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. Fishery performance.

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. <u>NEFSC clam survey and dredge efficiency.</u>

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. <u>Stock biomass and fishing mortality.</u>

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.

<u>Landings</u>

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.

<u>Surfclam mortality caused by clam dredges</u>
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.

<u>Efficiency of the Clam Dredge on the R/V *Delaware II*</u>
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.

<u>Annual Fishing Mortality Rates (F) based on Catch and ESB</u>
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}.

<u>Uncertainty in ESB and catch-ESB ratios</u>
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 $1 \le$ HAUL $\le$ 3 and $1 \le$ 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).

<u>Somatic growth in modeling</u>

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.

Recruitment modeling in KLAMZ

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.

<u>DMV (KLAMZ model results)</u>

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 σ_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

<u>SNJ, LI, SNE, GBK and SVA regions (KLAMZ model)</u>

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 $\rho = \ln\left[\left(B_t + P_t\right)/B_t\right] = \ln\left[\left(1136 - 57\right)/1136\right] = -0.051\ \mathrm{y}^{-1}$ (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.

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