

An Assessment of Offshore Surf Clam, *Spisula solidissima*,
Populations off the Middle Atlantic Coast of the United States

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ABSTRACT

Total 1978 landings of surf clams, *Spisula solidissima*, from offshore (>3 miles) Middle Atlantic waters were 31.4 million pounds of meat, or 27% decline from 1977. The sharp decline in landings was recommended in the Surf Clam - Ocean Quahog Management Plan of the Mid-Atlantic Fishery Management Council. Approximately 92% of the 1978 catch was taken off the Delmarva Peninsula, with 8% taken off New Jersey, and 0.2% off Southern Virginia - North Carolina.

Stratified mean catch per tow indices from NMFS shellfish surveys during January and December 1978 indicated no significant change in resource abundance of harvestable (>12 cm shell length) clams off Delmarva, Northern New Jersey, or Southern New Jersey. Pre-recruit indices (i.e., mean catch per tow of clams <11.9 cm) increased dramatically off Delmarva and Northern New Jersey during 1978.

Commercial catch/effort (bushels/hour) data from logbook records further suggest relative resource stability as quarterly mean catch per effort indices for the three vessel classes (0-50, 51-100, 101+ GRT) varied only slightly within offshore areas throughout 1978.

Average recruitment to the fishery should be maintained during the next several years. Accordingly, if the distribution and level of annual Middle Atlantic landings in 1979 and 1980 approximate those in 1978, commercially exploitable biomass should not change markedly in the immediate future. Significant increase in population size of harvestable clams should occur in 1981-1982 if natural mortality remains constant and fishing mortality remains minimal until then on pre-recruits sampled off Delmarva and Northern New Jersey.

Introduction

Offshore surf clam, *Spisula solidissima*, populations in the U.S. Atlantic Fishery Conservation Zone (3-200 mi = FCZ) have been managed since 17 November 1977 by a Fishery Management Plan (FMP) for the surf clam and ocean quahog fisheries developed by the Mid-Atlantic Fishery Management Council and implemented by the U.S. Department of Commerce through the National Marine Fisheries Service (NMFS). A principal objective of the FMP is to first stabilize the abundance of recently declining Middle Atlantic surf clam populations and then to rebuild these populations to levels that would sustain total annual harvests of 50 million pounds of meats. To achieve this objective, the FMP established a variety of regulations including an annual total landings quota of 1.8 million bushels (approximately 30 million pounds of meat). Resultingly, total Middle Atlantic surf clam catches from the FCZ declined 27% between 1977 and 1978 (43.0 to 31.4 million pounds; Table 1).

In this report, the effects of the 1978 surf clam harvest are examined relative to population abundance and size composition of offshore (>3 mi) Middle Atlantic surf clam resources. Data analyzed include: (1) research vessel survey results, 1976-1978; (2) commercial fishery vessel logbook records required by the FMP, 1978; (3) dock-side NMFS commercial surf clam vessel Middle Atlantic trip interview records, 1978; and (4) commercial length-frequency samples of surf clams collected during 1976-1978. The present report updates and expands commercial and research data previously presented (Brown et al. 1977; Serchuk et al. 1979).

Historical Perspective

Although the commercial harvest of surf clams began around 1870, as a bait fishery, the modern food fishery originated in the 1940's in response to wartime demands for shellfish and other protein foods (Westman and Bidwell 1946). Between 1944 and 1945, total landings increased four-fold (1.2 to 4.8 million pounds), with virtually all of the catch taken from inshore beds off Long Island, New York. In 1950, extensive offshore New Jersey beds, more dense and yielding more meat per bushel than the Long Island beds, were discovered which subsequently sustained average annual landings of 10 million pounds during 1950-1959 (Lyles 1969), and served as the major fishery resource base until the early 1970's. In this early period, production increases were also influenced by improvements in harvesting efficiency and steady increases in fleet size (Serchuk et al. 1979).

Until the mid-1960's, the offshore beds off of Northern New Jersey (those near Pt. Pleasant) were the mainstay of the surf clam fishery. As these beds became depleted, the inshore surf clam resources off Southern New Jersey (near Cape May and Wildwood) were more heavily fished. Between 1965-1970, the percentage of the total Middle Atlantic surf clam landings from the FCZ decreased from 75% to 21% (Table 1), while the inshore landings increased nearly five-fold (11.1 million pounds in 1964 to 53.1 million pounds in 1970). This trend was strikingly reversed in 1971 by the discovery and beginning of fishing on abundant offshore surf clam beds off Southern Virginia - North Carolina; from 1971-1974, total Middle Atlantic landings

were dominated by catches from this area. The subsequent collapse of the Virginia fishery stimulated a northward return of the fleet. Since 1976, the bulk of the Middle Atlantic landings have been from the offshore Delmarva region (near Ocean City, Maryland).

Research Vessel Survey Results

Distribution and relative abundance of Middle Atlantic surf clam populations have been evaluated through federal research vessel survey cruises conducted since 1965 (Ropes 1979; Serchuk et al. 1979). Results of research cruises from 1965-1977 have been previously summarized in Brown et al. (1977) and Serchuk et al. (1979).

The most recent continuous annual surf clam research vessel survey series commenced in 1976. Four Middle Atlantic surveys were conducted between 1976 and 1978 (Table 2) with the R/V DELAWARE II employing a 121.92 cm (48 in) wide hydraulic dredge. The 1976 and 1977 surveys used a grid-type survey sampling design, with stations spaced approximately 10 nautical miles apart along 10 nautical mile transect intervals. In the two 1978 cruises, a stratified random sampling scheme was employed; thus, the Middle Atlantic survey area was stratified into relatively homogeneous geographical zones on the basis of depth, bottom type, and general ecological conditions (Figure 1). Strata groupings corresponding to previously established surf clam assessment offshore fishing areas (Brown et al. 1977; Serchuk et al. 1979) are:

Northern New Jersey (NNJ):	Strata 21, 25 and 88-90
Southern New Jersey (SNJ):	Strata 17 and 87
Delmarva (DMV):	Strata 9, 10, 13, 14, and 82-86

Sampling stations were allocated to strata roughly in proportion to each stratum area and assigned to specific locations within strata at random. Additional random samples were also allotted to strata possessing known large concentrations of surf clams. A 4-min tow was taken at each station after which volume and numbers captured, shell-length, and other relevant data were recorded.

To compare the 1976 and 1977 results with the later surveys, station data from the 1976 and 1977 surveys were post-stratified before analysis into the sampling strata used in 1978.

Following procedures given by Cochran (1977:91), stratified mean catch, in numbers, per tow for strata groupings (NNJ, SNJ, and DMV) was calculated by

$$\bar{Y}_{st} = \frac{\sum_{h=1}^L (N_h \bar{Y}_h)}{L}$$

where \bar{Y}_{st} = stratified mean catch, in numbers, per tow

N_h = area of the hth stratum

\bar{Y}_h = mean catch, in numbers, per tow of the hth stratum, and

L = number of strata in the strata grouping

Individual strata catch length frequencies were prorated from measured sub-samples, and then the stratified mean catches partitioned into 1 cm length intervals. Relative abundance catch (numbers) per tow indices were derived for pre-commercial sized clams (i.e., pre-recruits, ≤ 11.9 cm shell length), commercial sized clams (≥ 12.0 cm shell length), and total clams caught per tow.

Research Vessel Relative Abundance Indices

Research vessel relative abundance indices (stratified mean number per tow) obtained from the 1976-1978 Middle Atlantic shellfish assessment cruises are presented by offshore surf clam fishery areas (NNJ, SNJ, and DMV) in Table 3. Results derived from each of these areas are separately discussed.

Northern New Jersey

All Northern New Jersey relative abundance indices declined sharply between 1976 and 1977, primarily due to population losses caused by anoxic bottom water conditions during summer 1976. Total numbers per tow declined 81% (8.27 to 1.57); pre-recruit and commercial-size indices declined 16% and 90%, respectively (Table 3). Significantly, the relative effects of the anoxic and fishing mortality during the year were severer on harvestable sized clams than on pre-recruits (Figures 2 and 3).

Between 1977 and December 1978 (Cruise 78-07), the commercial-sized relative abundance indices remained at relatively low levels (0.47 to 0.97 clams per tow). Pre-recruit indices, however, stable in 1977 and January 1978 (Cruise 78-01), increased 33 fold in the December 1978 survey, with the latter value (27.80) being the highest in the 1976-1978 period. Due to this successful recruitment, the total number per tow index in December 1978 was 28.77, 22 times larger than in January 1978, and 3.5 fold greater than the 1976 value.

Southern New Jersey

Total and commercial-sized relative abundance indices in Southern New Jersey exhibited no apparent trends between 1976 and 1978 (Figures 4 and 5),

fluctuating between 1.44-9.56 and 0.66-7.97 respectively (Table 3). Pre-recruit indices, however, steadily increased from 0.24 clams per tow in 1976 to 2.00 clams per tow in December 1978 (Figure 5).

The Southern New Jersey commercial-sized catch per tow indices reflect, in part, the differential geographic effects of the 1976 bottom water anoxic in offshore New Jersey; the 1976 index of recruit sizes was about half that obtained in Northern New Jersey (3.09 vs 7.25), but 6 times greater in 1978 than the corresponding 1978 Northern New Jersey commercial-size index (3.54 vs 0.97-Table 3). In any case, the fluctuations in catch per tow in Southern New Jersey were much less drastic than in the Northern New Jersey area.

Delmarva

All Delmarva relative abundance indices declined by greater than 44% between 1976 and 1977 (pre-recruit: -45%; commercial size: -59%; total: -48%) (Table 3; Figures 6 and 7). Since 1977, the commercial size indices have annually trended slightly downward (5.84 in 1977; 4.14 in December 1978), although this decline is probably not significant given the sampling variability associated with the shellfish surveys. Contrariwise, the marked increase in the pre-recruit index in December 1978 (394.23) from the previous values observed during 1976 - January 1978 (3.50, 1.45, and 2.57) implies a recent significant increase in the abundance of pre-recruit clams in the Delmarva region. Large catches of pre-recruit individuals in the December 1978 survey in stratum 85 (off of Ocean City, Maryland) and stratum 9 indicated a wide-spread distribution of small clams in offshore waters from Chincoteague to Cape Charles, Virginia.

Preliminary analysis of the January 1979 shellfish research vessel survey cruise, conducted with a 152.40 cm (60 in) wide hydraulic clam dredge equipped with a submersible pumping system, corroborated the December 1978 pre-recruit findings since the increased abundance of small clams in both Delmarva and Northern New Jersey was noted in this latest survey as well.

Commercial Catch Per Effort

Relative abundance indices for Middle Atlantic surf clam populations during 1978 were also derived from commercial catch per unit effort data (bushels landed per hour fished). Commercial logbook records, mandated by the surf clam FMP, were examined for individual trip information on catch (bushels), hours fished, catch location (LORAN bearings, or latitude-longitude designation), date of catch, and vessel size. Since three vessel tonnage size classes are recognized in the surf clam FMP, catch per effort indices were calculated separately for each vessel class. These classes are:

<u>Vessel Class</u>	<u>Gross Registered Tonnage (GRT)</u>	<u>Number of Vessels</u>
1	1-50	20
2	51-100	58
3	101+	74

Each vessel trip record that possessed complete or sufficient data for analysis was assigned to a principal assessment - offshore fishery area (NNJ, SNJ, or DMV) based on supplied catch location information. LORAN C-Y bearings demarcating these major areas are provided in Figure 1. Catch and effort data were further categorized temporally by calendar quarter.

Mean catch per hour was computed, by area and calendar quarter, for each vessel class by

$$M_{c/f} = \frac{1}{n} \sum_{i=1}^n \frac{c_i}{f_i}$$

where $M_{c/f}$ = mean catch (bushels) per hour fished
 c_i = catch in bushels in trip i
 f_i = number of hours fished in trip i , and
 n = total number of trips

Standard deviations and standard errors were also computed for each of the mean catch per hour estimates (Cochran 1977).

Commercial Abundance Indices in 1978

Catch and effort statistics derived from vessels operating in the Middle Atlantic surf clam fishery during 1978 are summarized by major area fished, vessel class and calendar quarter in Table 4 and Figures 8-10. Results from each of the fishery are discussed separately below.

Northern New Jersey

A total of 102 trip records from the offshore Northern New Jersey area were amenable to analysis. No Class 1 vessels reported sufficient data for deriving abundance indices for any calendar quarter during 1978. Catch per hour fished for vessels in Classes 2 and 3 varied considerably both within and between quarters during the year (Figure 8), although no significant differences were detected in vessel class mean catch per effort values among calendar quarters. Mean quarterly catch per hour for Class 2 vessels ranged from 13.80 bushels per hour (Quarter 2) to 26.74 bushels per hour (Quarter 4)

(Table 4). For Class 3 vessels, seasonal mean catch rates varied between 19.30 bushels per hour (Quarter 4) and 24.19 bushels per hour (Quarter 2). Overall, the weighted mean catch per hour for Class 2 and 3 vessels was 17.67 and 21.01 bushels, respectively, implying that Class 3 vessels operating in Northern New Jersey caught 19% more per hour than Class 2 vessels in this region. This difference, however, is not statistically significant.

Southern New Jersey

Vessels operating during 1978 in offshore Southern New Jersey completed 292 trips amenable for catch and effort analysis (Class 1: 57 trips, Class 2: 115 trips; Class 3: 120 trips). In every quarter, mean catch per effort was highest for Class 3 vessels and lowest for Class 1 vessels (Figure 9; Table 4). Within a vessel class, no significant differences in quarterly mean catch rates were detected. The lack of significant declines in catch per hour throughout the year suggests no significant reduction in the abundance of Southern New Jersey surf clams if effort was proportional to fishing mortality rates.

Mean quarterly catch rates for Class 1 vessels ranged from 11.10 - 13.19 bushels per hour. Class 2 quarterly mean catch per tow values varied between 14.92 and 22.69 bushels per hour, while Class 3 quarterly mean catch per effort indices ranged between 17.82 and 27.52 bushels per hour. Yearly weighted mean catch rates for vessel Classes 1, 2, and 3 were 12.28, 18.76, and 23.64, respectively. The mean catch rates for vessel Classes 2 and 3 in Southern New Jersey were thus slightly greater than corresponding values for Northern New Jersey.

Delmarva

A total of 3,062 trips during 1978 in offshore Delmarva were analyzed for commercial catch per effort data (Class 1: 218 trips; Class 2: 1,087 trips; Class 3: 1,757 trips). Delmarva vessel trip records comprised 89% of the total Middle Atlantic offshore logbook records sufficiently detailed for 1978 commercial catch/effort analysis.

Temporal patterns in Delmarva surf clam catch rates, both within and between vessel class groupings, were similar to those noted in Southern New Jersey, viz: within each calendar quarter, Class 3 vessels exhibited the highest mean catch per hour and Class 1 vessels the lowest, and within each vessel class, seasonal mean catch rates exhibited little fluctuation throughout the year (Table 4; Figure 10).

Mean quarterly catch per effort values within any of the three vessel classes in Delmarva never varied over time by more than 3.3 bushels per hour. Average overall catch rates for the three tonnage classes were 16.67, 20.13, and 29.74 bushels per hour, respectively, and hence were higher than corresponding vessel class catch rates in either Northern or Southern New Jersey.

Yield Per Recruit

Yield per recruit analyses for Middle Atlantic surf clams were accomplished using the Paulik and Gales' (1964) model with $W_{\infty} = 174.8$ g, $k = 0.3189$, $t_0 = 0.1874$ years, $t_r = 0.25$ years, $M = 0.25$ (slightly greater than the total mortality rate of unexploited Canadian surf clam populations sampled by Caddy and Billard 1976), $t_{\lambda} = 16.0$ years, $F = 0.1-2.0$, and $t_c = 0.25-8.0$ years. Growth relationships (von Bertalanffy growth-in-length equation;

shell length-drained meat weight equation) and associated growth parameters were determined from commercial surf clam samples taken off the Delmarva Peninsula (Table 5; Figure 11).

Maximum yield per recruit (F_{\max}) occurs at an age of first capture (t_c) of 4.5 years and an instantaneous fishing mortality of $F = 2.0$ (Table 6; Figure 12). Under these conditions, the mean shell length at first capture is 12.5 cm.

For almost all F values, conditional maximum yield per recruit increases as age at first capture is increased until age 4 (about 11.8 cm shell length). At F levels less than 1.5, yield per recruit decreases when age at first capture is increased beyond age 4.

If high fishing mortality rates (i.e., >1.5) are maintained, few individuals >12 cm shell length survive to spawn, and thus reproduction may be dependent on recent year classes of small individuals. Moderate fishing levels support a heterogeneous age structure in the spawning population, that may be necessary when several poor year classes occur in succession.

Commercial Catch Size Composition

Shell length-frequency distributions of commercial landings of surf clams from the principal Middle Atlantic assessment-offshore fishery areas (NNJ, SNJ, and DMV) during 1976-1978 are presented in Figures 13-15. Length-frequency samples were obtained from dock-side catch sampling in which typically five subsamples of six clams were measured from a trip landing. Overall offshore areal commercial size composition was derived by weighting

each sample length frequency distribution by the total catch in bushels taken during the trip and then summing over all sampled trips during the year. Surf clam catches in depths less than 10 fm were excluded from analysis since these would normally not be from the offshore populations.

Commercial length-frequency distributions in all three of the major offshore regions during 1976-1978 are similar (Figures 13-15). Modal size values occurred at 16-17 cm shell length with clams larger than 20 cm or smaller than 12 cm rarely present in the sampled landings. The virtual absence of clams smaller than 12 cm implies size selectivity in the fishery since research vessel survey size-frequency distributions in 1976-1978 indicated significant segments of the Middle Atlantic populations to be smaller than 12 cm (Table 3). The commercial catch composition hence reflects culling practices or the concentration of harvests on beds of predominantly large surf clams. Since maximum yield per recruit occurs at a size at first capture of about 12 cm, there appears little need to implement a minimum size restriction in the current fishery to increase potential biological yield. Future changes in cull sizes or significant dredge-induced mortality on pre-recruit clams, however, may necessitate re-evaluation of size at first capture considerations if yield per recruit is to be maximized.

Current Status and Future Outlook of Middle Atlantic Surf Clam Populations

In 1978, total landings of surf clams from offshore Middle Atlantic populations were 31.4 million pounds (Table 1). Of this total, approximately 28.8

million pounds were taken from the Delmarva area (92% of 1978 commercial FCZ landings), 2.5 million pounds from offshore New Jersey (8%), and less than 0.06 million pounds from Southern Virginia-North Carolina (0.2%).

Research vessel survey relative abundance indices during 1978 indicated no significant declines in commercial size (≥ 12 cm shell length) surf clam abundance in any of the three major offshore fishery areas during the year. Commercial quarterly mean catch per effort indices varied only slightly within offshore areas throughout 1978 further suggesting relative resource stability.

Survey catch per tow indices for intermediate sized surf clams (9-11 cm shell length) have not fluctuated greatly since 1976, particularly off Southern New Jersey and Delmarva. Hence, average recruitment to the fishery should be maintained during the next several years. Accordingly, if the distribution and level of annual Middle Atlantic landings in 1979 and 1980 approximate those in 1978, the commercially exploitable biomass should not change markedly in the immediate future. However, if total catches of surf clams from the Middle Atlantic assessment areas greatly exceed the 30 million lb level in 1979 or 1980, accelerated declines in the abundance of clams ≥ 12 cm shell length will probably result. Growth rate analyses (Figure 11; Jones et al. 1978) imply that the wide-spread pre-recruit resources, indicated during the December 1978 and January 1979 research vessel surveys off Delmarva and Northern New Jersey will recruit to the fishery by 1981 or 1982. Significant increases in population size of harvestable clams

should occur in these years if natural mortality remains constant and fishing mortality remains minimal on these pre-recruit clams until then. Future research vessel survey monitoring of the relative abundance of pre-recruits in 1980 and 1981 should more precisely establish the relative size and impact of these surf clams on harvestable resource abundance.

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Table 1. Total Middle Atlantic surf clam landings ($\times 10^{-3}$ lbs of meat), landings from the FCZ and percentage of total landings taken beyond 3 miles from shore.

Year	Total	> 3 Miles	Percent caught > 3 miles from shore
1965	44,087	33,000	74.85
1966	45,078	32,400	71.88
1967	45,943	24,700	53.76
1968	40,534	20,000	49.34
1969	49,562	15,900	32.08
1970	67,155	14,100	21.00
1971	52,362	50,053	95.59 ^a
1972	63,310	55,272	87.30 ^a
1973	82,308	72,579	88.18 ^a
1974	96,069	74,430	77.48 ^a
1975	86,880	44,270	50.96 ^a
1976	49,032	42,558	86.80 ^a
1977	51,200	42,968	83.92 ^a
1978		31,399 ^b	

^aProrations for 1971-1977 are based on data presented in the series Fisheries of The United States, published annually by the U.S. Fish and Wildlife Service, and in later years The National Marine Fisheries Service. Earlier data based on interview information collected by the Bureau of Commercial Fisheries.

^bSummation of log book reports, includes landings of approximately 27,200 lbs by vessels registered in New England ports.

Table 2. Ocean shellfish research cruises used in the analysis of surf clam populations.

Cruise dates (month/year)	Research vessel	Time of tow (minutes)	Knife width (inches)
12/78 (78-07)	DELAWARE II	4	48
1-2/78 (78-01)	DELAWARE II	4	48
1-3/77 (77-01)	DELAWARE II	4	48
4-5/76 (76-01)	DELAWARE II	4	48

Table 3. Summary of stratified mean catch per tow data for surf clams during shellfish assessment cruises, 1976-1978.

Area	Cruise	Total #/tow	#/Tow $\leq 119\text{mm}$	#/Tow $\geq 120\text{mm}$
N. N.J.	78-07	28.77	27.80	0.97
	78-01	1.32	0.85	0.47
	77-01	1.57	0.86	0.71
	76-01	8.27	1.02	7.25
S. N.J.	78-07	5.54	2.00	3.54
	78-01	9.56	1.59	7.97
	77-01	1.44	0.78	0.66
	76-01	3.33	0.24	3.09
DMV	78-07	398.37	394.23	4.14
	78-01	7.44	2.57	4.87
	77-01	7.29	1.45	5.84
	76-01	14.06	3.50	10.56

Table 4. Commercial catch/effort data for surf clam vessels operating in the FCZ off New Jersey and Delmarva in 1978.

Area	Tonnage class	Quarter	Tot. bu clams	Tot.hr. fished	Mean bu/hr.	σ bu/hr.	SE bu/hr.	Min. bu/hr.	Max. bu/hr.	# Trips
N.N.J.	1-50	1	0	0.00	-	-	-	-	-	0
		2	0	0.00	-	-	-	-	-	0
		3	0	0.00	-	-	-	-	-	0
		4	0	0.00	-	-	-	-	-	0
	51-100	1	384	16.00	23.37	7.18	5.08	18.29	28.44	2
		2	1,782	104.00	18.13	13.58	4.09	0.63	45.00	11
		3	4,774	385.5	13.80	8.19	1.35	3.75	40.00	37
		4	2,290	79.00	26.74	9.22	2.47	11.00	44.80	14
	101+	1	0	0.00	-	-	-	-	-	0
		2	6,517	270.50	24.19	8.79	2.44	11.58	46.83	13
		3	3,370	159.00	19.41	5.96	1.72	7.50	27.29	12
		4	3,217	167.00	19.30	13.51	3.75	6.44	53.33	13
S.N.J.	1-50	1	258	22.00	11.73	0.00	0.00	11.73	11.73	1
		2	1,243	77.00	14.42	10.69	4.78	6.58	32.90	5
		3	2,628	238.50	11.10	6.93	1.33	1.72	24.00	27
		4	2,585	199.00	13.19	6.85	1.40	3.60	28.67	24
	51-100	1	2,354	157.00	14.92	3.49	1.10	8.73	22.86	10
		2	8,464	542.00	15.46	3.15	0.51	8.20	24.00	38
		3	6,720	344.50	19.57	12.33	2.18	6.67	53.00	32
		4	7,806	360.00	22.69	14.87	2.51	0.75	75.83	35
	101+	1	3,841	205.30	17.82	4.62	1.39	12.80	25.14	11
		2	14,862	760.50	20.11	13.55	2.29	3.13	63.30	35
		3	9,714	398.00	23.98	12.10	2.29	7.00	46.94	28
		4	15,910	561.00	27.52	17.81	2.63	0.33	73.14	46
DMV	1-50	1	1,173	82.50	13.74	3.42	1.53	9.20	16.70	5
		2	16,152	1044.00	16.73	14.76	1.74	6.67	130.67	72
		3	17,454	1022.00	17.03	6.03	0.65	5.40	32.50	85
		4	9,347	592.80	16.32	5.79	0.77	7.11	41.00	56
	51-100	1	10,165	485.25	22.23	7.82	1.41	9.75	37.58	31
		2	107,092	5359.75	20.28	7.02	0.37	3.75	69.33	357
		3	91,566	4601.70	19.88	6.98	0.36	1.33	45.33	380
		4	80,159	3961.10	20.04	5.99	0.34	6.50	40.00	319
	101+	1	47,827	1632.50	28.15	16.36	1.94	8.67	89.90	71
		2	282,544	10511.15	27.46	13.82	0.61	1.04	90.67	509
		3	256,737	8451.75	31.24	17.10	0.68	0.22	117.33	641
		4	216,309	7302.50	30.31	17.36	0.75	2.67	121.50	536

Table 5. Calculated mean shell lengths and meat weights at age for surf clams from offshore waters of the Middle Atlantic.

Age	Shell ¹ length (mm)	Meat ² weight (g)
1	38.17	3.63
2	73.40	20.18
3	99.01	44.25
4	117.63	69.52
5	131.17	92.51
6	141.01	111.84
7	148.16	127.33
8	153.36	139.38
9	157.14	148.57
10	159.89	155.49
11	161.88	160.62
12	163.33	164.42
13	164.39	167.23
14	165.16	169.29
15	165.72	170.80
16	166.12	171.88

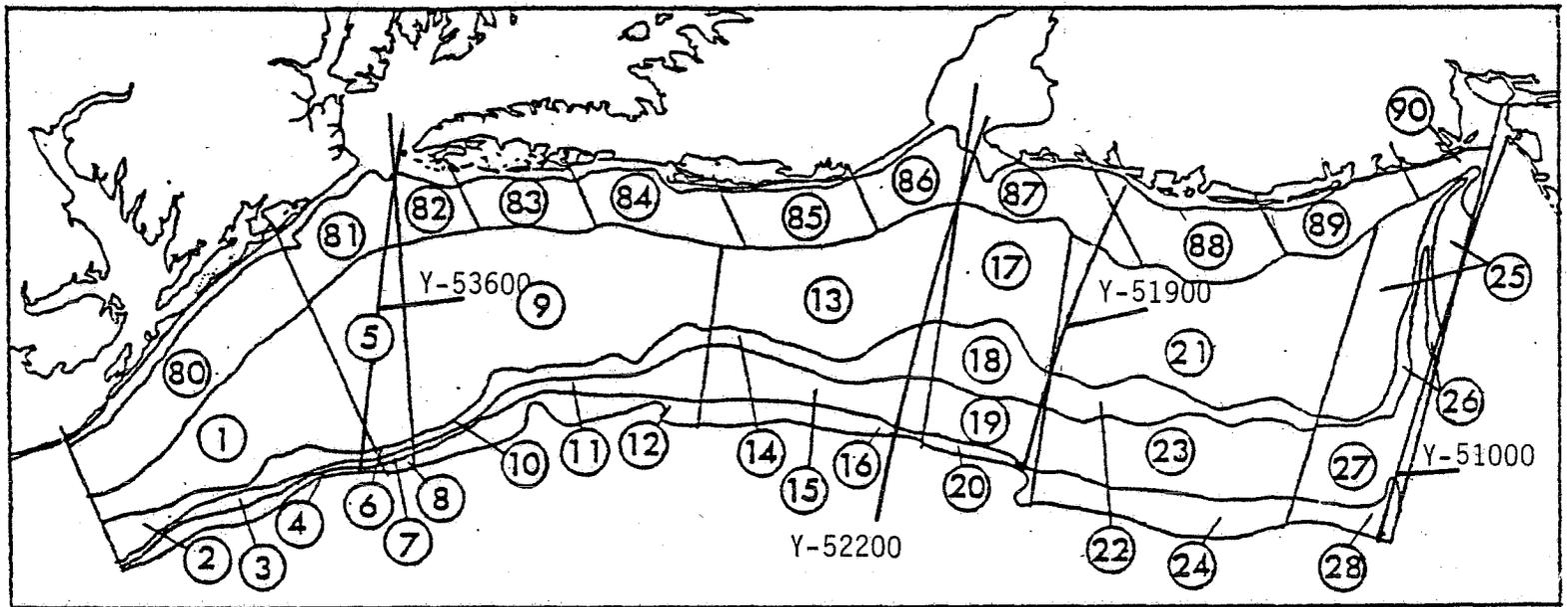
¹Computed from $L_t = 167.20 [1 - e^{-0.3189(t-0.1874)}]$ (source NMFS commercial samples).

²Computed from $\log_{10} W = -3.5876 + 2.6224 \log_{10} L$ (source NMFS commercial samples).

Table 6. Yield per recruit (g) for Middle Atlantic offshore surf clams with various instantaneous rates of fishing mortality (F) and age at first selection (t_c). Natural mortality (M)=0.25, and age at recruitment = 0.25, shell lengths (mm) corresponding to various ages in parentheses.

F	AGE AT ENTRY							
	2.0 (73.40)	2.5 (87.23)	3.0 (99.01)	3.5 (109.06)	4.0 (117.63)	4.5 (124.94)	5.0 (131.17)	5.5 (136.48)
0.1	14.13	14.06	13.74	13.22	12.55	11.77	10.92	10.05
0.2	19.46	19.87	19.84	19.41	18.69	17.73	16.63	15.44
0.3	21.46	22.41	22.77	22.59	21.99	21.06	19.89	18.59
0.4	22.07	23.52	24.26	24.35	23.92	23.07	21.92	20.58
0.5	22.09	23.96	25.03	25.38	25.12	24.37	23.27	21.93
0.6	21.84	24.07	25.43	26.01	25.90	25.26	24.21	22.89
0.7	21.48	24.00	25.62	26.39	26.43	25.88	24.90	23.60
0.8	21.08	23.85	25.69	26.63	26.80	26.35	25.42	24.15
0.9	20.68	23.66	25.69	26.78	27.07	26.69	25.82	24.58
1.0	20.29	23.56	25.64	26.87	27.26	26.96	26.13	24.92
1.1	19.92	23.24	25.57	26.92	27.40	27.17	26.39	25.20
1.2	19.57	23.04	25.49	26.94	27.51	27.33	26.59	25.44
1.3	19.25	22.84	25.40	26.95	27.59	27.47	26.77	25.63
1.4	18.96	22.64	25.31	26.94	27.64	27.58	26.91	25.80
1.5	18.68	22.46	25.21	26.92	27.69	27.67	27.03	25.94
1.6	18.43	22.29	25.12	26.90	27.72	27.74	27.14	26.07
1.7	18.20	22.13	25.03	26.87	27.74	27.80	27.23	26.18
1.8	17.98	21.98	24.95	26.84	27.76	27.86	27.31	26.27
1.9	17.78	21.84	24.86	26.81	27.77	27.90	27.37	26.36
2.0	17.59	21.71	24.78	26.78	27.78	27.94	27.43	26.43

Figure 1. Ocean shellfish survey strata off the United States Atlantic coast, New Jersey to Cape Hatteras. Loran C-Y bearings delineating surf clam assessment areas are also given.



Offshore								
Strata No.	Square Miles	Depth (fms)	Strata No.	Square Miles	Depth (fms)	Strata No.	Square Miles	Depth (fms)
1	1163	15-25	9	2171	15-25	25	648	15-25
2	175	25-30	10	152	25-30	17	749	15-25
3	126	30-40	11	229	30-40	18	249	25-30
4	117	40-60	12	204	40-60	19	274	30-40
5	453	15-25	13	1127	15-25	20	120	40-60
6	62	25-30	14	219	25-30	21	1650	15-25
7	46	30-40	15	394	30-40	22	312	25-30
8	74	40-60	16	211	40-60	23	714	30-40
						24	476	40-60
Inshore								
80	767	5-15	84	417	5-15	88	578	5-15
81	360	5-15	85	382	5-15	89	382	5-15
82	180	5-15	86	203	5-15	90	182	5-15
83	241	5-15	87	479	5-15			

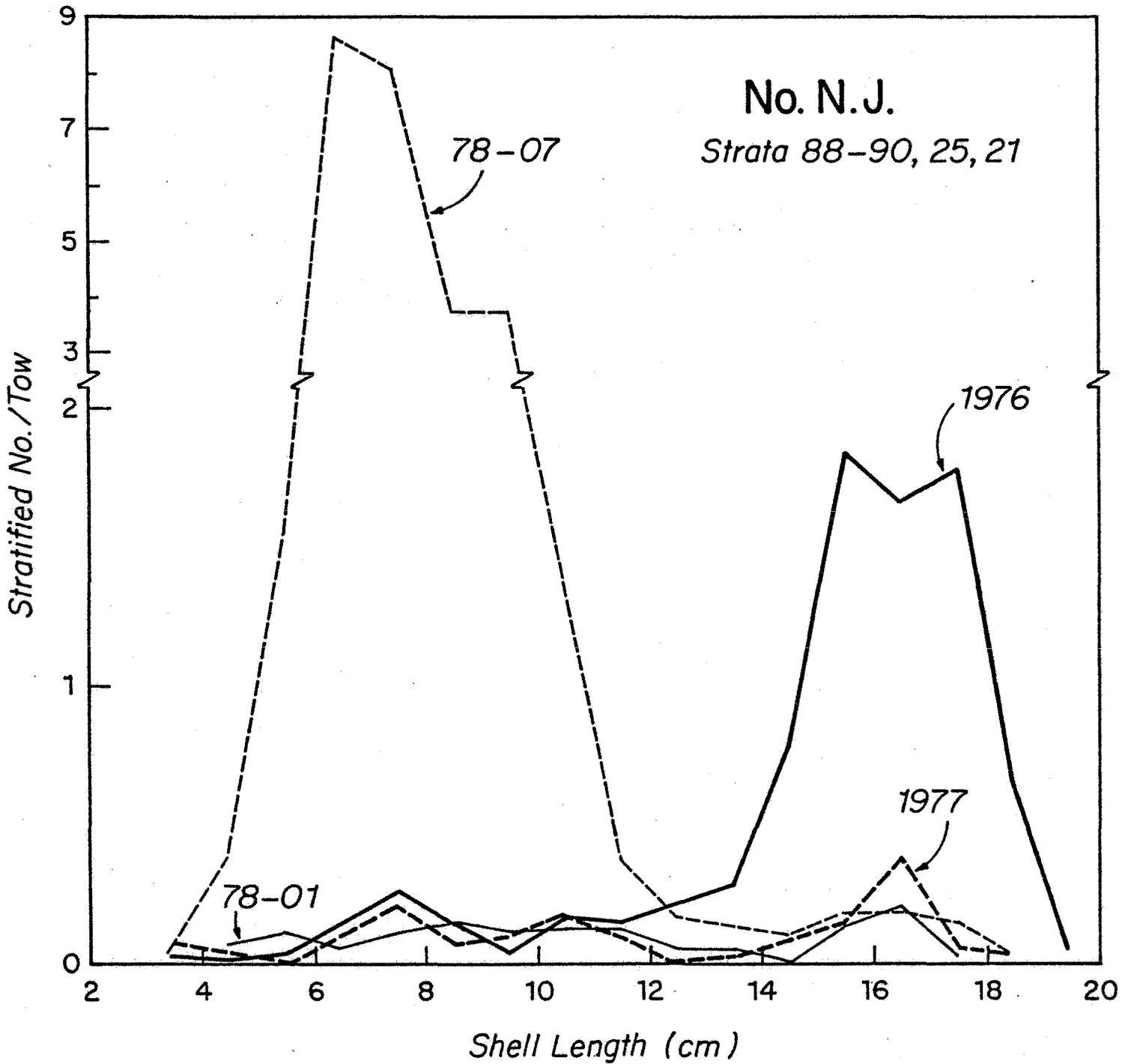


Figure 2. Stratified mean number of surf clams taken per 4 minute tow with 48" survey dredge in each 1 cm shell length group, from Northern New Jersey 1976-1978.

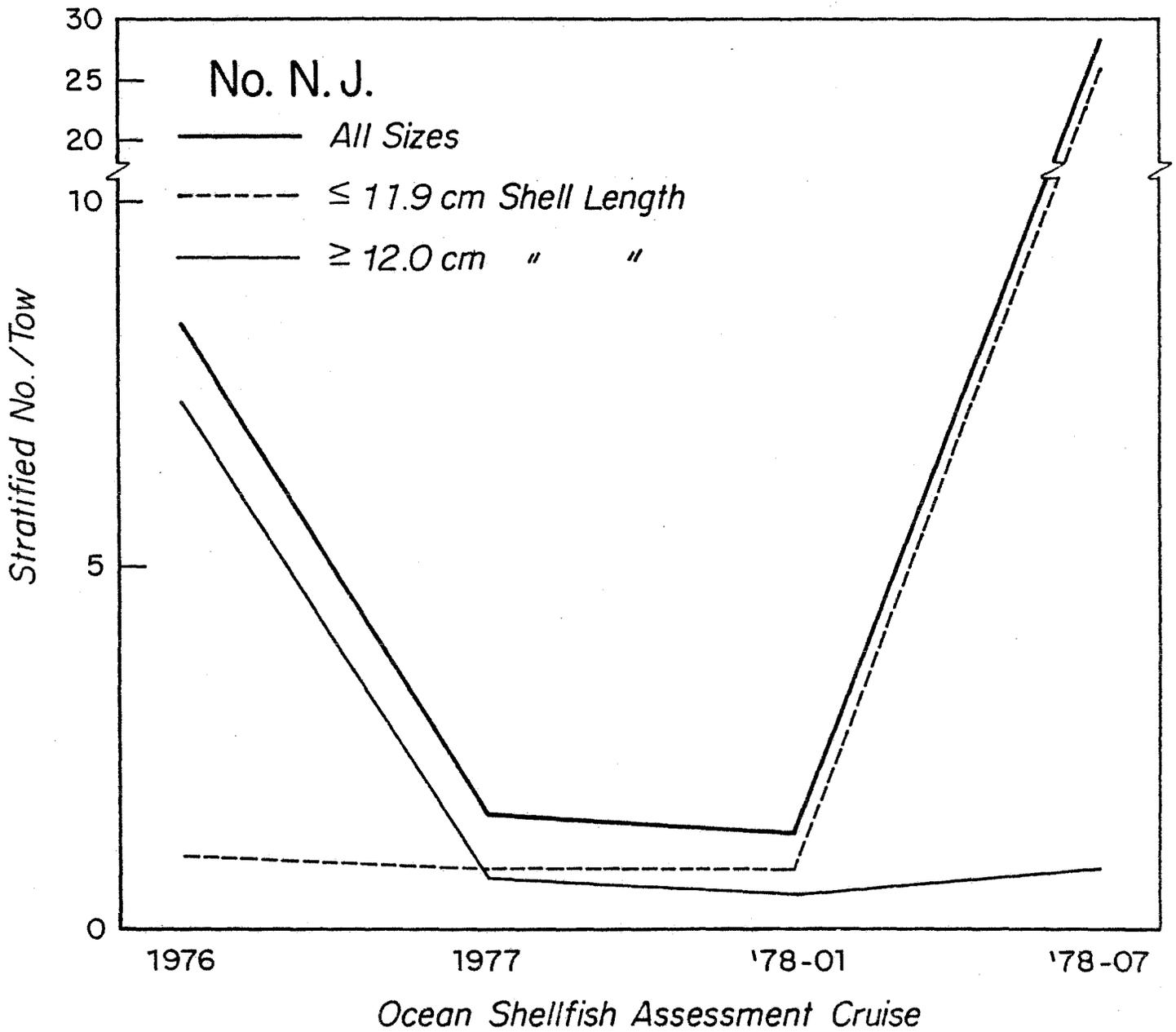


Figure 3. Stratified mean number of surf clams taken per 4 minute tow with 48" survey dredge off Northern New Jersey, 1976-1978. Values given for all sizes, pre-recruits (<11.9 cm shell length), and harvestable sizes (>12.0 cm shell length).

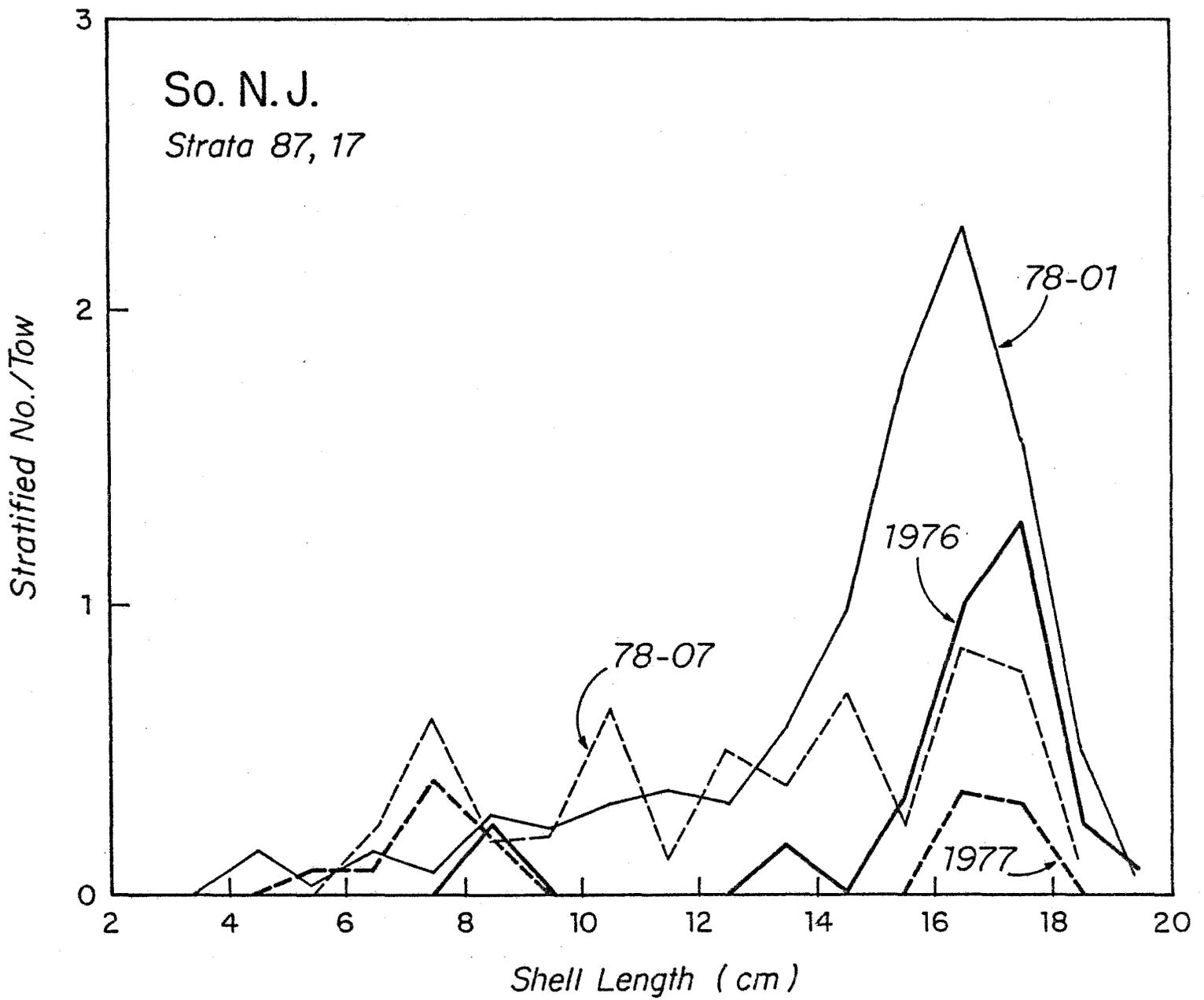


Figure 4. Stratified mean number of surf clams taken per 4 minute tow with 48" survey dredge in each 1 cm shell length group, from Southern New Jersey, 1976-1978.

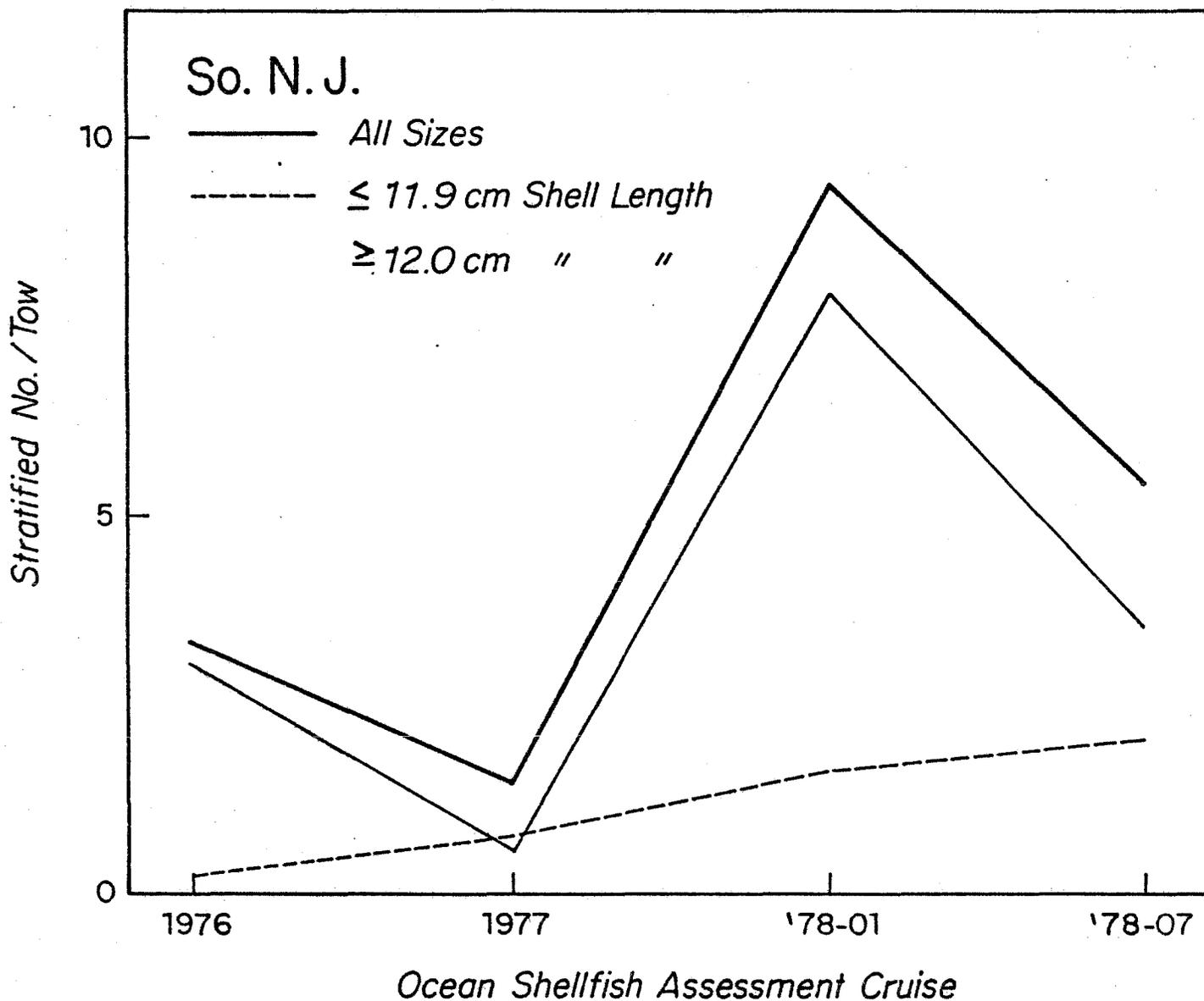


Figure 5. Stratified mean number of surf clams taken per 4 minute tow with 48" survey dredge off Southern New Jersey, 1976-1978. Values given for all sizes, pre-recruits (<11.9 cm shell length) and harvestable sizes (>12.0 cm shell length).

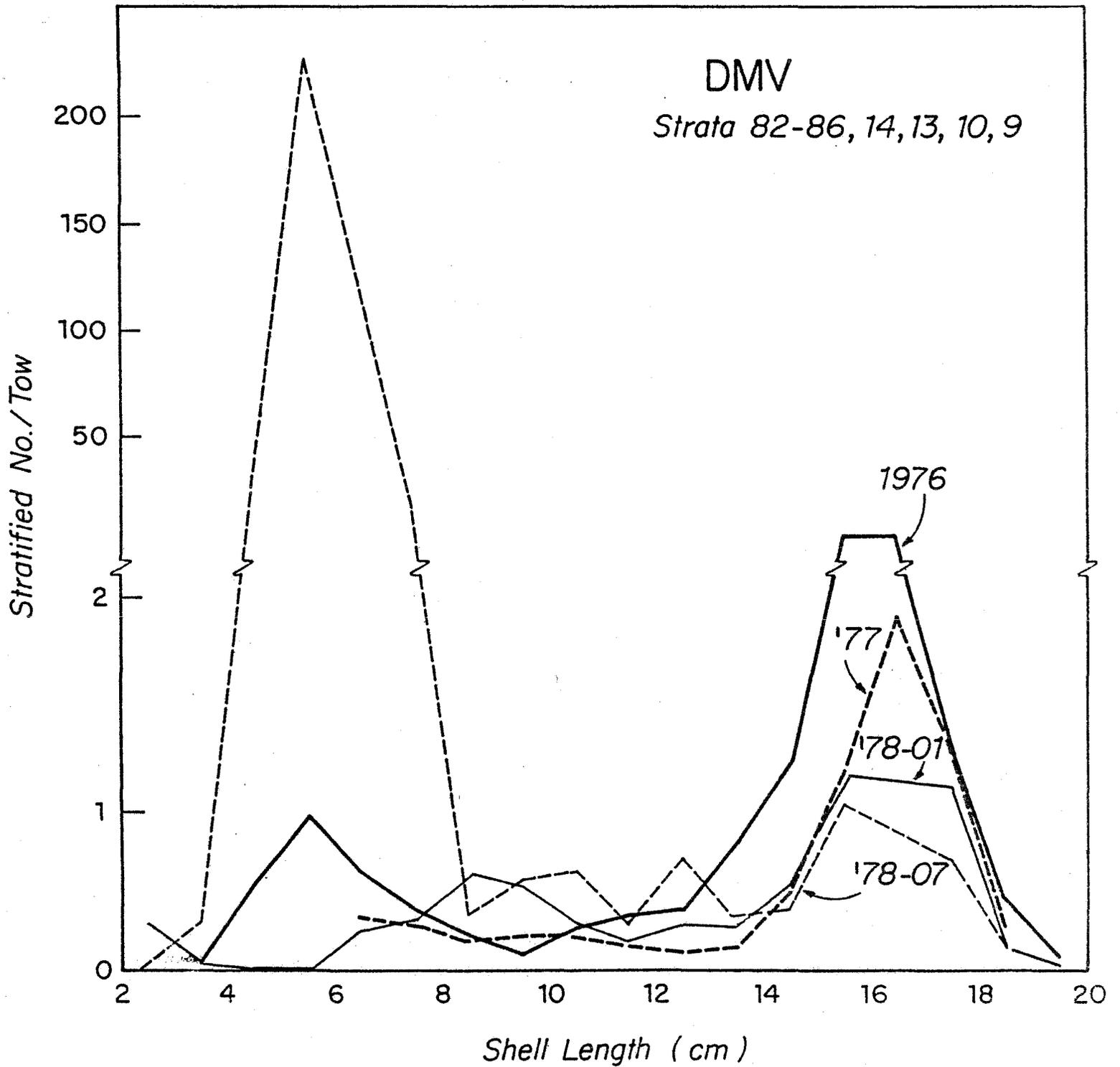


Figure 6. Stratified mean number of surf clams taken per 4 minute tow with 48" survey dredge in each 1 cm shell length group, from Delmarva 1976-1978.

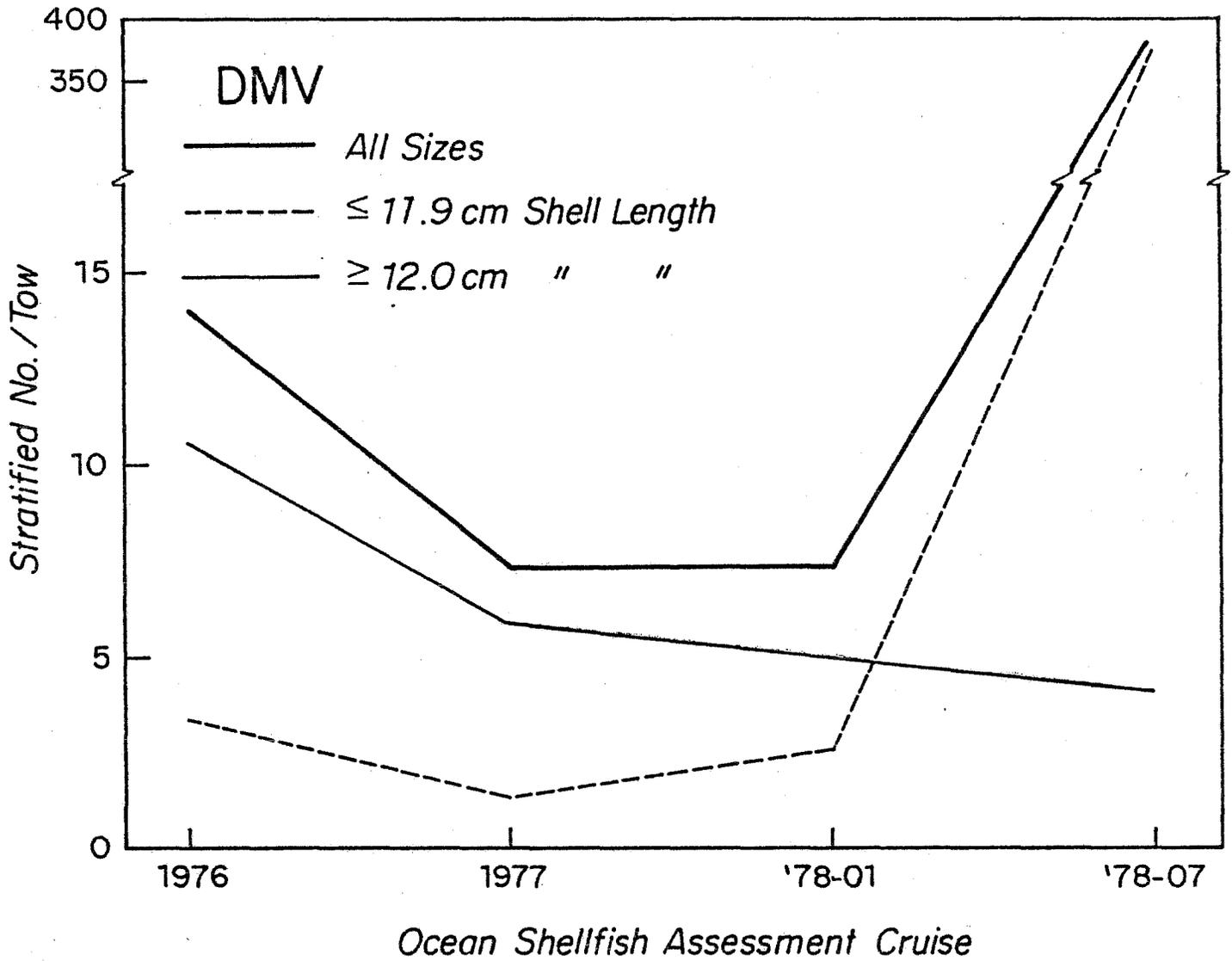


Figure 7. Stratified mean number of surf clams taken per 4 minute tow with 48" survey dredge off Delmarva, 1976-1978. Values given for all sizes, pre-recruits (<11.9 cm shell length) and harvestable sizes (>12.0 cm shell length).

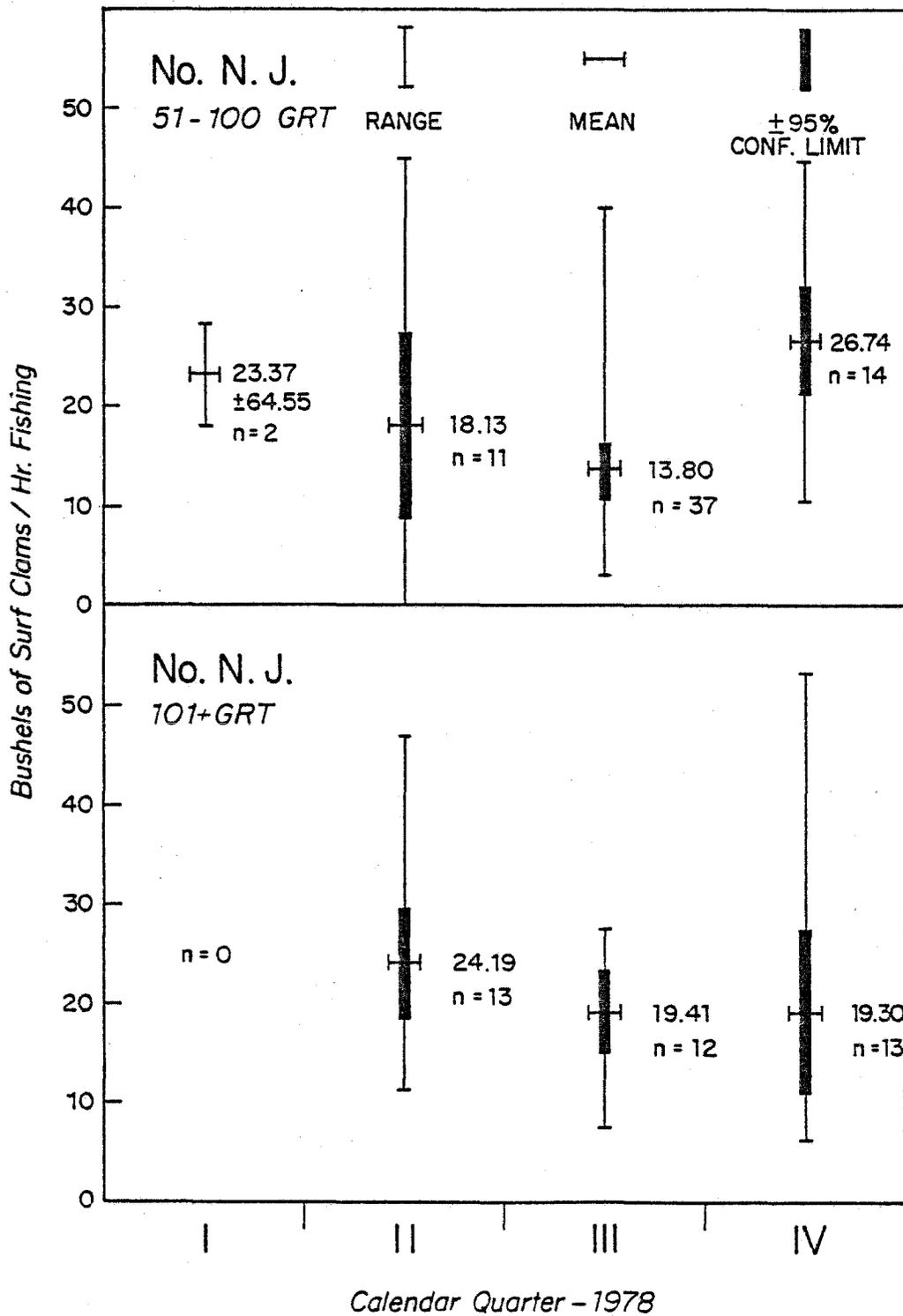


Figure 8. Commercial catch per effort data for vessels operating off Northern New Jersey during 1978. Values expressed as bushels of surf clams per hour fishing.

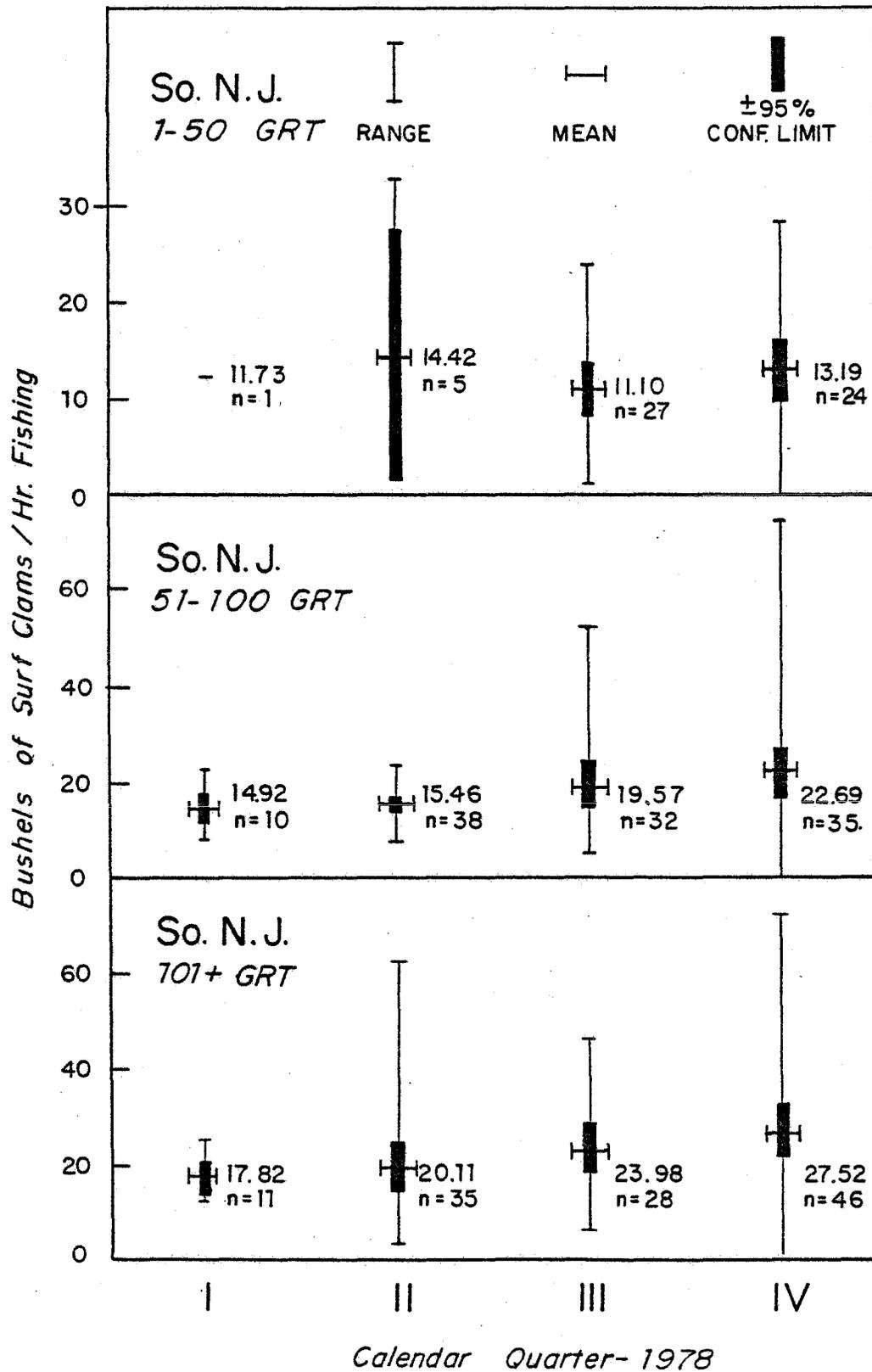


Figure 9. Commercial catch per effort data for vessels operating off Southern New Jersey during 1978. Values expressed as bushels of surf clams per hour fishing.

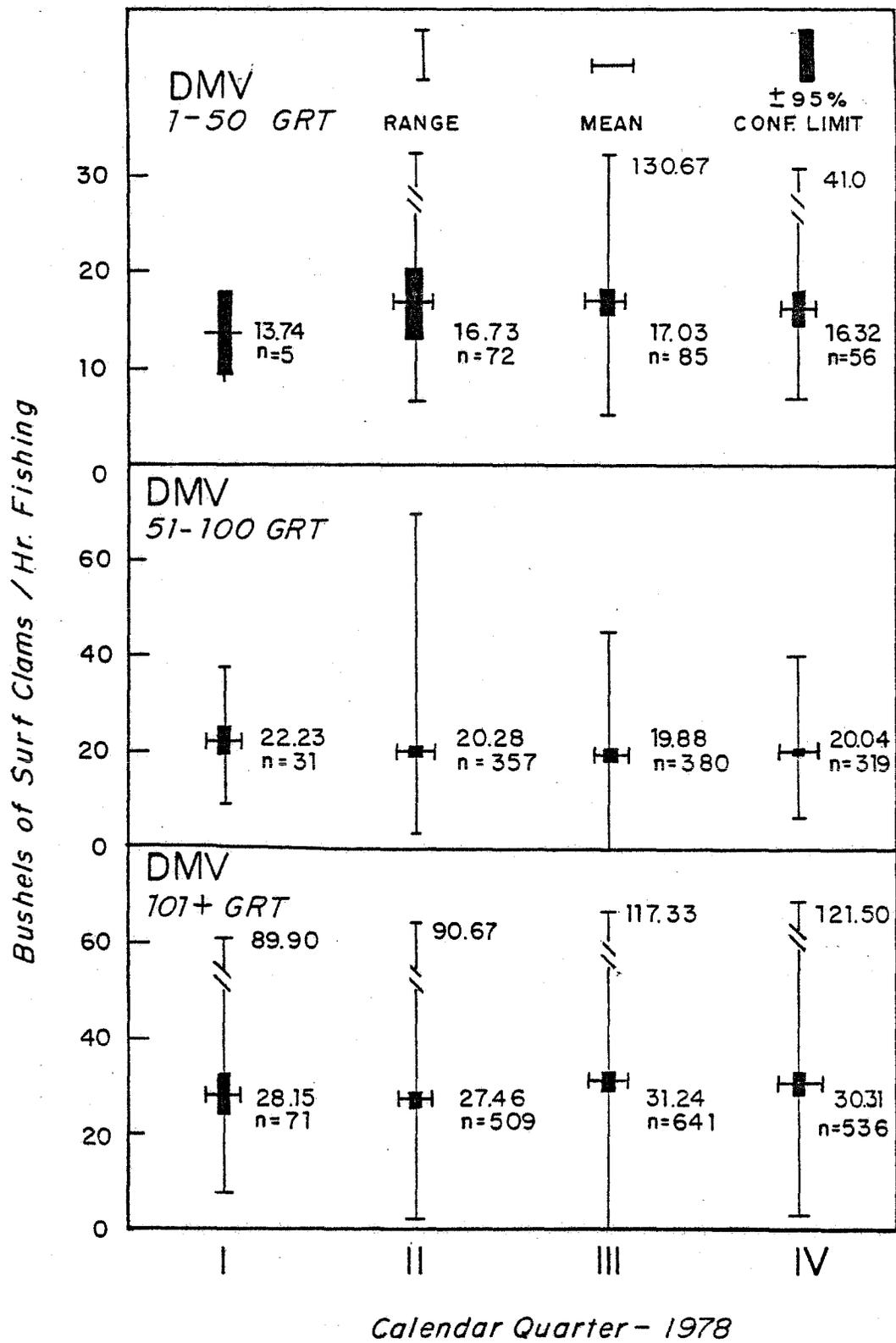


Figure 10. Commercial catch per effort data for vessels operating off Delmarva during 1978. Values expressed as bushels of surf clams per hour fishing.

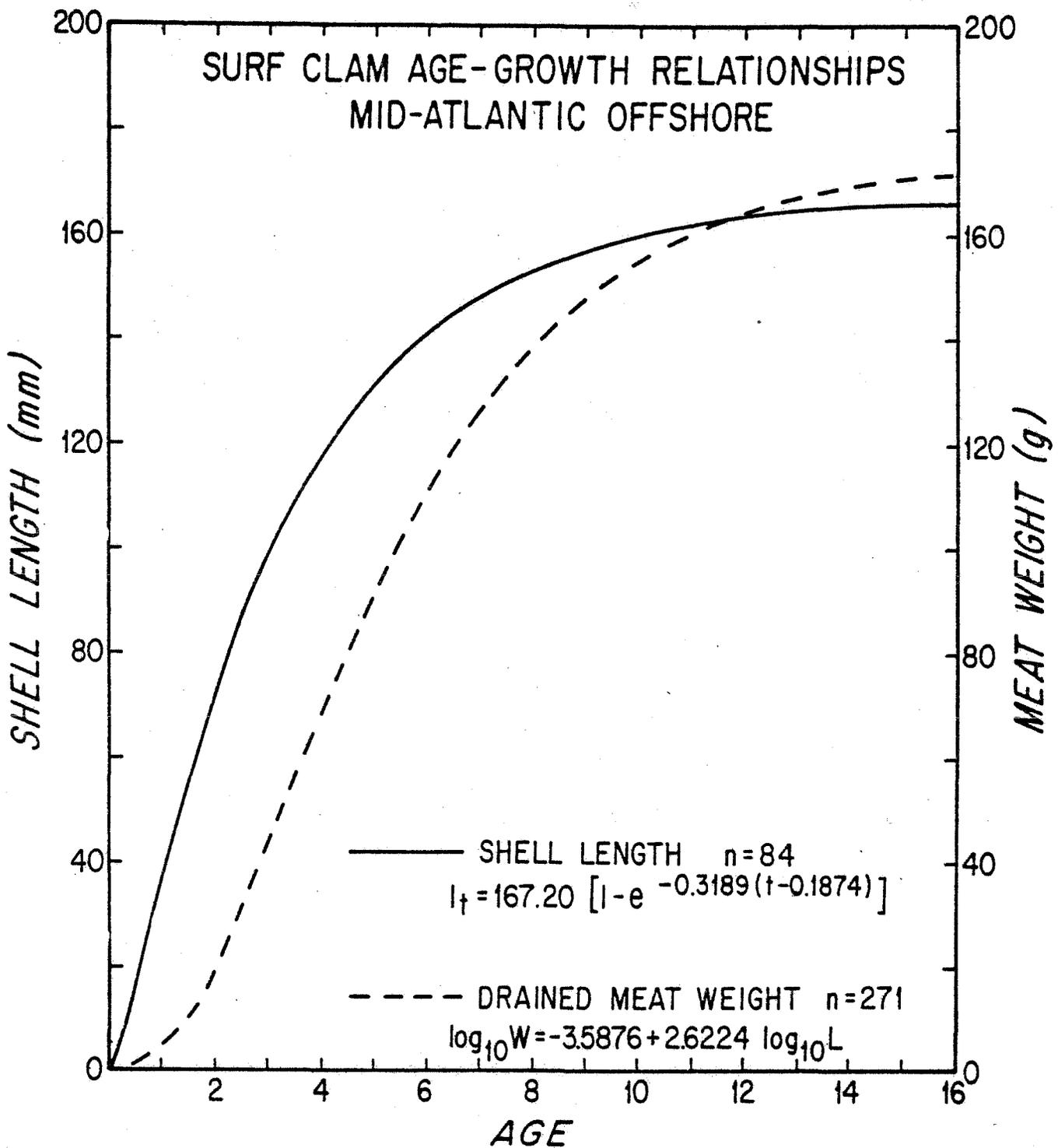


Figure 11. Age-growth relationships for surf clams from offshore waters of the Mid-Atlantic. Shell lengths expressed in mm, meat weights in grams.

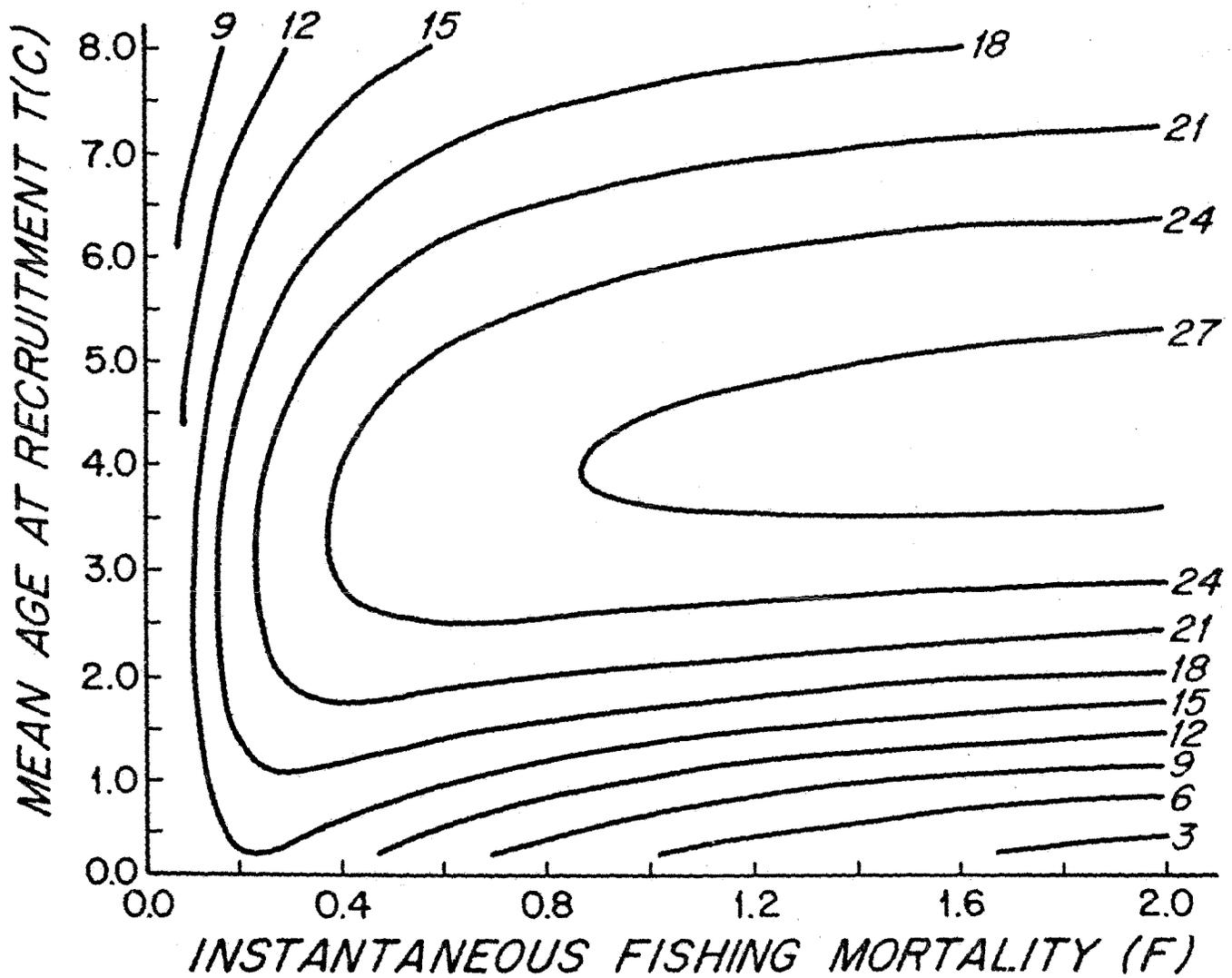


Figure 12. Yield per recruit isopleth for offshore Mid-Atlantic surf clams.

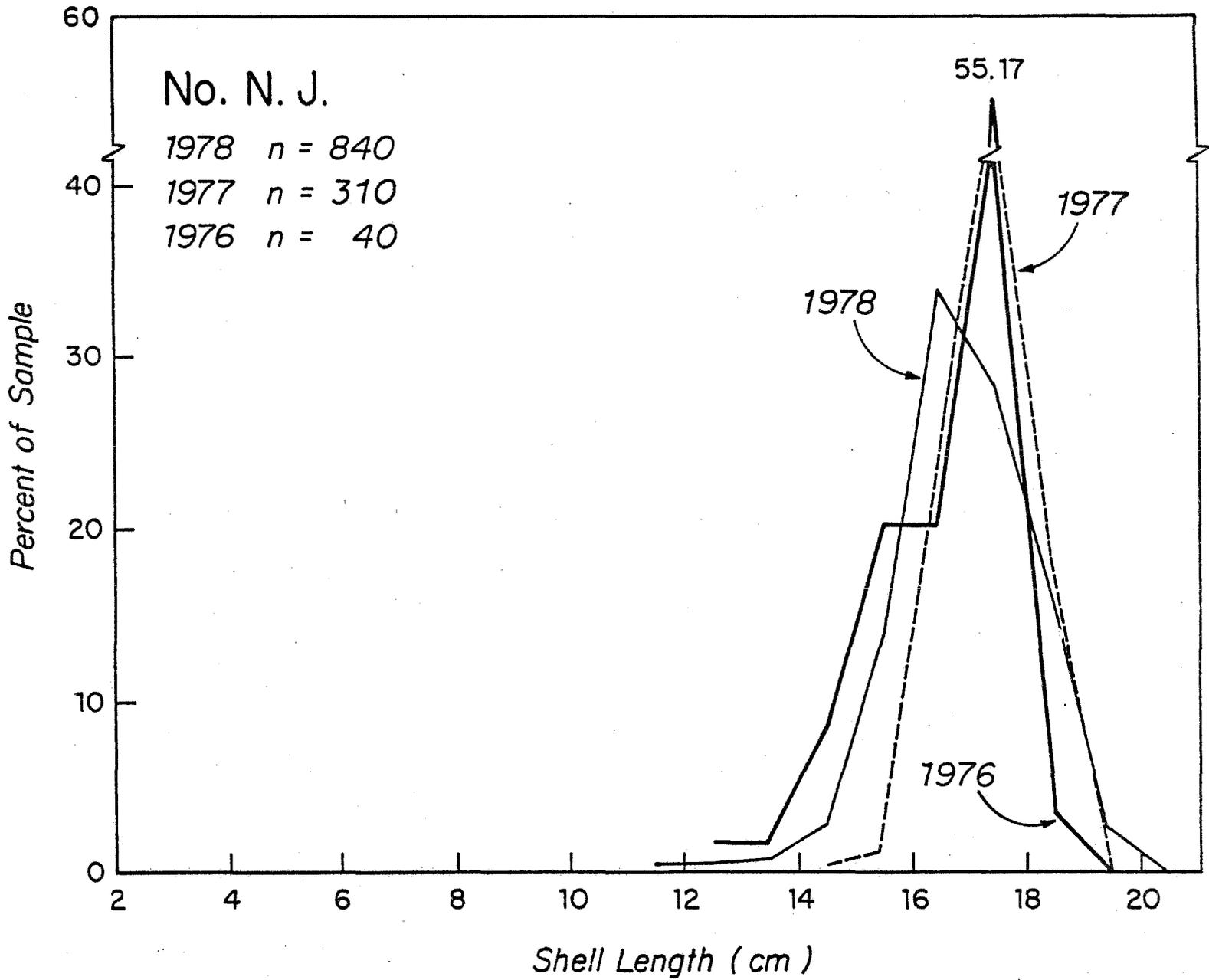


Figure 13. Length frequency composition of offshore commercial surf clam catches off Northern New Jersey sampled from 1976 through 1978.

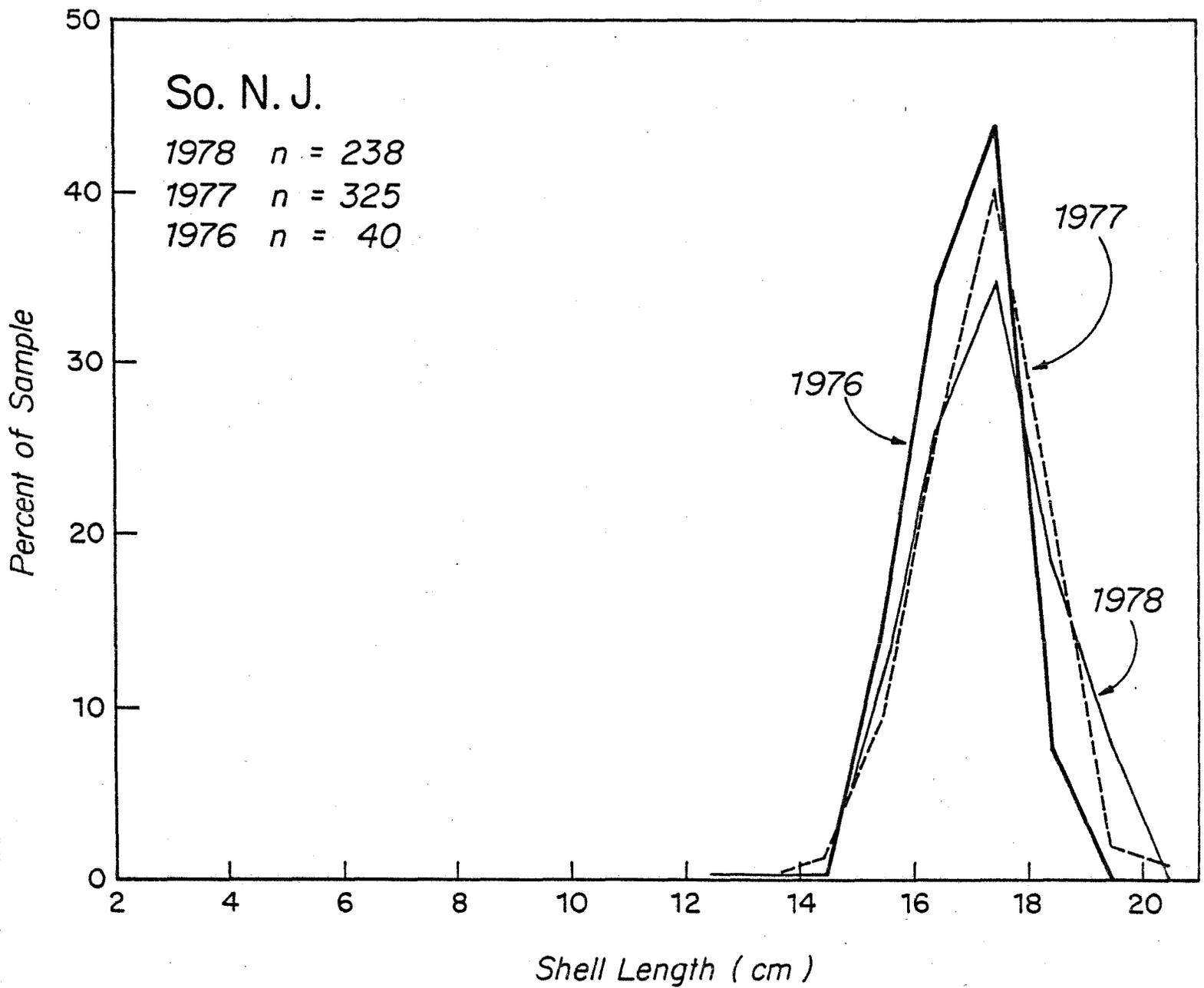


Figure 14. Length frequency composition of offshore commercial surf clam catches off Southern New Jersey sampled from 1976 through 1978.

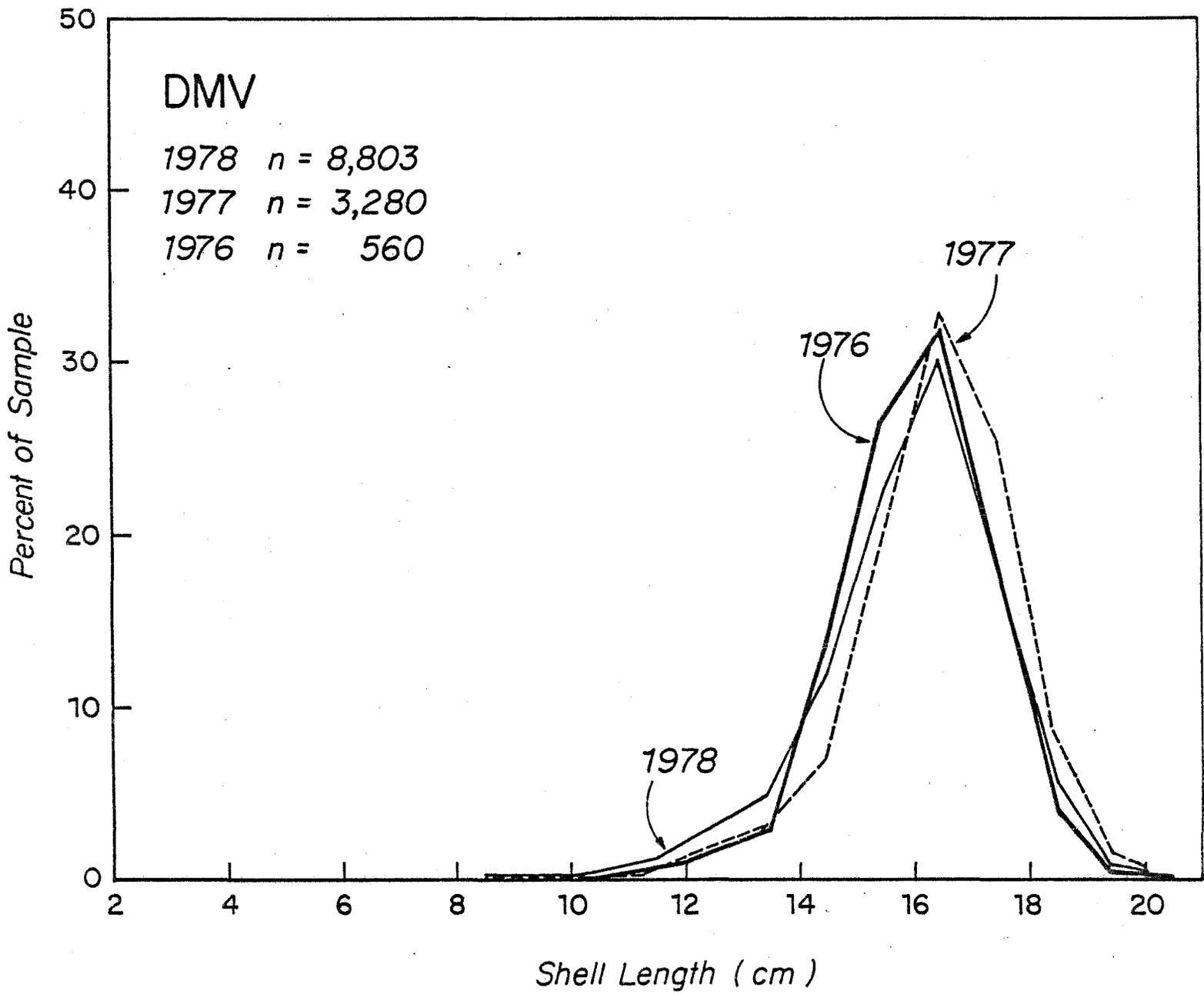


Figure 15. Length frequency composition of offshore commercial surf clam catches off Delmarva sampled from 1976 through 1978.