Size Composition, Sex Ratio, and Size at Maturity of Offshore Northern Lobsters

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ABSTRACT

The fishery for northern lobsters, Homarus americanus, in the offshore waters of the North Atlantic is developing rapidly and is expected to alter certain biological characteristics of the stocks. Samples of lobsters have been taken during research cruises and from commercial catches to document the existing size composition, sex ratio, and size at maturity. These records will provide useful indices of population changes as fishing effort increases.

The data in this report are from five of the major fishing areas--Hudson, Veatch, Oceanographer, Lydonia, and Corsair Canyons. Lobsters from canyons 200 km. from shore were substantially smaller than those from areas farther offshore. The size of lobsters generally increased with depth and the proportion of females generally increased with increasing size. Females dominated the samples and sometimes were 70 percent of the catch. The numbers of egg-bearing females are reported. The smallest female with external eggs was 8.0 cm. in carapace length.

INTRODUCTION

Landings of northern lobsters (Homarus americanus) from the offshore trawl fishery of the North Atlantic have been increasing rapidly during the past 10 years. Otter trawls took 484 metric tons of lobsters in 1958 and over 2,500 metric tons in 1968. As the fishery develops, it is important to document the changes in the size composition and sex ratio of the stocks. These data, together with catch and effort statistics, will be needed to assess the effect of fishing on the abundance of offshore lobsters. Sampling of the catch was too limited in earlier years to detect changes in population structure. During the past 3 years, however, sampling of commercial landings and of catches from research cruises has been more extensive and has provided information by fishing area that will be a base for future comparison.

The early history of the offshore fishery was described by Firth (1940) and Schroeder (1959). The first reports of lobsters caught by trawling date back to the early 1900's, when beam and otter trawls were introduced to American waters. These lobsters were incidental catches in the fisheries for various groundfish. Incidental catches continue but usually are not included in the catch statistics of the lobster fishery. The earliest otter trawl catch of lobsters that is recorded was 4 metric tons landed in New York in 1921; the exact location of the catch is unknown. Even through 1960, little information was gathered on the location of the offshore catches.

Statistics of the Bureau of Commercial Fisheries do not separate inshore and offshore catches of lobsters; however, practically all of the fishing inshore is done with pots whereas otter trawls are used offshore. Trawl catches from the New England region to the Chesapeake date back to the late 1920's; and though a few inshore catches are included, these data serve to document the increase in offshore landings that has occurred over the years and show that these catches remained less than 45 metric tons annually through 1946. Skud (in press) described the increased catches of recent years. From 1947, the landings increased steadily and approached 500 metric tons for the first time in 1955 (table 1). This growth continued and the peak offshore landing--2,500 metric tons in 1968--accounted for 16.9 percent of the total U.S. catch of lobsters. Landings from the offshore fishery contribute substantially to the total landings in Massachusetts, Rhode Island, New York, and

Table 1.--U.S. catch of lobsters by the inshore pot fishery and offshore trawl fishery

Year	Pot fishery	Trawl fishery	Total	Percentage of catch by trawls
	- - - - -Metric tons- - - -			Percent
1943	7,420	30	7,450	0.4
1944	8,095	37	8,132	0.5
1945	10,275	34	10,309	0.3
1946	10,840	35	10,875	0.3
1947	10,802	51	10,853	0.5
1948	9,417	59	9,476	0.6
1949	11,102	124	11,226	1.1
1950	10,394	129	10,523	1.2
1951	11,680	89	11,769	0.8
1952	11,195	159	11,354	1.4
1953	12,479	275	12,754	2.2
1954	12,078	386	12,464	3.1
1955	12,649	482	13,131	3.7
1956	11,515	510	12,025	4.2
1957	13,316	357	13,673	2.6
1958	11,858	484	12,342	3.9
1959	12,589	592	13,181	4.5
1960	13,311	810	14,121	5.7
1961	11,621	1,056	12,677	8.3
1962	12,124	1,236	13,360	9.2
1963	12,369	1,366	13,735	9.9
1964	12,177	1,855	14,032	13.2
1965	11,221	2,481	13,702	18.1
1966	11,612	1,774	13,386	13.3
1967	10,083	1,949	12,032	16.2
1968*	12,300	2,500	14,800	16.9

*Preliminary.

New Jersey. None of the Maine catch includes offshore lobsters.

The fishery operates at the edge of the Continental Shelf, 100 to 300 km. from shore, mainly in depths between 200 and 500 m. The vessels, which are usually about 30 m. long, operate on a year-round basis. The average fishing trip lasts 10 days; the lobsters are held alive in tanks until the vessel returns to port. Catches during a trip may range from 1 to 9 metric tons, but the daily average is about one-half a metric ton. Lobsters weighing less than 2.25 kg. are termed selects and command a premium price; larger lobsters are called jumbos and sell for 50¢ to $1.00 less per kilogram. The average annual price to the fisherman is about $1.75 per kilogram. for selects and $1.25 for the jumbos, but the price of selects has been as high as $2.50 per kilogram in late winter and early spring.

The gear used in this offshore fishery is the standard bottom trawl described by Bruce (1967). If the bottom is rough, rollers are added to the foot rope of the nets to help prevent snagging. The boats fish around the clock, and tows last 3 to 4 hours.

Skud (1966) reported on preliminary sampling of the offshore fishery but did not discuss the differences among individual fishing grounds. The objectives of the present paper are to present the results of research cruises and sampling of the commercial catch, and to compare size composition, sex ratio, and size at maturity of the lobsters caught in offshore fishing areas.

SAMPLING

Most of the samples of lobsters were taken from catches at submarine canyons along the edge of the Continental Shelf (fig. 1). As the sampling stations had marked differences, we discuss each of the canyon areas separately.

Samples from the commercial catch were taken throughout the year. At least 100 lobsters, representing all size categories, were measured (carapace length) and sexed from each of the landings sampled. In addition, data on the vessel, gear, date sailed, date landed, days fished, fishing days lost, area and depth of catch, and total catch were obtained from interviews with the vessel captains.

During research cruises aboard the Albatross IV and the Delaware, more detailed data on tows were obtained, including the time and distance as well as the range in depth of each tow. Hydrographic data were collected after each tow. Sampling during the research cruises was concentrated in particular fishing areas to determine seasonal changes in size composition of sex ratio. Since these same areas were also regularly fished by the commercial fleet, we could compare the catches of commercial and research vessels. The sex, carapace length, and weight of each lobster were recorded. The number of females with external eggs (berried) was also noted. A summary of the research cruises is presented in table 2.

The research cruises also provided information on sublegal or prerecruit lobsters which was not available from commercial landings because of minimum-size restrictions (7.8-8.1 cm. carapace length in various States). Though the fishery operates in international waters, which have no restrictions on lobster fishing, State laws apply to the landings; consequently the offshore fishery is subject to the same size regulations that control the inshore fishery. All of the New England States also prohibit the landing of berried lobsters.

COMPOSITION OF CATCHES FROM OFFSHORE CANYONS

The five canyon areas discussed in this paper were selected as sampling sites because of their commercial importance or their geographic separation, to provide a composite of

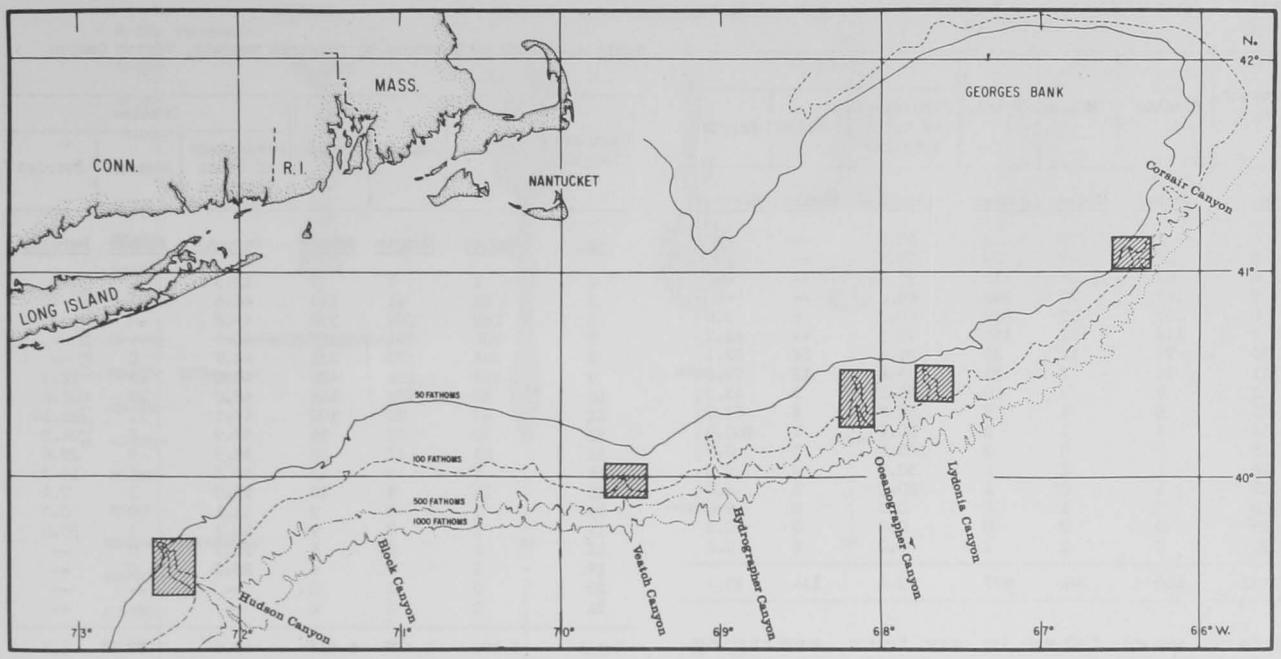

Figure 1.--Sampling locations for lobsters on the Continental Shelf off southern New England.

Table 2.--Lobster research cruises: locations, fishing data, and catch, 1965-67

Cruise and vessel	Canyon	Tows	Total time	Depth range	Lobster catch
		Number	Hours	Meters	Number
65-5 Albatross IV	Veatch	6	6	113-146	108
Apr. 22-25, 1965	Oceanographer	2	2	126-182	5
	Lydonia	2	2	160-237	16
	Corsair	3	6	171-271	30
65-8 Albatross IV	Veatch	5	11	273-455	174
June 6-17, 1965	Oceanographer	1	1	337	26
	Corsair	13	14	124-173	159
65-11 Delaware	Veatch	3	3	106-109	77
Oct. 2-3, 1965	Corsair	5	5	91-273	0
66-5 Albatross IV	Hudson	2	2.5	200-246	104
Apr. 22-26, 1966	Veatch	4	4	118-206	168
	Oceanographer	2	2	209-273	12
	Lydonia	10	10	109-237	314
	Corsair	6	6	127-182	1
66-8 Albatross IV	Veatch	7	7	135-246	217
June 15-19, 1966	Oceanographer	10	10	167-237	140
	Lydonia	10	10	146-355	141
	Corsair	10	10	126-260	81
66-10 Albatross IV	Veatch	4	4	109-218	47
July 30-Aug. 2, 1966	Lydonia	5	5	118-228	38
66-9 Delaware	Veatch	2	2	109	439
Oct. 22-24, 1966	Lydonia	6	6	91-127	23
67-8 Albatross IV	Hudson	4	4	136-300	88
Apr. 30-May 2, 1967	Veatch	14	14	109-364	515
67-11 Albatross IV	Hudson	11	10.5	109-182	548
June 22-26, 1967	Veatch	9	8.5	136-164	323
	Oceanographer	9	8.5	118-218	268
67-8 Delaware	Hudson	6	9.25	109-127	279
Oct. 11-13, 1967	Veatch	5	8	113-135	422
	Oceanographer	6	8	100-136	54

the offshore fishery. There are other offshore grounds that are fished by commercial vessels. These include an area 35 km. southwest of Hudson Canyon between the 200- and 400-m. contours, and the Southwest Part, Southeast Part, and north central areas of Georges Bank.

The oceanographic features of the area have been reported by Colton, Marak, Nickerson, and Stoddard (1968). The temperature at the depths where lobsters are caught differs as much as 5.0° C. between canyons. Generally there is a cooling trend from west to east. Periodically a tongue of water from the Gulf Stream intrudes into the area of Oceanographer and Lydonia Canyons, warming the bottom water to somewhat higher temperatures than occur westward at Veatch Canyon. Corsair Canyon, far to the east, is consistently the coldest area.

Hudson Canyon

Hudson Canyon (lat. 39°35' N., long. 72°25' W.) lies 100 km. south of eastern Long Island, N.Y., and is the farthest west and south of the sampled areas. The canyon was sampled during research cruises in April, June, and October 1967. Tows made at various depths between 100 and 215 m. took a total of 907 lobsters (table 3).

During the June cruise, six tows in the Hudson Canyon area caught 470 lobsters--an average of 78 per 1-hour tow. In October, 279

Table 3.--Catch of lobsters by research vessels, Hudson Canyon, 1965-67

Carapace length	Females	Males	Total	Females		
				Percentage of total lobsters	Berried	Berried
Cm.	Number	Number	Number	Percent	Number	Percent
4	1	1	2	50.0	--	--
5	24	9	33	72.7	--	--
6	87	28	115	75.7	--	--
7	167	75	242	69.0	--	--
8	158	72	230	68.7	6	3.8
9	119	31	150	79.3	49	41.2
10	73	12	85	85.9	38	52.1
11	16	7	23	69.6	12	75.0
12	9	1	10	90.0	3	33.3
13	6	1	7	85.7	5	83.3
14	1	1	2	50.0	1	100.0
15	3	0	3	100.0	0	0.0
16	1	1	2	50.0	0	0.0
17	1	0	1	100.0	0	0.0
18	0	1	1	0.0	0	0.0
19	0	0	0	0.0	0	0.0
20	0	1	1	0.0	0	0.0
Total	666	241	907	73.4	114	17.1

lobsters were taken in six tows, averaging 30 per 1-hour tow. Soft or recently shed lobsters were taken in June but not in October.

The October catch included 189 lobsters with carapace lengths of 8 cm. or larger (i.e., above the legal minimum). Of these, 160 were females and 99 (62 percent) of the females were berried. The females were from 8 to 15 cm. long and the berried individuals averaged 9.8 cm. Eggs of the berried lobsters had been extruded recently and were in prenaupliar condition.

Females dominated the catch in all but the largest size categories and accounted for 70 percent of the total, but the ratio of females to males decreased with depth. In a regression analysis in which the ratio of females to males was a dependent variable on depth, there was a significant negative relation ($b = -0.298$, $s_b = 0.111$; $b/s_b = 2.685$, $P = 0.02$). Though the sex ratio changed, the mean size of lobsters did not increase significantly with increasing depth.

Veatch Canyon

Veatch Canyon (lat. 40°00' N., long. 69°35' W.) is 130 km. south of Nantucket Island, Mass. It was fished more frequently during research cruises than any other of the offshore areas. Catches here are usually good, and the area receives considerable effort from commercial fishing vessels. The canyon was sampled in April, June, and October 1965; April, June, July, and October 1966; and April, June, and October 1967. Table 4 summarizes data obtained from these research cruises, and table 5 summarizes the samples taken from catches by commercial vessels from December 1965 through June 1967.

Table 4.--Catch of lobsters by research vessels, Veatch Canyon, 1965-67

Carapace length	Females	Males	Total	Females		
				Percentage of total lobsters	Berried	Berried
Cm.	Number	Number	Number	Percent	Number	Percent
4	1	7	8	12.5	--	--
5	62	71	133	46.6	--	--
6	162	208	370	43.8	--	--
7	286	351	637	44.9	--	--
8	264	327	591	44.7	0	--
9	194	226	420	46.2	25	12.9
10	94	102	196	48.0	25	26.6
11	47	62	109	43.1	11	23.14
12	33	23	56	58.9	8	24.2
13	21	15	36	58.3	5	23.8
14	7	6	13	53.8	1	14.3
15	14	5	19	73.7	1	7.1
16	1	8	9	11.1	0	0.0
17	2	7	9	22.2	1	50.0
18	1	5	6	16.7	0	--
19	1	3	4	25.0	0	--
20	0	0	0	--	--	--
21	0	2	2	--	--	--
Total	1,190	1,428	2,618	45.5	77	6.5

Table 5.--Samples of the commercial catch of lobsters from Veatch Canyon, December 1965 to June 1967

Carapace length	Females	Males	Total	Percentage of females
Cm.	Number	Number	Number	Percent
8	334	283	617	54.1
9	825	620	1,445	57.1
10	583	371	954	61.1
11	364	243	607	60.0
12	369	163	532	69.4
13	298	120	418	71.3
14	177	95	272	65.1
15	107	80	187	57.2
16	65	76	141	46.1
17	41	59	100	41.0
18	21	64	85	24.7
19	17	35	52	32.7
20	6	29	35	17.1
21	0	8	8	--
22	0	3	3	--
Total	3,207	2,249	5,456	58.8

During research cruises, more lobsters were caught per hour in shoaler water: 49 per hour in 100 to 182 m. (55-100 fathoms) and 12 per hour in depths greater than 182 m. (fig. 2). Greater depths yielded fewer but larger lobsters; lobsters taken below 182 m. averaged 10 cm. in carapace length and 900 g. (2 pounds), and those taken in shallower water averaged 8 cm. and 450 g. (fig. 3). Commercial catches generally produced a higher yield in weight of

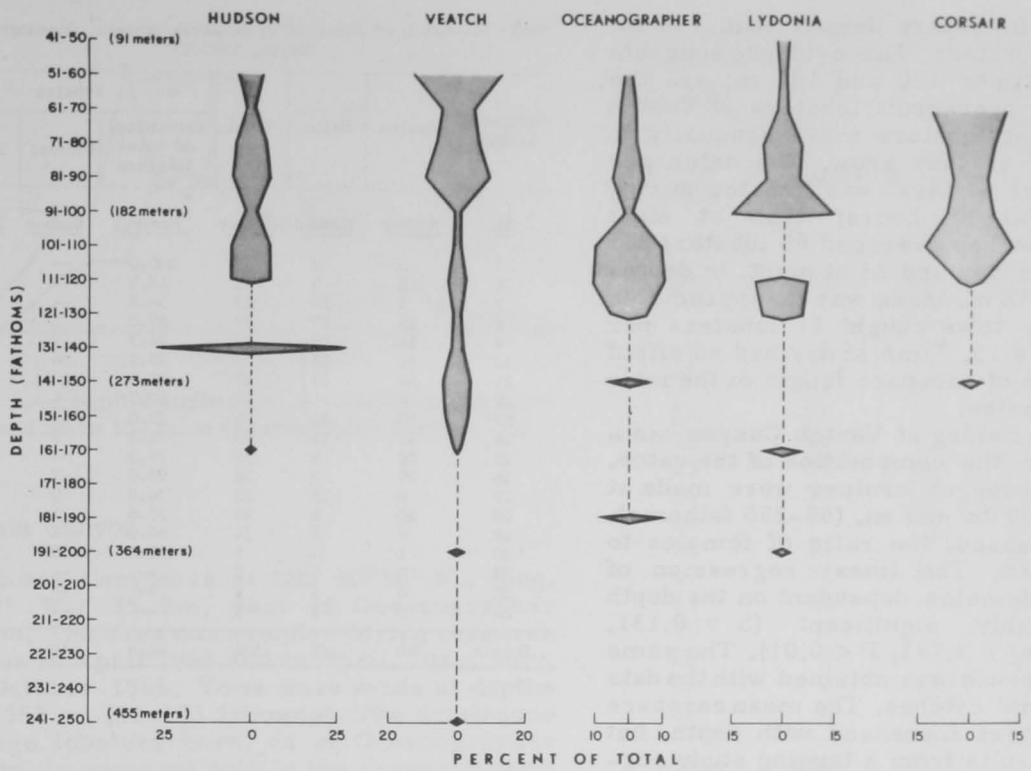

Figure 2.--Percentage of lobsters caught at various depths in the offshore fishery.

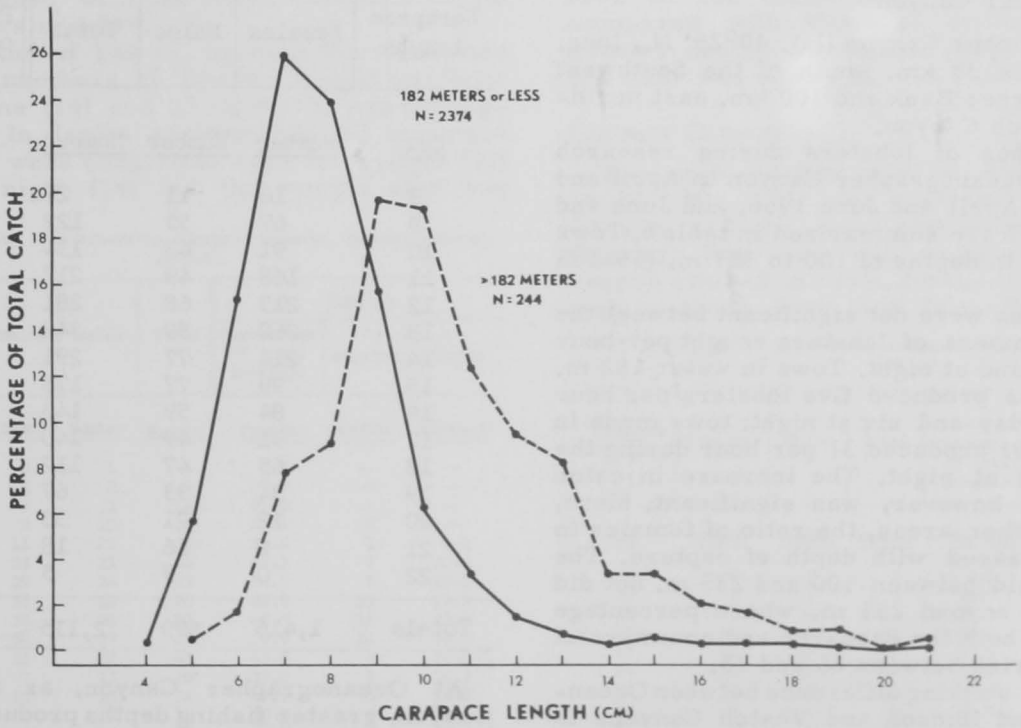

Figure 3.--Length distributions of lobsters caught above and below 182 m. by research vessels at Veatch Canyon.

catch per day in waters deeper than 180 m. than in shoaler waters. This evidence suggests that waters between 100 and 182 m. are the realm of most prerecruit lobsters at Veatch Canyon and that lobsters move gradually to deeper waters as they grow. The catch per hour in shoaler waters was greater during daylight (0600-1800 hours) than at night (1800-0600). Catches averaged 65 lobsters per hour during the day and 28 at night. In depths greater than 182 m. there was no appreciable difference; day tows caught 11 lobsters per hour, night tows 13. Time of day had no effect on the variation of carapace length or the ratio of females to males.

The depth of fishing at Veatch Canyon has a direct effect on the composition of the catch. Tows during research cruises were made at depths from 100 to 450 m. (55-250 fathoms). As depth increased, the ratio of females to males increased. The linear regression of percentage of females dependent on the depth fished is highly significant ($b = 0.131$, $s_b = 0.035$, $b/s_b = 3.743$, $P < 0.01$). The same level of significance was obtained with the data from commercial catches. The mean carapace length of lobsters increased with depth, but preliminary results from a tagging study suggest seasonal changes in the relation of size to depth. Not enough tows have been made in all months at all depths to show these differences.

Oceanographer Canyon

Oceanographer Canyon (lat. 40°25' N., long. 68°10' W.) is 30 km. south of the Southwest Part of Georges Bank and 100 km. east northeast of Veatch Canyon.

The catches of lobsters during research cruises at Oceanographer Canyon in April and June 1965, April and June 1966, and June and October 1967 are summarized in table 6. Tows were made in depths of 100 to 337 m. (55-185 fathoms).

Differences were not significant between the average numbers of lobsters caught per hour in daylight and at night. Tows in water 182 m. deep or less produced five lobsters per hour during the day and six at night; tows made in deeper water produced 31 per hour during the day and 24 at night. The increase in catch with depth, however, was significant. Here, as in the other areas, the ratio of females to males increased with depth of capture. The increase held between 100 and 235 m. but did not extend beyond 235 m. where percentage females in both the research and commercial samples varied between 65 and 75.

The most striking difference between Oceanographer and Hudson and Veatch Canyons is the preponderance of large lobsters, 12 cm. and more in carapace length. This difference was also evident in commercial samples (table 7).

Table 6.--Catch of lobsters by research vessels, Oceanographer Canyon, 1965-67

Carapace length	Females	Males	Total	Females		
				Percentage of total lobsters	Berried	Berried
Cm.	Number	Number	Number	Percent	Number	Percent
5	3	0	3	100.0	--	--
6	2	9	11	18.2	--	--
7	8	15	23	34.8	--	--
8	10	17	27	37.0	1	10.0
9	19	16	35	54.3	3	15.8
10	40	13	53	75.5	6	15.0
11	34	13	47	72.3	10	29.4
12	44	21	65	67.7	4	9.1
13	62	12	74	83.8	13	21.0
14	43	15	58	74.1	8	18.6
15	26	9	35	74.3	4	15.4
16	27	9	36	75.0	7	25.9
17	8	15	23	34.8	0	--
18	10	8	18	55.6	1	10.0
19	9	5	14	64.3	1	11.1
20	1	4	5	20.0	0	--
21	0	5	5	--	--	--
22	0	1	1	--	--	--
23	0	1	1	--	--	--
Totals	346	188	534	64.8	58	16.8

Table 7.--Samples of the commercial catch of lobsters from Oceanographer Canyon, February 1966 to June 1967

Carapace length	Females	Males	Total	Percentage of females
Cm.	Number	Number	Number	Percent
8	16	11	27	59.3
9	67	55	122	54.9
10	91	43	134	67.9
11	168	49	217	77.4
12	213	68	281	75.8
13	260	89	349	74.5
14	214	77	291	73.5
15	99	77	176	56.2
16	84	59	143	58.7
17	91	49	140	65.0
18	65	47	112	58.0
19	34	33	67	50.7
20	12	21	33	36.4
21	2	16	18	11.1
22	0	5	5	0.0
Totals	1,416	699	2,115	67.0

At Oceanographer Canyon, as at Veatch Canyon, greater fishing depths produced larger lobsters. The mean carapace length of lobsters caught was 11 cm. at depths of 182 m. or less, and 13 cm. at depths of 182 m. or more (fig. 4).

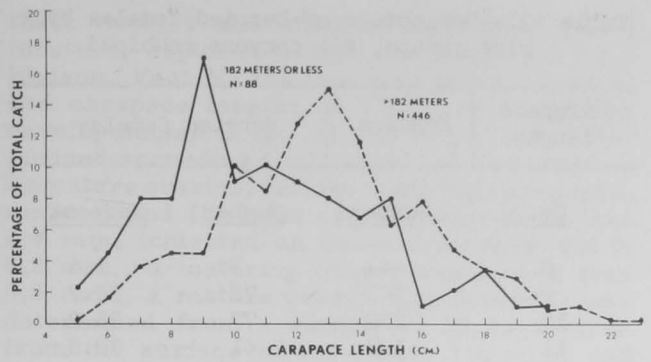

Figure 4.--Length distributions of lobsters caught above and below 182 m. at Oceanographer Canyon.

Lydonia Canyon

Lydonia Canyon is at lat. 40°30' N., long. 67°40' W., 35 km. east of Oceanographer Canyon. The area was sampled during research cruises in April 1965 and in April, June, July, and October 1966. Tows were made at depths 90 to 355 m. (50-195 fathoms). The dominance of large lobsters here, as at Oceanographer Canyon, is apparent both in the research catch (table 8) and the commercial samples (table 9).

Depth did not have a significant effect on the ratio of females to males, or the mean size of the catch, and the proportion of females did not increase with the mean carapace length of lobsters in a tow.

In depths of 182 m. or less, the difference between numbers of lobsters caught per hour in daytime (14) and at night (18) was not significant. In depths greater than 182 m., more lobsters were caught per hour in daylight (33) than at night (14) but the sample size was small and more data are needed to substantiate this difference. When catches from all tows in 182 m. or less were combined and compared with those in all tows made at greater depths, significant difference in catch per hour was apparent.

Table 8.--Catch of lobsters by research vessels, Lydonia Canyon, 1965-67

Carapace length	Females	Males	Total	Females		
				Percentage of total lobsters	Berried	Berried
Cm.	Number	Number	Number	Percent	Number	Percent
5	0	1	1	0.0	--	--
6	2	2	4	50.0	--	--
7	3	9	12	25.0	--	--
8	9	10	19	47.4	0	--
9	11	21	32	34.4	1	9.1
10	23	21	44	52.3	7	30.4
11	29	24	53	54.7	5	17.2
12	58	12	70	82.9	15	25.9
13	56	26	82	68.3	14	25.0
14	50	27	67	59.7	12	30.0
15	21	22	43	48.8	4	19.0
16	7	13	20	35.0	1	14.3
17	16	18	34	47.1	3	18.8
18	9	9	18	50.0	3	33.3
19	5	13	18	27.8	1	20.0
20	0	9	9	--	--	--
21	0	5	5	--	--	--
22	0	3	3	--	--	--
23	0	1	1	--	--	--
Totals	289	246	535	54.0	66	22.8

Table 9.--Samples of the commercial catch of lobsters from Lydonia Canyon, December 1965 to July 1966

Carapace length	Females	Males	Total	Percentage of females
Cm.	Number	Number	Number	Percent
8	22	21	43	51.2
9	52	60	112	46.4
10	63	45	108	58.3
11	86	57	143	60.1
12	91	45	136	66.9
13	98	61	159	61.6
14	75	48	123	61.0
15	57	44	101	56.4
16	33	57	90	36.7
17	30	47	77	39.0
18	21	42	63	33.3
19	9	44	53	17.0
20	5	30	35	14.3
21	2	19	21	9.5
22	0	7	7	0.0
Totals	644	627	1,271	50.7

Corsair Canyon

The area sampled is at lat. 41°15' N., long. 66°22' W., 154 km. northeast of Lydonia Canyon and 15 km. southwest of Corsair Canyon. The area was sampled during research cruises in April, June, and October 1965 and in April, June, and July 1966. Table 10

Table 10.--Catch of lobsters by research vessels, Corsair Canyon, 1965-66

Carapace length	Females	Males	Total	Females		
				Percentage of total lobster	Berried	Berried
Cm.	Number	Number	Number	Percent	Number	Percent
9	0	3	3	0.0	--	--
10	2	1	3	66.7	1	50.0
11	7	3	10	70.0	3	42.9
12	24	8	32	75.0	13	54.2
13	18	15	33	54.5	7	38.9
14	30	11	41	73.2	15	50.0
15	30	8	38	78.9	19	63.3
16	28	18	46	60.9	16	57.1
17	19	4	23	82.6	5	26.3
18	20	8	28	71.4	12	60.0
19	1	6	7	14.3	1	100.0
20	2	1	3	66.7	2	100.0
21	0	3	3	--	--	--
Totals	181	89	270	67.0	94	51.9

summarizes the results. Catches averaged between 8 and 12 lobsters per hour in this area in April and June 1965 and June 1966; but only one lobster was taken in a total of 11 tows made in October 1965 and April and July 1966. The results of sampling are presented primarily to show the great size of lobsters in the area.

MOLTING

Only a few soft (recently molted) lobsters have been taken during the research cruises (table 11). Soft lobsters are known to seek protective areas and would not be expected to enter the catch in substantial numbers. The percentage of soft lobsters was highest at Veatch Canyon in July 1966, when 39.6 percent of 47 lobsters collected were soft. Though we can be reasonably sure in assigning July and perhaps August as peak months of molting at Veatch Canyon, there is also a suggestion that molting occurred later in the eastern areas where the winter temperatures are lower.

Table 11.--Percentage soft (recently molted) lobsters in the catch by research vessels

Month and year	Hudson	Veatch	Oceanographer	Lydonia	Corsair
	Percent	Percent	Percent	Percent	Percent
April 1965	--	0.9	0.0	0.0	0.0
April 1966	0.0	0.0	0.0	0.3	0.0
April 1967	0.0	2.8	--	--	--
June 1965	--	1.7	0.0	--	0.0
June 1966	--	1.8	0.0	0.0	0.0
June 1967	0.9	7.4	2.2	--	--
July 1966	--	39.6	0.0	2.6	--
Oct. 1965	--	1.3	--	--	0.0
Oct. 1966	--	0.9	--	4.3	--
Oct. 1967	0.0	0.2	4.8	0.0	--

MATURITY

Table 12 shows the number of female lobsters and the number and percentage berried from the five canyon areas. The smallest berried lobster had a carapace length of 8 cm. Between carapace lengths of 10 and 16 cm. only 30 percent of the females were berried, though all females within this size range were considered to be sexually mature.

Templeman (1935, 1944) reported a method for determining maturity of females by the increase in the width of the abdomen relative to total length. We measured the width of the second abdominal segment and carapace length of 1,700 female lobsters from the five canyons. The lengths were 4 to 20 cm. In our analysis we included all females, whether berried or not, and used both the actual width of the abdominal segment and its ratio to the carapace length (Perkins and Skud, 1966).

Table 12.--Percentage of berried females by size groups, all canyons combined

Carapace length	Females	Berried females	
Cm.	Number	Number	Percent
8	441	7	1.6
9	343	78	22.7
10	232	77	33.2
11	133	41	30.8
12	168	43	25.6
13	163	44	27.0
14	121	37	30.6
15	94	28	29.8
16	64	24	37.5
17	46	9	19.6
18	40	16	40.0
19	16	3	18.8
20	3	2	66.7
Total	1,864	409	21.9

The relation of the actual width of the second abdominal segment to carapace length represents a significant curvilinear regression which is best fitted by the cubic regression equation $Y = a + b x + c x^2 + d x^3$. For convenience the carapace lengths were grouped into 5-mm. divisions and the mean width of the segments within each of these divisions was considered as the corresponding dependent variable. Figure 5 shows the second abdominal width-carapace length ratios and the corresponding carapace lengths.

From observations of berried lobsters, we know that maturity is attained by some females that have a carapace length of 8 cm. The data plotted in figure 5 show an inflection at 7.7 cm., and an asymptote is reached at about 10 cm. This indicates that the morphometric changes are associated with maturity and suggests that all females above 10 cm. are mature.

To test this hypothesis, 54 female lobsters were examined to determine the condition of

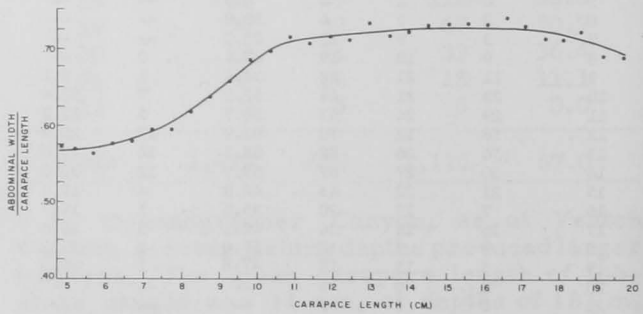

Figure 5.--Ratio of the width of the second abdominal segment to carapace length.

their ovaries and internal egg size. These lobsters, captured in May and June 1967 from Hudson, Veatch, and Oceanographer Canyons, had carapace lengths of 7.6 to 10.7 cm. The developmental stage of the ovary was categorized according to (1) color (white indicated immature ovaries; yellow, maturing; and green, mature) and (2) mean egg diameter (less than 0.4 mm. indicated an immature ovary; 0.4 to 0.8 mm., a maturing ovary; and larger than 0.8 mm., a mature ovary). Egg diameter was determined from a sample of 10 eggs taken from the surface of the ovary. The width and length of each egg were measured, and an average of the two measurements was used as the "size." Lobsters with immature eggs had carapace lengths of 7.6 to 8.4 cm.; females with developing eggs were 7.6 to 9.1 cm.; and those with mature eggs were 8.0 to 10.7 cm.

Measurements of the width of the second abdominal segment had been taken for 41 of these females from Hudson, Veatch, and Oceanographer Canyons. When the measurements of the ovarian eggs of these 41 individuals were plotted against the corresponding width of the abdominal segment, a definite relation was apparent (fig. 6). The highly significant correlation between the egg size and the abdominal width ($r = 0.897$, $P < 0.01$), and between egg size and carapace length confirms the relation of morphometric changes and maturity. Though exceptions can be anticipated, on the basis of our samples all females over 10 cm. in length (carapace) and/or with an abdominal width greater than 6 cm. are mature.

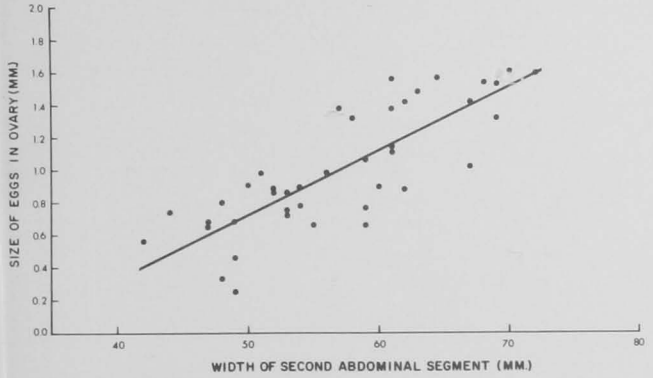

Figure 6.--Relation between width of second abdominal segment and size of internal eggs.

SUMMARY

The trawl-fishery for lobsters in the offshore waters of the North Atlantic is described and the increase in landings during recent years is discussed. This fishery contributed less than 1 percent to the U.S. lobster landings before 1948, but accounted for 17 percent of the total in 1968.

Samples of lobsters were obtained during research cruises and from commercial catches in five fishing areas--Hudson, Veatch, Oceanographer, Lydonia, and Corsair Canyons. The size composition, sex ratio, and number of egg-bearing lobsters are summarized by canyon.

Lobsters were smaller and apparently more numerous in the areas of the Continental Shelf west of and including Veatch Canyon than in areas to the east. At several canyons the average size of lobsters and the ratio of females to males increased with depth, and at some canyons there were striking differences between the numbers of lobsters caught in shoal waters (100-182 m.) and those taken in deep waters (over 182 m.). At Veatch Canyon, more lobsters were taken in shoal waters, whereas at Lydonia catches were much better in deep water than in shoal areas. There were also differences of day and night catches at the various canyons.

Females dominated the catch, at times accounting for 70 percent of a sample. The ratio of females to males was about 1:1 at sizes below 8 cm. carapace length. From 9 to 15 cm. the proportion of females increased but declined thereafter; at the largest sizes, 19 to 21 cm., males predominated. Skud (in press) examined the size composition and sex ratio by canyon area and hypothesized that the differences were due mainly to the effects of fishing.

Molting occurred from spring through fall in most areas. July appeared to be the month of peak molting at Veatch Canyon, and there was an indication that greatest molting activity occurs later in the areas east of Veatch Canyon.

The number of egg-bearing females in each size group was tallied on the research cruises, and these data, coupled with measurements of the second abdominal segments and ovarian eggs, showed that maturity may be attained at a carapace length of 8.0 cm. and indicated that all females are mature at a carapace length of 10.0 cm. or at an abdominal width (second segment) greater than 6 cm.

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