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An Assessment of the Ocean Quahog, *Arctica islandica*, Resource and Fishery in FCZ Waters off the Northeastern USA - Autumn 1983.

by

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SUMMARY

Total ocean quahog landings increased dramatically during 1976-1979, from 1.5 million to about 34.7 million pounds of meats per year. Annual landings have since stabilized at about 35 million pounds. During 1982 total landings were 34.8 million pounds, of which 98.6% were derived from the FCZ fishery, primarily off New Jersey (74%) and the Delmarva Peninsula (26%). Small quantities are also taken from inshore Rhode Island waters (1982 landings about 450 thousand pounds), and most recently off northern Maine.

The FCZ fishery has been regulated since 1977 under provisions of the Surf Clam and Ocean Quahog Fishery Management Plan (FMP) developed by the Mid-Atlantic Fishery Management Council. The primary management measure has been an annual landings quota: 30 million pounds in 1978 and 1979, 35 million pounds in 1980, and 40 million pounds in 1981-1983.

Trends in fishery performance during 1979-1983 were evaluated using mandatory logbook data submitted by each permitted vessel. The offshore ocean quahog fishery is primarily prosecuted with dredging vessels greater than 100 GRT. Average catch per hour fishing for the large vessels varied little during the period, although average catch rates were significantly higher for the Delmarva area (152 bushels/hour) than off New Jersey (121 bushels/hour). The catch is primarily composed of quahogs 65-105 mm shell length. Little size selectivity by the fishery is apparent as the size composition of landings is similar to that from resource surveys of the exploited areas.

Resource surveys of the ocean quahog resource in the Georges Bank to Cape Hatteras region have been conducted by the Northeast Fisheries Center since 1965. Abundance indices for six assessment areas in the region were extremely stable during 1965-1982, indicating little fluctuation in abundance. Total standing stock of quahogs in the region is estimated to be 2.67 billion pounds of meats. The majority of the resource occurs on Georges Bank (29%), and off Southern New England (26%), with smaller percentages off Long Island (19%), New Jersey (19%), Delmarva (7%), and southern Virginia-North Carolina (<1%).

Although annual landings are currently but 1.2% of the total estimated stock, harvests considerably in excess of 40 million pounds per year are not warranted due to the extremely slow growth rate and poor annual recruitment exhibited by the populations. Annual landings off New Jersey and the Delmarva Peninsula are currently about 5% of the total resource in these areas. If current harvest levels and patterns are maintained, the quahog resource and fishery in the New Jersey-Delmarva area should remain stable for the next 5-7 years, after which the fishery will probably shift northward and to the east to take advantage of higher marginal catch rates.

INTRODUCTION

The ocean quahog, *Arctica islandica*, resource in FCZ (Fishery Conservation Zone) waters off the northeast United States has been managed since November 1977 under provisions of the Surf Clam and Ocean Quahog Fishery Management Plan (FMP), developed by the Mid-Atlantic Fishery Management Council. The primary management measures have been quota restrictions for FCZ waters: 3 million bushels in 1978 and 1979, 3.5 million bushels in 1980, and 4 million bushels in 1981-1983 (one standard bushel is considered to yield about 10 pounds of quahog meats). The primary objectives of the quotas have been to promote orderly development of the fishery, while limiting catch to approximately the sustainable annual productivity of the resource. Initial quotas were established based on two previous stock assessments (Murawski and Serchuk 1979a; Serchuk and Murawski 1980). These assessments presented standing stock estimates of ocean quahog biomass from Northeast Fisheries Center (NEFC) shellfish surveys of the region from Montauk Point, New York, to Cape Charles, Virginia. A range of sustainable yield estimates were derived using the model of Gulland (1971) for computing MSY for virgin or newly developing fisheries. The range of estimates accounted for the uncertainty in natural mortality and growth rate parameters and non-harvest, dredge-induced quahog mortality.

This assessment updates the two previous ones and provided further information on recent population dynamics studies of the FCZ quahog resource (Murawski et al. 1982). NEFC surveys since 1979 have documented a substantial FCZ quahog resource off Southern New England, and on Georges

Bank. Accordingly stock size estimates are given for the New England and Georges Bank regions as well as for resources off Long Island, New Jersey, the Delmarva Peninsula, and off Southern Virginia-North Carolina (Figure 1). Also presented are an analysis of commercial catch and effort based on vessel logbook data, size frequency distributions of quahogs in the commercial catch and in standardized surveys, yield-per-recruit calculations, and projections of fishing impacts on the stocks during the next several years.

COMMERCIAL FISHERY

Landings

Harvesting of ocean quahogs began during World War II, in the Rhode Island Sound area. Annual USA landings remained relatively low, never exceeding 2.5 million pounds of shucked meats per year until the mid-1970's (Table 1) when rapid declines in Mid-Atlantic surf clam, *Spisula solidissima*, stocks stimulated the initial harvesting of FCZ ocean quahogs in waters off New Jersey and the Delmarva Peninsula. Landings from the FCZ fishery, focused primarily off New Jersey, Maryland, and Virginia, increased steadily during 1976 to 1979 from 4 million to 31.6 million pounds of meats. Since 1979, annual FCZ landings have stabilized at 30-35 million pounds (Table 1).

Conversely, inshore Rhode Island landings have declined from 3.2 million pounds in 1980 to about 0.5 million pounds in 1982. During 1982-1983 a small coastal fishery off northern Maine developed, primarily to supply small (50-60 mm) ocean quahogs as a market substitute for hard clams, *Mercenaria mercenaria*. This fishery has reportedly landed about 20 thousand bushels to date (about 0.2 million pounds of meats).

Commercial Vessel Performance

The FCZ ocean quahog fishery is prosecuted primarily from the ports of Cape May-Wildwood, New Jersey, Ocean City, Maryland, and Cincoteague, Virginia. The major fishing areas lie north and south of a line defining the major axis of Delaware Bay. Vessels from Cape May-Wildwood concentrate north of the entrance to Delaware Bay; Ocean City and Chincoteague vessels work primarily to the south. During 1983 about 66% of the total FCZ landings was taken off New Jersey; the remaining 34% was caught off the Delmarva Peninsula.

Commercial vessel catch, effort, and catch-per-unit of effort (CPUE) for the FCZ quahog fishery are summarized in Tables 2 and 3. Separate analyses are presented for the New Jersey and Delmarva fishery areas. Data were derived from mandatory vessel logbooks submitted to the National Marine Fisheries Service. Data presented in Tables 2 and 3 are quarterly totals (1979-1983) for each of three vessel size classes:

Class 1: 1-50 GRT

Class 2: 51-100 GRT

Class 3: 101+ GRT

Vessel size class 3 accounts for by far the largest proportion of vessel trips, catch, and total hours fished in both assessment areas, with class 2 and 1 vessels contributing lesser amounts. During 1983 about 95.1% of the total FCZ quahog catch was derived from class 3 vessels, 4.7% by class 2, and 0.2% by class 1. Because of the relatively low number of trips by class 1 and 2 vessels, CPUE indices for classes 1 and 2 are more variable than those for class 3 (particularly off Delmarva). Quarterly CPUE indices for class 3 vessels are presented for the New Jersey and Delmarva fishing areas in Figure 2. Average CPUE values for class 3 vessels operating off Delmarva were greater than corresponding indices off New Jersey (in every quarter the Delmarva index was larger than the New Jersey index). A slight increasing trend in CPUE for both areas is evident from late 1980-1983. Average differences in CPUE by vessel class were large. For the entire period class 3 vessels were about 48% more efficient than class 2 and 67% more efficient than class 1:

	Average CPUE			
	New Jersey	Delmarva	Total	% Total Catch
Class 1	68	129	77	(0.2)
Class 2	90	64	87	(5.8)
Class 3	121	152	129	(94.0)
% total catch	(73.5)	(26.5)		

Over the entire 1979-1983 period about 94% of the catch was taken by class 3 vessels with 74% of the total catch landed off New Jersey and 26% off Delmarva.

The relative stability of class 3 CPUE throughout the 1979-1983 time period (particularly off New Jersey where about 75% of the landings are derived) reflects the stable abundance of the ocean quahog resource in areas utilized by the fishery. Although CPUE indices for particular vessels declined following exploitation in a particular small area, this was offset by access to high density quahog areas close by. Although slight declines were noted in survey abundance indices for some areas exploited by the fishery during 1976-1978 and 1980-1982, these differences were not statistically significant (see "Resource Surveys").

BIOLOGICAL SAMPLING OF THE FISHERY

Samples of ocean quahogs for size composition analyses were obtained from commercial catches from the New Jersey and Delmarva fishery areas during 1977-1983. A sample of 30 individual shell length measurements (to mm) was obtained per vessel trip. These data were weighted by the total number of bushels in the sampled trip, and combined with other measurements for each fishery area and year. Length frequency distributions, average shell lengths, and sampling data are presented in Table 4. Shell length frequency distributions for commercial samples obtained during 1980-1982 are presented in Figure 3.

Average shell size changed little in the New Jersey assessment area during 1977-1981, but increased slightly during 1982-1983. This recent increase is associated with a slight shift of the fishery northward and to shallower waters (Table 5) than in previous years. Average shell

size and depth of capture of quahogs off Delmarva changed little during 1977-1983. The bulk of Delmarva quahog landings are taken in deeper waters than off New Jersey, reflecting the more offshore distribution of the resource to the south. Average 1980-1982 size compositions of quahog landings were compared to size data from corresponding resource surveys in the areas actually being fished (Figure 3). Survey size distributions were nearly identical to those in the fishery, indicating little commercial culling. Also significant was the general lack of small quahogs (less than 65 mm) in the areas being fished. If small quahogs were present in these regions they would have been retained by the survey dredge since the spacing of bars in the after-portion of the survey gear is narrower than in commercial dredged. Thus, the fishery appears to exhibit little size selectivity in exploiting the available resource.

RESOURCE SURVEYS

A series of 14 resource surveys of the Middle Atlantic shelf clam stocks has been conducted during 1965-1982 (Table 6). Objectives, equipment, and procedures employed during these surveys have been reviewed elsewhere (Murawski et al. 1982, Murawski and Serchuk 1979a, Serchuk and Murawski 1980). The survey data provide a basis for evaluating the relative abundance and distribution of the resource, monitoring the effects of fishing on abundance and recruitment, and for estimating the harvestable standing stock.

Survey strata are divided into six geographical regions for the assessment purposes: Southern Virginia-North Carolina, Delmarva, New Jersey, Long Island, Southern New England, and Georges Bank. Stratum membership, depth ranges, and areas (square nautical miles) are given in Figure 1.. Within each survey stratum, random tows of 5-minute duration are conducted with a 1.5 meter (60") wide hydraulic clam dredge. Earlier surveys utilized smaller dredges towed for different durations. Catch data for earlier surveys have been standardized to current gear and tow time. Distance towed during each standard survey haul is calculated using a doppler speed log aboard the NOAA R/V DELAWARE II. This device gives an accurate determination of the total distance over bottom covered during each tow. Average distance towed during the most recent survey was 0.13 nautical miles, or about 790.4 linear feet. Since the dredge is 5 feet wide, the average total area covered by a survey tow is 3,952 square feet (0.0001069 n. miles^2).

Total catch in numbers is recorded for each survey tow, and a subsample measured for size-frequency analysis. Meat weight per tow is calculated by multiplying the number of quahogs caught in each shell length interval by average meat weights (Murawski and Serchuk 1979b), and summing over all length intervals. For each stratum, average catch per tow is expressed in both numbers and drained meat weight. For each geographic area, stratified catch per tow value is determined, using the area of each stratum as a weighting coefficient (Figure 1).

An estimate of absolute quahog abundance in any geographic region can be derived by multiplying the total bottom area of the region by the average stratified mean catch per tow, and dividing by the mean area covered in a standard survey tow. This value is a minimum population estimate since the survey gear is not 100% efficient in retaining all quahogs encountered in its path. This estimation technique has been used in previous Middle Atlantic ocean quahog assessments (Murawski and Serchuk 1979; Serchuk and Murawski 1980) and in quahog assessments elsewhere (Fogarty 1981; Rowell and Chaisson 1983).

Previous quahog assessments have indicated little temporal fluctuation in Mid-Atlantic resource abundance. Thus, for analysis purposes, the survey time-series was grouped into four periods, each of 5-yr duration: 1965-1969, 1970-1974, 1975-1979, 1980-present. Abundance indices were computed for each individual 5-yr period (Tables 7 and 8). Stratified mean weight per tow (kg) values, for each assessment area and 5-yr period, are given in Table 7. Catch per tow in numbers, and corresponding length frequency distributions are given in Table 8.

Relative densities of ocean quahog varied significantly among the six assessment areas. Lowest densities were off Southern Virginia-North Carolina and the Delmarva Peninsula; New Jersey, and Georges Bank areas exhibited moderate densities; the highest relative densities were off Long Island and Southern New England. Although quahog densities differed significantly among assessment areas, relative abundance of quahogs within areas changed little over the 17-yr time period (1965-1982). These areas that are currently exploited (Delmarva, New Jersey) exhibited no detectable declines in abundance or recruitment (as measured by statistically significant differences in survey indices). Analysis of abundance in those survey strata encompassing the areas of greatest commercial landings indicate no significant change in resource status since the initiation of intensive FCZ fishing.

Almost no quahogs less than 50 mm (2 inches) were captured during 1978-1982 in any of the survey strata where commercial fishing has occurred, implying a virtual lack of recruitment in these areas (Table 8, Figure 3).

In general, the predominance of small quahogs (less than 60 mm) occurred off Long Island and Southern New England, largest quahogs were found off New Jersey (Table 8). Quahogs from 60-100 mm ($2\frac{1}{4}$-4 inches) shell length comprised the bulk of the resource in all survey regions.

Minimum Population Estimates

Standing stock estimates of harvestable quahog biomass (meat weight) were derived from areal expansion of survey mean catch per tow data. Weight per tow indices for the 1980-1982 period were used in all calculations, except those for the Southern Virginia-North Carolina area. In this region the 1975-1979 catch per tow index was considered most reflective of actual abundance since it was based on a greater number of tows (74), taken over a larger area (Table 7).

For each survey region, the average catch per tow was divided by 0.0001069 (the area in square nautical miles of a standard survey tow) and then multiplied by the total area of that region (Table 9). This provided an estimate of the meat weight biomass (kg) in each survey region. These values were then expressed in metric tons and pounds (Table 9).

An estimated total biomass of 2.67 billion pounds of quahog meat was derived for the entire region from Georges Bank to Southern Virginia-North Carolina. The largest proportions of this biomass occur on Georges Bank and in Southern New England, followed by New Jersey, Long Island, Delmarva, and Southern Virginia-North Carolina:

Region	Percent of estimated total ocean quahog biomass
Southern Virginia-North Carolina	0.13
Delmarva	7.43
New Jersey	19.17
Long Island	18.73
Southern New England	25.97
Georges Bank	28.58

This estimate is slightly lower than the 3.33 billion pound value given in previous assessments (Murawski and Serchuk 1979a, Serchuk and Murawski 1980), although the present estimates pertain to a larger area than in prior analyses. The current geographical estimate results from using a larger value for the area covered during a standard dredge tow than in past assessments. Previously, average survey dredge path distances were based on odometer readings during 1965 and 1969. More recent estimates were derived from highly accurate doppler radar calculations of distance over bottom, and are thought to be more reliable. Nevertheless, the estimate of total standing stock changed by only about 20%.

YIELD PER RECRUIT

Yield per recruit analyses were performed to evaluate the effects of various harvesting rates and sizes (ages) at entry on the yield potential in the FCZ quahog fishery. Growth and natural mortality parameters used in these analyses were based on population dynamics studies (Murawski and Serchuk 1979a; Murawski et al. 1980. The standard Thompson-Bell yield per recruit model was modified to accommodate the large number of age groups in ocean quahog populations.

A critical parameter in any yield-per-recruit model is the instantaneous rate of natural mortality in the population (M). In unexploited populations, this rate is usually inversely proportional to life-span: short-lived species have a high natural mortality rate and vice versa. In previous quahog assessments, a wide range of natural mortality rates was used since knowledge of the species' life-span was uncertain. However, a more refined estimate of natural mortality is now available. Based on the age-size relationships given in Figure 4 and the size composition data in Table 8 and Figure 3, it is apparent that a significant proportion of the quahog population is in excess of 100 years old. Assuming an average shell size of 96.9 mm at age 100, then at least 17% of the New Jersey resource and 16% of the Delmarva resource is in excess of 100 years (these calculations are based on the percent of the total catch-per-tow index in the size intervals greater than 100 mm). If, on average, 17% of a population survives to age 100 then the equivalent instantaneous natural mortality rate (M) is 0.018. Accordingly, yield-

per-recruit analyses were performed assuming three instantaneous natural mortality rates: 0.01, 0.02, and 0.03. This represents a considerable reduction in the range of M values used in previous analyses (0.01-0.10).

The yield-per-recruit (Y/R) results are summarized in Table 10. Separate analyses were conducted for the New Jersey and Delmarva areas since length-weight relationships for these areas differ (Figure 4). Age at recruitment was assumed to be 12 years (equivalent to 50 mm shell length); four ages at first selection (t_c) by the fishery were evaluated (12, 17, 28, and 45 years, equivalent to 50, 60, 70, and 80 mm shell length).

For M values of 0.01 and 0.02, and an age at first selection of 12 years, yield per recruit is maximized in both New Jersey and Delmarva resources at F values between 0.03 and 0.05. When age at first entry is increased between 17 and 45, Y/R is maximized at F levels above 0.03. At comparable F, M, and t_c values, Y/R in Delmarva area (Table 10), is slightly greater than in New Jersey, due primarily to the greater mean weight at age of Delmarva quahogs.

If the minimum age at entry is assumed to be 12 yield potential of cohorts will be maximized at F-values between 0.03-0.05 (Table 13). For t_c=17 years, Y/R is maximized at F = 0.03-0.07. These results can be used to derive an estimate of the percentage of the resource that could be harvested on an annual basis (utilization rate, U) to achieve Y/R maximization. The utilization rate corresponding to particular F and M combinations can be computed from: $U = F \cdot A / Z$, where A is the annual mortality rate, and Z is the sum of F and M (instantaneous total mortality rate).

Maximum yield per recruit is achieved for an age at entry of 12 years at utilization rates of 1.0-4.8% (assuming M = 0.01-0.02). If age at entry is increased to 17 years, the corresponding range of utilization rates resulting in maximum Y/R is 1.0-6.7%. Differences in absolute Y/R are, however, relatively small between the two age at entry values for F's between 0.03-0.07.

If the minimum age at entry is assumed to be 28-45 years (or about 70-80 mm shell length) utilization rates corresponding to maximum yield-per-recruit range between 3.9 and >9.4%.

CURRENT ASSESSMENT

Annual FCZ landings during 1980-1982 were relatively stable, averaging about 33 million pounds of meats per year. This landings level represents an annual harvest of about 1.2% of the estimated 2.67 billion pounds of biomass in the Georges Bank-Cape Hatteras area. If only the ocean quahog standing stock biomass in the New Jersey and Delmarva areas is considered, annual FCZ landings constitute 4.6% of the harvestable stock.

Resource surveys of the New Jersey and Delmarva areas have not revealed any detectable declines in total quahog abundance. These surveys were designed, however, to evaluate resource conditions over relatively large areas, and are imprecise in documenting fishery effects in small localized areas such as those being fished. Logbook data have shown that in some areas, quahog densities have declined to levels prompting vessels to shift to more productive fishing areas. The surveys indicate that no increases in recruitment have occurred in response to the fishery;

the size distribution of the resource has remained quite stable (Table 8). Thus, relative stability in CPUE, catch distribution, and resource abundance is projected for the next several (5-7) years under current harvest patterns. However, given the lack of significant recruitment, an extremely slow quahog growth rate, and an estimated 4.6% harvest rate in the New Jersey-Delmarva region, resource declines in the areas currently being exploited are inevitable. As CPUE indices decline in the Southern New Jersey and Delmarva areas, a north and eastward expansion of the fishery seems likely (an increasing proportion of New Jersey landings are being derived from fishing grounds north of Atlantic City).

One approach to the estimation of appropriate annual harvest levels for the fishery is to apply utilization rates resulting in maximum yield per recruit to the total standing stock estimates. For natural mortality rates of 0.01-0.02 and age at first selection of 12 years appropriate utilization rates are 1-5%. If this harvest rate is applied to the entire population, annual landings range from 27-134 million pounds. As the size at first harvest is increased from 2-3 inches, the utilization rate resulting in maximum yield per recruit also increases to 3.9->9.4%.

Presently little gain in Y/R would be achieved by reducing fishing mortality on individuals less than 70 mm, since a minor portion of the stock exists at these sizes (the issue is moot). Since the growth rate of individuals in excess of 70 mm is very slow (Figure 4), increases in stock biomass are approximately balanced by natural mortality losses. Thus, differences in Y/R at various fishing mortality rates on individuals greater than 70 mm (2 3/4 inches) are negligible (Table 10).

Current utilization rates in the Delmarva and New Jersey areas (4.6%) are within the range of values maximizing yield per recruit for 60+ mm sizes (2.9-6.7%). If this rate is used for computing harvest levels, the resulting recommended catch is (0.046 x 709.9 million pounds=) 32.6 million pounds for the New Jersey-Delmarva region. At this rate of harvest, the resource in the New Jersey-Delmarva area would last 22 years. However, as resource abundance is reduced marginal CPUE rates would prompt effort shifts to other regions.

The current harvest quota of 40 million pounds appears appropriate for controlling the rate of harvest of the Delmarva-New Jersey resource at about 5% per year. This is about the harvest rate resulting in maximum yield per recruit for 60 mm+ sizes. Virtually all New Jersey and Delmarva quahogs are in excess of 60 mm. If the entire region from Cape Hatteras to Georges Bank is considered, harvest rates of 1-5% are indicated by the Y/R model since a larger number of small quahogs exist in the other areas. At these rates 27-134 million pound annual harvests would be generated. However, given the relatively poor recruitment prospects throughout the region, annual landings substantially in excess of 40 million pounds are probably excessive. If 134 million pounds were harvested annually, it would probably all come from the Southern New Jersey and Delmarva regions assuming no restriction on catch from particular areas. The resulting mortality rates on these stocks would exceed values resulting in maximum yield per recruit. Furthermore at 134 million pounds fishery could be sustained for only about 20 years, which is less than the time

necessary for quahogs to grow to the minimum sizes currently being landed. The current annual quota of 40 million pounds allows substantially more time for resource rebuilding given the highly uncertain recruitment prospects. Thus, a 40 million pound quota appears most efficacious given that virtually all ocean quahog landings will be derived from off New Jersey and Delmarva during the next several years, and that recruitment increases are highly unlikely in the near future. Equally, a 40 million pound level allows sufficient generation time for new recruitment to replace current stocks in the long term.

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Table 1. Landings of ocean quahog (thousands of pounds of meats) from state waters and the Fishery Conservation Zone (FCZ), 1967-1983.

YEAR	STATE WATERS	FCZ	TOTAL
1967	44.1		44.1
1968	224.9		224.9
1969	639.3		639.3
1970	1,746.0		1,746.0
1971	2,030.3		2,030.3
1972	1,399.3		1,399.3
1973	1,457.2		1,457.2
1974	804.6		804.6
1975	1,254.4		1,254.4
1976	1,446.2	4,089.2	5,535.3
1977	2,464.6	16,081.8	18,546.4
1978	2,686.0	20,279.0	22,965.0
1979	3,095.0	31,629.0	34,724.0
1980	3,215.0	30,617.0	33,832.0
1981	903.0	35,204.0	36,107.0
1982	456.0	34,336.0	34,792.0
1983			21,296.6[3]

Through 9/10/83

Most of the landings of quahogs from state waters are from Rhode Island Sound

Based on processor logbook reports

Table 2. Commercial ocean quahog catch and effort statistics for the New Jersey assessment area, 1979-1983. Data are presented by calendar quarter for each of three vessel size classes (see text), and were derived from vessel trip logbook reports.

Year-Quarter		Number of Trips Analyzed			Total catch (bushels)			Total hours fished			Mean Bushels/hours		
		Vessel class			Vessel class			Vessel class			Vessel class		
		1	2	3	1	2	3	1	2	3	1	2	3
1979	1	-	45	235	-	31238	279888	-	212	1893	-	147	148
	2	-	68	375	-	49855	409093	-	363	3436	-	137	119
	3	5	71	378	5325	39365	403583	31	421	3417	172	94	118
	4	-	63	404	-	38557	463739	-	335	3509	-	116	132
Total		5	247	1392	5325	159015	1556303	31	1330	12256	173	120	127
1980	1	-	43	406	-	28510	445233	-	255	3727	-	112	119
	2	-	73	414	-	44358	478521	-	475	4698	-	93	102
	3	-	44	340	-	26945	380725	-	322	3767	-	84	101
	4	3	45	253	2373	25339	281927	20	286	2692	119	89	105
Total		3	205	1413	2373	125152	1586406	20	1338	14884	119	94	107
1981	1	-	36	376	-	22941	462647	-	233	3708	-	99	125
	2	-	43	373	-	24154	447703	-	275	3524	-	88	127
	3	2	54	359	1020	34335	435093	28	424	3712	36	81	117
	4	3	60	324	581	34874	343390	16	441	3107	36	79	111
Total		5	193	1432	1601	116304	1688833	44	1372	14050	36	85	120
1982	1	-	61	456	-	36876	578592	-	477	4646	-	77	125
	2	-	47	332	-	32049	461631	-	429	3388	-	75	136
	3	8	61	335	3000	42885	423934	71	616	3318	42	70	128
	4	-	30	340	-	25892	462807	-	321	3297	-	81	140
Total		8	199	1463	3000	137702	1926964	71	1843	14649	42	75	132
1983	1	-	44	348	-	31189	421236	-	426	3356	-	73	126
	2	5	36	350	1839	23565	424453	38	293	3466	48	81	122
	3[1]	2	25	139	784	18046	163830	16	209	1282	49	86	128
Total[2]		7	105	837	2623	72800	1009519	54	928	8103	49	78	125

[1]Data for logbook reports through 9/5/83.

[2]Not including data as noted above.

Table 3. Commercial ocean quahog catch and effort statistics for the Delmarva assessment area, 1979-1983. Data are presented by calendar quarter for each of three vessel size classes (see text), and were derived from vessel trip logbook reports.

Year-Quarter		Number of Trips Analyzed			Total catch (bushels)			Total hours fished			Mean bushels/hour		
		Vessel class			Vessel class			Vessel class			Vessel class		
		1	2	3	1	2	3	1	2	3	1	2	3
1979	1	-	5	75	-	3464	105986	-	82	609	-	42	174
	2	-	26	87	-	12947	112823	-	306	784	-	42	144
	3	-	11	64	-	4285	78806	-	118	471	-	36	167
	4	-	17	97	-	10884	118467	-	123	789	-	88	150
Total		-	59	323	-	31580	416082	-	629	2653	-	50	156
1980	1	3	-	75	5047	-	92965	39	-	720	129	-	129
	2	-	-	119	-	-	174560	-	-	911	-	-	192
	3	-	4	104	-	2560	134427	-	28	902	-	91	149
	4	-	4	123	-	6182	154216	-	46	1312	-	134	118
Total		3	8	421	5047	8742	556168	39	74	3845	129	118	145
1981	1	-	-	142	-	-	181948	-	-	1406	-	-	129
	2	-	1	116	-	1248	155037	-	7	1133	-	178	137
	3	-	1	102	-	608	140652	-	10	1042	-	61	135
	4	-	2	89	-	544	121312	-	13	867	-	42	140
Total		-	4	449	-	2400	598949	-	30	4448	-	80	135
1982	1	-	-	159	-	-	226187	-	-	1494	-	-	151
	2	-	-	155	-	-	225665	-	-	1357	-	-	166
	3	-	2	113	-	1445	150660	-	16	1059	-	90	142
	4	-	2	165	-	3180	231552	-	28	1486	-	114	156
Total		-	4	592	-	4625	834064	-	44	5396	-	105	155
1983	1	-	3	158	-	2144	217151	-	15	1199	-	145	181
	2	-	4	171	-	2610	256997	-	19	1480	-	141	174
	3[1]	-	-	58	-	-	90704	-	-	486	-	-	187
Total[2]		-	7	387	-	4754	564852	-	33	3166	-	143	178

[1]Data are for logbook reports through 9/5/83.

[2]Not including data as noted above.

Table 4. Size composition (percent) and associated statistics for ocean quahogs sampled from commercial catches off New Jersey (NJ) and the Delmarva Peninsula (DMV), 1977-1983.

Shell Lengh (mm)	1977		1978		1979		1980		1981		1982		1983[1]	
	NJ	DMV	NJ	DMV	NJ	DMV	NJ	DMV	NJ	DMV	NJ	DMV	NJ	DMV
30- 39														
40- 49	0.1													
50- 59	0.2		<0.1					>0.1		0.1				
60- 69	0.8	1.4	1.7	0.7	2.1	0.8	2.1	1.2	5.6	1.4	1.6	0.4		0.3
70- 79	12.9	5.9	13.8	16.5	26.3	23.4	21.5	27.4	38.9	27.4	10.0	22.5	3.7	11.2
80- 89	48.0	65.5	39.7	53.8	42.3	59.8	60.6	59.3	45.6	58.5	27.6	57.4	22.4	58.6
90- 99	32.4	24.0	35.4	24.5	26.1	15.2	15.0	11.5	10.0	12.3	35.7	16.5	55.8	28.0
100-109	5.0	3.3	9.0	4.4	2.6	0.8	0.8	0.6		0.2	21.7	2.9	17.3	1.7
110-119	0.5				0.5	>0.1					3.3	0.3	0.9	0.1
120-129	0.2				0.2						0.1			
130-139														
Mean Length (mm)	87.9	87.2	88.8	86.5	85.3	84.2	84.1	83.3	81.0	83.2	92.6	85.0	93.9	87.0
(inches)	3.5	3.4	3.5	3.4	3.4	3.3	3.3	3.3	3.2	3.3	3.7	3.4	3.7	3.4
Number Measured	750	90	2,460	417	870	1,020	480	1,440	90	1,554	779	2,611	1,980	1,716

[1]Through August 1983

Table 5. Fishing depths (mean, minimum, maximum) for sampled ocean quahog trips, 1978-1983. Data are presented for all trips in the Middle Atlantic Bight, and for the New Jersey and Delmarva assessment areas separately.

Year	Area	Mean Depth		Minimum Depth		Maximum Depth	
		Meters	Fathoms	Meters	Fathoms	Meters	Fathoms
1977	ALL	37	20	27	15	49	27
	NJ	35	19	27	15	42	23
	DMV	45	25	42	23	49	27
1978	ALL	41	22	27	15	51	28
	NJ	39	21	27	15	46	25
	DMV	46	25	40	22	51	28
1979	ALL	46	25	37	20	53	29
	NJ	42	23	37	20	51	28
	DMV	48	26	40	22	53	29
1980	ALL	45	25	24	13	53	29
	NJ	41	22	29	16	49	27
	DMV	46	25	24	13	53	29
1981	ALL	48	26	40	22	51	28
	NJ	42	23	40	22	44	24
	DMV	48	26	40	22	51	28
1982	ALL	46	24	29	16	55	30
	NJ	39	21	29	16	49	27
	DMV	47	26	35	21	55	30
1983[1]	ALL	43	23	26	14	49	27
	NJ	40	22	26	14	48	26
	DMV	45	25	38	21	49	27

[1] Through August 1983.

Table 6. Summary of research vessel cruises used in the analysis of ocean quahog population dynamics, 1965-1982. Survey gears were hydraulic clam dredges.

Research Vessel	Cruise Data Month	Year	Dredge Knife Width (cm)	Time of Tows (min)	Number of Stations	Ring Size[α] or Bar Space (cm)
Undaunted	May	1965	76	5	375	5.1
Undaunted	October	1965	76	5	217	5.1
Albatross IV	August	1966	76	5	240	5.1
Albatross IV	June	1969	76	5	278	5.1
Delaware II	August	1970	122	4	199	3.0
Delaware II	June	1974	76	5	241	5.1
Delaware II	April	1976	122	4	259	3.0
Delaware II	January	1977	122	4	224	3.0
Delaware II	January	1978	122	4	324	3.0
Delaware II	December	1978	122	4	163	2.5
Delaware II	January	1980	152	5	229	5.1
Delaware II	August	1980	152	5	231	5.1
Delaware II	August	1981	152	5	261	5.1
Delaware II	August	1982	152	5	272	5.1

[α]portion of dredge where catch is accumulated.

Table 7. Numbers of dredge surveys, survey tows, areas of sampled strata, and relative abundance (meat weight per standard survey tow, kg) of ocean quahogs in FCZ assessment areas off the United States East Coast. Individual survey tows are standardized to a 1.5 m (60") wide dredge towed for 5 minutes.

Assessment Area	Time Period	Number of Surveys	Number of Survey Tows	Total Area of Sampled Strata (nm)	Weight per Tow (kg, meat weight)
Southern Va.- North Carolina	1965-1969	4	150	3,106	0.03
	1970-1974	2	76	3,090	0.09
	1975-1979	3	74	3,106	0.05
	1980-1982	3	27	2,851	0.02
Delmarva	1965-1969	4	342	5,919	1.03
	1970-1974	2	137	5,715	1.03
	1975-1979	4	258	6,130	1.08
	1980-1982	4	250	5,926	1.62
New Jersey	1965-1969	4	424	7,332	3.38
	1960-1974	2	157	6,856	5.12
	1975-1979	4	346	7,601	2.34
	1980-1982	4	360	7,601	3.26
Long Island	1965-1969	4	172	4,478	6.06
	1970-1974	2	70	4,478	8.26
	1975-1979	4	226	5,799	4.62
	1980-1982	4	150	4,478	5.41
Southern New England	1965-1969	1	22	2,864	7.22
	1970-1974	2	5	672	7.95
	1975-1979	2	80	7,254	3.34
	1980-1982	4	96	5,650	5.95
Georges Bank	1980-1982	3	59	7,937	4.66

Table 8. Abundance (stratified mean number per tow) of ocean quahogs from six FCZ assessment areas off the Northeast United States, 1965-1982. Indices are given for 5 year time periods, and by size interval. A standard survey tow was of 5 minutes duration with a 1.5 m (60") wide hydraulic clam dredge.

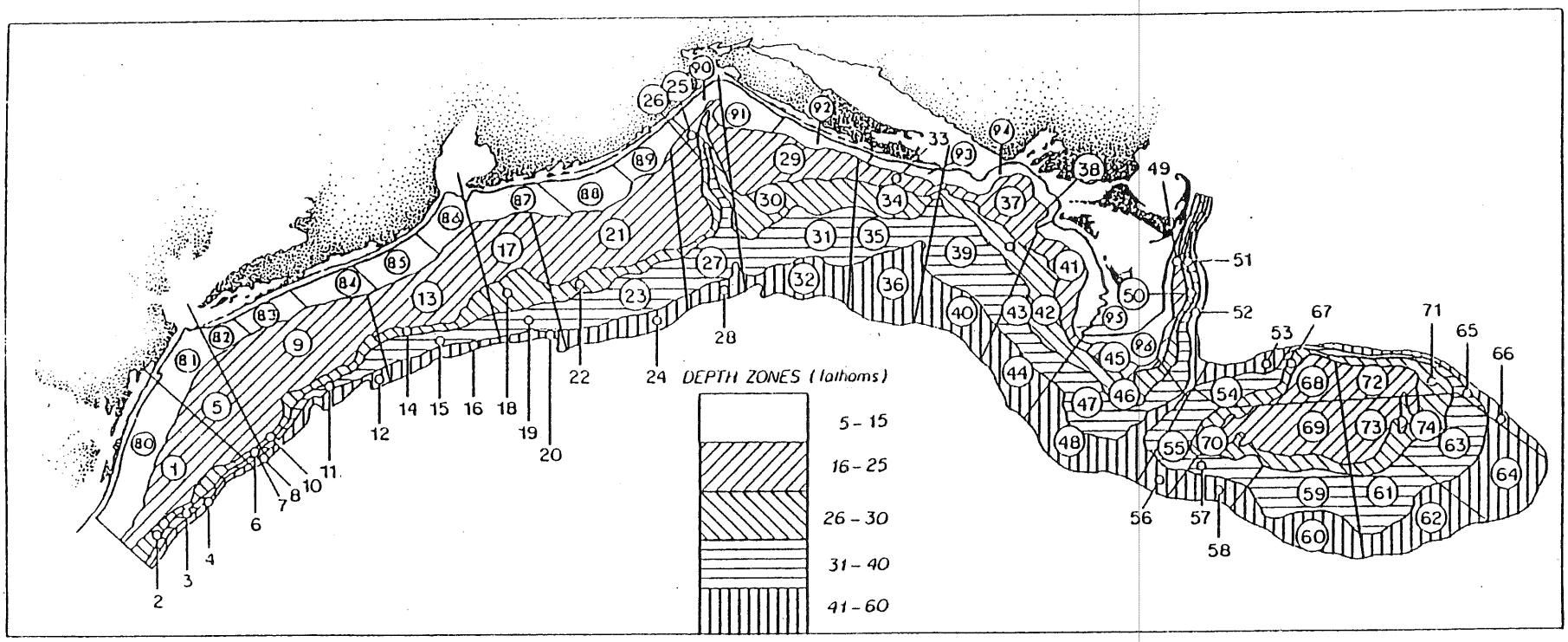
Assessment Area	Time Period	Total Number per tow	Abundance (Number per tow) by Size Interval (mm)										
			20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99	100-109	110-119	120-129	130-139
Southern Va.-North Carolina	1965-1969	1.01				0.04	0.03	0.21	0.42	0.17	0.11	0.03	0.01	
	1970-1974	2.60			0.01	0.03	0.09	0.47	0.53	1.12	0.32	0.01		
	1975-1979	1.17							0.11	0.38	0.64	0.05		
	1980-1982	0.56							0.06	0.30	0.18	0.03		
Delmarva	1965-1969	31.66		0.05		0.10	2.13	4.92	9.41	10.98	3.61	0.45		
	1970-1974	28.19					1.54	5.68	3.75	8.84	6.87	1.37	0.14	
	1975-1979	34.62		0.02	0.08	0.49	1.59	9.14	10.20	7.96	4.37	0.74	0.03	
	1980-1982	47.63				0.07	0.78	7.77	15.39	15.80	7.03	0.72	0.04	0.01
New Jersey	1965-1969	104.31	0.02	0.05	0.24	0.82	2.39	13.77	34.55	33.61	14.47	4.01	0.39	
	1970-1974	164.37				0.37	7.57	27.85	52.65	48.48	22.30	4.79	0.26	0.07
	1975-1979	73.31	0.02	0.04	0.13	0.66	2.94	9.77	23.79	22.67	10.89	2.07	0.29	0.03
	1980-1982	99.16	0.00	0.01	0.06	0.22	2.21	9.56	32.82	37.15	14.46	2.42	0.22	0.01
Long Island	1965-1969	245.08	0.24	1.50	5.02	17.24	16.30	36.17	82.95	71.00	13.47	1.15	0.04	
	1970-1974	328.51	0.09	0.35	2.28	16.17	44.57	48.25	97.52	89.64	25.40	4.23		
	1975-1979	215.94	0.04	0.14	2.00	19.69	53.83	35.20	49.70	43.02	11.28	1.02	0.01	
	1980-1982	245.78	0.00	0.05	0.18	8.96	71.84	48.45	49.05	50.71	15.10	1.42	0.03	
Southern New England	1965-1969	305.14			9.22	13.82	23.03	60.56	116.29	69.39	12.78	0.05		
	1970-1974	293.38			1.94	0.97	9.96	31.46	138.38	96.45	14.22			
	1975-1979	146.45				0.95	19.15	46.92	49.28	24.73	4.96	0.46		
	1980-1982	230.56			0.02	0.78	10.84	50.14	96.16	60.55	11.46	0.61	0.01	
Georges Bank	1980-1982	213.37	0.21	0.53	0.48	1.57	20.40	83.37	75.69	26.96	3.97	0.19		

Table 9. Minimum ocean quahog population estimates (meat weight, metric tons and pounds) in each of six Northwest Atlantic assessment areas. Estimates are based on areal expansion of survey catch-per-tow data.

Assessment region	Area of region (n.m.^{2})	Mean catch per tow(kg)	Population estimate (metric tons, meats)	Population estimate (millions of lbs)
Southern Virginia-North Carolina	3,106	0.0533	1,548	3.41
Delmarva	5,926	1.6233	89,981	198.41
New Jersey	7,601	3.2628	231,980	511.52
Long Island	4,478	5.4111	226,652	499.77
Southern New England	5,650	5.9470	314,294	693.01
Georges Bank	7,937	4.6595	345,928	762.77
Total	34,698		1,210,383	2,668.90

Table 10. Yield per recruit (grams, drained meat weight) of ocean quahogs from 2 FCZ fishery areas off the Northeast USA. M is instantaneous natural mortality rate, t_c is the age at first selection, L_c is the shell size (mm) at first selection. Growth data are those given in Figure 4.

				Fishing Mortality Rate (F)									
Area	M	t_c	L_c	.01	.02	.03	.04	.05	.06	.07	.08	.09	.10
New Jersey	.01	12	50	10.93	13.31	13.45	13.05	12.57	12.11	11.70	11.35	11.05	10.78
		17	60	11.07	13.85	14.30	14.13	13.81	13.49	13.20	12.94	12.71	12.52
		28	70	11.00	14.40	15.38	15.57	15.37	15.23	15.08	14.95	14.95	14.83
		45	80	10.31	14.28	15.85	16.48	16.74	16.85	16.88	16.88	16.87	16.85
	.02	12	50	6.66	8.97	9.79	10.05	10.09	10.03	9.93	9.82	9.70	9.59
		17	60	6.59	9.07	10.08	10.51	10.69	10.76	10.77	10.75	10.72	10.68
		28	70	6.14	8.74	9.95	10.57	10.92	11.12	11.25	11.32	11.38	11.41
		45	80	5.13	7.60	8.89	9.63	10.09	10.40	10.62	10.78	10.90	10.99
	.03	12	50	4.48	6.53	7.54	8.07	8.36	8.52	8.59	8.63	8.63	8.62
		17	60	4.31	6.39	7.50	8.14	8.53	8.78	8.95	9.06	9.14	9.20
		28	70	3.72	5.65	6.76	7.44	7.90	8.21	8.44	8.62	8.75	8.85
		45	80	2.73	4.26	5.19	5.80	6.23	6.54	6.78	6.97	7.11	7.24
Delmarva	.01	12	50	11.93	14.64	14.89	14.53	14.06	13.60	13.19	12.83	12.52	12.24
		17	60	12.05	15.17	15.77	15.65	15.36	15.05	14.76	14.50	14.28	14.08
		28	70	11.92	15.68	16.81	17.07	17.05	16.94	16.81	16.68	16.55	16.44
		45	80	11.09	15.41	17.14	17.87	18.18	18.32	18.37	18.39	18.39	18.38
	.02	12	50	7.32	9.93	10.90	11.25	11.33	11.31	11.23	11.13	11.02	11.91
		17	60	7.22	10.00	11.16	11.69	11.93	12.03	12.07	12.07	12.05	12.02
		28	70	6.68	9.55	10.91	11.63	12.03	12.28	12.44	12.54	12.61	12.66
		45	80	5.54	8.22	9.63	10.46	10.97	11.32	11.57	11.75	11.89	12.00
	.03	12	50	4.96	7.27	8.43	9.07	9.42	9.62	9.74	9.79	9.82	9.82
		17	60	4.76	7.08	8.34	9.08	9.54	9.84	10.05	10.19	10.29	10.37
		28	70	4.07	6.20	7.43	8.20	8.72	9.08	9.35	9.55	9.71	9.83
		45	80	2.95	4.62	5.64	6.31	6.78	7.13	7.39	7.60	7.77	7.90



Southern Va.-North Carolina

Stratum	Miles
1	1,163
2	175
3	126
4	117
5	453
6	62
7	46
8	74
80	767
81	360

Delmarva

Stratum	Miles
9	2,171
10	152
11	229
12	204
13	1,127
14	219
15	394
16	211
82	180
83	241
84	417
85	382
86	203

New Jersey

Stratum	Miles
17	749
18	249
19	274
20	120
21	1,650
22	312
23	714
24	476
25	648
26	188
27	451
28	149
87	479
88	578
89	382
90	182

Long Island

Stratum	Miles
29	1,096
30	669
31	932
32	627
33	363
34	203
35	601
36	694
91	340
92	191
93	83

Southern New England

Stratum	Miles
37	672
38	280
39	967
40	573
41	602
42	343
43	432
44	383
45	392
46	416
47	871
48	1,109
49	244
50	150
51	139
52	307
94	229
95	446
96	495

Georges Bank

Stratum	Miles
53	268
54	278
55	364
56	209
57	184
58	300
59	538
60	810
61	576
62	701
63	694
64	988
65	164
66	266
67	210
68	370
69	938
70	520
71	146
72	504
73	501
74	433

Figure 1. Ocean quahog and surf clam survey strata off the northeast United States. Survey strata comprising each of six assessment areas are listed, along with the area (square nautical miles) of each.