985) because the ratio J_t and recruitment biomass contain the same information. Schnute's (1985) original delay difference equation is:

$$B_{t+1} = (1+\rho)\,\tau_t\, B_t - \rho\,\tau_t\tau_{t-1}\, B_{t-1} + w_{t+1,k} N_{t+1} - \rho\tau_t w_{t-1,k-1}\, N_t$$

To derive the equation used in KLAMZ, substitute recruitment biomass R_{t+1} for the product $w_{t+1,k}\,N_{t+1,k}$ and adjusted recruitment biomass $J_t\,R_t = (w_{t-1,k-1}/w_{t,k})\; w_{t,k}\;N_{t,k} = w_{t-1,k-1}\;N_t$ in the last term on the right hand side. The advantage in using the alternate parameterization for biomass dynamic calculations in KLAMZ is that recruitment is estimated directly in units of biomass and the number of growth parameters is reduced.

Growth

As described in Schnute (1985), biomass calculations in the KLAMZ model are based on Schnute and Fournier's (1980) re-parameterization of the von Bertalanffy growth model:

$$w_a = w_{k-1} + (w_k - w_{k-1})\,(1+\rho^{1+a-k})\,/\,(1-\rho)$$

where $w_k=V$ and $w_{k-1}=v$. Schnute and Fournier's (1980) growth model is the same as the traditional von Bertalanffy growth model $\{W_a= W_{max}\,[1 - exp(-K(a-t_{zero})]$ where W_{max}, K and t_{zero} are parameters$\}$. The two growth models are the same because $W_{max} = (w_k - \rho\, w_{k-1})/(1-\rho)$, $K = -ln(\rho)$ and $t_{zero} = ln[(w_k - w_{k-1})/(w_k - \rho\, w_{k-1})] / ln(\rho)$.

In the KLAMZ model, the growth parameters J_t can vary with time but ρ is constant. Use of time-variable J_t values with ρ is constant is the same as assuming that the von Bertalanffy parameters W_{max} and t_{zero} change over time. It is possible to accommodate a wide range growth patterns by changing only W_{max} and t_{zero}. Growth parameters are usually estimated externally, rather than directly in the KLAMZ model. The KLAMZ model uses catch-at-age information indirectly, if catch-at-age is used to estimate growth parameters.

Numerical population dynamics (growth turned off)

Growth can be turned on off so that abundance, rather than biomass, is tracked in the KLAMZ model. Set J_t=1 and ρ=0 in the delay difference equation, and use N_t (for numbers) in place of B_t to get:

$$\mathrm{N}_{t+1} = \tau_t \, \mathrm{N}_t + \mathrm{R}_{t+1}$$

All of the calculations in KLAMZ for biomass dynamics are also valid for numerical dynamics.

Instantaneous growth rates

Instantaneous growth rate (IGR) calculations in the KLAMZ model are an extension to the original Deriso-Schnute delay difference model. IGRs are used extensively in KLAMZ for calculating catch biomass and projecting stock biomass forward to the time at which surveys occur. The IGR for new recruits depends only on growth parameters:

$$G_t^{New} = \ln\left(\frac{w_{k+1,t+1}}{w_{k,t}}\right) = \ln(1 + \rho - \rho J_t)$$

IGR for old recruits is a biomass-weighted average that depends on the current age structure and growth parameters. It can be calculated easily by projecting biomass of old recruits S_t=B_t-R_t (escapement) forward one year with no mortality:

$$S_t^* = (1+\rho)S_t - \rho\tau_{t-1}B_{t-1}$$

where the asterisk (*) means just prior to the start of the subsequent year t+1. By definition, the IGR for old recruits in year t is $G_t^{Old} = \ln\left(S_t^*/S_t\right)$. Dividing by S_t gives:

$$G_t^{Old} = \ln\left[(1+\rho) - \rho\tau_{t-1}\frac{B_{t-1}}{S_t}\right]$$

IGR for the entire stock is the biomass weighted average of the IGR values for new and old recruits:

$$G_t = \frac{R_t G_t^{New} + S_t G_t^{Old}}{B_t}$$

All IGR values are zero if growth is turned off.

Recruitment

In the Excel version of the KLAMZ model, annual recruitments are calculated $R_t = e^{\Omega_t}$ where Ω_t is a log transformed annual recruitment parameter usually estimated in the model. In the C++ version, recruitments are calculated based on log geometric mean recruitment (μ) and a set of annual log scale deviation parameters (ω_t):

$$\Omega_t = \mu + \omega_t$$

The deviations ω_t are constrained to average zero.[3] With the constraint, estimation of μ and the set of ω_t values (1+ n years parameters) is equivalent to estimation of the smaller set (n years) of Ω_t values.

Natural mortality

Natural mortality rates (M) are assumed constant in the Excel version of the KLAMZ model but can change from year to year in the C++ version based on covariates (e.g. predator density) or natural mortality rate process errors. Natural mortality rate process errors represent variation in predation, disease, parasitism and other factors that affect natural mortality rates in fish populations. Annual process error parameters are estimated to improve model fit to survey and other data. Calculations are basically the same as for survey covariates and survey process errors described below.

Fishing mortality and catch

Fishing mortality rates (F_t) are calculated so that predicted and observed catch data (landings plus estimated discards in units of weight) "agree". It is not necessary, however, to assume that catches are measured accurately (see "Observed and predicted catch").

Fishing mortality rate calculations in Schnute (1985) are applicable when catches are in units of numbers but catch data are usually in units of weight. Calculation of predicted catches in units of weight is more complicated because somatic growth occurs throughout the year as fishing occurs.

The KLAMZ model uses a generalized catch equation that incorporates continuous growth through the fishing season. By the definition of instantaneous rates, the catch equation expresses catch as the product:

$$\hat{C}_t = F_t \overline{B}_t$$

where $\hat{C}_t$ was predicted catch weight (landings plus discard) and $\overline{B}_t$ is average biomass.

Following Ricker (1970) and Zhang and Sullivan (1988), let $X_t=G_t-F_t-M_t$ be the net instantaneous rate of change for biomass.[4] If the rates for growth and mortality are equal, then X_t=0, $\overline{B}_t = B_t$ and $C_t = F_t B_t$. If the growth rate G_t exceeds the combined rates of natural and fishing mortality ($F_t + M_t$), then $X_t > 0$. If mortality exceeds growth, then $X_t < 0$. In either case, with X_t 0, average biomass is computed:

$$\overline{B}_t \approx -\frac{\left(1 - e^{X_t}\right) B_t}{X_t}$$

When X_t 0, the expression for $\overline{B}_t$ is an approximation because G_t approximates the rate of change in mean body weight due to von Bertalanffy growth. However, the approximation is reasonably accurate and preferable to calculating catch biomass with the

---

[3] The constraint is implemented by adding $L = \lambda \overline{\varpi}^2$ to the objective function, generally with λ = 1000.

[4] By convention, the instantaneous rates G_t, F_t and M_t are always expressed as numbers 0.

traditional catch equation that ignores growth during the fishing season.[5] Average biomass can be calculated for new recruits, old recruits or for the whole stock by using either G_t^{New}, G_t^{Old} or G_t.

In the Excel version of KLAMZ, the modified catch equation is solved analytically for F_t given C_t, B_t, G_t and M. In the C++ version, fishing mortality rates are calculated using a log geometric mean parameter (Φ) and a set of annual log scale deviation parameters (ψ_t):

$$F_t = e^{\Phi+\psi_t}$$

where the deviations ψ_t are constrained to average zero.

Surplus production

Annual surplus production was calculated exactly by projecting biomass at the beginning of each year forward with no fishing mortality:

$$\mathrm{B}_t^* = (1+\rho)\,\mathrm{e}^{-M}\,\mathrm{B}_t - \rho\,\mathrm{e}^{-M}\,\mathrm{L}_{t-1}\,\mathrm{B}_{t-1} - \rho\,\mathrm{e}^{-M}\,\mathrm{J}_t\,\mathrm{R}_t$$

By definition, surplus production $P_t=B^*_t-B_t$.

Per recruit modeling

Per recruit model calculations in the Excel version of the KLAMZ simulate the life of a hypothetical cohort of arbitrary size (e.g. R=1000) with constant M, F (survival) and growth (and J) in a population initially at zero biomass. In the first year:

$$\mathrm{B}_1 = \mathrm{R}$$

In the second year:

$$\mathrm{B}_2 = (1+\rho)\,\tau\,\mathrm{B}_1 - \rho\,\tau\,\mathrm{J}\,\mathrm{R}_1$$

In the third and subsequent years:

$$\mathrm{B}_{t+1} = (1+\rho)\,\tau\,\mathrm{B}_t - \rho\,\tau^2\,\mathrm{B}_{t-1}$$

This iterative calculation is carried out until the sum of lifetime cohort biomass from one iteration to the next changes by less than a small amount (0.0001). Total lifetime biomass, spawning biomass and yield in weight are calculated by summing biomass, spawning biomass and yield over the lifetime of the cohort (in each iteration). Lifetime biomass, spawning biomass and yield per recruit are calculated by dividing totals by initial recruitment (R).

Status determination variables

The user may specify a range of years (e.g. the last three years) to use in calculating recent average fishing mortality $\overline{F}_{\mathrm{Re}cent}$ and biomass $\overline{B}_{\mathrm{Re}cent}$ levels. These status determination variables are often useful in calculation of status ratios such as $\overline{F}_{\mathrm{Re}cent} / F_{MSY}$ and $\overline{B}_{\mathrm{Re}cent}/\mathrm{B_{MSY}}$.

---

[5] The traditional catch equation $C_t = F_t(1-e^{-Z_t})B_t / Z_t$ where $Z_t=F_t+M_t$ underestimates catch biomass for a given level of fishing mortality F_t and overestimates F_t for a given level of catch biomass. The errors can be substantial for fast growing fish, particularly if recent recruitments were strong.

Goodness of Fit and Parameter Estimation

Parameters estimated in the KLAMZ model are chosen to minimize an objective function based on a sum of weighted negative log likelihood (NLL) components:

$$\Xi = \sum_{v=1}^{N_\Xi} \lambda_v L_v$$

where N_Ξ is the number of NLL components (L_v) and the λ_v are emphasis factors used as weights. The objective function Ξ may be viewed as a NLL or a negative log posterior (NLP) distribution, depending on the nature of the individual L_v components and modeling approach. Except during sensitivity analyses, weighting factors for objective function components (λ_v) are usually set to one. An arbitrarily large weighting factor (e.g. λ_v =1000) is used for "hard" constraints that must be satisfied in the model. Arbitrarily small weighting factors (e.g. λ_v =0.0001) can be used for "soft" model-based constraints. For example, an internally estimated spawner-recruit curve or surplus production curve might be estimated with a small weighting factor to summarize stock-recruit or surplus production results with minimal influence on biomass, fishing mortality and other estimates from the model. Use of a small weighting factor for an internally estimated surplus production or stock-recruit curve is equivalent to fitting a curve to model estimates of biomass and recruitment or surplus production in the output file, after the model is fit (Jacobson et al. 2002).

<u>NLL kernels</u>

NLL components in KLAMZ are generally programmed as "concentrated likelihoods" to avoid calculation of values that do not affect derivatives of the objective function. For x~N(μ,σ^2), the complete NLL for one observation is:

$$L = \ln(\sigma) + \ln\left(\sqrt{2\pi}\right) + 0.5\left(\frac{x-u}{\sigma}\right)^2$$

The constant $\ln\left(\sqrt{2\pi}\right)$ can always be omitted because does not affect derivatives. If the standard deviation is known or assumed known, then ln(σ) can be omitted as well because it is a constant that does not affect derivatives. In such cases, the concentrated negative log likelihood is:

$$L = 0.5\left(\frac{x-\mu}{\sigma}\right)^2$$

If there are N observations with possible different variances (known or assumed known) and possibly different expected values:

$$L = 0.5\sum_{i=1}^{N}\left(\frac{x_i-\mu_i}{\sigma_i}\right)^2$$

If the standard deviation for a normally distributed quantity is not known and is (in effect) estimated by the model, then one of two equivalent calculations is used. Both approaches assume that all observations have the same variance and standard deviation. The first approach is used when all observations have the same weight in the likelihood:

$$L = 0.5N \ln\left[\sum_{i=1}^{N}(x_i - u)^2\right]$$

where N is the number of observations. The second approach is equivalent but used when the weights for each observation ($_i$) may differ:

$$L = \sum_{i=1}^{N}\lambda_i\left[\ln(\sigma) + 0.5\left(\frac{x_i - u}{\sigma}\right)^2\right]$$

In the latter case, the maximum likelihood estimator:

$$\hat{\sigma} = \sqrt{\frac{\sum_{i=1}^{N}(x_i - \hat{x})^2}{N}}$$

(where $\hat{x}$ is the average or predicted value from the model) is used for . The maximum likelihood estimator is biased by $N/(N\text{-}d_f)$ where d_f is degrees of freedom for the model. The bias may be significant for small sample sizes but d_f is usually unknown.

In practice, it is often useful to use a different emphasis factor ($_{v,i}$) for each observation so that the emphasis for specific observations or specific instances of a constraint can be increased or decreased. KLAMZ allows the user to specify observation- an instance-specific weights for most types of data and constraints.

<u>Observed and predicted catch</u>

In the AD Model Builder version, fishing mortality rates (based on the parameters Φ and ψ_t) are estimated to satisfy a NLL for observed and predicted catches:

$$L = \sum_{t=0}^{N} w_t\left(\frac{\hat{C}_t - C_t}{\kappa_t}\right)^2$$

where the standard error $\kappa_t = CV_{catch}\hat{C}_t$ with CV_{catch} and weights are w_t supplied by the user. The weights can be used, for example, if catch data in some years are less precise than in others. The AD Model Builder version of KLAMZ can potentially estimate any or every catch in the time series.

Solving the generalized catch equation

A few years of catches can be estimated in the Excel version of KLAMZ (see below) but catches are generally assumed measured without error. The Excel version does not compute a NLL for catch. Instead, F_t values are calculated iteratively using the Newton-Raphson method (Kennedy and Gentle 1980).

Subtracting predicted catch (from the generalized catch equation, see above) from the observed catch data gives:

$$g(F_t) = C_t + \frac{F_t\left(1 - e^{X_t}\right)}{X_t}B_t = 0$$

where $X_t=G_t-M_t-F_t$. If $X_t=0$, then $\overline{B}_t = B_t$ and $F_t=C_t/B_t$.

If $X_t \neq 0$, then the Newton-Raphson algorithm is used to solve for F_t. At each iteration of the algorithm, the current estimate F_t^i is updated using:

$$F_t^{i+1} = F_t^i - \frac{g\left(F_t^i\right)}{g'\left(F_t^i\right)}$$

where $g'\left(F_t^i\right)$ is the derivative F_t^i. Omitting subscripts, the derivative is:

$$g'(F) = -\frac{Be^{-F}\left[\left(e^F - e^\gamma\right)\gamma + e^\gamma F\gamma - e^\gamma F^2\right]}{X^2}$$

where $\gamma=G-M$. Iterations continue until $g\left(F_t^i\right)$ and $abs\left[g\left(F_t^{i+1}\right) - g\left(F_t^{i+1}\right)\right]$ are both ≤ 0.00001.

Initial values are important in algorithms that solve the catch equation numerically (Sims 1982). If $M_t+F_t > G_t$ so that $X_t < 0$, then the initial value F_t^0 is calculated according to Sims (1982). If $M_t+F_t < G_t$ so that $X_t > 0$, then initial values are calculated based on a generalized version of Pope's cohort analysis (Zhang and Sullivan 1988):

$$F_t^0 = \gamma_t - \ln\left[\frac{\left(B_t e^{0.5\gamma_t} - C_t\right)e^{0.5\gamma_t}}{B_t}\right]$$

Initial population age structure

In the KLAMZ model, old and new recruit biomass during the first year (R_1 and $S_1=B_1-R_1$) and biomass prior to the first year (B_0) are estimated as log scale parameters. Survival in the year prior to the first year ("year 0") is $\tau_0 = e^{-F_0-M_1}$ with F_0 chosen to obtain catch C_0 (specified as data) from the estimated biomass B_0. IGRs during year 0 and year 1 are assumed equal ($G_0=G_1$) in catch calculations.

Biomass in the second year of as series of delay-difference calculations depends on biomass (B_0) and survival (τ_0) in year 0:

$$\mathrm{B}_2 = (1+\rho)\,\tau_1\,\mathrm{B}_1 - \rho\,\tau_1\,\tau_0\,\mathrm{B}_0 + \mathrm{R}_2 - \rho\,\tau_1\,\mathrm{J}_1\,\mathrm{R}_1$$

There is, however, there is no direct linkage between B_0 and escapement biomass ($S_1=B_1-R_1$) at the beginning of the first year.

The missing link between B_0, S_1 and B_1 means that the parameter for B_0 tends to be relatively free and unconstrained by the underlying population dynamics model. In some cases, B_0 can be estimated to give good fit to survey and other data, while implying unreasonable initial age composition and surplus production levels. In other cases, B_0 estimates can be unrealistically high or low implying, for example, unreasonably high or low recruitment in the first year of the model (R_1). Problems arise because many different combinations of values for R_1, S_1 and B_0 give similar results in terms of goodness of fit. This issue is common in stock assessment models that use forward simulation calculations because initial age composition is difficult to estimate. It may be exacerbated in delay-difference models because age composition data are not used.

The KLAMZ model uses two constraints to help estimate initial population biomass and initial age structure.[6] The first constraint links IGRs for escapement (G^{Old}) in the first years to an adjacent value. The purpose of the constraint is to ensure consistency in average growth rates (and implicit age structure) during the first few years. For example, if IGRs for the first n_G years are constrained[7], then the NLL for the penalty is:

$$L_G = 0.5 \sum_{t=1}^{n_G} \left[\frac{\ln\left(G_t^{Old} \big/ G_{n_G+1}^{Old} \right)}{\sigma_G} \right]^2$$

where the standard deviation σ_G is supplied by the user. It is usually possible to use the standard deviation of Q_t^{Old} for later years from a preliminary run to estimate σ_G for the first few years. The constraint on initial IGRs should probably be "soft" and non-binding ($\lambda \approx 1$) because there is substantial natural variation in somatic growth rates due to variation in age composition.

The second constraint links B_0 to S_1 and ensures conservation of mass in population dynamics between years 0 and 1. In other words, the parameter for escapement biomass in year 1 is constrained to match an approximate projection of the biomass in year 0, accounting for growth, and natural and fishing mortality. The constraint is intended to be binding and satisfied exactly (e.g. =1000) because incompatible values of S_1 and B_0 are biologically impossible. In calculations:

$$S_1^p = B_0 e^{G_1 - F_0 - M_1}$$

where S_1^p is the projected escapement in year 1 and B_0 is the model's estimate of total biomass in year 0. The instantaneous rates for growth and natural mortality from year 1 (G_1 and M_1) are used in place of G_0 and M_0 because the latter are unavailable. The NLL for the constraint:

$$L = \left[\ln\left(\frac{S_1^p}{S_1} \right)^2 \right]^2 + \left(S_1^p - S_1 \right)^2$$

uses a log scale sum of squares and an arithmetic sum of squares. The former is effective when S_1 is small while the latter is effective when S_1 is large.

<u>Goodness of fit for survey trends</u>

The NLL used to measure goodness-of-fit for observed and predicted abundance index data with lognormal errors is:

$$L = 0.5 \sum_{j=1}^{N_v} \left[\frac{\ln\left(I_{v,j} \big/ \hat{I}_{v,j} \right)}{\sigma_{v,j}} \right]^2$$

[6] Quinn and Deriso (1999) describe another approach attributed to a manuscript by C. Walters.

[7] Normally, n_G 2.

where $I_{v,t}$ is an abundance index datum from survey v, hats "^" denote model estimates, $\sigma_{v,j}$ was a log scale standard error (see below), and N_v was the number of observations. There are two approaches to calculating standard errors for log normal abundance index data in KLAMZ and it is possible to use different approaches for different types of abundance index data in the same model (see below).

Abundance indices with statistical distributions other than log normal may be used as well, but are not currently programmed in the KLAMZ model. For example, Butler et al. (in press) used abundance indices with binomial distributions in a delay-difference model for cowcod rockfish.

Standard errors for goodness of fit

In the first approach, all observations for one type of abundance index share the same standard error, which is calculated based on overall goodness of fit. The first approach implicitly estimates the standard error based on goodness of fit, along with the rest of the parameters in the model (see "NLL kernels" above).

In the second approach, each observation has a potentially unique standard error that is calculated based on its CV. The second approach calculates log scale standard errors from arithmetic CVs supplied as data by the user (Jacobson et al. 1994):

$$\sigma_{v,t} = \sqrt{\ln\left(1 + CV_{v,t}^2\right)}$$

Arithmetic CV's are usually available for abundance data. It is sometimes convenient to use $CV_{v,t}$=1.31 to get $\sigma_{v,t}$=1.

There are advantages and disadvantages to both approaches. CV's carry information about the relative precision of abundance index observations. However, CV's usually overstate the precision of data as a measure of fish abundance.[8] Implicitly estimated standard errors are often larger and more realistic, but imply that all observations in the same survey are equally reliable.

Predicted values for abundance indices

Predicted values for abundance indices are calculated:

$$\hat{I}_{v,t} = Q_v A_{v,t}$$

where Q_v is a survey scaling parameter (constant here but see below) that converts units of biomass to units of the abundance index. $A_{v,t}$ is available biomass at the time of the survey.

In the simplest case, available biomass is:

$$A_{v,t} = s_{v,New} R_t e^{-X_t^{New} \Delta_{v,t}} + s_{v,Old} S_t e^{-X_t^{Old} \Delta_{v,t}}$$

where $s_{v,New}$ and $s_{v,Old}$ are survey selectivity parameters for new recruits (R_t) and old recruits (S_t); $X_t^{New} = G_t^{New} - F_t - M_t$ and $X_t^{Old} = G_t^{Old} - F_t - M_t$; $j_{v,t}$ was the Julian date at the time of the survey, and $\Delta_{v,t}=j_{v,t}/365$ was the fraction of the year elapsed at the time of the survey.

Survey selectivity parameter values ($s_{v,New}$ and $s_{v,Old}$) are specified by the user and must be set between zero and one. For example, a survey for new recruits would have

[8] The relationship between data and fish populations is affected by a host of factors (process errors) that are not accounted for in CV calculations.

$s_{v,New}$=1 and $s_{v,Old}$=0. A survey that measured abundance of the entire stock would have $s_{v,New}$=1 and $s_{v,Old}$=1.

Terms involving $\Delta_{v,t}$ are used to project beginning of year biomass forward to the time of the survey, making adjustments for mortality and somatic growth.[9] As described below, available biomass $A_{v,t}$ is adjusted further for nonlinear surveys, surveys with covariates and surveys with time variable $Q_{v,t}$.

Scaling parameters (Q) for log normal abundance data

Scaling parameters for surveys with lognormal statistical errors were computed using the maximum likelihood estimator:

$$Q_v = e^{\frac{\sum_{i=1}^{N_v}\left[\ln\left(\frac{I_{v,i}}{A_{v,i}}\right)\Big/\sigma^2_{v,j}\right]}{\sum_{j=1}^{N_j}\left(1\Big/\sigma^2_{v,j}\right)}}$$

where N_v was the number of observations with individual weights greater than zero. The closed form maximum likelihood estimator gives the same answer as if scaling parameters are estimated as free parameters in the assessment model assuming lognormal survey measurement errors.

Survey covariates

Survey scaling parameters may vary over time based on covariates in the KLAMZ model. The survey scaling parameter that measures the relationship between available biomass and survey data becomes time dependent:

$$\hat{I}_{v,t} = Q_{v,t} A_{v,t}$$

and

$$Q_{v,t} = Q_v e^{\sum_{r=1}^{n_v} d_{r,t}\theta_r}$$

with n_v covariates for the survey and parameters θ_r estimated in the model.

Covariates might include, for example, a dummy variable that represents changes in survey bottom trawl doors or a continuous variable like average temperature data if environmental factors affect distribution and catchability of fish schools. Dummy variables are either 0 or 1, depending on whether the effect was present in a particular year. With dummy variables, Q_v is the value of the survey scaling parameter with no intervention ($d_{r,t}$=0). For ease in modeling, it is useful to center continuous covariates around their mean:

$$d_{r,t} = d'_{r,t} - \overline{d'_r}$$

where $d'_{r,t}$ is the original covariate. With covariates that are continuous and mean-centered, Q_v is the value of the survey scaling parameter under average conditions ($d_{r,t}$=0)

[9] It may be important to project biomass forward if an absolute estimate of biomass is available (e.g. from a hydroacoustic or daily egg production survey), if fishing mortality rates or high or if the timing of the survey varies considerably from year to year.

and units for the covariate parameter are easy to interpret (for example, units for the parameter are 1/ °C if the covariate is mean centered temperature in °C).

Covariate effects and available biomass are multiplied to compute an adjusted available biomass:

$$A'_{v,t} = A_{v,t} e^{\sum_{r=1}^{n_v} d_{r,t}\theta_r}$$

The adjusted available biomass $A'_{v,t}$ is used instead of the original value $A_{v,t}$ in the closed form maximum likelihood estimator described above.

It is possible to use a survey covariate to adjust for differences in relative stock size from year to year due to changes in the timing of a survey. However, this adjustment may be made more precisely by letting the model calculate $\Delta_{v,t}$ as described above, based on the actual timing data for the survey during each year.

Nonlinear abundance indices

With nonlinear abundance indices, and following Methot (1990), the survey scaling parameter is a function of available biomass:

$$Q_{v,t} = Q_v A_{v,t}^{\Gamma}$$

so that:

$$\hat{I}_{v,t} = \left(Q_v A_{v,t}^{\Gamma}\right) A_{v,t}$$

Substituting $e^{\gamma}=\Gamma+1$ gives the equivalent expression:

$$\hat{I}_{v,t} = Q_v A_{v,t}^{e^{\gamma}}$$

where γ is a parameter estimated by the model and the survey scaling parameter is no longer time dependent. In calculations with nonlinear abundance indices, the adjusted available biomass:

$$A'_{v,t} = A_{v,t}^{e^{\gamma}}$$

is computed first and used in the closed form maximum likelihood estimator described above to calculate the survey scaling parameter. In cases where survey covariates are also applied to a nonlinear index, the adjustment for nonlinearity is carried out first.

Survey Q process errors

The AD Model Builder version of the KLAMZ model incorporates a very useful ability to let survey scaling parameters change, in a tightly controlled fashion, from year to year (NEFSC 2002):

$$Q_{v,t} = Q_v e^{\varepsilon_{v,t}}$$

where the deviations $\varepsilon_{v,t}$ are constrained to average zero. Variation in survey Q process errors is controlled by the NLL penalty:

$$L = 0.5 \sum_{j=1}^{N_v} \left[\frac{\varepsilon_{v,j}}{\sigma_v}\right]^2$$

where the log scale standard deviation σ_v is supplied by the user (e.g. see NEFSC 2002).

Recruitment models

Recruitment parameters in KLAMZ may be freely estimated or estimated around an internal recruitment model, possibly based on spawning biomass. An internally estimated recruitment model may be used to reduce variability in recruitment estimates (often necessary if data are limited), to summarize stock-recruit relationships, or to make use of information about recruitment in similar stocks. There are four types of internally estimated recruitment models in KLAMZ: 1) random variation around a constant mean; 2) random walk around a constant mean (autocorrelated variation); 3) random variation around a Beverton-Holt recruitment model; and 4) random variation around a Ricker recruitment model.

The first step in recruit modeling is to calculate the expected log recruitment level $E[ln(R_t)]$ given the recruitment model. For random variation around a constant mean, the expected log recruitment level is the log geometric mean recruitment:

$$E[\ln(R_t)] = \sum_{j=1}^{N} \ln(R_j) \Big/ N$$

For a random walk around a constant mean recruitment, the expected log recruitment level is the logarithm of recruitment during the previous year:

$$E[\ln(R_t)] = \ln(R_{t-1})$$

with no constraint on recruitment during the first year R_1.

For the Beverton-Holt recruitment model, the expected log recruitment level is:

$$E[\ln(R_t)] = \ln\left[e^a T_{t-\ell} \big/ \left(e^b + T_{t-\ell}\right)\right]$$

where $a=e^{\alpha}$ and $b=e^{\beta}$, the parameters and are estimated in the model, T_t is spawning biomass, and is the lag between spawning and recruitment. Spawner-recruit parameters are estimated as log transformed values (e^{α} and e^{β}) to enhance model stability and ensure the correct sign of values used in calculations. Spawning biomass is:

$$T_t = m_{new} R_t + m_{old} S_t$$

where m_{new} and m_{old} are maturity parameters for new and old recruits specified by the user. For the Ricker recruitment model, the expected log recruitment level is:

$$E[\ln(R_t)] = \ln\left(S_{t-\ell} e^{a - bS_{t-\ell}}\right)$$

where $a=e^{\alpha}$ and $b=e^{\beta}$, and the parameters and are estimated in the model.

Given the expected log recruitment level, log scale residuals for the recruitment model are calculated:

$$r_t = \ln(R_t) - E[\ln(R_t)]$$

Assuming that residuals are log normal, the NLL for recruitment residuals is:

$$L = \sum_{t=t_{first}}^{N} \lambda_t \left[\ln(\sigma_r) + 0.5 \left(r_t \big/ \sigma_r \right)^2 \right]$$

where λ_t is an instance-specific weight usually set equal one. The additional term in the NLL [$ln(\sigma_r)$] is necessary because the variance σ_r^2 is estimated internally, rather than specified by the user.

The log scale variance for residuals is calculated using the maximum likelihood estimator:

$$\sigma_r^2 = \frac{\sum_{j=t_{first}}^{N} r_j}{N}$$

where N is the number of residuals. For the recruitment model with constant variation around a mean value, t_{first}=1. For the random walk recruitment model, t_{first}=2. For the Beverton-Holt and Ricker models, t_{first}= +1 and the recruit model imposes no constraint on variability of recruitment during years 1 to (see below). The biased maximum likelihood estimate for σ^2 (with N in the divisor instead of the degrees of freedom) is used because actual degrees of freedom are unknown. The variance term is calculated explicitly because it is used in other calculations.

Constraining the first few recruitments

It may be useful to constrain the first years of recruitments when using either the Beverton-Holt or Ricker models if the unconstrained estimates for early years are erratic. In the KLAMZ model, this constraint is calculated:

$$NLL = \sum_{t=1}^{t_{first}-1} \lambda_t \left\{ \ln(\sigma_r + 0.5 \left[\frac{\ln\left(R_t / E\left(R_{t_{first}}\right)\right)}{\sigma_r} \right]^2 \right\}$$

where t_{first} is the first year for which expected recruitment $E(R_l)$ can be calculated with the spawner-recruit model. In effect, recruitments that not included in spawner-recruit calculations are constrained towards the first spawner-recruit prediction. The standard deviation and weights used are the same as used in calculating the NLL for the recruitment model.

Prior information about abundance index scaling parameters (Q)

A constraint on one or more survey scaling parameters (Q_v) may be useful if prior information about potential values is available (e.g. NEFSC 2000; NEFSC 2001; NEFSC 2002). In the Excel version, it is easy to program these (and other) constraints in an *ad-hoc* fashion as they are needed. In the AD Model Builder version, log normal and beta distributions may be used as prior information in estimating Q_v for any abundance index

The user must specify which surveys have prior distributions, minimum and maximum legal bounds (q_{min} and q_{max}), the arithmetic mean $(\overline{q})$ and the arithmetic CV for the prior the distribution. Goodness of fit for Q_v values outside the bounds (q_{min}, q_{max}) are calculated:

$$L = \begin{vmatrix} 10000\left(Q_v - q_{\max}\right)^2 \ if \ Q_v \geq q_{\max} \\ 10000\left(q_{\min} - Q_v\right)^2 \ if \ Q_v \leq q_{\min} \end{vmatrix}$$

Goodness of fit for Q_v values inside the legal bounds depend on whether the distribution of potential values is log normal or follows a beta distribution.

Lognormal case

Goodness of fit for lognormal Q_v values within legal bounds is:

$$L = \left[\frac{\ln(Q_v) - \tau}{\varphi} \right]^2$$

where the log scale standard deviation $\varphi = \sqrt{\ln(1 + CV)}$ and $\tau = \ln(\overline{q}) - \frac{\varphi^2}{2}$ is the mean of the corresponding log normal distribution.

Beta distribution case

The first step in calculation goodness of fit for Q_v values with beta distributions was to calculate the mean and variance of the corresponding "standardized" beta distribution:

$$\overline{q}' = \frac{\overline{q} - q_{\min}}{D}$$

and

$$Var(q') = \left(\frac{\overline{q}\ CV}{D} \right)^2$$

where the range of the standardized beta distribution is $D=q_{max}-q_{min}$. Equating the mean and variance to the estimators for the mean and variance for the standardized beta distribution (the "method of moments") gives the simultaneous equations:

$$\overline{q}' = \frac{a}{a + b}$$

and

$$Var(q') = \frac{ab}{(a + b)^2 (a + b + 1)}$$

where a and b are parameters of the standardized beta distribution.[10] Solving the simultaneous equations gives:

$$b = \frac{(\overline{q}' - 1)\left[Var(q') + (\overline{q}' - 1)\overline{q}'\right]}{Var(q')}$$

and:

$$a = \frac{b\overline{q}'}{1 - \overline{q}'}$$

Goodness of fit for beta Q_v values within legal bounds was calculated with the NLL:

$$L = (a - 1)\ln(Q'_v) + (b - 1)\ln(1 - Q'_v)$$

where $Q'_v = Q_v / (Q_v - q_{\min})$ is the standardized value of the survey scaling parameter Q_v.

Surplus production modeling

Surplus production models can be fit internally to biomass and surplus production estimates in the model (Jacobson et al. 2002). Models fit internally can be used to

---

[10] If x has a standardized beta distribution with parameters a and b, then the probability of x is

$$P(x) = \frac{x^{a-1}(1 - x)^{b-1}}{\Gamma(a,b)}.$$

constrain estimates of biomass and recruitment, to summarize model estimates in terms of surplus production parameters, or as a source of information in tuning the model. The NLL for goodness of fit assumes normally distributed process errors in the surplus production process:

$$L = 0.5 \sum_{j=1}^{N_P} \left(\frac{\tilde{P}_j - P_j}{\sigma} \right)^2$$

where N_p was the number of surplus production estimates (number of years less one), $\tilde{P}_t$ was a predicted value from the surplus production curve, P_t was the assessment model estimate, and the standard deviation σ was supplied by the user based, for example, on preliminary variances for surplus production estimates.[11] Either the symmetrical Schaefer (1957) or asymmetric Fox (1970) surplus production curve may be used to calculate $\tilde{P}_t$ (Quinn and Deriso 1999).

It may be important to use a surplus production curve that is compatible with assumptions about the underlying spawner-recruit relationship. More research is required, but the asymmetric shape of the Fox surplus production curve appears reasonably compatible with the assumption that recruitment follows a Beverton-Holt spawner-recruit curve (Mohn and Black 1998). In contrast, the symmetric Schaefer surplus production model appears reasonably compatible with the assumption that recruitment follows a Ricker spawner-recruit curve.

The Schaefer model has two log transformed parameters that are estimated in KLAMZ:

$$\tilde{P}_t = e^{\alpha} B_t - e^{\beta} B_t^2$$

The Fox model also has two log transformed parameters:

$$\tilde{P}_t = -e\left(e^{e^{\alpha}}\right) \frac{B_t}{e^{\beta}} \log\left(\frac{B_t}{e^{\beta}}\right)$$

See Quinn and Deriso (1999) for formulas used to calculate reference points (F_{MSY}, B_{MSY}, MSY, and K) for both surplus production models.

Catch/biomass

Forward simulation models like KLAMZ may estimate absurdly high fishing mortality rates. The likelihood constrain used to prevent this potential problem was calculated:

$$L = 0.5 \sum_{t=0}^{N} d_t^2$$

where:

[11] Variances in NLL for surplus production-biomass models are a subject of ongoing research. The advantage in assuming normal errors is that negative production values (which occur in many stocks, e.g. Jacobson et al. 2001) are accommodated. In addition, production models can be fit easily by linear regression of P_t on B_t and B_t^2 with no intercept term. However, variance of production estimate residuals increases with predicted surplus production. Therefore, the current approach to fitting production curves in KLAMZ is not completely satisfactory.

$$d_t = \begin{vmatrix} (C_t/B - \kappa)\, if\ \ C_t/B > \kappa \\ 0\ otherwise \end{vmatrix}$$

with the threshold value κ normally set by the user to about 0.95. Values for κ can be linked to maximum F values using the modified catch equation described above. For example, to use a maximum fishing mortality rate of about F 4 with M=0.2 and G=0.1 (maximum X=4+0.2-0.1=4.1), set κ $F/X(1-e^{-X})$=4 / 4.1 (1-e^{-4})=0.96.

Uncertainty

The AD Model Builder version of the KLAMZ model automatically calculates variances for parameters and quantities of interest (e.g. R_t, F_t, B_t, F_{MSY}, B_{MSY}, $\overline{F}_{\mathrm{Re}cent}$, $\overline{B}_{\mathrm{Re}cent}$, $\overline{F}_{\mathrm{Re}cent}/F_{MSY}$, $\overline{B}_{\mathrm{Re}cent}/B_{MSY}$, etc.) by the delta method using exact derivatives. If the objective function is the log of a proper posterior distribution, then Markov Chain Monte Carlo (MCMC) techniques implemented in AD Model Builder libraries can be used estimate posterior distributions representing uncertainty in the same parameters and quantities.

Bootstrapping

A FORTRAN program called BootADM can be used to bootstrap survey data in the KLAMZ model. BootADM extracts the standardized residuals:

$$r_{v,j} = \frac{\ln\left(I_{v,j} \Big/ \hat{I}_{v,j} \right)}{\sigma_{v,j}}$$

log scale standard deviations ($_{v,j}$, originally from survey CV's or estimated from goodness of fit), and predicted values $\left(\hat{I}_{v,j}\right)$ for all active survey observations in a "base case" KLAMZ model run. The standardized residuals are resampled from a single pool with replacement to form new sets of bootstrapped survey "data":

$$^{x}I_{v,j} = \hat{I}_{v,j} e^{r\sigma_{v,j}}$$

where r is a resampled residual. BootADM builds new KLAMZ data files and runs the KLAMZ model repetitively, collecting the bootstrapped parameter and other estimates at each iteration and writing them to a comma separated text file that can be processed in Excel to calculate bootstrap variances, confidence intervals, bias estimates, etc. for all parameters and quantities of interest (Efron 1982).

Projections

Stochastic projections can be carried out using another FORTRAN program called SPROJDDF based on bootstrap output from BootADM. Basically, bootstrap estimates of biomass, recruitment, spawning biomass, natural and fishing mortality during the terminal years are used with recruit model parameters from each bootstrap run to start and carry out projections.[12] Given a user-specified level of catch or fishing mortality, the delay-difference equation is used to project stock status for a user-specified number of years. Recruitment during each projected year is based on simulated spawning biomass, log normal random numbers, and spawner-recruit parameters (including the residual variance) estimated in the bootstrap run. This approach is similar to carrying out projections based on parameters and state variables sampled from a posterior distribution for the basecase model fit. It differs from most current approaches because the spawner-recruit parameters vary from projection to projection.

References

Butler, J.L., L.D. Jacobson, J.T. Barnes, and H.G. Moser. 2003. Biology and population dynamics of cowcod (Sebastes levis) in the southern California Bight. Fish. Bull. 101: 260-280.

Chapman, D.W. 1971. Production. In: W.E. Ricker (ed.). Methods for assessment of fish production in fresh waters. IBP Handbook No. 3. Blackwell Scientific Publications, Oxford, UK.

Conser, R.J. 1995. A modified DeLury modeling framework for data limited assessment: bridging the gap between surplus production models and age-structured models. A working paper for the ICES Working Group on Methods of Fish Stock Assessment. Copenhagen, Denmark. Feb. 1995.

Deriso, R, B. 1980. Harvesting strategies and parameter estimation for an age-structured model. Can. J. Fish. Aquat. Sci., 37: 268-282.

Efron, B. 1982. The jackknife, the bootstrap and other resampling plans. Society for Industrial and Applied Mathematics, Philadelphia, PA, 92 p.

Fournier, D., and C.P. Archibald. 1982. General theory for analyzing catch at age data. Can. J. Fish. Aquat. Sci. 39: 1195-1207.

Fox, W. W. R. Jr. 1970. An exponential yield model for optimizing exploited fish populations. Trans. Am. Fish. Soc. 99: 80-88.

Jacobson, L.D., N.C.H. Lo, and J.T. Barnes. 1994. A biomass based assessment model for northern anchovy *Engraulis mordax*. Fish. Bull. U.S. 92: 711-724.

Jacobson, L.D., J.A.A. De Oliveira, M. Barange, M.A. Cisneros-Mata, R. Felix-Uraga, J.R. Hunter, J.Y. Kim, Y. Matsuura, M. Niquen, C. Porteiro, B. Rothschild, R.P. Sanchez, R. Serra, A. Uriarte, and T. Wada. 2001. Surplus production, variability and climate change in the great sardine and anchovy fisheries. Can. J. Fish. Aquat. Sci. 58: 1891-1903.

Jacobson, L.D., S.X. Cadrin, and J.R. Weinberg. 2002. Tools for estimating surplus production and F_{MSY} in any stock assessment model. N. Am. J. Fish. Mgmt. 22:326–338

Kennedy, W.J. Jr., and J.E. Gentle. 1980. Statistical computing. Marcel Dekker, Inc., New York.

Methot, R.D. 1990. Synthesis model: an adaptable framework for analysis of diverse stock assessment data. Int. N. Pac. Fish. Comm. Bull. 50: 259-277.

[12] At present, only Beverton-Holt recruitment calculations are available in SPROJDDF.

Mohn, R., and G. Black. 1998. Illustrations of the precautionary approach using 4TVW haddock, 4VsW cod and 3LNO plaice. Northwest Atlantic Fisheries Organization NAFO SCR Doc. 98/10.

NEFSC. 2000. Ocean quahog, p. 172-304. *In:* Report of the 31st Northeast Regional Stock Assessment Workshop (31st SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. Northeast Fish. Sci. Cent. Ref. Doc. 00-15.

NEFSC. 2001. Sea scallops. In: Report of the 32st Northeast Regional Stock Assessment Workshop (32st SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. Northeast Fish. Sci. Cent. Ref. Doc. 01-18.

NEFSC. 2002. Longfin squid. *In*: Report of the 34th Northeast Regional Stock Assessment Workshop (34th SAW): Stock Assessment Review Committee (SARC) consensus summary of assessments. Northeast Fish. Sci. Cent. Ref. Doc. 02-07.

Prager, M.H. 1994. A suite of extensions to a nonequilibrium surplus-production model. Fish. Bull. 92: 374-389.

Quinn II, T.J., and R.B. Deriso. 1999. Quantitative fish dynamics. Oxford University Press, NY.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bull. Fish. Res. Bd. Can. No. 191. 382p.

Schaefer, M.B. 1957. A study of the dynamics of the fishery for yellowfin tuna in the eastern tropical Pacific Ocean. Inter-Am. Trop. Tuna Comm. Bull. 2: 245-285.

Schnute, J. 1985. A general theory for analysis of catch and effort data. Can. J. Fish. Aquat. Sci. 42: 414-429.

Sims, S.E. 1982. Algorithms for solving the catch equation forward and backward in time. Can. J. Fish. Aquat. Sci. 39: 197-202.

Zhang, C. I., and P. J. Sullivan. 1988. Biomass-based cohort analysis that incorporates growth. Trans. Am. Fish. Soc. 117: 180-189.

Appendix B.
(of "C. Atlantic Surfclam" SARC-37 Report):

A Review of Invertebrate Subcommittee meeting, 14-16 April 2003 – *Spisula solidissima*
By Dr. Mike Bell, Lowestoft, UK

The purpose of the meeting was to review the information and methods available for the SARC 37 surfclam stock assessment. This document describes my views, as an outside observer, of the effectiveness of the stock assessment process, in terms of both procedure (representation, meeting process) and scientific quality (biological and fisheries data, analytical approach).

The procedural aspects of the meeting could not be faulted. The agenda was clear and comprehensive, and sufficient relevant information was presented on each agenda item to allow in depth discussion of the scientific and technical issues. The presence of surfclam fishing industry representatives was a huge benefit for the meeting, particularly when it came to discussing technical issues of dredge and vessel performance. Wide industry participation at such meetings should certainly be encouraged in the future.

The science presented at the meeting was also of a very high standard. There were two principal themes for the discussions. Firstly, the meeting focused on the annual research surveys of surfclams, particularly the technical aspects of converting survey catch rates to biomass density estimates in the light of information on dredge performance and efficiency. Secondly, the meeting considered how this survey information can be used together with data on fishery removals to estimate historical trends and current status of both stock and fishery.

Discussions on the research surveys concentrated firstly on how best to use dredge sensor data (principally inclinometer and pump flow measurements) to judge when the survey dredge was fishing effectively. This is important for determining the effective area from which a survey catch is taken. Rigorous, in depth discussions resulted in a agreed criteria for determining the start and finish positions of a survey tow, with dredge performance between these positions considered to be a component of dredge efficiency. Information on survey and commercial dredge efficiency was drawn from a number of experiments and analyses. These included use of the new patch depletion model – an innovative and sophisticated approach for making best use of the available information. Some uncertainty about survey dredge efficiency remains, since estimates differ somewhat between the sources. However, discussions at the meeting led to the placing of effective bounds on the range of possible variation through comparison of the performance of research and commercial vessels. An important outcome of this meeting will be that the swept area biomass estimates for surfclams are as scientifically rigorous and defensible as is possible given the current survey data.

The research survey data are used to 'tune' the analytical assessment model. This is the 'KLAMZ' delay-difference model, a sophisticated forward simulation approach using fishery and survey data together with information on growth. The (provisional) outcome of the model shows a similar current surfclam stock status to the previous assessment (SARC 30), but a very different view of historical stock trends. This outcome is encouraging in the sense that recent biomass estimates appear to be robust to model assumptions. The updated view of historical trends is certainly plausible given the survey data, and probably the is best that is possible given the current state of understanding. However, some problems with the model were identified, such as the difficulty in modelling the fishing down of the older age groups and the sensitivity to assumptions about recruitment. Taken together, these difficulties indicate that there is still much uncertainty about historical stock trends. Critically, the assessment also needs to reconcile the marked difference between modelled and observed trends in recent LPUE.

The suggested way forward for analytical assessment is to use explicitly age-based models. Besides moving away from some of the difficulties in defining growth within the 'KLAMZ' model, an age-based approach would be more transparent to all stakeholders in the assessments. Age in surfclams is readily determined and the introduction of routine age determination for fishery catch samples (as opposed to inferring age from size) would further facilitate the use of explicit age-based assessments in future. It will also be important to consider spatial patterns in both population processes and exploitation. Spatial patterns are important because fishery trends may be influenced by the targeting of high catch rate areas within a sedentary stock, and because locally acting and density-dependent factors may be very significant for bivalve population dynamics. Consideration of spatial factors (and gear width) in analyses of commercial CPUE will be helpful in this context. Interpretation of survey and fishery data also needs to take place in relation to what is considered 'normal' population behaviour. For example, are zero catches in recent research surveys in the inshore and southern stock areas a cause for concern? Or, are they merely a consequence of the temporal and spatial dynamics of recruitment in surfclams? The time series of age-composition and abundance data from the research surveys represents a substantial resource for investigating the temporal and spatial scales at which year class strength varies. It may be crucial to determine the influence of environmental factors on this variation – are recent temperature trends likely to change the long-term geographic range of successful reproduction in surfclams?

In summary, the assessment process witnessed at this meeting was of very high quality. The meeting was conducted in a spirit of rigorous science with free and frank discussion of its limitations. The assessment results represent the best current scientific understanding of the status of surfclam stocks. Some areas for future progress were nevertheless identified, indicating a continuing positive trend in the state of surfclam assessment science.

Mike Bell

14 May 2003