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ASSESSMENT AND STATUS OF SURF CLAM *SPISULA SOLIDISSIMA* (DILLWYN) POPULATIONS IN OFFSHORE MIDDLE ATLANTIC WATERS OF THE UNITED STATES

by

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Introduction

The USA commercial fishery for surf clams, *Spisula solidissima* (Dillwyn), in the Northwest Atlantic Fishery Conservation Zone (FCZ: 3-200 n. mi) has been managed by a Fishery Management Plan for the Atlantic Surf Clam and Ocean Quahog Fisheries (FMP) implemented on 17 November 1977 and subsequently amended effective 1 October 1979 and 1 January 1980. During 1979, the fishery was regulated by annual and quarterly landings quotas, weekly effort restrictions on allowable fishing hours per vessel, a moratorium on new vessel entry, and closed fishing areas containing small surf clams. Licensing and reporting requirements were also mandatory for both surf clam dealers and vessel owner/operators.

This report provides an updated assessment of the status of the Mid-Atlantic surf clam populations within the FCZ. Included are reported commercial landings statistics through 1979; commercial catch composition data, 1976-1979; commercial catch per effort indices, 1978-1979; and research vessel relative abundance and recruitment indices, May 1965-Jan 1980. New information is presented on surf clam growth rates, shell length-meat weight relationships, and yield per recruit analyses. Trends in the commercial fishery are discussed and related to the population dynamics of the offshore (FCZ) Mid-Atlantic surf clam resources.

Data and analyses herein reported both update and expand previous assessment reports (Brown et al. 1977; Serchuk et al. 1979; Murawksi and Serchuk 1979). Background life history aspects of the surf clam are detailed in Ropes (1980) and Murawski and Serchuk (1980).

The present paper does not include research survey data derived from the August 1980 Mid-Atlantic shellfish resource assessment survey. These data are currently being analyzed and will be imparted in a subsequent report.

Commercial Fishery

Reported Landings Statistics

Provisional 1979 Mid-Atlantic FCZ landings of surf clams totaled 29.1 million pounds, a 7% decrease from the 1978 reported catch of 31.4 million pounds (Table 1). In both 1978 and 1979, total annual landings were regulated by quotas of 1.8 million bushels (~30 million pounds, meat weight), and hence the landings data reflect these constraints. FCZ landings accounted for 83.3% of the total 1979 USA commercial catch of surf clams, approximately the same proportional representation as observed during 1976-1978.

The 1979 offshore landings were the lowest since 1970, just prior to the increased exploitation of the offshore Virginia resource. However, the importance of the offshore fishery relative to the total USA surf clam harvest is currently greater than it was during 1965-1970, when the offshore landings averaged 48.0% of the total domestic catch. This is largely due to reduced catches in many of the inshore New Jersey fisheries ($\leq$3 miles). Inshore landings in 1979 were 5.8 million pounds, the second lowest level recorded in the 15-year period, 1965-1979.

Distribution of Landings by Area, Vessel Class, and Calendar Quarter

Catch and effort statistics for 1978 and 1979 were derived from commercial vessel logbook records containing individual trip data on catch (bushels), hours fished, catch location, and date of catch. A total of 3,456 trip records

in 1978 and 4,449 records in 1979 possessed sufficient catch and effort information by area to be amenable for analysis (Tables 2 and 3). Individual vessel trip records were assigned to principal offshore fishery areas (Northern New Jersey, Southern New Jersey, or Delmarva) within vessel tonnage categories (1-50 GRT, 51-100 GRT, or >100 GRT). Individual entries were further classified by calendar quarter.

Spatial distribution of landings and effort were similar in 1978 and 1979. The bulk of the landings were taken from Delmarva (92.0% in 1978; 90.7% in 1979), with Southern New Jersey and Northern New Jersey accounting for approximately 6% and 2%, respectively, of the total annual FCZ landings in both years (Table 4). Effort, expressed either as hours fished or number of trips, paralleled the areal pattern of catch; about 89% of the total offshore effort was expended in Delmarva, 8-8.5% in Southern New Jersey, and 2.5-3% in Northern New Jersey.

Tonnage Class 3 vessels (>100 GRT) accounted for 70% of the Mid-Atlantic offshore landings in 1978 and 74% of the harvest in 1979. Total landings by Class 2 vessels (50-100 GRT) in 1978 and 1979 comprised 26% and 23%, respectively, of the annual offshore fishery yields, while Class 1 vessels (1-50 GRT) produced 4% of the total FCZ catch during both years. Within each of the offshore fishing areas, the relative distribution of landings among vessel classes was nearly identical between 1978 and 1979 (Figure 1). Vessel class catch percentages for the Northern and Southern New Jersey fisheries were similar during 1978-1979 (Class 1: ~8%; Class 2: ~33%; Class 3: ~59%), although 1978 Northern New Jersey data (Figure 1) slightly overestimate the relative importance of the Class 2 and 3 vessels since no

Class 1 logbook records were sufficient for analysis.

In Delmarva, Class 3 vessels took more than 70% of the catch in 1978 and 1979, and thus accounted for a larger percentage of the landings than did Class 3 catches in the offshore New Jersey fisheries. Contrariwise, Class 1 and 2 catches were proportionally less significant in Delmarva than in the two more northerly areas.

The seasonal (quarterly) distribution of catch and effort was generally similar, within all fishing areas, during both years (Table 5). In 1978, 67% of the total FCZ catch and effort (hours fished) occurred between April through September (Quarters 2 and 3), while in 1979, 59% of the offshore catch and effort was accounted for in these months. These data reflect the quarterly quota limitations in effect during the two years; 61.2% of the total allowable annual catch (1.8 million bushels) was allotted to the spring and summer quarters. In both years, quarterly quotas were variously exceeded or significantly underattained resulting in changes in quotas during the year and modifications in the permissable weekly fishing effort per vessel. Fishing effort regulations were altered six times in 1978 and on four occasions in 1979. Two fishery closures occurred in 1978: one for three weeks in March, and the other for 10 days in December. Resultingly, any internal seasonal trends in fishery performance are difficult to discern due to confoundments imposed by the regulatory system.

Commercial Abundance Indices

Commercial abundance indices (bushels landed per hour fished) for each vessel class, by area, and calendar quarter, during 1978 and 1979 are presented

in Table 6. The mean catch per hour for each category was derived from logbook records by dividing the total catch by total effort reported from all trips in each category. This procedure is different from that used by Murawski and Serchuk (1979) in which mean catch per hour was computed by averaging the individual trip catch/effort values from all trips within each vessel class/area/calendar quarter category. Both procedures, however, produced nearly identical indices. Results from each fishery area are discussed separately below.

Northern New Jersey

A total of 102 trips in 1978 and 129 trips in 1979 were used in the catch/effort calculations. In both years, no meaningful differences or trends were detected in quarterly catch per effort values within vessel classes implying that yearly mean indices can be considered representative of vessel class performance. The overall 1978 mean catch per hour values for Class 2 and 3 vessels (no data were available for Class 1 vessels) was 15.8 and 22.0, respectively. In 1979, the yearly mean catch rates for vessel classes 1-3 were 30.9, 24.1, and 34.3, respectively (Table 6). Catch rates in 1979 were accordingly 53% higher for Class 2 vessels, and 56% higher for Class 3 vessels than in 1978. The relatively high 1979 Class 1 index seems to be anomalous in relation to the other two vessel class rates in 1979 (i.e., higher than Class 2 and nearly equal to Class 3), and inconsistent with the trend observed in all areas in 1978 for Class 1 vessels to exhibit the lowest annual catch rate of any of the tonnage classes. This disparity may be a consequence of the low number of trips used in the Class 1 calculations (11), or may reflect localized fishing

operations in areas of high clam abundance not regularly fished by Class 2 and 3 vessels.

Southern New Jersey

Catch per effort values were derived from 292 trip records in 1978 and 398 records in 1979. Quarterly catch rates for each vessel class in 1979 were generally more variable than in 1978; Class 1 quarterly indices in 1979 ranged between 10.2 and 31.6 bushels per hour (vs 11.0-16.1 in 1978), Class 2 indices varied betwee 14.5 and 20.3 bushels per hour (vs 15.0-21.7 in 1978), and Class 3 values ranged between 18.7 and 38.4 bushels per hour (vs 18.7-28.4 in 1978). Mean 1979 catch rates for the three vessel classes (1-3) were 23.2, 16.9, and 25.7, respectively (Table 6). Corresponding 1978 indices were 12.5, 18.1, and 23.0. Hence, between years, the Class 1 catch rate increased 86%, the Class 2 index decreased by 7%, and the Class 3 value increased by 12%.

As in Northern New Jersey, the 1979 Class 1 mean catch rate in Southern New Jersey was intermediate between the 1979 Class 2 and Class 3 indices. This contrasts with the pattern of increasing catch rates with vessel size noted in 1978. The similarity of vessel class rankings in both Northern and Southern New Jersey in 1979 suggests that Class 1 vessels were, in fact, more efficient than Class 2 vessels in the New Jersey fishery.

Unlike 1978, each of the Southern New Jersey vessel class indices in 1979 were lower than corresponding vessel class catch rates from Northern New Jersey. Generally, the 1979 values were between 25-30% less than the Northern New Jersey values. Since almost all of the 1979 Southern and Northern New Jersey catch rates (apart from Class 2 in Southern New Jersey) were higher than those in 1978, the commercial data imply that the Northern New Jersey surf clam

resource became relatively more abundant in 1979 than did the Southern New Jersey populations. If commercial catch effort is assumed proportional to mean stock size, then

the differential vessel class indices between 1978 and 1979 in Northern and Southern New Jersey suggest that recruitment has recently been much more successful in the Northern than in the Southern New Jersey populations.

Delmarva

Commercial abundance indices were calculated from 3,062 vessel trips in 1978 and 3,922 trips in 1979. Average vessel class catch rates in 1978 were 16.1 (Class 1), 20.1 (Class 2), and 28.8 bushels per hour (Class 3). Corresponding 1979 vessel class indices, 16.0, 19.5, and 32.8, respectively, were virtually identical to the 1978 values (Table 6). Quarterly catch rates, within each vessel category, exhibited little fluctuation in either year. In 1978, none of the quarterly rates in any class varied by more than 3.5 bushels per hour; in 1979, quarterly rates within vessel classes never differed by more than 8.1 bushels per hour, with most values varying by less than 2 bushels per hour.

In both years, mean yearly catch rates increased with vessel size. As previously noted, this pattern was not observed in either of the 1979 New Jersey fisheries.

In 1978, the average catch rates for all vessel classes in Delmarva were higher than corresponding tonnage class values in both of the New Jersey offshore areas. In 1979, however, all of the annual Delmarva indices were lower than the comparable Northern New Jersey values (Table 6). Since the 1979 overall vessel class indices in Delmarva were about equal to those in 1978, the 1979

results suggest that the abundance of commercial sized clams in Delmarva has not significantly changed during the past year. Hence, the lowered ranking of the 1979 Delmarva catch rates relative to Northern New Jersey values implies a marked increase in clam abundance in the latter region rather than a population decline in Delmarva.

Commercial Catch Composition

Shell length-frequency distributions of commercial surf clam landings from the three principal Mid-Atlantic offshore fishery areas (Northern New Jersey, Southern New Jersey, and Delmarva) were derived from dock-side catch samples from individual trips. For each area, the size composition of the landings was calculated by weighting the length-frequency distribution from each trip by the total trip catch (in bushels), and then summing over all sampled trips during the year.

The size distributions of landings from all of the offshore areas during 1976-1979 were quite similar (Figure 2). Modal shell lengths occurred at 16-17 cm; mean lengths ranged between 15.5-17.3 cm. Clams larger than 20 cm or smaller than 12 cm were seldom present in the sampled catch. The rarity of clams smaller than 12 cm in the commercial landings implies fishery size-selection since research vessel survey size-frequency distributions for 1976-1980 revealed that significant segments of the offshore Mid-Atlantic population were often less than 12 cm (Figure 3). Hence, commercial culling practices or concentration of commercial effort in areas of large-sized clams must regularly occur.

The Delmarva commercial size frequency distributions during 1978-1979 indicate that clams less than 12 cm have recently become more common in the landings from this region. Clams 12 cm or smaller comprised 2% of the Delmarva catch in 1978 and 7% in 1979; prior to 1978, less than 1% of the annual catch was comprised by these smaller individuals. This may reflect a recent change to a lower cull size and/or the appearance of a recruiting year-class in the population. This latter explanation seems plausible upon examination of the 1980 Delmarva research survey size-frequency distribution (Figure 3). A pronounced size mode at 6.5-8.5 cm is evident.

Research Vessel Survey Catches

Research vessel shellfish assessment surveys in offshore Mid-Atlantic waters have been conducted since 1965 (Table 7). In each survey, standard tows of four or five minute duration were performed at pre-selected sampling locations with an hydraulic dredge. Since dredge knife width and time of tow varied among surveys, all individual station catch data have been standardized to a 1.2 cm (48-inch) dredge towed for 4 minutes.

Since 1978, a stratified random sampling design has been used in the shellfish surveys with the survey area stratified into geographical zones based on water depth and latitude (Murawski and Serchuk 1979: Figure 1). Sampling stations were allotted to strata in general proportion to the area of each stratum; within strata, stations were randomly assigned to specific locations. Survey data from 1965-1977, obtained using a grid-type sampling design, were post-stratified before analysis into the sampling strata used in the most recent surveys.

Survey strata were grouped into three sets corresponding to the geographical boundaries of the principal offshore surf clam fishery areas (i.e., Northern New Jersey, Southern New Jersey, and Delmarva) to facilitate comparisons with the commercial fishery data. For each strata set, relative abundance indices were calculated in terms of stratified mean number and mean weight per tow. Length frequency data and shell length-meat weight relationships were used to derive catch per tow indices for pre-recruit sized clams (<12 cm, shell length), commercial-sized clams (≥12 cm, shell length), and total clams caught.

Survey Indices of Relative Abundance

Stratified mean catch per tow indices, 1965-1980, are presented for each of the offshore surf clam fishery areas in Tables 8 and 9. Trends in survey abundance in each area are separately discussed.

Northern New Jersey

Between 1965 and 1978 (Jan), total catch per tow indices (numbers and weight) in Northern New Jersey declined by more than 95% (Tables 8 and 9). Almost all of this decline was due to reduction in commercial-sized clams (Figure 4A); the commercial-size abundance indices declined from a mean value of 20.2 clams per tow during 1965-1969 to 0.5 clams per tow in December 1978. Similarly, the weight per tow of commercial-size clams declined by nearly 98% during this period (Table 9). A virtual absence of recruitment success is implied by the relatively low pre-recruit indices between May 1965 to Jan 1978 (3.54 to 0.85).

In December 1978, the pre-recruit index increased to 27.8, the highest value observed in the time-series, resulting in sharp increases in both the total number and weight per tow values (Figures 4A and 5). Potentially strong recruitment of the 1976 year-class is indicated by the December 1978 survey size frequency distribution (Figure 3); the modal peak at 6.5-7.5 cm corresponds to the size range for age 2 clams (1976 year class). Age analysis of these clams have subsequently corroborated this inference (see Growth section).

The January 1980 total and pre-recruit number per tow indices (20.31 and 15.95, respectively) continued to reflect the dominance of the 1976 year-class in the Northern New Jersey resource. The pre-recruit index was the second highest ever, and the total number per tow index was within the range of relatively high values noted in the late 1960's (Table 8; Figure 4A). Both of the 1980 commercial-sized relative abundance indices (number and weight) were the highest since 1976, and were 4.5 and 3.6 fold greater, respectively, than the 1978 (Dec) values. Total biomass (meat weight) per tow in 1980 resultingly increased to 1.25 kg (Figure 5), the highest level in four years (Table 9).

Southern New Jersey

Total number and weight per tow indices in Southern New Jersey declined during 1965-1970, increased in 1974, and subsequently declined again in 1976 and 1977. Since 1978, the indices have stabilized above the 1976 and 1977 values but considerably below the relatively high values observed in 1965-1969 (Figures 4B and 5). The January 1980 total number per tow index of 8.71 was 83% less than the 1965-1969 average catch per tow; the 1980 total weight per tow was 75% lower than the late 1960 average (1.47 vs 5.99) (Tables 8 and 9).

In 1978 (both surveys), pre-recruit indices (numbers) indicated a recent modest improvement in year-class success. Survey length-frequency data from the 1977 and 1978 cruises (Figure 3) suggest that this improvement was probably due to the 1974 and 1976 year-classes. The extremely low 1980 pre-recruit index (0.46) and the absence of any clams less than 9 cm in the 1980 survey size frequency distribution (Figure 3) imply that since 1976 recruitment has been much poorer.

The 1980 commercial-sized catch per tow index (8.25) was more than twice the Dec 1978 value (3.54) and was higher than any value since 1974. The Southern New Jersey index was also about twice as great as the 1980 Northern New Jersey commercial size index (Table 8). However, since recruitment of the 1976 year class in Northern New Jersey will be very much better than in Southern New Jersey (as evinced by the pre-recruit indices), future survey commercial-size indices are likely to be higher in the Northern New Jersey resource than in the Southern New Jersey populations.

Delmarva

Total number per tow indices of Delmarva surf clams were relatively stable between 1965-1976, declined during 1977, and have recently increased to record high levels (Figure 4C). The 1980 total and pre-recruit indices were the second highest in the survey time series, exceeded only by the Dec 1978 values (Table 8). Differences between the 1978 (Dec) and 1980 indices should be considered more apparent than real since the extremely large 1978 values resulted from a few tows in which unusually large quantities of pre-recruit surf clams were taken. Both surveys similarly indicated a wide-spread distribution of small clams and hence the indices reflect improved abundance rather than an increase and subsequent decline in population size.

Size frequency distributions from both 1978 surveys and the 1980 (Jan) survey (Figure 3) exhibit sequential progressions in modal shell length characteristic of the growth rate expected of surf clams spawned in 1977. Hence, unlike the Northern New Jersey population in which a successful 1976 year-class appears dominant, the Delmarva resource has produced a strong 1977 year-class. In both areas, the respective dominant year-classes are of approximately equal strength as evinced by similar pre-recruit indices at age 3 (NNJ, Dec 1979: 27.80; DMV, Jan 1980: 35.31) (Table 8).

The 1980 Delmarva commercial-size number per tow (8.60) and weight per tow (0.88 kg) indices were larger than they were during 1977-1978. Despite this recent improvement in the relative number and biomass of commercial-sized clams, the 1977-1980 commercial catch per tow indices are considerably lower than survey indices of commercial clams in Delmarva obtained during 1965-1976 (Table 9). Hence, these data suggest that landings from Delmarva since 1977 have reduced exploitable biomass.

Growth

Growth equations for the New Jersey and Delmarva surf clam populations were derived by asymptotic regressions of shell length on age using age samples collected from the December 1978 shellfish assessment survey. The New Jersey age sample consisted of 291 clams; 196 clams were in the Delmarva sample. Ages were determined from both internal and external annual growth lines (Jones et al. 1978; Ropes and O'Brien 1979). Ages were coded relative to survey scheduling assuming an October 1 birthdate, e.g., an age 1 surf clam was assumed to be 1.25 years old when caught in the December survey. Shell length of the

age samples ranged between 31 and 191 mm; the youngest and oldest clams used in the analyses were 1.25 and 31.25 years old, respectively.

The resultant asymptotic regressions were of the form

$$l_t = L_\infty - ce^{-Kt}$$

where l_t = shell length in millimeters at time t; L_∞ = asymptotic shell length; K = the Pütter growth coefficient, which has the dimensions of 1/time (Ricker 1979); and C = a parameter equal to the difference between L_∞ and the value of l when t = 0.

By using the transformation

$$t_o = \frac{\ln (c/L_\infty)}{K}$$

the asymptotic regression was expressed in terms of the familiar von Bertalanffy growth expression

$$l_t = L_\infty (1 - e^{-K(t-t_o)})$$

where t_o = the time at which a clam would have zero length if it had always grown according to the von Bertalanffy relationship.

The Mid-Atlantic surf clam growth equations derived from these analyses are

$$l_t = 166.64 (1-e^{-.2731(t + .0255)}) \qquad \text{New Jersey}$$

$$l_t = 166.43 (1-e^{-.2984(t - .0794)}) \qquad \text{Delmarva}$$

Length-at-age estimates from these equations are nearly identical (Table 10; Figure 6A) implying a general similarity in shell growth among the offshore populations. Growth is rapid during the earliest years. Assuming a commercial fishery cull size at 120 mm, Mid-Atlantic surf clams recruit to the fishery

at age 5 and remain in the fishable stock for at least 20 years. Upon recruitment, 120 mm surf clams have attained approximately 72% of the asymptotic shell size.

The calculated L_∞ values from both growth equations approximate the mean shell size of surf clams in the commercial landings during 1976-1979. Since surf clams as large as 180-190 mm are frequently observed in the commercial catch, the calculated L_∞ values underestimate the true asymptotic shell length. This may have resulted from: (1) a low number of very large clams in the survey samples; (2) size-selective mortality operating in the offshore surf clam fishery causing the mean shell size of non-harvested clams of each cohort to be less than it would otherwise be; or (3) inaccurate age determinations of the age samples. Offshore surf clam growth curves derived from previous Mid-Atlantic studies (Loesch and Ropes 1977; Jones et al. 1978; Murawski and Serchuk 1979) provide mean lengths at age similar to those in the present analyses, particularly for age groups 1-6. Differences in growth rates in samples taken from localized beds may be an important, confounding factor in the estimation of L_∞ if commercial exploitation is concentrated on beds of large-sized clams. The random design of the research survey, however, should produce age and growth results representative, on average, of the total population.

The growth curves derived for the New Jersey and Delmarva populations, tend to be compatible with the survey size frequency modal progressions for the 1976 year class in Northern New Jersey and the 1977 year-class in Delmarva (Figure 3). Accordingly, the underestimation of the true L_∞ values does not appear to significantly bias the calculated size at age values for young clams.

Length-Weight Relationships

Shell length-drained meat weight relationships were determined from 1143 clams obtained in the January 1980 research vessel survey. Linear regressions were fitted with the length (mm) and weight (g) data converted to natural logarithms. Regression equations were calculated separately for four areas: Southern New England - Long Island, New Jersey, Delmarva, and North Carolina (Table 11). Sample sizes obtained from Southern New England - Long Island and North Carolina were relatively small, and hence the resultant length-weight equations for these areas should be considered preliminary (Table 11).

For commercial-sized clams (120-190 mm), meats weights for similar sized individuals generally decrease from Southern New England - Long Island to North Carolina (Table 12). This contrasts with the north to south cline in relative meat weight for ocean quahogs in which meat weight at shell length increased southward (Murawski and Serchuk 1979b). If density dependent factors limit growth, however, both trends are generally accordant in reflecting the latitudinal density gradients of the two offshore species (i.e., surf clams most dense in the southern Mid-Atlantic; ocean quahogs most dense in the northern Mid-Atlantic). The direct effects of density on relative meat yield in both species, however, has yet to be confirmed.

At all shell sizes, the calculated meat weight for New Jersey surf clams was higher than that for similar-sized Delmarva clams (Table 12; Figure 6B). Since shell size at age differs little between the two areas (Figure 6A), the New Jersey clams have a higher meat yield at age than clams from Delmarva (Table 10). Seasonal or annual variations in these relationsips may exist but

could not presently be evaluated since all length-weight data were derived from the January 1980 survey.

Yield Per Recruit

Yield per recruit analyses for New Jersey and Delmarva surf clams were performed using the allometric growth model of Paulik and Gales (1964). For New Jersey clams, the following parameters were employed: W_∞ = 189.9 g, K = .2731, t_o =-.0255, t_r = .25 years, t_λ = 24 years, and M = .25. The parameters used in the Delmarva analysis were: W_∞ = 155.8 g, K = .2984, t_o = .0794, t_r = .25 years, t_λ = 24 years, and M = .25. Both analyses were accomplished by varying F between 0.01 and 2.00, and for t_c values between 0.25 and 8.00 years.

For New Jersey clams, unconditional maximum yield per recruit occurs at an optimal age of exploitation (t_y: Beverton and Holt 1957) of 4.75 years and an instantaneous fishing mortality rate of 2.0. For Delmarva clams, t_y is 4.5 years and F = 2.0. The unrealistically high F values result from the shape of the yield per recruit curve; the curve is asymptotic with the right hand segment becoming nearly flat as fishing mortality increases.

Conditional values of F providing maximum yield per recruit were derived by assuming that surf clams less than 12 cm are culled out in the commercial fishery and not retained. This premise is implied by the size frequency distributions of the commercial landings during 1976-1979 (Figure 2). Under these conditions in which the mean shell length at first capture is 12 cm, age at first capture (t_c) in the offshore New Jersey fishery is 4.64 years

and 4.36 years in the Delmarva fishery. The resultant F_{max} value (for the range of Fs used in the analyses) for both surf clam populations occurs at F = 2.0 (89% annual actual total mortality rate); corresponding $F_{0.1}$ values (Gulland 1977) for the New Jersey and Delmarva resources are both 0.35 (Figure 7).

Approximately 95% of maximum yield per recruit is achieved at F = 0.75 in each of the offshore surf clam populations. At $F_{0.1}$, 82% of the maximum yield per recruit is provided on a long term basis from both resources.

Although maximum yield per recruit occurs at relatively high fishing mortality rates (i.e., >2.0), few individuals >12 cm shell length survive to spawn when these F levels are maintained, and hence reproduction generally becomes dependent on smaller-sized, young individuals (<12 cm). More heterogeneous spawning populations normally reduce the risk of recruitment failure, especially when a succession of poor year-classes has occurred. Accordingly, more moderate fishing levels (0.3-0.7) may be desirable to provide this buffer.

Relative Exploitation Rates

Average relative exploitation rates during 1965-1969, 1974-1976, and 1978-1979 (three distinct periods in the development of the surf clam fishery) were derived for each of the offshore surf clam regions by dividing the mean areal commercial landings by the mean survey total weight per tow index (Table 13).

In offshore Northern New Jersey, the average relative exploitation rate during 1978-1979 was about 10% of the 1965-1969 value and 48% less than the 1974-1976 rate. Assuming fishing mortality is proportional to the relative exploitation values, significant reductions in fishing mortality have occurred in recent years. Since the strong 1976 year-class will first recruit to the

fishery in 1981 exploitable biomass should further increase. Hence, at present landings levels (<1 million lbs, meats), fishing mortality will further decline. Contrariwise, landings in 1981 could be increased without increasing the rate of fishing mortality. The 1980 (Jan) pre-recruit number per tow index was several fold greater than any corresponding pre-recruit index during 1965-1977, and accounted for 79% of the total Northern New Jersey number per tow value (Table 8). Accordingly, recruit biomass in 1980 and 1981 may become nearly as large as it was during 1965-1969. This is further implied by the 1980 (Jan) total number per tow index (20.31), a value similar to those obtained between 1965-1969 (Table 8). If the recruit biomass doubles in 1980-1981 from the 1980 (Jan) level due to the strong 1976 year class and fishery exploitation is increased to the modest 1974-1976 level, a catch of 2.6 million pounds (meats) would be generated. Given a doubling of recruit biomass and a fishing mortality equivalent to the 1965-1969 level, a catch of nearly 15 million pounds could be expected.

Although current number and weight per tow indices in Northern New Jersey indicate substantial recent improvement in population abundance, this increase is largely due to one year-class (1976). Hence, the structure of the resource differs significantly from that in previous years, particularly 1965-1969, when multiple year-classes comprised the population. Resultingly, large increases in fishing mortality in 1981 (near the 1965-1969 level) may adversely impact future stock levels and overall population stability. Present commercial and survey data suggests that 1981-1982 landings of 3-6 million pounds from Northern New Jersey (implying relative F values 1-2 times those in 1974-1976) may be compatible with the FMP objective of rebuilding the surf clam populations to allow eventual harvesting approximating the 50 million pound level, and current resource abundance levels.

In Southern New Jersey, the 1978-1979 relative exploitation rate was 44% less than during 1974-1976 but four-fold greater than the 1965-1969 value (Table 13). Although recent landings have averaged about 2 million pounds (slightly less than during the late 1960's), the survey weight per tow indices are only 17% of the 1965-1969 mean value. The 1978-1980 survey weight and number per tow values have been relatively stable (Tables 8 and 9) but are well below the indices noted during 1965-1974.

Since recent recruitment in Southern New Jersey has only been modest and relatively much poorer than in Northern New Jersey or Delmarva (Table 8), annual landings in 1981 and 1982 in excess of 2-3 million pounds per year may not maintain the resource at its current level.

The 1978-1979 Delmarva relative exploitation rate was 19% higher than the 1974-1976 value (Table 13) implying an increase in fishing mortality during the last two years. Exploitation indices for 1965-1969 do not exist since the Delmarva fishery did not commence until 1970.

Landings in 1978-1979 averaged 27.6 million pounds, the highest in the history of the fishery. Although the average survey weight per tow index increased 23% between 1974-1976 and 1978-1979, landings in the latter period averaged 46% greater than in the former period. The 1980 (Jan) number and weight per tow indices are higher than the 1974-1976 values due to the strong 1977 year-class. While exploitable biomass should markedly increase in 1982 when this year-class recruits to the fishery, the current recruit biomass will have to sustain the Delmarva fishery until then, as it has in the past six years when incoming recruitment was relatively poor (Tables 8 and 9). In this regard, a comparison of relative exploitation rates between 1974-1976 and 1978-1979 based on rates derived by dividing the areal landings by the average

recruit weight per tow from the surveys (4.76 lbs/tow in 1974-1976; 1.55 lbs/tow in 1978-1979) indicates a 4.5 fold increase in relative fishing mortality (3.99 in 1974-1976; 17.83 in 1978-1979). The early Delmarva fishery was sustained by accumulated biomass prior to fishery inception. The remaining age-groups within the commercial-sized component of the present resource will have to support the fishery until the 1977 year-class recruits in 1982. Accordingly, 1980-1982 annual landings at the 1978-1979 levels may result in sequential declines in spawning stock biomass. Given the Jan (1980) recruit weight per tow index (.88 kg or 1.94 lbs) and a relative fishing mortality rate equivalent to the 1974-1976 level, an annual catch of about 7.8 million pounds would ensue. (The 1980 catch has already exceeded this level). To generate annual catches of 27.6 million pounds (the average 1978-1979 level) with the equivalent 1974-1976 relative exploitation rate would require that relative exploitable biomass, as assessed from the survey recruit weight per tow index, would need to increase 3.6 fold during 1980-81 (to 3.14 kg or 6.93 lbs/tow). This latter index would be higher than any previously observed recruit weight per tow value (Table 9).

The risks associated with stock size reductions resulting from continued annual 27-28 million pound harvests from Delmarva during 1980 and 1981 need to be evaluated relative to the probable stock size increases resulting from recruitment of the 1977 year-class into the exploitable biomass in 1982. If natural mortality remains constant and fishing mortality remains minimal on this year-class, the relative size (in numbers) of the recruit component of the population in 1982 would approximate the highest levels observed (i.e., 1974 indices), independent of the 1980 recruit population size.

Implications of the Current Assessment of Offshore Middle Atlantic Surf Clam Populations.

Results of the present assessment analyses indicate that commercial landings and fishing patterns were virtually identical in 1978 and 1979. Approximately 91-92% of the annual offshore landings (31.4 and 29.1 million pounds, respectively) were taken in the offshore Delmarva waters. Tonnage class 3 vessels (>100 GRT) accounted for greater than 70% of the total offshore surf clam catch during both years.

Commercial catch per effort indices (bushels/hour fished) increased during 1979 for all vessel classes in Northern New Jersey and for Class 1 and 3 in Southern New Jersey. In Delmarva, the overall 1979 commercial abundance indices were similar to those from 1978, except for the Class 3 index which slightly increased. On face value, these data would suggest relative resource stability in Delmarva and improved resource abundance in Northern and Southern New Jersey. The 1979 commercial catch/effort data, however, overestimate relative abundance to the extent that increased fishing power and/or increasing searching time for productive beds occurred relative to 1978. Double rigging (two dredges) of many class 3 vessels transpired in 1979, as well as general increases in dredge sizes. No adjustments in the reported catch and effort statistics were made for these fishing power changes since proper weighting factors are not available. Hence, the 1979 commercial indices, particularly the class 3 values, should be considered as liberal rather than conservative estimates of relative resource conditions within each of the offshore areas.

Size composition of the commercial landings has remained relatively stable in all offshore areas, with mean shell length of the catches ranging between 15.5-17.5 cm. Although clams less than 12 cm have traditionally not been landed from any offshore region, a small but increasing percentage of these small clams appeared in the 1978 and 1979 Delmarva size-frequency samples.

Stratified mean catch per tow indices from NMFS shellfish assessment surveys in December 1978 and January 1980 indicated recent increases in surf clam abundance in Northern New Jersey and in Delmarva. Pre-recruit indices and survey length-frequency data imply that these increases were due to a relatively strong 1976 year-class in Northern New Jersey and a strong 1977 year-class in Delmarva. Based on age and growth relationships derived from age samples from the December 1978 survey, these year-classes should recruit to the commercial fishery in 1981 and 1982, respectively, at about the size/age at first capture of maximum yield per recruit.

In Southern New Jersey, the recent survey indices have been relatively stable. While the 1978 pre-recruit indices (January and December surveys) indicated recent modest recruitment success, the relative magnitude of this recruitment is very much less than in either the Northern New Jersey or Delmarva populations.

Relative exploitation rates in 1978-1979 for the Northern and Southern New Jersey populations were less than corresponding values during 1974-1976 implying recent declines in fishing mortality. In 1981, landings from the Northern New Jersey fishery could be substantially increased without increasing current fishing mortality levels, because of significant increases in exploitable biomass resulting from recruitment of the 1976 year-class into the fishery. Annual yields of 3-6 million pounds in 1981 and 1982 from Northern New Jersey (including the currently "closed" areas) would be commensurate with FMP objectives given current knowledge of resource conditions. In Southern New Jersey, annual landings in 1981 and 1982 of 2-3 million pounds would probably maintain present population levels.

The 1978-1979 average relative exploitation rate in Delmarva was 19% higher than during 1974-1976 suggesting that fishing mortality has increased in the last several years. Although the 1980 (Jan) total and pre-recruit survey catch per tow indices were near historically high levels, the 1980 commercial weight and number per tow indices were well below corresponding indices observed during 1965-1976. This is a consequence of a 46% increase in Delmarva surf clam landings during 1978-1979 from the 1974-1976 average annual catch level, and the current dominance of the 1977 year-class in the population. Since the 1977 year-class will probably not enter the commercial fishery to any extent until mid or late 1982, the present harvestable-sized biomass will have to sustain the fishery in the immediate future. If in 1981-1982, relative exploitation values are reduced to the 1974-1976 average, annual landings of about 8 million pounds would be generated. Larger yields could be taken at the same exploitation rate only if exploitable biomass increases in 1980 and 1981. No significant increase in exploitable biomass, however, is likely to occur until the 1977 year-class enters the fishery in 1982. Given current survey pre-recruit indices and minimal fishing mortality on the 1977 year-class before 1982, population biomass in late 1982 may well reach the highest levels observed due to this exceptional recruitment. The risks associated with maintaining current annual catch levels in Delmarva (~28 million pounds) through 1982 and the concommitant reductions in harvestable biomass that will likely ensue during this period should be evaluated relative to the anticipated increases in biomass from recruitment of the 1977 year-class in late 1982. The desirability of sustaining a multi-age population of surf clam in Delmarva as a buffer against future recruitment variability suggests that annual harvests in 1981 and 1982 of less than 28 million pounds may be appropriate.

The three major Mid-Atlantic offshore surf clam areas significantly differ in relative resource abundance. The present projections of future landings from these areas reflect these differential population conditions and assume exploitation patterns, within any overall landings scheme, will be accordant with these conditions.

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Table 1. Total USA commercial landings of surf clams (x 10^{-3} lbs of meat), total USA commercial landings from the Fishery Conservation Zone (3-200 miles), and the annual percentage of total USA commercial landings taken beyond 3 miles from shore.

Year	Total Landings	>3 Miles	Percent Caught >3 Miles[1] from shore
1965	44,088	33,000	74.9
1966	45,113	32,400	71.8
1967	45,054	24,700	54.8
1968	40,552	20,000	49.3
1969	49,575	15,900	32.1
1970	67,318	14,100	20.9
1971	52,535	50,053	95.3
1972	63,371	55,272	87.1
1973	82,370	72,579	88.1
1974	96,110	74,430	77.4
1975	86,956	44,270	50.9
1976	49,133	42,558	86.6
1977	51,036	42,968	84.2
1978	39,237	31,393	80.0
1979	34,912	29,070	83.3

[1] Proration for 1971-1979 are based on data presented in Fisheries of the United States, 1971-1979. Earlier data are based on interview information by the US Bureau of Commercial Fisheries.

Table 2. Distribution of commercial surf clam catch and effort in 1978, by area fished, vessel size class, and calendar quarter, for surf clam vessels operating in the Fishery Conservation Zone off New Jersey and Delmarva. All data were derived from commercial vessel trip logbook records.

Area	Vessel Class (GRT)	Quarter 1			Quarter 2			Quarter 3			Quarter 4			Entire Year		
		Catch (Bu)	Hours Fished	Trips	Catch (Bu)	Hours Fished	Trips	Catch (Bu)	Hours Fished	Trips	Catch (Bu)	Hours Fished	Trips	Catch (Bu)	Hours Fished	Trips
No. New Jersey																
	1-50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	51-100	384	16	2	1782	104	11	4774	385.5	37	2290	79	14	9230	584.5	64
	>100	-	-	-	6517	270.5	13	3370	159	12	3217	167	13	13104	596.5	38
	Total	384	16	2	8299	374.5	24	8144	544.5	49	5507	246	27	22334	1181	102
So. New Jersey																
	1-50	258	22	1	1243	77	5	2628	238.5	27	2585	199	24	6714	536.5	57
	51-100	2354	157	10	8464	542	38	6720	344.5	32	7806	360	35	25344	1403.5	115
	>100	3841	205.3	11	14862	760.5	35	9714	398	28	15910	561	46	44327	1924.8	120
	Total	6453	384.3	22	24569	1379.5	78	19062	981	87	26301	1120	105	76385	3864.8	292
Delmarva																
	1-50	1173	82.5	5	16152	1044	72	17454	1022	85	9347	592.8	56	44126	2741.3	218
	51-100	10165	485.25	31	107092	5359.75	357	91566	4601.7	380	80159	3961.1	319	288982	14407.8	1087
	>100	47827	1632.5	71	282544	10511.15	509	256737	8451.75	641	216309	7302.5	536	803417	27897.9	1757
	Total	59165	2200.35	107	405788	16914.9	938	365757	14075.45	1106	305815	11856.4	911	1136525	45047	3062
All Areas																
	1-50	1431	104.5	6	17395	1121	77	20082	1260.5	112	11932	791.8	80	50840	3277.8	275
	51-100	12903	658.25	43	117338	6005.15	406	103060	5331.7	449	90255	4400.1	368	323556	16395.8	1266
	>100	51668	1837.8	82	303923	11542.15	557	269821	9008.75	681	235436	8030.5	595	860848	30419.2	1915
GRAND TOTAL		66002	2600.55	131	438656	18668.9	1040	392963	15600.95	1242	337623	13222.4	1043	1235244	50092.8	3456

Table 3. Distribution of commercial surf clam catch and effort in 1979, by area fished, vessel size class, and calendar quarter, for surf clam vessels operating in the Fishery Conservation Zone off New Jersey and Delmarva. All data were derived from commercial vessel trip logbook records.

Area	Vessel Class (GRT)	Quarter 1			Quarter 2			Quarter 3			Quarter 4			Entire Year		
		Catch (Bu)	Hours Fished	Trips	Catch (Bu)	Hours Fished	Trips	Catch (Bu)	Hours Fished	Trips	Catch (Bu)	Hours Fished	Trips	Catch (Bu)	Hours Fished	Trips
No. New Jersey																
	0-50	1674	56	6	1248	36	3	-	-	-	388	15	2	3310	107	11
	51-100	4363	141.5	17	5754	213.25	26	1202	70	6	1475	107	8	12794	531.75	57
	> 100	2423	57	8	5406	279	27	2557	56.5	6	12558	277	20	22944	669.5	61
	Total	8460	254.5	31	12408	528.25	56	3759	126.5	12	14421	399	30	39048	1308.25	129
So. New Jersey																
	0-50	716	26	3	727	23	2	5188	209.75	20	490	48	4	7121	306.75	29
	51-100	2020	99.5	11	5459	253	38	17089	951	90	5339	367	35	29907	1770.5	174
	> 100	16418	675.5	53	17652	943.5	78	13589	406	37	13534	352	27	61193	2377	195
	Total	19154	801.0	67	23838	1319.5	118	35866	1566.75	147	19363	767	66	98221	4454.25	398
Delmarva																
	0-50	5279	343.8	38	17146	1033.5	91	14428	889.95	77	8552	578	50	45405	2845.25	256
	51-100	46509	2377.2	198	92048	4628.3	430	96483	4815	426	56922	3166.75	265	291962	14987.25	1319
	> 100	188967	6657.8	477	264054	8509	645	311218	8520.5	732	244433	7110.5	493	1008672	30797.8	2347
	Total	240775	9378.8	713	373248	14170.8	1166	422129	14225.45	1235	309907	10855.25	808	1346039	48630.3	3922
All Areas																
	0-50	7669	425.8	47	19121	1092.5	96	19616	1099.7	97	9430	641	56	55836	3259	296
	51-100	52892	2618.2	226	103261	5194.55	494	114774	5836	522	63736	3640.75	308	334663	17289.5	1550
	> 100	207808	7390.3	538	287112	9731.5	750	327364	8983	775	270525	7739.5	540	1092809	33844.3	2603
GRAND TOTAL		268369	10434.3	811	409494	16018.55	1340	461754	15918.7	1394	343691	12021.25	904	1483308	54392.8	4449

Table 4. Percentages of annual total offshore surf clam catch, hours fished, and number of vessel trips, by area fished and calendar quarter, for 1978 and 1979. All data were derived from commercial vessel logbook records.

	1978					1979				
Area	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Total	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Total
	CATCH					CATCH				
No. New Jersey	<.1	.7	.7	.4	1.8	.6	.8	.3	1.0	2.6
So. New Jersey	.5	2.0	1.5	2.1	6.2	1.3	1.6	2.4	1.3	6.6
Delmarva	4.8	32.9	29.6	24.8	92.0	16.2	25.2	28.5	20.9	90.7
TOTAL	5.3	35.5	31.8	27.3	100.0	18.1	27.6	31.1	23.2	100.0
	HOURS FISHED					HOURS FISHED				
No. New Jersey	<.1	.7	1.1	.5	2.4	.5	1.0	.2	.7	2.4
So. New Jersey	.8	2.8	2.0	2.2	7.7	1.5	2.4	2.9	1.4	8.2
Delmarva	4.4	33.8	28.1	23.7	89.9	17.2	26.1	26.2	20.0	89.4
TOTAL	5.2	37.3	31.1	26.4	100.0	19.2	29.4	29.3	22.1	100.0
	TRIPS					TRIPS				
No. New Jersey	.1	.7	1.4	.8	3.0	.7	1.3	.3	.7	2.9
So. New Jersey	.6	2.3	2.5	3.0	8.4	1.5	2.7	3.3	1.5	8.9
Delmarva	3.1	27.1	32.0	26.4	88.6	16.0	26.2	27.8	18.2	88.2
TOTAL	3.8	30.1	35.9	30.2	100.0	18.2	30.1	31.3	20.3	100.0

Table 5. Quarterly percentage distribution, by area, of surf clam catch and effort (days fished) for surf clam vessels operating in the Fishery Conservation Zone off New Jersey and Delmarva in 1978 and 1979. All data were derived from commercial vessel logbook records.

	1978					1979				
Area	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Total	Jan-Mar	Apr-Jun	Jul-Sep	Oct-Dec	Total
			CATCH					CATCH		
No. New Jersey	1.7	37.2	36.5	24.7	100.0	21.7	31.8	9.6	36.9	100.0
So. New Jersey	8.4	32.2	25.0	34.7	100.0	19.5	24.3	36.5	19.7	100.0
Delmarva	5.2	35.7	32.2	26.9	100.0	17.9	27.7	31.4	23.0	100.0
TOTAL	5.3	35.5	31.8	27.3	100.0	18.1	27.6	31.1	23.2	100.0
			HOURS FISHED					HOURS FISHED		
No. New Jersey	1.4	31.7	46.1	20.8	100.0	19.5	40.4	9.7	30.5	100.0
So. New Jersey	9.9	35.7	25.4	29.0	100.0	18.0	29.6	35.2	17.2	100.0
Delmarva	4.9	37.5	31.2	26.3	100.0	19.3	29.1	29.3	22.3	100.0
TOTAL	5.2	37.3	31.1	26.4	100.0	19.2	29.4	29.3	22.1	100.0

Table 6. USA commercial catch per effort (bushels per hour fished) and number of vessel trips ( ) for surf clam vessels operating in the Fishery Conservation Zone off New Jersey and Delmarva in 1978 and 1979. Data are presented by area fished, calendar quarter, and vessel tonnage category (1-50 GRT; 51-100 GRT; >100 GRT). All data were derived from commercial logbook records.

Area	Calendar Quarter	1978						1979					
		1-50		51-100		>100		1-50		51-100		>100	
No. New Jersey													
	Q 1	-	-	24.0	(2)	-	-	29.9	(6)	30.8	(17)	42.5	(8)
	2	-	-	17.1	(11)	24.1	(13)	34.7	(3)	27.0	(26)	19.4	(27)
	3	-	-	12.4	(37)	21.2	(12)	-	-	17.2	(6)	45.3	(6)
	4	-	-	29.0	(14)	19.3	(13)	25.9	(2)	13.8	(8)	45.3	(20)
	Entire Year	-	-	15.8	(64)	22.0	(38)	30.9	(11)	24.1	(57)	34.3	(61)
So. New Jersey													
	Q 1	11.7	(1)	15.0	(10)	18.7	(11)	27.5	(3)	20.3	(11)	24.3	(53)
	2	16.1	(5)	15.6	(38)	19.5	(35)	31.6	(2)	15.5	(38)	18.7	(78)
	3	11.0	(27)	19.5	(32)	24.4	(28)	24.7	(20)	18.0	(90)	33.5	(37)
	4	13.0	(24)	21.7	(35)	28.4	(46)	10.2	(4)	14.5	(35)	38.4	(27)
	Entire Year	12.5	(57)	18.1	(115)	23.0	(120)	23.2	(29)	16.9	(174)	25.7	(195)
Delmarva													
	Q 1	14.2	(5)	20.9	(31)	29.3	(71)	15.4	(38)	19.6	(198)	28.4	(477)
	2	15.5	(72)	20.0	(357)	26.9	(509)	16.6	(91)	19.9	(430)	31.0	(645)
	3	17.1	(85)	19.9	(380)	30.4	(641)	16.2	(77)	20.0	(426)	36.5	(732)
	4	15.8	(56)	20.2	(319)	29.6	(536)	14.8	(50)	18.0	(265)	34.4	(493)
	Entire Year	16.1	(218)	20.1	(1087)	28.8	(1757)	16.0	(256)	19.5	(1319)	32.8	(2347)
	TOTAL	15.5	(275)	19.7	(1266)	28.3	(1914)	17.1	(296)	19.4	(1550)	32.3	(2603)

Table 7. Summary of research vessel cruises used in the analysis of surf clam population dynamics, 1965-1980.

Research Vessel	Dates of Cruise	Dredge Knife Width (cm)	Time of Tow (min)	Number of Stations	Ring Size or[a] Bar Space (cm)
Undaunted	5-6/65	76	5	374	5.1
Undaunted	10-11/65	76	5	217	5.1
ALBATROSS IV	8/66	76	5	240	5.1
ALBATROSS IV	6-7/69	76	5	278	5.1
DELAWARE II	8/70	122	4	199	3.0
DELAWARE II	6/74	76	5	241	5.1
DELAWARE II	4-5/76	122	4	259	3.0
DELAWARE II	1-3/77	122	4	224	3.0
DELAWARE II	1-2/78	122	4	324	3.0
DELAWARE II	12/78	122	4	163	2.5
DELAWARE II	1-2/80	152	5	229	5.1

[a]portion of dredge where catch is accumulated.

Table 8. Stratified mean catches per survey tow (numbers) for surf clams during shellfish assessment cruises, 1965-1980. Data are standardized to a 1.2 m wide dredge towed for 4 minutes.

CRUISE		AREA								
		N. New Jersey			S. New Jersey			Delmarva		
Year	Month	Total	<12 cm	≥12 cm	Total	<12 cm	≥12 cm	Total	<12 cm	≥12 cm
1965	May-Jun	24.41	3.54	20.87	67.93	44.94	22.99	17.74	5.86	11.88
1965	Oct-Nov	22.91	1.26	21.65	53.10	6.79	46.31	17.96	4.28	13.86
1966	Aug	19.25	1.77	17.48	44.57	1.17	43.40	20.85	6.53	14.32
1969	Jun-Jul	22.01	1.07	20.94	38.29	1.32	36.97	16.83	2.25	14.58
1970	Aug	16.52	1.92	14.60	10.37	0.76	9.62	12.59	1.09	11.50
1974	Jun	13.73	0.88	12.85	31.61	0.64	30.97	23.50	1.88	21.62
1976	Apr-May	8.27	1.02	7.25	3.33	0.24	3.09	14.06	3.50	10.56
1977	Jan-Mar	1.57	0.86	0.71	1.44	0.78	0.66	7.29	1.45	5.84
1978	Jan-Feb	1.32	0.85	0.47	9.56	1.59	7.97	7.44	2.57	4.87
1978	Dec	28.77	27.80	0.97	5.54	2.00	3.54	398.37	394.23	4.14
1980	Jan-Feb	20.31	15.95	4.36	8.71	0.46	8.25	43.91	35.31	8.60

Table 9. Stratified mean catches per survey tow (kg, meat weight) for surf clams during shellfish assessment cruises, 1965-1980. Data are standardized to a 1.2 m wide dredge towed for 4 minutes.

Cruise		AREA								
		NNJ			SNJ			DMV		
Year	Month	Total	Pre-recruit[a]	Recruit	Total	Pre-recruit	Recruit	Total	Pre-recruit	Recruit
1965	May-Jun	3.08	.16	2.92	5.70	2.37	3.33	1.45	.20	1.25
1965	Oct-Nov	3.39	.06	3.33	6.85	.37	6.48	1.80	.17	1.63
1966	Aug	2.90	.09	2.81	5.57	.06	5.51	2.27	.14	2.13
1969	Jun-Jul	3.45	.04	3.41	5.85	.07	5.78	1.77	.08	1.69
1970	Aug	2.65	.07	2.58	1.71	.03	1.68	1.50	.04	1.46
1974	Jun	2.17	.04	2.13	5.63	.03	5.60	2.92	.06	2.86
1976	Apr-May	1.32	.03	1.29	0.62	.01	0.61	1.52	.06	1.46
1977	Jan-Mar	0.15	.03	0.12	0.15	.02	0.13	.90	.04	.86
1978	Jan-Feb	0.10	.03	0.07	1.43	.06	1.37	.74	.06	.68
1978	Dec	0.77	.60	0.17	0.62	.07	0.55	3.86	3.33	.53
1980	Jan-Feb	1.25	.64	0.61	1.47	.03	1.44	1.58	.70	.88

[a]Pre-recruits are surf clams <12 cm, shell length

Table 10. Calculated mean shell lengths (mm) and drained meat weights (g) at age for offshore Middle Atlantic surf clam populations[e].

AGE	New Jersey Shell Length[a]	New Jersey Meat Weight[b]	Delmarva Shell Length[c]	Delmarva Meat Weight[d]
1	40.7	3.5	40.0	3.0
2	70.8	16.9	72.6	15.7
3	93.7	37.3	96.8	34.8
4	111.1	60.5	114.8	55.7
5	124.4	83.2	128.1	75.5
6	134.5	103.7	138.0	92.7
7	142.2	121.3	145.3	107.0
8	148.0	135.9	150.8	118.5
9	152.5	147.8	154.8	127.5
10	155.9	157.2	157.8	134.4
11	158.4	164.7	160.0	139.7
12	160.4	170.5	161.7	143.8
13	161.9	175.0	162.9	146.8
14	163.0	178.5	163.8	149.8
15	163.9	181.2	164.5	150.8
16	164.5	183.3	165.0	152.1
17	165.0	184.8	165.4	153.0
18	165.4	186.0	165.6	153.7
19	165.7	187.0	165.8	154.2
20	165.9	187.7	166.0	154.6
21	166.1	188.2	166.1	154.9
22	166.2	188.6	166.2	155.1
23	166.3	188.9	166.3	155.3
24	166.4	189.2	166.3	155.4

[a]Calculated from: $L_t = 166.64\ [1-e^{-.2731(t+.0255)}]$

[b]Calculated from: $W = .000100SL^{2.8251}$

[c]Calculated from: $L_t = 166.43\ [1-e^{-.2984(t-.0794)}]$

[d]Calculated from: $W = .000111SL^{2.7675}$

[e]Surf clams are spawned in Late summer-autumn thus an October 1 birthdate is assumed.

Table 11. Statistics describing regression equations between shell length (mm) and drained meat weight (g) for surf clams obtained in January 1980 NMFS research vessel shellfish assessment survey.

Area	Regression Statistics			
	Intercept (a)	Slope (b)	Correlation Coefficient (c)	Sample Size (d)
So. New England - Long Island	-7.9726	2.5779	.924	132
New Jersey	-9.2061	2.8251	.987	461
Delmarva	-9.1063	2.7675	.986	525
North Carolina	-7.0583	2.3033	.985	25
All Areas	-9.1936	2.8049	.982	1143

Table 12. Calculated drained meat weight (g) at shell length (mm) for offshore Middle Atlantic surf clam populations derived from shell length -meat weight regression equations.

Shell Length (mm)	Calculated Mean Weight (g)				
	SNE-LI	NJ	DMV	NC	ALL
30	2.2	1.5	1.4	2.2	1.4
40	4.7	3.4	3.0	4.2	3.2
50	8.3	6.3	5.6	7.0	5.9
60	13.2	10.6	9.3	10.7	9.9
70	19.7	16.4	14.2	15.3	15.2
80	27.8	23.9	20.5	20.8	22.1
90	37.6	33.3	28.4	27.3	30.8
100	49.4	44.9	38.0	34.8	41.4
110	63.1	58.7	49.5	43.3	54.1
120	79.0	75.1	63.0	52.9	69.1
130	97.1	94.2	78.6	63.6	86.4
140	117.5	116.1	96.5	75.5	106.4
150	140.4	141.1	116.8	88.5	129.1
160	165.8	169.3	139.7	102.7	154.7
170	193.8	200.9	165.2	118.0	183.4
180	224.6	236.2	193.5	134.6	215.3
190	258.2	275.1	224.7	152.5	250.6
200	294.7	318.0	259.0	171.6	289.4

Table 13. Relationship between average commercial surf clam landings ($x10^{-6}$ lbs, meats), by offshore area, and average NMFS shellfish assessment survey stratified mean weight per tow (lbs, meats) of surf clams, 1965-1969, 1974-1976, and 1978-1979.

Area	1965-1969			1974-1976			1978-1979		
	Commercial Landings (A)	Survey wt/tow (B)	Relative Exploitation Rate (A/B)	Commercial Landings (A)	Survey wt/tow (B)	Relative Exploitation Rate (A/B)	Commercial Landings (A)	Survey[1] wt/tow (B)	Relative Exploitation Rate (A/B)
No. New Jersey	23.10	7.08	3.26	2.17	3.77	0.58	.67	2.23	0.30
So. New Jersey	2.63	13.21	0.20	10.37	6.90	1.50	1.94	2.31	0.84
Delmarva	-	4.01	-	18.97	4.89	3.88	27.63	6.00	4.61

[1] Average of 1978 (Dec) and 1980 (Jan) survey values.

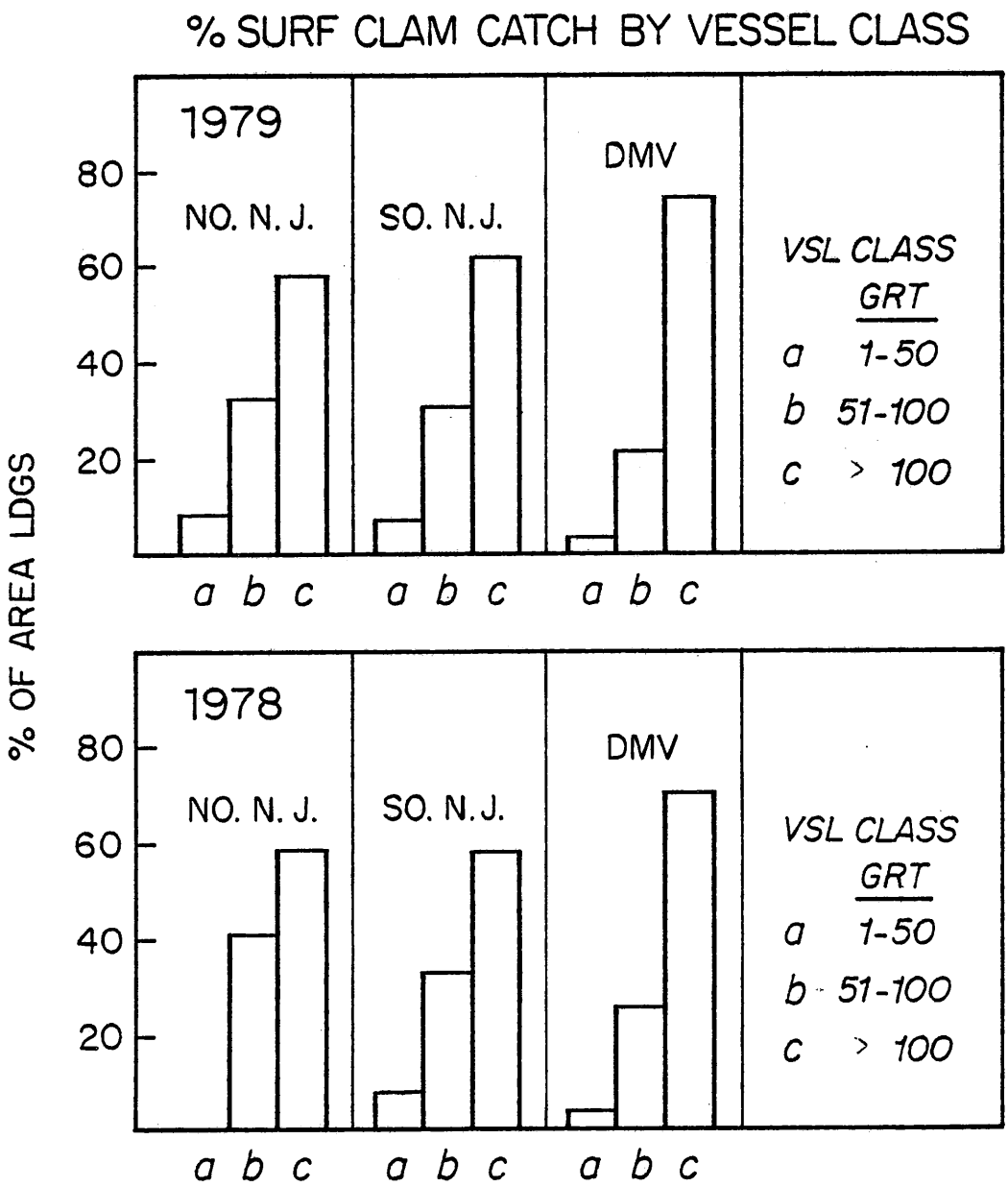

Figure 1. Percentage distribution of surf clam landings, by vessel tonnage class, from offshore Northern New Jersey, Southern New Jersey, and Delmarva in 1979 and 1978.

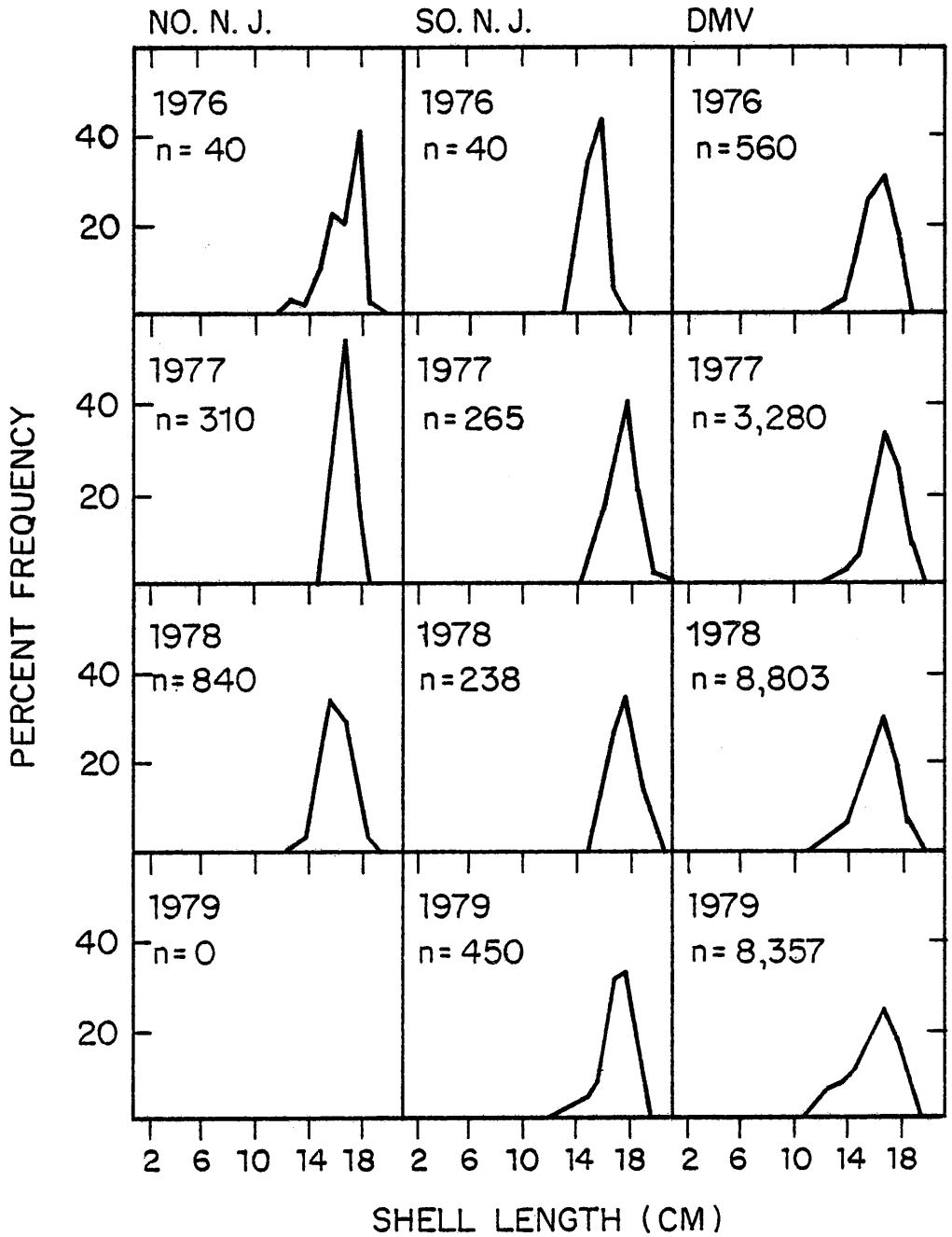

Figure 2. Shell length-frequency distributions of commercial surf clam landings from offshore Northern New Jersey, Southern New Jersey, and Delmarva, 1976-1979.

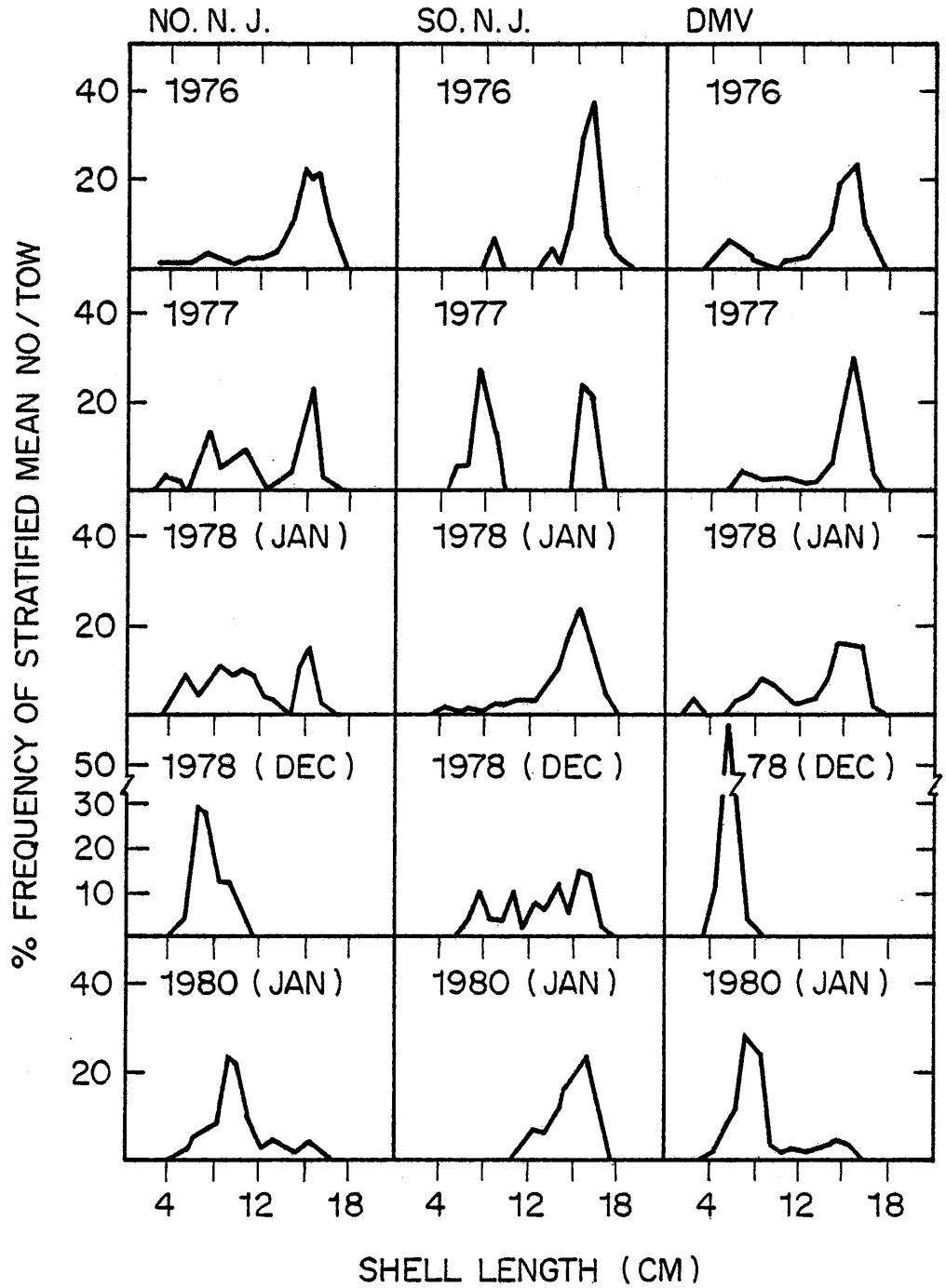

Figure 3. Shell length-frequency distributions of surf clams in NEFC shellfish assessment research vessel surveys in offshore Northern New Jersey, Southern New Jersey, and Delmarva, 1976-1980 (Jan).

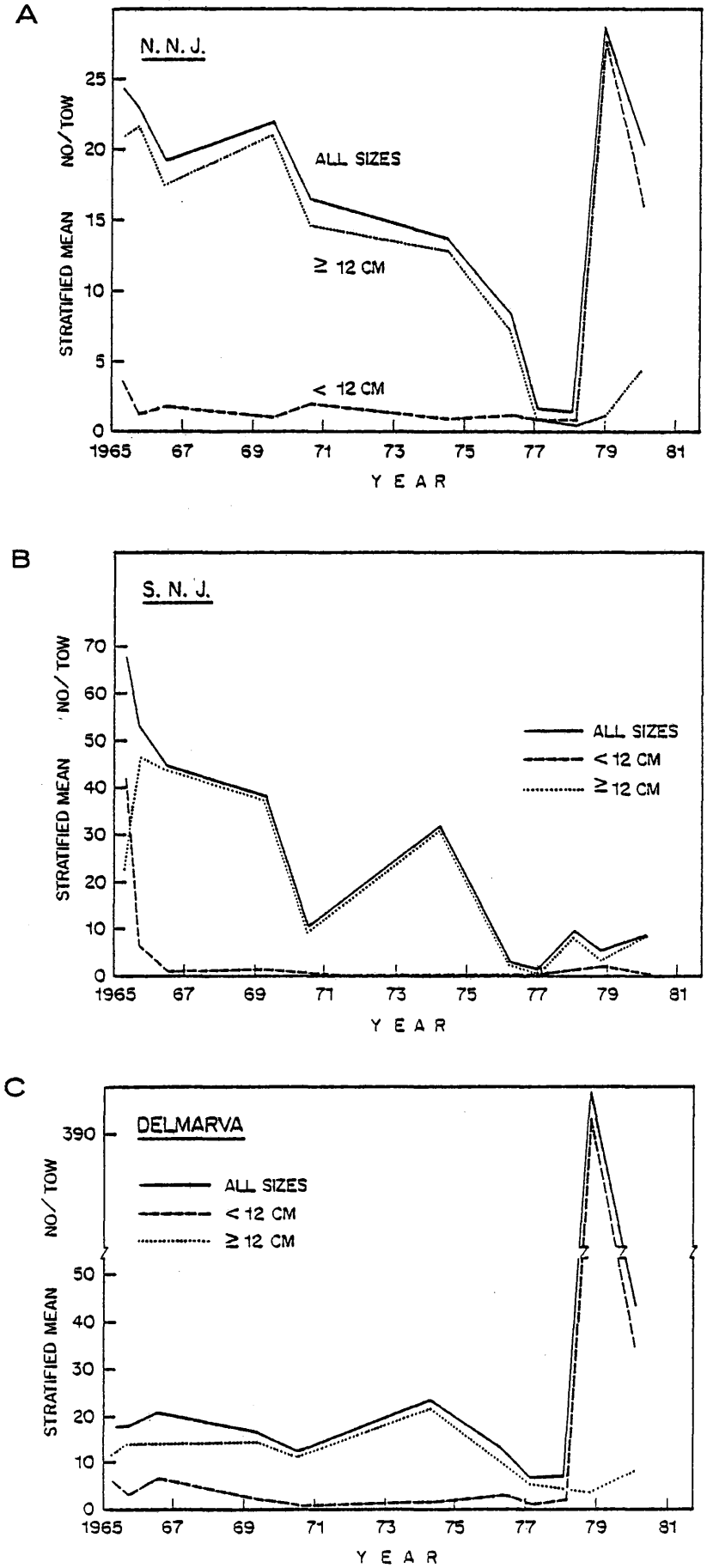

Figure 4. Stratified mean number of surf clams per standardized tow (four minutes; 48" dredge) in NEFC shellfish assessment research vessel surveys, 1965-1980 (Jan) in offshore Northern New Jersey (A), Southern New Jersey (B), and Delmarva (C). Survey indices are presented for pre-recruit clams (<12 cm shell length), harvestable-sized clams (≥12 cm shell length), and total clams (all sizes) per tow.

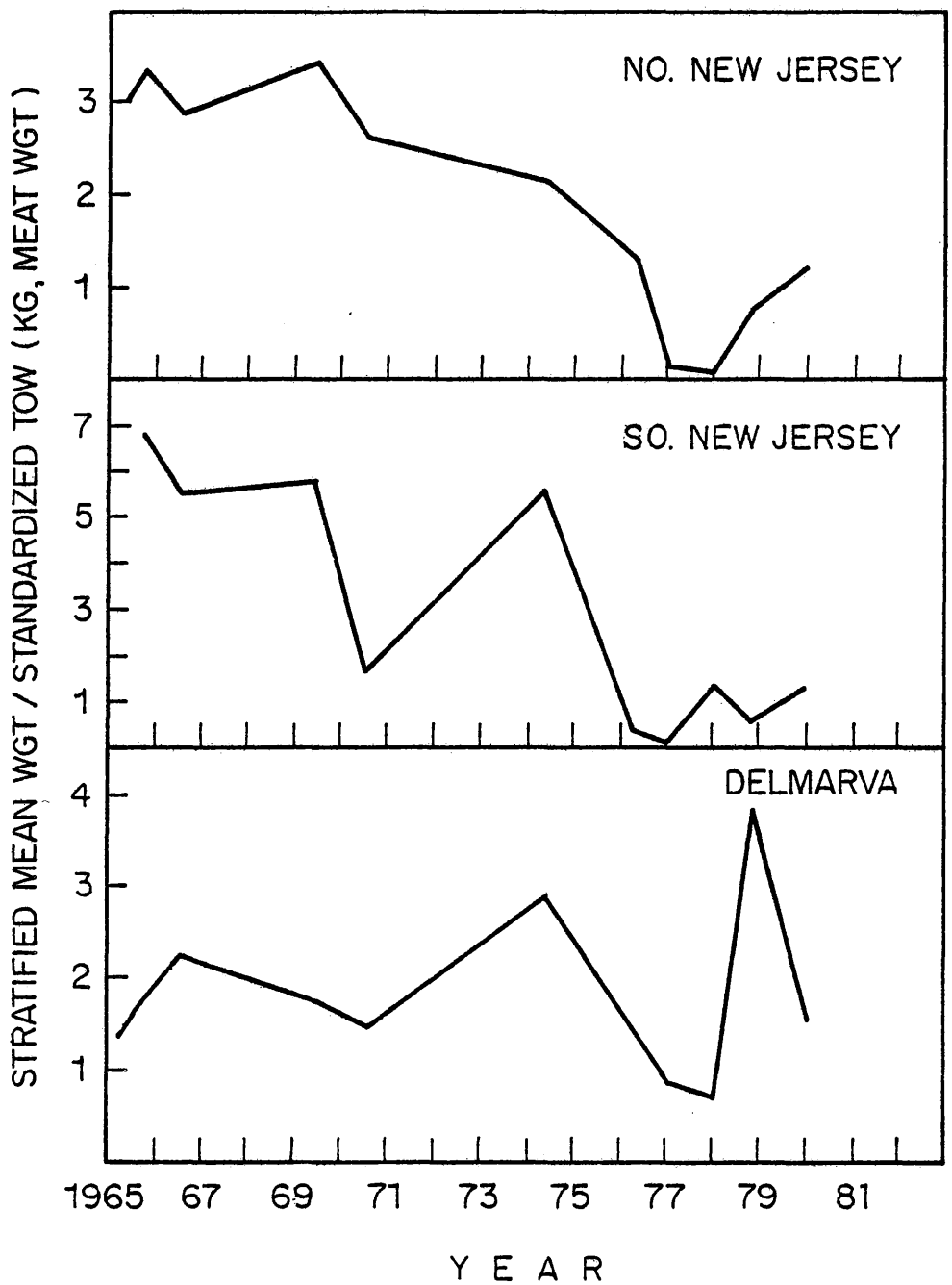

Figure 5. Total stratified mean weight (kg, meat) of surf clams per standardized tow (four minutes; 48" dredge) in NEFC shellfish assessment research vessel surveys in offshore Northern New Jersey, Southern New Jersey, and Delmarva, 1976-1980 (Jan).

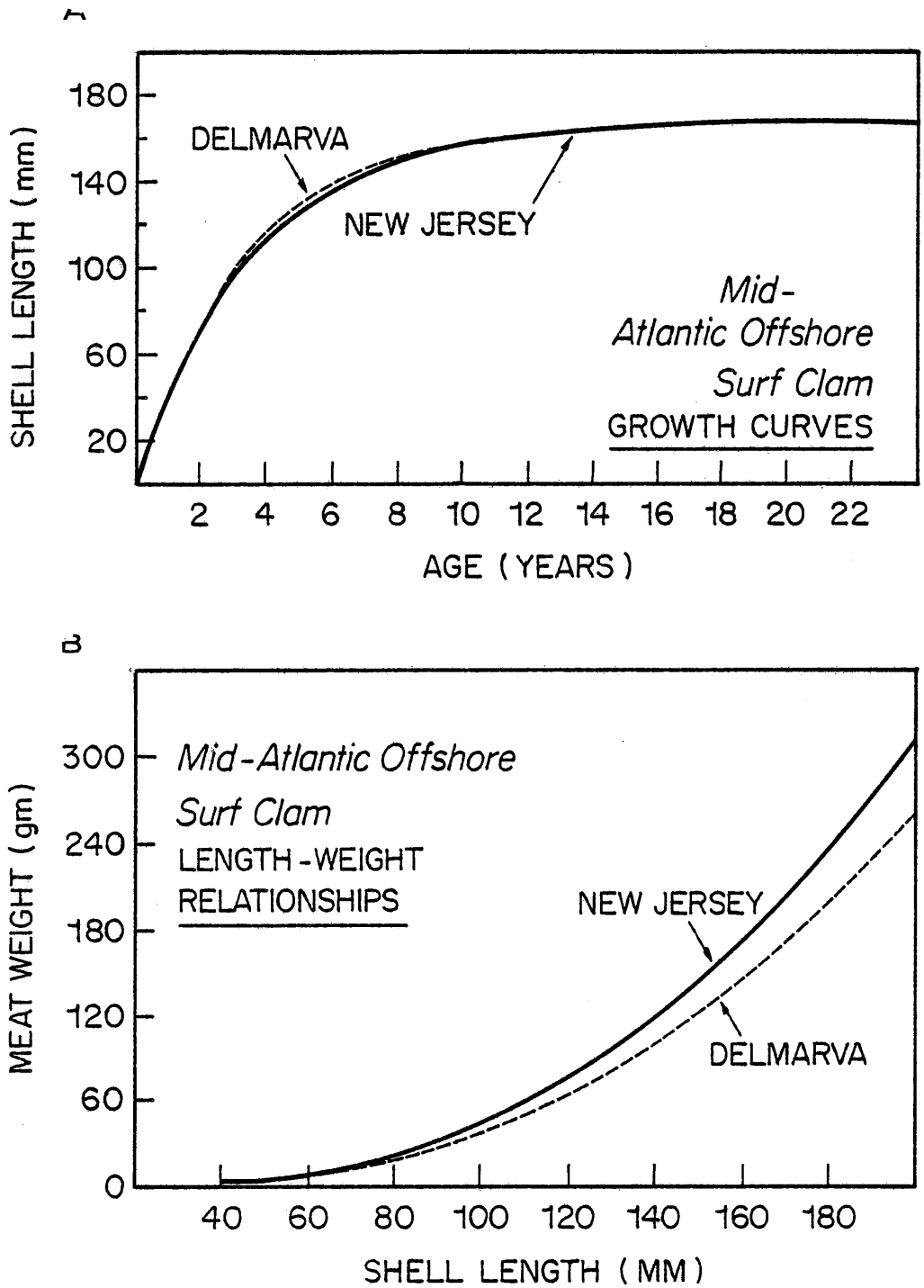

Figure 6. Growth curves (A) and length-weight relationships (B) for surf clams from offshore New Jersey and Delmarva derived from research vessel survey data.

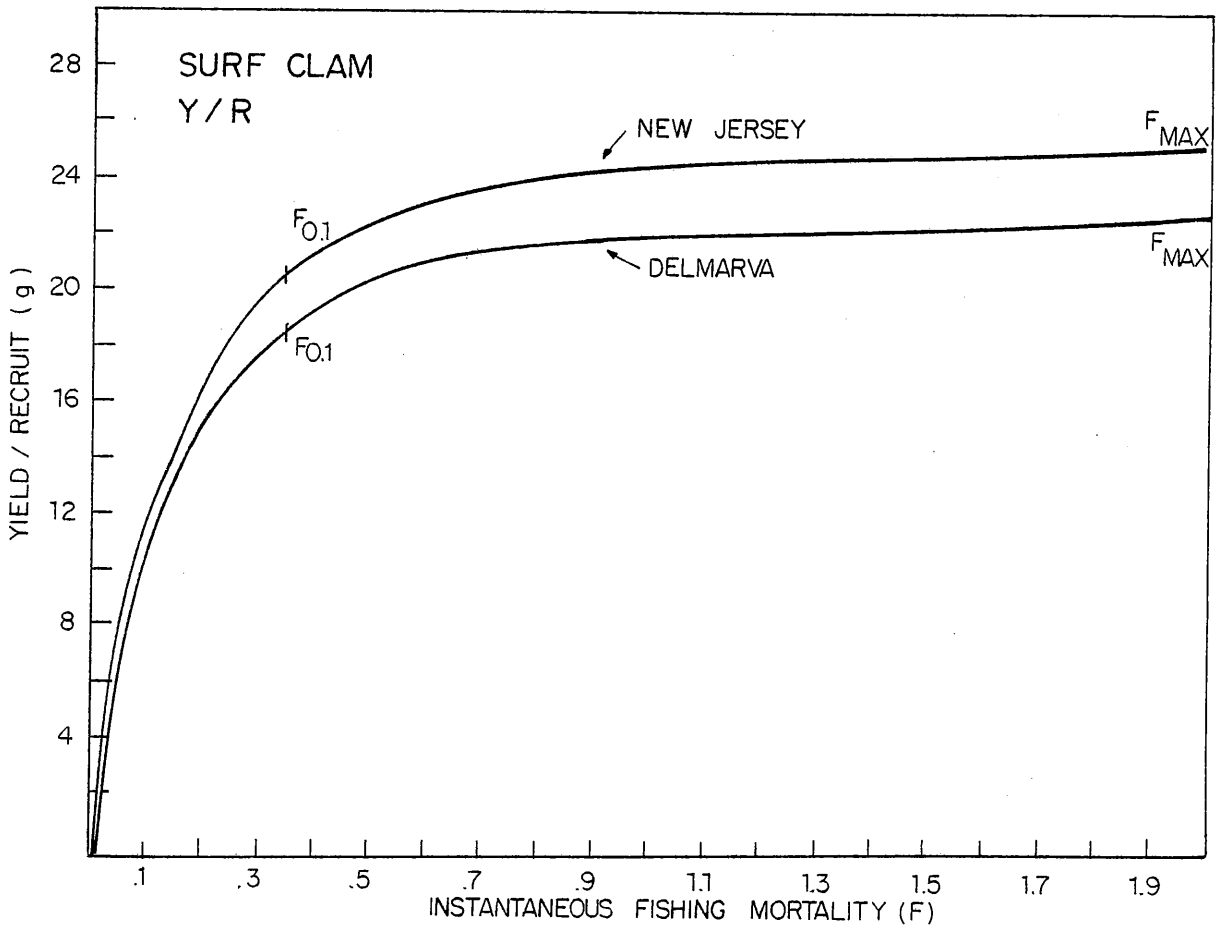

Figure 7. Yield per recruit curves for surf clams from offshore New Jersey and Delmarva.