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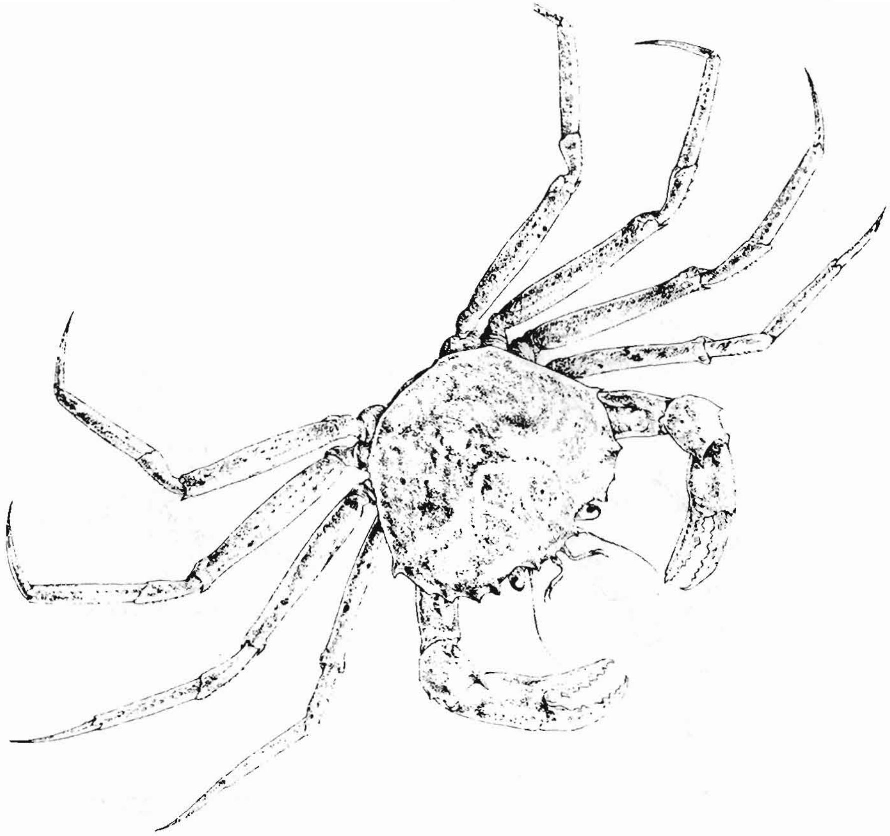

Deep-Sea Red Crab, *Geryon quinquedens*, Survey off Northeastern United States

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ABSTRACT—A quantitative survey of the deep-sea red crab, Geryon quinquedens, *was conducted in continental slope waters off the northeastern United States in June-July 1974. Red crabs were present in all geographic areas sampled, between offshore Maryland and eastern Georges Bank. They were found at water depths ranging from 274 to 1,463 m (150-800 fm), but there were striking differences in size and number of red crabs related to depth. The estimated number of red crabs of commercial size, 114 mm (4.5 in) or larger in carapace width, in the survey area was 43 million and the standing crop biomass 27 million kg (59 million pounds). Both number and biomass of crabs were greater at intermediate depths, 320-914 m (175-500 fm), than in either shallower or deeper waters. Size of crabs ranged from 8 to 142 mm (0.3-5.6 in). Males were substantially larger (average weight 413 g; 0.9 lb) than females (average weight 244 g; 0.5 lb). Largest crabs occurred in shallow waters and smallest crabs occurred in deepest waters. An up-slope migration is deduced from this pronounced size-depth relationship. Other topics included in this report are: notes on red crab biology, estimates of density of the American lobster, and descriptions of bottom sediments and topography.*

The red crab, *Geryon quinquidens*, above, was drawn from a live male specimen weighing 1-lb and measuring 4 inches point-to-point across the carapace.

INTRODUCTION

A quantitative survey of the deep-sea red crab, *Geryon quinquedens* Smith, an epibenthic brachyuran of the family Geryonidae, was conducted in continental slope waters off the northeastern United States in June-July 1974 by the National Marine Fisheries Service. The area surveyed extends from offshore Maryland northeastward to the Corsair Canyon region on the eastern end of Georges Bank (Fig. 1). Operations were conducted at water depths from 229 to 1,646 m (125-900 fm).

Primary purposes of the survey were to determine the distribution and to obtain estimates of the numbers and biomass of red crabs in the area sampled. Secondary objectives were to assess the size composition of this species and obtain supplementary information on its life history and ecology.

Previous Studies

Geographically, the range of the deep-sea red crab is limited, according to present records, to the western portions of the North and South Atlantic Oceans. It is a common resident in the Gulf of Maine, ranging as far northward as Casco Bay, Me., and to lat. 43°52′N in the central Gulf. Its northernmost occurrence off eastern Nova Scotia is approximately lat. 43°15′N, long. 60°50′W. From these localities it occurs southward along the continental slope to Cuba, the Gulf of Mexico, and Brazil (Rathbun, 1937; Chace, 1940; Schroeder, 1959). Bathymetrically, it ranges from 40 to 2,155 m (22-1,178 fm), but is principally an inhabitant of the bathyal zone. Records of its occurrence at depths shallower than about 210 m (115 fm) all pertain to specimens from the Gulf of Maine.

Published information is rather limited regarding the practical aspect of showing the density of occurrence of red crabs within its geographic and bathymetric ranges. The relative catch rates of this crab in different geographic

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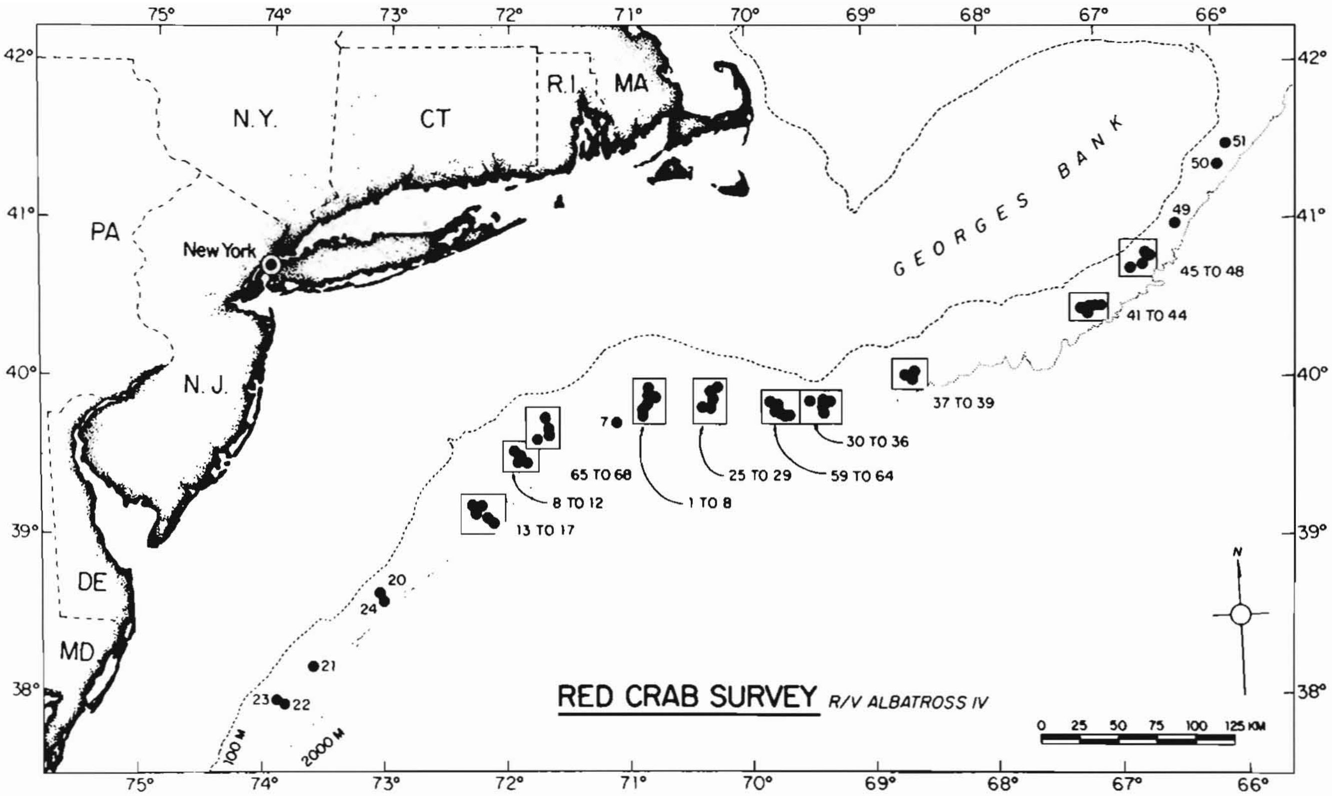


Figure 1.—Sampling stations (solid dots) occupied by the research vessel *Albatross IV* during the red crab survey, June-July 1974. Details of station locations, environmental characteristics, and sampling are given in Table 1.

areas and water depths have been derived from catches made with a variety of trawls and baited traps (pots). Schroeder (1955, 1959) reported the number of crabs per 1-h haul in numerous samples taken on the continental slope between offshore Virginia and Nova Scotia. Sampling gear used in that study consisted of otter trawls having groundrope lengths of 11, 15, and 18 m (35, 50, and 60 ft). Best catches, which averaged 126-245 crabs per 1-h haul, were made in the New York-Virginia region at water depths from 274 to 732 m (150-400 fm). McRae (1961) reported on the results of trawling by the U.S. Bureau of Commercial Fisheries[1]. They sampled a large area, extending from the Cape Ann, Mass. region in the Gulf of Maine southward to offshore Virginia, using New England otter trawls and Gulf of Mexico shrimp trawls. Red crabs were taken at water depths from 110 to 1,463 m (60-800 fm), with largest catches taken between 366 and 549 m (200 and 300 fm). In general the crab catches were small to moderate; the single largest catch consisted of 253.11 kg (558 lb) of crabs caught in a

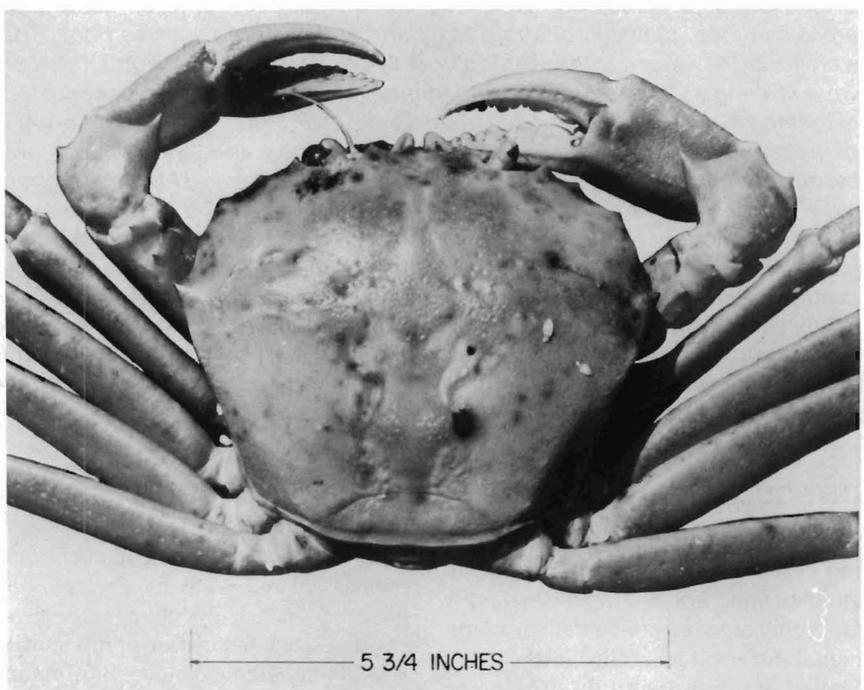


Figure 2.—Dorsal view of an adult male red crab from the continental slope south of Martha's Vineyard, Massachusetts. Several small stalked barnacles may be seen attached to the carapace which is 142 mm (5.6 in) in width.

[1]Renamed the National Marine Fisheries Service in 1970 when transferred into the newly established National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce.

70-min haul at depths from 366 to 457 m (200-250 fm). Meade (1970) and Meade and Gray (1973) reported on exploratory red crab fishing with trawls and baited traps off southern New England in 1969 conducted by the University of Rhode Island and Rhode Island Department of Natural Resources. They reported several large catches, up to 1587.6 kg (3,500 lb) per h, were made at depths between 439 and 549 m (240 and 300 fm) on the slope off southern New England between Veatch and Atlantis Canyons. Gear used was a standard otter trawl with a 53.3-m (175-ft) groundrope and otter doors that were 2.29 m (7.5 ft) long and weighed 499 kg (1,100 lb). Their work included limited fishing with modified king crab pots that yielded catches of 72-111 kg (158 and 245 lb) of red crabs per pot. In 1971 the National Marine Fisheries Service conducted experimental fishing for red crabs using several kinds of baited traps (Anonymous, 1971). Fishing was successfully carried out at depths from 150 to over 1,097 m (84-600 fm) in the vicinity of Block, Hudson, and Baltimore Canyons. High concentrations of *Geryon* were found at depths between 457 and 914 m (250 and 500 fm). Best catches were made in the Hudson Canyon region where lobster pot catches averaged 55.3 kg (122 lb) of crabs per day, and a single king crab pot caught 323.9 kg (714 lb) of crabs in an 18-h set. Red crabs in the Norfolk Canyon area were studied by Haefner and Musick (1974). They reported both the number and weight of red crabs caught with a 13.7 m (45 ft) otter trawl and in specially constructed crab traps baited with long-finned hake, *Urophycis chesteri*. Red crabs were most abundant at depths between 265 and 512 m (145 and 280 fm) where 27.4 kg (60.5 lb) per 0.5-h haul were taken with the trawl. Interestingly, they reported finding more crabs in areas adjacent to the canyon than in the canyon proper.

Fishery

Red crabs (Fig. 2) presently support a small fishery in southern New England. Recent landings have ranged from near zero to as much as 45,360 kg (100,000 lb) per month. Several vessels fish specifically for red crabs, at least part time. Another source of red crabs is the incidental catch in the offshore lobster fishery. The principal ports handling red crabs are New Bedford, Mass. and Galilee (Point Judith), R.I. Because of the newness of this fishery the fishing methods and processing procedures are in the developmental stages and consequently vary considerably. The principal fishing methods employed at this time are baited lobster pots or modified crab pots. Some of the vessels bring the crabs to port alive, on ice or in circulating sea water tanks (Holmsen and McAllister, 1974). Others butcher the crabs at sea, by removing and discarding the carapace and viscera. The legs and attached muscle meat are frozen and brought to shore for further processing. In 1974 there were two processing plants that handled significant quantities of red crabs: (1) Galilee Offshore Marine, Inc.[2], Galilee, R. I., and (2) New Bedford Atlantic Associates, New Bedford, Mass. Recent market developments have caused a substantial curtailment in red crab landings and processing.

Other Species

A second species of red crab—*Geryon affinis* A. Milne Edwards and Bouvier—occurs off the U.S. east coast, but it has a more southerly distribution. It is a deep-water species, like *G. quinquedens*, and is known from U.S. waters from the Florida Straits northward to the offing of Chesapeake Bay (Schroeder, 1959). In a negative way our survey data support this distributional information in that we did not catch any specimens of *G. affinis*. Commercial boats fishing for deep-sea red crabs catch a few *G. affinis* specimens in the southern New England region, but we have no records of exact location or number caught.

[2]The use of trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

MATERIALS AND METHODS

Survey operations were conducted from *Albatross IV*, a 57 m (187-ft) research vessel operated for the Northeast Fisheries Center by the National Ocean Survey, Office of Fleet Operations, NOAA. Sampling gear of two principal types was used on this survey: (1) an underwater photographic system (Fig. 3) which took in situ photographs of the sea bottom and constituent epibenthic fauna, and (2) an otter trawl used for catching red crabs.

Photographs of the sea bottom were obtained for the purpose of determining

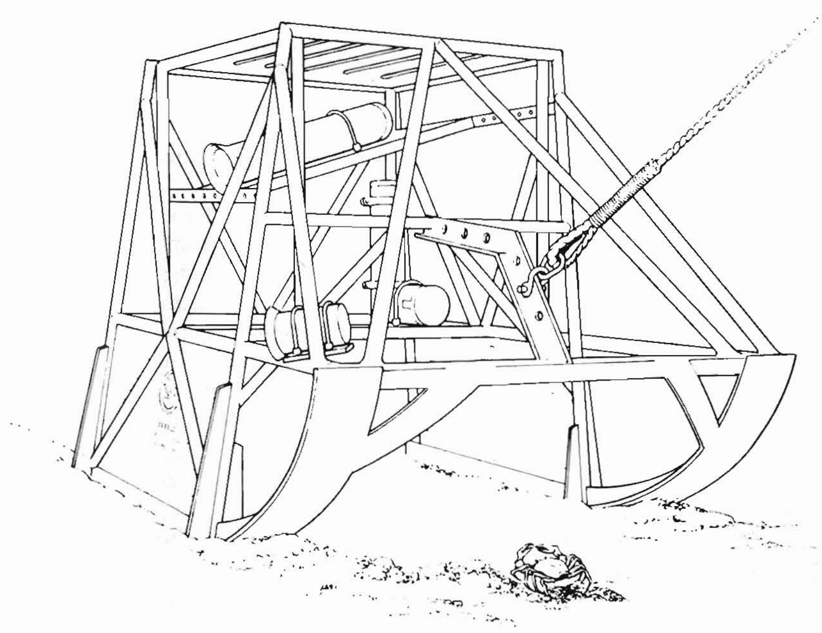


Figure 3.—Front-oblique view of the sled-mounted photographic system. Camera is mounted at upper right-center of sled, the electronic flash unit is in the forward corner, the power pack is fastened horizontally at the left center of the sled, and the orientation pinger is mounted vertically in the rear corner.

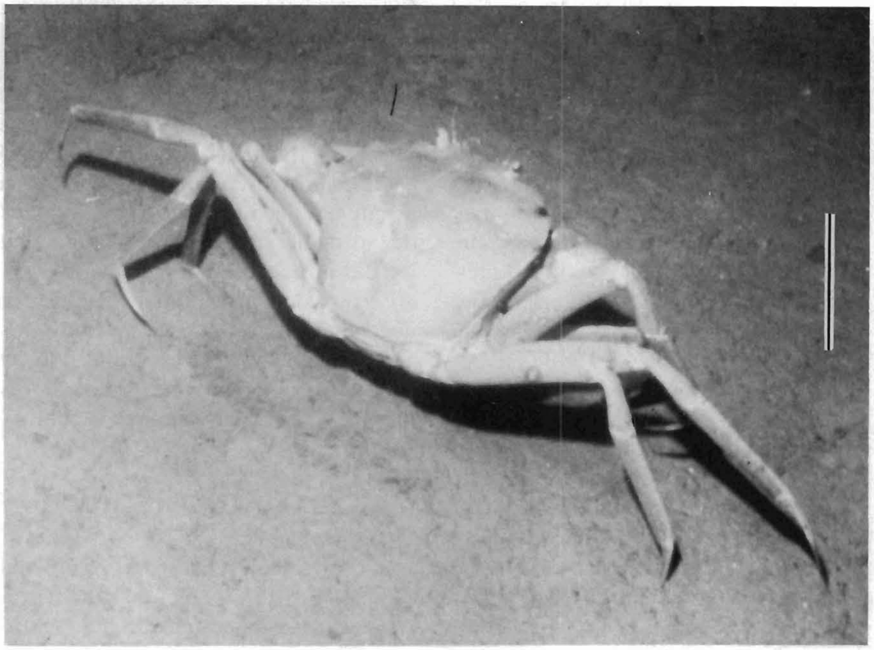


Figure 4.—Adult red crab photographed in situ on the continental slope sea bottom south of Nantucket Shoals, using the sled-mounted photographic system. Size of this specimen is approximately 13 cm (5.1 in) carapace width. This is an enlarged portion of a photograph covering a much larger area of sea bottom. Scale bar is 10 cm (3.9 in).

the density (number per unit area of sea bottom) of red crabs (Fig. 4). The photographic system consisted of a 70-mm (2.75-in) camera and stroboscopic light mounted on a large steel sled. Dimensions of the sled are: 2.7 m (9 ft) long, 2.1 m (7 ft) wide, and 1.9 m (6 ft 8 in) high. It was constructed of heavy-gauge 6.4-cm (2.5-in) diameter steel pipe, and runners 25.4 cm (10 in) broad and 2.5 cm (1 in) thick. The sled weighs 1,225 kg (2,700 lb). The camera was a Hydro-Products Deep Sea Photographic Camera, Model PC-705; the strobe unit was a Hydro-Products, Deep Sea Strobe, Model PF-730. Film used was Kodak Ektachrome EF daylight (color) and Kodak Tri-X Pan (black and white).

The photo sled was towed slowly, from 1 to 2 knots, along the bottom at each station where the topography of the sea floor was suitable. Suitability of the bottom was evaluated immediately prior to launching by means of a fathometer. At the shallower depths, less than 585 m (320 fms), we used an ELAC fathometer and in deep water an EDO instrument. The tow duration of the photo sled at each station ranged from 30 to 75 min, depending on local conditions (bottom roughness, anchored fishing gear, etc.). The camera was programmed to obtain a photograph every 10 sec; thus the maximum number of photographs during one tow was approximately 400. Upon completion of the photo-sled tow, the film was removed, and a short strip (1-2 m; 3-6 ft) was developed to monitor focus, strobe light position, exposure, etc. The remainder of the film was brought to the laboratory ashore and sent to commercial film processors for developing and printing. A total of 18,000 photographs was obtained at 33 stations (Table 1). Of this total, 8,262 photographs representing the best quality for enumeration purposes were selected for quantitative analyses.

To maximize the accuracy of information acquired from the photographic enumeration, only the best-lighted area nearest the camera in individual photographs, which represented a bottom area of 31.8 m^2, was examined and the faunal components counted. All areas darkened or obscured by shadows from sediment clouds and other factors that obscured the view were deducted in determining crab density. Standard coefficients of diminished visibility of organisms, based on the square of the distance from the camera, were derived from a random sample. For purposes of analysis the study area was divided into four geographic zones labeled A through D (Fig. 7). The area of each zone, in thousands of hectares, is: A, 453; B, 253; C, 439; and D, 418. Population estimates of the red crab were calculated by multiplying crab density by the geographic area (determined from nautical charts), within each geographic zone and water depth class.

An otter trawl was used to collect samples of red crabs for determining size composition, sex ratios, and other aspects of their biology and life history. The trawl used was a 4.9-m (16-ft) semi-balloon otter trawl. Trawl groundrope was 5.8 m (19 ft) long; wire extension pieces were 4 m (12 ft) long; mesh of the wings and body was No. 9 thread, 3.8 cm (1.5 in), stretched measure; codend mesh was No. 15 thread, 3.2 cm (1.25 in). The trawl was fished at 43 stations (see Table 1). It was towed at a speed of from 1.5 to 2 knots for 30 min (except at stations 25, 43, and 50, which were of only 15 min duration and the catch statistics were prorated to 30 min equivalents). Trawl contents were sorted and processed (identified, counted, weighed) aboard ship. Selected components were preserved and brought to the laboratory ashore for additional study. Size (carapace width), weight, sex, and other biological information was obtained for the red crabs in each haul. Width was measured with calipers from the outermost face of the fifth antero-lateral spine on each side of the carapace. Weights of small specimens or small quantities were measured with Chatillion spring balances; for large quantities a bar-beam balance was used.

The term "young" or "young crab", as used in this report, refers to small *Geryon* without externally evident sex-related morphological characteristics which distinguish males from females. Water temperature was measured by means of XBT's; one XBT at each station (see columns 11 and 12 in Table 1). A standard set of descriptive terms from Heezen and Hollister (1971) was employed in characterizing the bottom topography.

The total number of red crabs caught with the otter trawl was 1,441 of which 795 were females, 641 were males, and 5 were young. Records of the number caught and their average size in terms of weight and carapace width are listed for each station in Table 2. Red crabs were taken at 33 stations; they were com-

Table 1.—Station and collection data pertaining to the otter trawl and sled-mounted camera operated from R/V *ALBATROSS IV* 28 June and 8-24 July 1974.

Station No.	Gear	Date	Time	Start Lat. N.	Start Long. W.	End Lat. N	End Long. W.	Water depth Fathoms	Water depth Meters	Bottom water temperature °F	Bottom water temperature °C
1	Trawl	6/28	0727	40°00.0′	70°53.0′	40°01.0′	70°51.0′	150-170	274-311	48.5	9.2
2	Trawl	7/9	0610	39°57.0′	70°52.0′	39°59.0′	70°51.5′	210-225	384-412	44.5	6.9
	Camera	22	2130	39°58.0′	70°59.0′	39°58.0′	71°03.0′	195-200	357-366	46.5	8.1
3	Trawl	9	0818	39°56.5′	70°48.5′	39°56.0′	70°46.5′	250-250	457-457	42.0	5.6
4	Trawl	9	2045	39°54.0′	70°53.0′	39°54.0′	70°52.0′	290-290	530-530	42.2	5.7
5	Camera	10	0230	39°51.5′	70°56.0′	39°51.5′	70°59.0′	450-460	823-841	39.9	4.4
6	Camera	10	0550	39 49.0′	70°56.0′	39°49.0′	71°00.0′	590-600	1,079-1,097	39.9	4.4
7	Trawl	10	1227	39°47.0′	71°07.0′	39°47.0′	71°08.0′	780-800	1,426-1,463	39.5	4.2
	Camera	10	0914	39°46.0′	71°04.0′	39°46.0′	71°01.0′	800-800	1,463-1,463	39.5	4.2
8	Trawl	10	2105	39°35.5′	72°00.5′	39°34.5′	72°02.5′	140-140	256-256	50.2	10.1
	Camera	10	2235	39°35.0′	72°02.0′	39°37.5′	71°59.5′	140-140	256-256	50.2	10.1
10	Trawl	11	0330	39°34.5′	71°57.0′	39°33.0′	71°57.0′	240-260	439-476	42.5	5.8
	Camera	11	0640	39°33.0′	71°57.5′	39°34.0′	71°56.0′	248-260	454-476	42.5	5.8
11	Camera	11	0825	39°33.0′	71°57.0′	39°34.0′	71°54.0′	300-300	549-549	41.9	5.5
12	Trawl	11	1136	39°32.0′	71°54.0′	39°30.5′	71°54.5′	405-418	741-765	41.0	5.0
13	Trawl	11	2128	39°14.5′	72°20.0′	39°13.5′	72°21.5′	170-175	311-320	46.9	8.3
	Camera	11	1910	39°14.0′	72°23.0′	39°15.0′	72°19.0′	170-178	311-326	46.9	8.3
14	Camera	11	2315	39°14.0′	72°21.0′	39°15.0′	72°18.5′	200-210	366-384	44.8	7.1
15	Trawl	12	0148	39°13.5′	72°20.0′	39°14.0′	72°19.5′	245-250	448-457	42.7	5.9
	Camera	12	0710	39°15.0′	72°18.0′	39°15.5′	72°22.0′	250-255	457-466	42.7	5.9
16	Camera	12	0750	39°14.5′	72°16.0′	39°15.5′	72°14.0′	290-290	530-530	42.9	6.0
17	Trawl	12	1016	39°14.0′	72°14.5′	39°12.5′	72°16.2′	398-400	728-732	41.4	5.2
	Camera	12	1220	39°12.0′	72°16.5′	39°13.0′	72°14.0′	390-400	713-732	41.4	5.2
18	Camera	12	1508	39°10.0′	72°13.0′	39°11.5′	72°10.0′	575-590	1,051-1,079	42.7	5.9
19	Trawl	12	2035	39°07.0′	72°10.0′	39°08.0′	72°09.5′	900-900	1,646-1,646	39.9	4.4
20	Trawl	13	0800	38°40.0′	73°05.0′	38°39.0′	73°06.0′	160-175	293-320	(47.5)	(8.6)
21	Trawl	13	1639	38°12.0′	73°40.0′	38°12.0′	73°39.0′	220-235	402-430	43.4	6.3
	Camera	13	1800	38°12.0′	73°39.5′	38°10.0′	73°41.0′	215-225	393-412	43.4	6.3
22	Camera	13	2158	37°56.3′	73°55.5′	37°58.5′	73°55.0′	150-150	274-274	54.8	12.7
23	Trawl	14	0035	37°57.5′	73°55.0′	37°58.0′	73°54.5′	185-205	338-375	47.5	8.6
24	Trawl	14	1510	38°37.0′	73°02.5′	38°36.5′	73°03.5′	600-675	1,097-1,234	40.1	4.5
25	Trawl	15	0610	40°01.5′	70°18.5′	40°02.0′	70°18.0′	135-140	247-256	50.7	10.4
27	Trawl	15	1018	39°55.0′	70°22.0′	39°55.2′	70°21.5′	250-260	457-476	42.2	5.7
	Camera	15	1150	39°55.0′	70°23.0′	39°55.0′	70°27.0′	240-270	439-494	42.2	5.7
28	Camera	15	2315	39°53.0′	70°25.0′	39°54.0′	70°22.0′	320-350	585-640	41.2	5.1
29	Trawl	15	1820	39°52.5′	70°23.0′	39°53.5′	70°23.0′	370-380	677-695	40.6	4.8
	Camera	15	2000	39°53.0′	70°23.5′	39°55.0′	70°19.0′	285-400	521-732	40.6	4.8
30	Camera	16	0420	39°55.5′	69°32.0′	39°56.0′	69°32.0′	150-155	274-284	49.8	9.9
31	Trawl	16	0650	39°55.0′	69°24.0′	39°55.5′	69°21.5′	198-235	362-430	50.2	10.1
	Camera	16	0810	39°55.0′	69°22.0′	39°54.5′	69°24.5′	200-250	366-457	50.2	10.1
32	Camera	16	1015	39°55.2′	69°22.0′	39°56.0′	69°19.0′	250-275	457-503	42.7	5.9
33	Trawl	16	1253	39°53.5′	69°24.0′	39°53.0′	69°25.0′	340-360	622-658	41.4	5.2
	Camera	16	1455	39°55.0′	69°18.5′	39°54.0′	69°21.5′	330-340	603-622	41.4	5.2
35	Trawl	16	2130	39°52.5′	69°24.0′	39°52.0′	69°25.0′	500-600	914-1,097	39.7	4.3
36	Trawl	16	2315	39°51.5′	69°24.0′	39°52.0′	69°22.0′	710-745	1,298-1,362	39.7	4.3
37	Trawl	17	0640	40°06.5′	68°37.5′	40°06.5′	68°39.5′	125-145	229-265	48.0	8.9
38	Camera	17	1050	40°05.2′	68°43.5′	40°05.5′	68°40.5′	190-240	348-439	46.0	7.8
39	Trawl	17	1315	40°04.5′	68°41.0′	40°04.0′	68°42.0′	210-260	384-478	47.1	8.4
	Camera	17	1430	40°04.0′	68°41.5′	40°05.5′	68°39.5′	235-245	430-448	47.1	8.4
40	Trawl	18	0144	40°29.8′	67°11.0′	40°30.5′	67°10.0′	160-170	293-311	46.9	8.3
	Camera	18	0240	40°30.0′	67°08.5′	40°29.5′	67°11.0′	155-160	284-293	46.9	8.3
41	Camera	18	0433	40°29.0′	67°08.5′	40°30.0′	67°06.0′	195-280	357-512	41.0	5.0
42	Trawl	18	0708	40°30.5′	67°05.0′	40°30.5′	67°06.5′	230-250	421-457	42.9	6.1
43	Trawl	18	1030	40°32.0′	67°02.5′	40°32.2′	67°02.4′	212-250	388-457	42.8	6.0
44	Trawl	18	1405	40°28.5′	67°08.0′	40°28.0′	67°09.0′	400-460	732-841	40.8	4.9
45	Trawl	18	2045	40°45.0′	66°47.0′	40°44.8′	66°47.2′	130-132	238-241	(50.0)	(10.0)
	Camera	18	2140	40°45.5′	66°45.5′	40°47.2′	66°42.0′	115-160	210-293	(50.0)	(10.0)
46	Camera	18	2352	40°46.0′	66°41.0′	40°45.5′	66°43.0′	195-200	357-366	44.9	7.2
47	Trawl	19	0345	40°50.0′	66°37.5′	40°48.0′	66°38.0′	240-260	439-478	41.5	5.3
48	Trawl	19	0823	40°48.0′	66°36.0′	40°48.0′	66°38.0′	250-320	457-585	42.0	5.6
49	Trawl	19	1240	41°00.5′	66°23.5′	41°00.0′	66°24.0′	420-475	768-869	41.0	5.0
50	Trawl	19	1630	41°23.0′	66 01.0′	(41°23.6′)	(66°00.7′)	180-(180)	329-(329)	44.4	6.9
51	Trawl	19	1925	41°29.0′	65 55.5′	41°29.5′	65°55.0′	195-205	357-375	44.0	6.7
59	Trawl	21	1028	39°55.5′	69°51.5′	39°55.5′	69°49.5′	118-200	216-366	54.8	12.7
	Camera	21	1315	39°55.5′	69°53.0′	39 55.0′	69°49.0′	140-145	256-265	54.8	12.7
60	Camera	21	1525	39°54.0′	69°48.5′	39°54.0′	69°50.0′	220-230	402-421	46.0	7.8
61	Trawl	21	1945	39°53.0′	69°48.5′	39°53.0′	69°49.8′	275-278	503-508	44.6	7.0
62	Camera	22	0214	39°52.5′	69°44.0′	39°52.0′	69°47.0′	305-315	558-576	42.2	5.7
63	Trawl	22	0808	39°51.0′	69°43.0′	39°51.0′	69°45.0′	410-420	750-768	40.6	4.8
	Camera	22	0628	39°51.0′	69°44.0′	39°51.0′	69°42.0′	410-420	750-768	40.6	4.8
64	Trawl	22	1134	39°50.0′	69°42.0′	39°49.5′	69°43.0′	550-555	1,006-1,015	41.9	5.5
65	Trawl	23	1258	39°50.0′	71°46.0′	39°50.5′	71°44.5′	150-150	274-274	50.7	10.4
66	Trawl	23	1645	39°48.0′	71°45.0′	39°49.0′	71°46.0′	195-210	357-384	44.9	7.2
67	Trawl	23	2050	39°44.0′	71°46.5′	39°42.5′	71°46.5′	250-255	457-466	43.1	6.2
	Camera	23	2205	39°43.0′	71°46.0′	39°41.0′	71°49.0′	225--525	412--960	43.1	6.2
68	Trawl	24	0042	39°40.0′	71°49.0′	39°39.5′	71°50.5′	310-330	567-603	41.7	5.4

monly absent in hauls taken in very shallow water and very deep water. The largest catch was made at station 66 where 218 crabs weighing 78.9 kg (174 lb) were taken in the standard 30-min haul. This catch is illustrated in Figure 8. One red crab was caught by means of a 1-m (3.3 ft) Naturalist's dredge, and thus not listed with the trawl caught specimens in Table 2. This specimen is a young crab 8.8 mm (0.3 in) in carapace width. It was taken on the slope south of Georges Bank at a depth of 914-1,051 m (500-575 fm), bottom sediment was silt-clay, and bottom water temperature

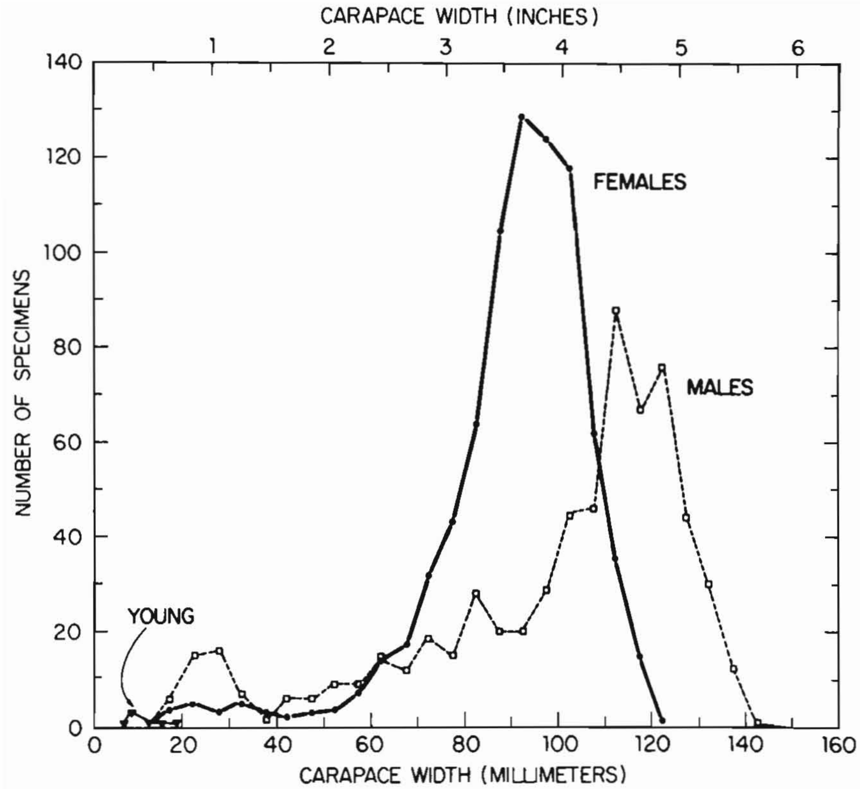


Figure 5.—Size frequency distribution of all red crabs caught during the survey, with females, males, and young plotted separately.

was estimated to have been 4.4°C (39.9°F). See Table 16 for additional details pertaining to this specimen.

SIZE

Variations Between Females, Males, and Young

Red crabs caught on this survey ranged in size from 8 mm (0.3 in) to 142 mm (5.6 in) in carapace width, and from 0.1 g (0.004 oz) to 964 g (2.1 lb) damp weight. Striking differences in size were observed between males and females and also for specimens of both sexes taken at various water depths. The size frequency-distribution of all trawl caught crabs from all depths combined is illustrated separately for females, males, and young in Figure 5. A detailed listing of size composition of crabs caught at each station, by sex, and by depth zones, was reported by Murray

Table 2.—Number of red crabs, their average carapace width and average weight, and total weight of all red crabs, caught with the otter trawl at each station. (Parentheses indicate prorated numbers and weights.)

Station number	Number				Average carapace width (mm)				Average weight (g)				Total weight (kg)
	Females	Males	Young	Total	Females	Males	Young	All spec.	Females	Males	Young	All spec.	
1	1	2	0	3	110	130	—	124	300	690	—	560	1.68
2	5	7	0	12	100	103	—	102	259	367	—	322	3.87
3	40	32	0	72	95	106	—	100	239	396	—	309	22.22
4	22	27	0	49	82	82	—	82	213	306	—	264	12.95
7	0	0	0	0	—	—	—	—	—	—	—	—	0
8	0	0	0	0	—	—	—	—	—	—	—	—	0
10	118	64	0	182	94	100	—	96	251	368	—	648	53.17
12	0	26	2	28	—	94	18	89	—	339	1	315	8.81
13	3	24	0	27	98	107	—	106	320	501	—	481	12.99
15	28	23	0	51	93	108	—	100	228	435	—	321	16.39
17	9	13	0	22	40	62	—	53	53	218	—	151	3.31
19	0	0	0	0	—	—	—	—	—	—	—	—	0
20	0	1	0	1	—	139	—	139	—	780	—	780	0.78
21	138	27	0	165	87	109	—	90	217	533	—	268	44.27
23	22	4	0	26	103	118	—	105	274	535	—	315	8.18
24	2	11	0	13	60	30	—	35	62	13	—	20	0.26
25	0	0	0	0	—	—	—	—	—	—	—	—	0
27	31	23	0	54	97	117	—	106	271	530	—	381	20.59
29	6	56	0	62	77	101	—	98	192	420	—	397	24.64
31	37	34	0	71	104	122	—	112	287	594	—	434	30.79
33	5	26	0	31	72	79	—	78	192	284	—	270	8.36
35	11	17	0	28	32	26	—	28	8	4	—	6	0.16
36	0	0	0	0	—	—	—	—	—	—	—	—	0
37	0	0	0	0	—	—	—	—	—	—	—	—	0
39	6	10	0	16	78	97	—	90	187	430	—	339	5.42
40	3	0	0	3	109	—	—	109	360	—	—	360	1.08
42	26	6	0	32	101	116	—	104	268	497	—	311	9.95
43	(12)	(15)	0	(27)	101	106	—	104	312	492	—	412	(11.13)
44	0	0	0	0	—	—	—	—	—	—	—	—	0
45	0	0	0	0	—	—	—	—	—	—	—	—	0
47	12	2	0	14	97	126	—	101	266	680	—	325	4.56
48	2	4	0	6	104	126	—	119	280	662	—	535	3.21
49	0	3	0	3	—	95	—	95	—	541	—	541	1.62
50	0	0	0	0	—	—	—	—	—	—	—	—	0
51	0	0	0	0	—	—	—	—	—	—	—	—	0
59	4	16	0	20	104	120	—	117	268	542	—	487	9.74
61	36	30	0	66	88	108	—	97	249	489	—	358	23.65
63	1	10	1	12	26	108	9	93	3	420	0.1	350	4.20
64	6	10	2	18	50	52	8	47	32	66	0.1	48	0.86
65	0	2	0	2	—	119	—	119	—	680	—	680	1.36
66	155	63	0	218	93	110	—	98	290	540	—	362	78.92
67	52	22	0	74	82	90	—	84	215	380	—	264	19.55
68	2	31	0	33	80	95	—	94	115	311	—	299	9.87

Table 3.—Average carapace width (in millimeters) of red crabs, listed by geographic zone and water depth class.

Water depth		Avg. carapace width (mm)				
		Geographic zones				
Meters	Fathoms	A	B	C	D	All[1]
			Females			
229- 320	125-175	98	—	105	109	104
320- 412	175-225	89	93	103	101	96
412- 503	225-275	93	90	93	97	93
503- 640	275-350	—	80	80	104	88
640- 914	350-500	40	—	70	—	55
914-1,280	500-700	60	—	38	—	49
			Males			
229- 320	125-175	109	119	121	—	116
320- 412	175-225	110	110	119	106	111
412- 503	225-275	108	97	110	107	106
503- 640	275-350	—	95	81	126	101
640- 914	350-500	62	94	102	95	88
914-1,280	500-700	60	—	36	—	33
			Young			
229- 320	125-175	—	—	—	—	—
320- 412	175-225	—	—	—	—	—
412- 503	225-275	—	—	—	—	—
503- 640	275-350	—	—	—	—	—
640- 914	350-500	—	18	9	—	14
914-1,280	500-700	—	—	8	—	8

[1]Mean of geographic zone values.

Table 4.—Average weight (in grams) of red crabs, listed by geographic zone and water depth class.

Water depth		Average weight (g)				
		Geographic zones				
Meters	Fathoms	A	B	C	D	All[1]
			Females			
229- 320	125-175	320	—	274	360	318
320- 412	175-225	225	290	284	312	278
412- 503	225-275	228	240	252	256	244
503- 640	275-350	—	115	209	280	201
640- 914	350-500	53	—	165	—	109
914-1,280	500-700	62	—	16	—	39
			Males			
229- 320	125-175	513	680	558	—	584
320- 412	175-225	533	540	555	492	530
412- 503	225-275	435	371	465	480	438
503- 640	275-350	—	311	296	662	423
640- 914	350-500	218	339	420	541	379
914-1,280	500-700	13	—	27	—	20
			Young			
229- 320	125-175	—	—	—	—	—
320- 412	175-225	—	—	—	—	—
412- 503	225-275	—	—	—	—	—
503- 640	275-350	—	—	—	—	—
640- 914	350-500	—	1	0.1	—	0.6
914-1,280	500-700	—	—	0.1	—	0.1

[1]Mean of geographic zone values.

(1974)[3]. This compilation pertains to the same cruises and same specimens analysed here.

Male crabs were substantially larger than females in carapace width and heavier in weight. Males ranged in carapace width from 17 to 142 mm (0.7-5.6 in); average width of all males caught was 99 mm (3.9 in); modal width was 112.5 mm (4.4 in). Males ranged in weight from 0.8 to 964 g (0.002-2.1 lb); average weight of all males caught was 413 g (0.9 lb); modal weight of males was 520 g (1.1 lb).

Female crabs ranged in carapace width from 18 to 121 mm (0.7-4.8 in); average width of all females caught was 90 mm (3.5 in); modal width was 92.5 mm (3.6 in). Females ranged in weight from 1 to 490 g (0.002-1.1 lb); average weight of all females caught was 244 g (0.5 lb); modal weight of females was 260 g (0.6 lb).

Young crabs ranged in carapace width from 8 to 18 mm (0.3-0.7 in), and from 0.1 to 1.1 g (0.004-0.04 oz) damp weight. Average carapace width was 12 mm (0.5 in); average weight was 0.4 g (0.01 oz). Since only 6 young were obtained, it was not feasible to ascertain differences in size as related to geographic areas.

Although procedures for aging this species have not been developed, some encouraging indications have emerged from the trawl-caught specimens suggesting that size-frequency patterns may contribute to the solution of this problem. Some pronounced modes are apparent for small specimens in the carapace width frequency-distribution graph illustrated in Figure 5. The limited size range of the young, plus the pronounced mode—especially distinct for males at 22-28 mm (approximately 1 in) but apparent also for small females—is suggestive of a year-class mode. If in fact this mode represents a single year class, it signifies that age determinations by the Petersen length-frequency method may be possible for this species.

Up-Slope Migration and Variations in Size with Depth

The first clear evidence of a size-related up-slope migration for this species was deduced from the pronounced inverse relationship between water depth and crab size for females, males, and young. Young crabs were found only in deep water, whereas the largest crabs occurred only in shallow water. Thus, as red crabs become older and larger they migrate up the continental slope into shallower water. The consistent increase in size associated with a decrease in water depth is shown clearly in Table 3 where females from deep water (all geographic zones combined) averaged 49 mm (1.9 in) in carapace width and were progressively larger in shallow water culminating at 104 mm (4.1 in) carapace width in the shallowest water. This same trend was revealed for males; they increased from 33 mm (1.3 in) average size in deep water to 116 mm (4.6 in) in shallow water. Changes in crab weight were related to water depth in a pattern similar to that described for carapace width (Table 4). Average individual weight of female crabs was 39 g (1.4 oz) in deep water and increased progressively to 360 g (0.8 lb) in shallow water. Males averaged 20 g (0.7 oz) in deep water and increased in average weight to 584 g (1.3 lb) in shallow water. This same trend was apparent in each geographic zone, although small samples in some areas resulted in some inconsistencies.

Another indication of up-slope migration, albeit based on relatively few specimens, was the increase in size of young red crabs in relation to water depth. The smallest young, which averaged 8 mm (0.3 in) were taken in the deepest water, 914-1,280 m (500-700 fm). Somewhat larger young, which averaged 14 mm (0.6 in), were taken in shallower water, 640-914 m (350-500 fm).

Variations with Geographic Area

Modest differences in crab size were related to geographic location. Crabs generally were smaller in the southwestern portion of the survey area (geographic zone A), intermediate in size in the Middle Atlantic and southern New England region (geographic zones B and C), and larger in the northeastern region (geographic zone D). Average carapace width, listed separately by sex and geographic zone, is given in Table 3. Females in zone D averaged about 11 percent broader in carapace width than those in zone A; size differential for males from these two zones was 12 percent. Essentially the same trend was revealed by average crab weight, but the magnitude of change was greater (Table 4). Females in geographic zone D were about 20 percent heavier in average weight than those in zone A; males in zone D averaged 19 percent heavier

[3]Murray, Harriett E. 1974. Size composition of Deep Sea Red Crabs (*Geryon quinquedens*) caught on *Albatross IV* cruises 74-6 and 74-7. Northeast Fisheries Center, Woods Hole, Mass.; Laboratory Reference No. 74-2.

than those in zone A. Although irregularities cropped up in the numerical averages, perhaps due in part to small samples, the general trends in both carapace width and weight held true for all depth classes where significant numbers of crabs were represented.

Variations with Water Temperature

Analyses of the relationship between crab size and bottom water temperature are listed in Tables 5 and 6. Table 5 gives the relationship in terms of carapace width and Table 6 lists the data pertaining to crab weight. These tabulations reveal consistent trends of small males and females inhabiting cold water, large males and females inhabiting warmer water, and intermediate size males and females in waters of moderate temperatures. Young crabs were found only in cold water, from 4.4° to 5.5°C (39.9°-41.9°F). Inasmuch as bottom water temperature is inversely related to water depth, these values merely reflect the relationship between crab size and water depth (see page 13 for a discussion of this subject). Undoubtedly, feeding conditions, predation, reproduction, and other major biological conditions are involved in regulating distribution, of which water temperature may subsequently be identified as a component. However, with the information presently available, we have been unable to detect any direct influence of water temperature on the distribution of red crabs.

Table 5.—Average carapace width (in millimeters) of females, males, and young red crabs, listed separately by geographic zone and water temperature.

Water temperature		Avg. carapace width (mm) Geographic zones				
°C	°F	A	B	C	D	All[1]
				Females		
4.0- 4.9	39.2-40.9	60	—	46	—	53
5.0- 5.9	41.0-42.7	80	94	89	98	90
6.0- 7.9	42.8-46.3	87	90	89	101	92
8.0- 9.9	46.4-49.9	102	—	110	89	100
10.0-12.9	50.0-55.4	—	—	104	—	104
				Males		
4.0- 4.9	39.2-40.9	30	—	86	—	58
5.0- 5.9	41.0-42.7	92	97	92	116	99
6.0- 7.9	42.8-46.3	109	105	107	109	108
8.0- 9.9	46.4-49.9	110	—	131	97	113
10.0-12.9	50.0-55.4	—	119	121	—	120
				Young		
4.0- 4.9	39.2-40.9	—	—	9	—	9
5.0- 5.9	41.0-42.7	—	18	8	—	13
6.0- 7.9	42.8-46.3	—	—	—	—	—
8.0- 9.9	46.4-49.9	—	—	—	—	—
10.0-12.9	50.0-55.4	—	—	—	—	—

[1]Mean of geographic zone values.

Table 6.—Average weight (in grams) of females, males, and young red crabs, listed separately by geographic zone and water temperature.

Water temperature		Average weight (g) Geographic zones				
°C	°F	A	B	C	D	All[1]
				Females		
4.0- 4.9	39.2-40.9	62	—	69	—	66
5.0- 5.9	41.0-42.7	186	249	229	268	233
6.0- 7.9	42.8-46.3	217	271	251	282	255
8.0- 9.9	46.4-49.9	280	—	300	244	275
10.0-12.9	50.0-55.4	—	—	285	—	285
				Males		
4.0- 4.9	39.2-40.9	13	—	334	—	174
5.0- 5.9	41.0-42.7	357	347	349	626	420
6.0- 7.9	42.8-46.3	533	402	466	493	474
8.0- 9.9	46.4-49.9	516	—	690	430	545
10.0-12.9	50.0-55.4	—	680	577	—	628
				Young		
4.0- 4.9	39.2-40.9	—	—	0.1	—	0.1
5.0- 5.9	41.0-42.7	—	1	0.1	—	0.6
6.0- 7.9	42.8-46.3	—	—	—	—	—
8.0- 9.9	46.4-49.9	—	—	—	—	—
10.0-12.9	50.0-55.4	—	—	—	—	—

[1]Mean of geographic zone values.

DISTRIBUTION, DENSITY, AND BIOMASS IN RELATION TO GEOGRAPHIC AREA AND WATER DEPTH

Bottom trawls and baited traps (lobster pots, king crab pots, fish traps, etc.) have been the traditional capture gear used for determining the distribution and relative abundance of red crabs. Some general comments and references are given in the Introduction. Inasmuch as the area fished is not accurately measured by either the trawl or baited-pot method, only approximate measures of density (number of crabs per unit area of sea bottom) can be obtained. Recent studies (Cooper et al.[4], in preparation) of the methodology of censusing megabenthic animals, such as the red crab, have enabled us to use a sampling technique that provides reasonably accurate measures of red crab density and estimates of red crab biomass.

In this survey the density of red crabs was measured using the photographic method, and, secondarily, an index of density was determined from trawl catches. The photographic method yielded the number of crabs per unit area of sea bottom, whereas the trawl samples provided relative densities based on the number of crabs caught per 30-min trawl haul. Because relative densities obtained from the trawl catches are less definitive, they will be presented before describing the photographic results.

In this section of the report the distribution and density of crabs in relation to geographic location and water depth are discussed first. This is followed by separate sections dealing with red crab biomass, variations in numbers of crabs associated with water temperature, and variations associated with size and sex.

Distribution and Density

Red crabs were caught in trawls or photographed in situ in all geographic areas from offshore Maryland to eastern Georges Bank, and at water depths ranging from 274 to 1,463 m (150-800 fm). Modest to small differences in density were associated with geographic location and striking differences in density were related to water depth.

Trawling Results

Rough estimates of the relative density (density-index values) of red crabs in the various geographic zones and in the several depth classes within zones are listed in Table 7. This tabulation presents the average number of crabs caught during a 30-min haul with the 16-ft semi-balloon otter trawl. Density-index values ranged from 0 to 218 crabs per haul. Low values, from 1 to 14, were typical of the shallow-water zone (229-320 m; 125-175 fm). High values were characteristic of intermediate depths, 42-218 crabs per haul at 320-412 m (175-225 fm) and 51-128 crabs per haul at 412-503 m (225-275 fm). Moderate to low values (2-40 crabs per haul) were representative of moderately deep waters, 503-1,280 m (275-700 fm); no crabs

Table 7.—Average number of red crabs caught per 30-min trawl haul listed by geographic zone and water depth class.

Water depth		Avg. red crab catch (no.) Geographic zones				
Meters	Fathoms	A	B	C	D	All[1]
229- 320	125-175	14	1	8	8	8
320- 412	175-225	96	218	42	14	92
412- 503	225-275	51	128	64	21	66
503- 640	275-350	—	33	40	6	26
640- 914	350-500	22	28	37	2	22
914-1,280	500-700	13	—	23	—	18
1,280-1,646	700-900	0	—	0	—	0

[1]Mean of geographic zone values.

[4]Cooper, R. A., J. Uzmann, R. L. Wigley, and R. B. Theroux. Abundance, distribution, and ecology of the megabenthos of the continental shelf of Massachusetts, with special reference to the American lobster, jonah crab, and red crab. In preparation.

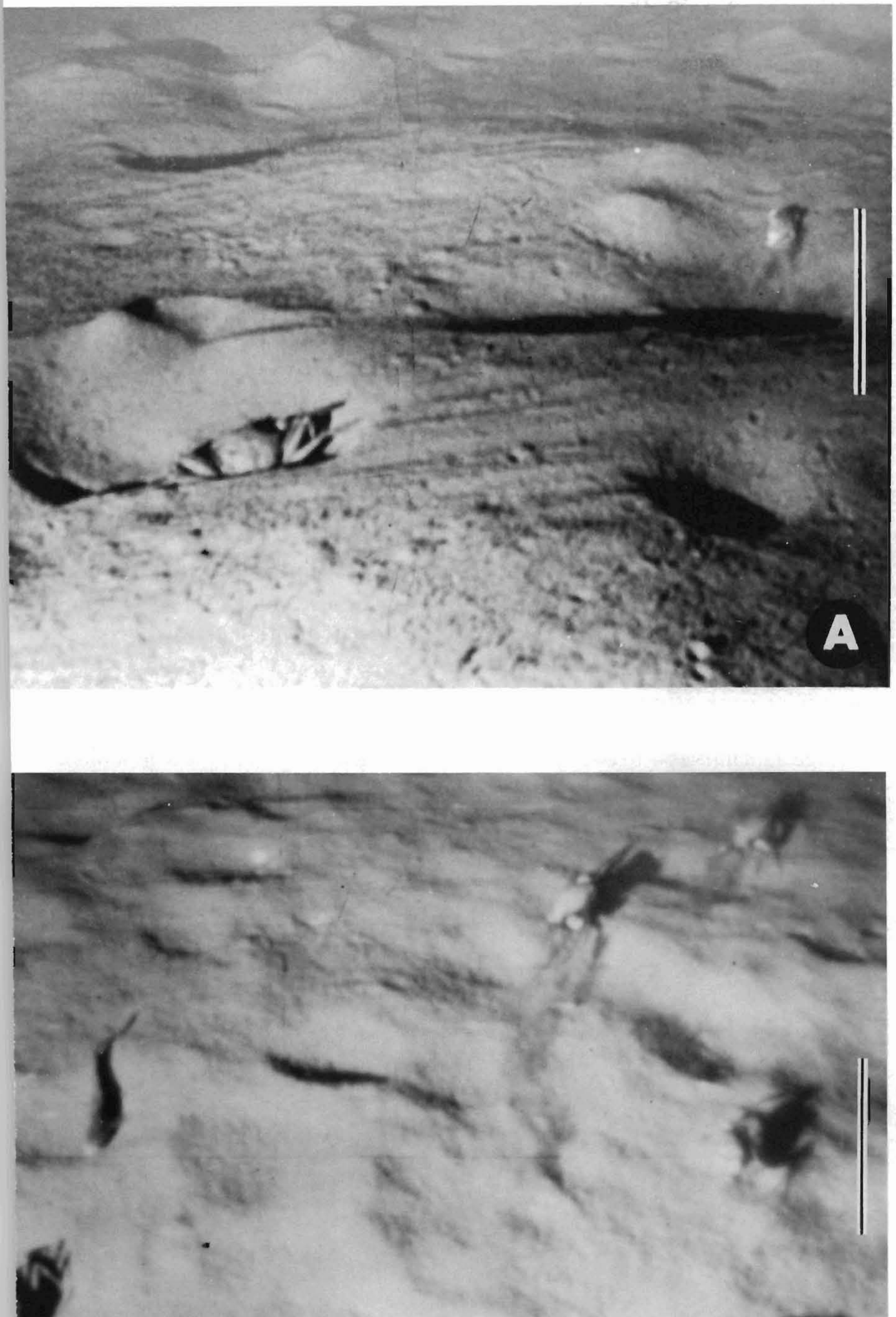


Figure 6.—Photographs of the bottom showing red crabs in their natural habitat. (A) A red crab partially hidden in a crater, and sediment features typified by cones, holes, craters, and linear striations. Scale bar is 1 m (3.3 ft). (B) Five red crabs and a fish on a moderately rough bottom. Scale bar is 1 m (3.3 ft).

were taken in the few samples obtained from water depths between 1,280 and 1,646 m (700 and 900 fm). Even though red crabs were absent in these deep-water samples, we expect small crabs to occur in low densities at these depths and deeper, down to the maximum depth recorded for this species (2,154 m; 1,178 fm). Briefly summarized, red crabs were common from offshore Maryland to western Georges Bank, but rather sparse in the Georges Bank region. Bathymetrically, crabs were sparse in relatively shallow waters, most common at intermediate depths, and moderately sparse to absent in deep water.

Photographic Results

Crab densities as determined by the photographic method are the most accurate available. Typical photographs of the sea bottom used for density evaluations are shown in Figure 6 (A and B). Our discussion in this section first pertains to red crabs of all sizes, followed by an analysis of only those of commercial size.

Results based on the photographic techniques (Table 8) revealed a density pattern similar to that described above from the trawl catches. Crabs—all sizes included—were sparse, only 13 to 28 per ha (2.5 acres), in the shallow water zone (229-320 m; 125-175 fm). Highest crab densities, 128-382 per ha, occurred at intermediate depths (320-640 m; 175-350 fm). Moderate to small quantities, 11-112 crabs per ha, were present in deep water (640-1,646 m; 350-900 fm). The lowest density, 10.9 crabs per ha, was found in the deepest waters sampled, 1,280-1,646 m (700-900 fm).

Another aspect of this topic is the number of red crabs in each water-depth class within each geographic zone (unit areas). Population estimates for each unit area are presented in tabular form in Figure 7. These values are based on the photographically-derived crab densities multiplied by the geographical area, as measured from nautical charts, in each unit area. Approximately 182 million crabs, all sizes included, are estimated to inhabit the study area. The largest number were found in geographic area C, particularly at water depths between 320 and 640 m (175-350 fm). Substantial quantities were also found in other geographic zones within this same depth range. Moderate quantities, 3.6 to 7.1 million crabs per unit area, occurred at water depths between 640 and 1,280 m (350-700 fm).

For the purposes of industrial considerations of the red crab resource it is desirable to examine the number and biomass of marketable size crabs. In the above analysis red crabs of all sizes,

Table 8.—Density of red crabs of all sizes, determined from sea-bottom photographs, expressed in terms of number per hectare (No./ha), listed by geographic zone and water depth class. The conversion factor to obtain number of crabs per acre (No./a) is 0.4.

Water depth		Red crab density (No./ha)				
		Geographic zones				
Meters	Fathoms	A	B	C	D	All[1]
229- 320	125-175	22.6	13.2	28.4	20.2	21.1
320- 412	175-225	270.8	—	376.4	127.8	258.3
412- 503	225-275	256.1	199.3	282.2	355.2	273.2
503- 640	275-350	197.7	266.7	381.6	—	282.0
640- 914	350-500	70.9	—	111.8	—	91.4
914-1,280	500-700	35.8	—	86.3	—	61.0
1,280-1,646	700-900	—	—	10.9	—	10.9

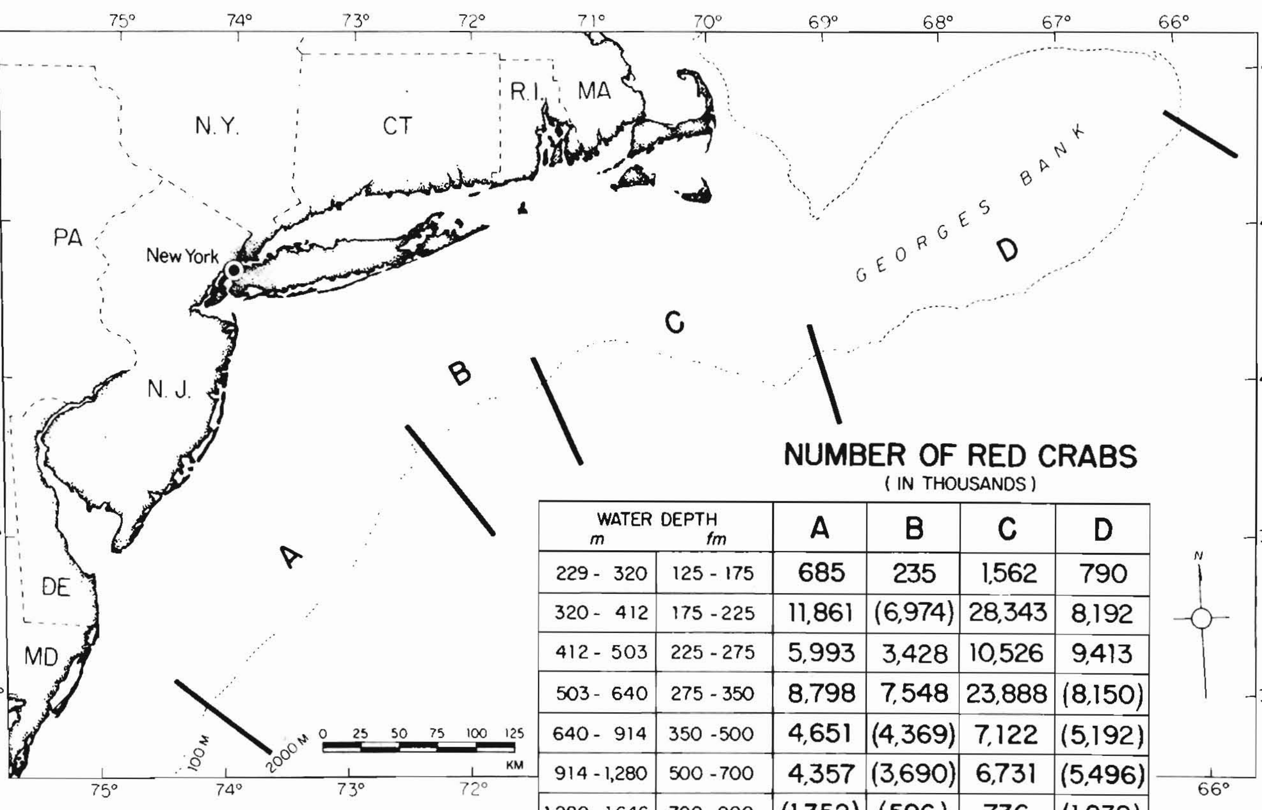
[1]Mean of geographic zone values.

including juvenile and young, were considered. Obviously, these and many of the younger adult crabs are too small for industrial utilization. In the following section are described the distribution and abundance of only those red crabs that are 114 mm (4.5 in), or larger, in carapace width. This is the minimum size presently accepted by the processing plants.

Commercial size red crabs were substantially less numerous than crabs of all sizes. A standing crop of 43 million red crabs of commercial size was estimated for the entire survey area. This is 24 percent of the number of crabs of all sizes, as described above. Estimates of the number of large red crabs in the various geographic zones and the several depth classes within each zone are listed in Table 9. Small to moderate quantities (from 235,000 to slightly more than 1 million per unit area) occurred in the shallow waters (less than 320 m; 175 fm). Largest quantities—to over 11 million per unit area—were found at intermediate depths (320-640 m; 175-350 fm). Moderate quantities—up to 3.5 million per unit area—were encountered in fairly deep water, 640-914 m (350-500 fm). No large crabs were obtained from water depths greater than 914 m (500 fm). Also evident in Table 9 are indications of substantial quantities of commercial size crabs occurring in deeper water toward the northeast (geographic zone D, water depth from 640 to 914 m; 350-500 fm), as compared with smaller quantities at the same depths in the southwestern part of the survey area (geographic zones A and B). It will be noted that proportional differences between large crabs (Table 9) and crabs of all sizes (Figure 7) were smaller in the shallower waters and greater in deep waters, because of the decrease in crab size associated with increased depth.

Biomass

Biomass of red crabs was evaluated by two methods: (1) the trawl method, which provided only an index of



NUMBER OF RED CRABS
(IN THOUSANDS)

WATER DEPTH m	fm	A	B	C	D
229 - 320	125 - 175	685	235	1,562	790
320 - 412	175 - 225	11,861	(6,974)	28,343	8,192
412 - 503	225 - 275	5,993	3,428	10,526	9,413
503 - 640	275 - 350	8,798	7,548	23,888	(8,150)
640 - 914	350 - 500	4,651	(4,369)	7,122	(5,192)
914 - 1,280	500 - 700	4,357	(3,690)	6,731	(5,496)
1,280 - 1,646	700 - 900	(1,352)	(596)	736	(1,232)

Figure 7.—Population estimates (total number per area) of red crabs of all sizes listed according to geographic zone and water depth class. Geographic zones are lettered A through D. Values in parentheses are estimates based on the average density of crabs in each water depth class.

Table 9.—Population estimates of red crabs of commercial size, 114 mm (4.5 in) or larger in carapace width.

Water depth		Population estimates[1]				
		Geographic zones				
Meters	Fathoms	A	B	C	D	All
229- 320	125-175	268	235	1,084	529	2,116
320- 412	175-225	1,243	870	11,278	1,835	15,226
412- 503	225-275	1,750	557	2,202	1,529	6,038
503- 640	275-350	[2](2,463)	2,058	3,626	5,460	13,607
640- 914	350-500	412	655	1,282	3,479	5,828
914-1,280	500-700	0	(0)	0	(0)	0
1,280-1,646	700-900	0	(0)	0	(0)	0
Total		6,136	4,375	19,472	12,832	42,815

[1]Numbers expressed in thousands per unit area, i.e. geographic zone-water depth class.
[2]Values in parentheses are estimated values based on the size composition of samples collected in adjacent geographic zones.

Table 10.—Biomass index, expressed as the average weight (kg) of red crabs caught per 30-min haul with an otter trawl, listed by geographic zones and water depth classes.

Water depth		Biomass index (avg. wt. in kg)					
		Geographic zones					Number of
Meters	Fathoms	A	B	C	D	All[1]	hauls
229- 320	125-175	6.9	0.7	3.8	2.7	3.5	11
320- 412	175-225	26.2	78.9	11.6	5.6	30.6	7
412- 503	225-275	16.4	36.4	22.2	6.6	20.4	9
503- 640	275-350	—	9.9	10.6	3.2	7.9	4
640- 914	350-500	3.3	8.8	14.4	0.8	6.8	6
914-1,280	500-700	0.3	—	0.5	—	0.4	3
1,280-1,646	700-900	0	—	0	—	0	3

[1]Mean of geographic zone values.

biomass, and (2) the photographic method.

Trawl Method

Total weight of red crabs caught in each haul of the otter trawl, expressed as kilograms per haul, provided an index (or relative quantity) of the standing crop biomass. Records of the individual trawl hauls are listed in Table 2, and the biomass index values, expressed as the average weight of crabs caught per 30-min haul and averaged for geographic and water depth categories, are listed in Table 10. The biomass index values ranged from zero in the deep-water (1,280-1,646 m; 700-900 fm) samples to 79 kg/haul (174 lb) in moderately shallow water (320-412m; 175-225 fm). The average value at intermediate depths (320-503 m; 175-275 fm) was about 25 kg (55 lb). An unusually large catch of red crabs was taken at Station 66, located in the vicinity of Block Canyon at a depth of 357 m (195 fm). This catch (Figure 8) consisted of 79 kg (174 lb) caught in the standard 30-min hauling time. Differences in the index values of crab biomass were clearly related to geographic location and water depth.

Because of large differences in size of crabs, especially in various water depth zones (see earlier section on Size), the biomass index varied most substantially among the various depth classes. In general, the values reveal essentially the same trends of quantity as those derived for numerical density and population estimates described above. The biomass index was high at moderate depths (320-503 m; 175-275 fm), and intermediate in shallow and moderately deep water. In very deep water (greater than 914 m; 500 fm) the biomass index ranged from a very small quantity to a complete absence.

Judging from the relationship between the crab catches listed in Table 10 and the standing crop biomass described in the following section, Photographic Method, it appears as though the small trawl used in this survey was rather effective in catching red crabs.

Moderate differences in biomass density occurred in different geographic areas and at various water depths. Geographically, the density of red crabs was greatest in the region south of Massachusetts and Rhode Island (geographic zone C). Standing crop estimates as high as 157 kg/ha were encountered there. Intermediate quantities were present in the Georges Bank region, geographic zone D, where the largest quantities were 114 kg/ha. In the Middle Atlantic area (geographic areas A and B) the largest biomass density was only 80-82 kg/ha.

Figure 8.—Red crab catch from a 30-min haul with an otter trawl near Block Canyon weighed 79 kg (174 lb).

Photographic Method

Estimates of standing crop biomass of red crabs, all sizes combined, were calculated from crab numerical densities derived from photographic analyses (Table 8) combined with crab weight information resulting from the trawl-caught samples. Results of these calculations are listed in Table 11, in which the biomass density values are expressed in terms of kilograms per hectare (kg/ha). Values given as kg/ha are roughly equivalent to pounds per acre (lb/a). To convert kg/ha to lb/a, multiply the former by 0.89.

Depth-related differences in biomass density were striking, even more so than numerical density. The marked differences in biomass resulted from the combination of both a reduction in numerical density and reduction in crab size with water depth. Water depths having the largest standing crop biomass ranged from 320 to 640 m (175-350 fm). The biomass within those depths ranged from 53 to 157 kg/ha, but generally averaged between 79 and 95 kg/ha. Biomass was small, with highest average values of only 10 kg/ha, in the shallow water zone (229-320 m; 125-175 fm). Moderately small (27 kg/ha) to very small (1.3 kg/ha) quantities of crabs were found in deepwater areas, below 640 m (350 fm).

Another useful measure of the quantity of red crabs, in addition to the biomass density, is the standing crop biomass—the total weight of red crabs within the survey area and within each of its subdivisions (unit areas, or geographic zone-bathymetric class). The standing crop biomass of red crabs, all sizes combined, has been calculated from the biomass densities (Table 11) and the appropriate area of coverage. These values are presented in Figure 9. The total standing crop biomass for the entire survey area was 53 million kg (116 million lb). Standing crop in the various unit areas ranged from a low of 77,000 kg to a maximum of nearly 12 million kg (169,000-26 million lb). Bathymetrically, the quantities were largest (approximately 1-12 million kg) at intermediate depths (320-640 m; 175-350 fm) and lowest (80-800,000 kg; 176,000-1.8 million lb) in the very shallow and very deep waters sampled. Geographically, the biomass was substantially larger off southern New England—geographic zone C—than in the other regions. The quantities present in the Middle Atlantic and the Georges Bank zones—geographic zones A and D—were small, particularly when the geographic area of each zone is taken into consideration. Geographic zone B encompasses a much smaller area (0.25 million hectares) than the other zones, but it contained a moderately large quantity of red crabs.

Commercial size red crabs accounted for slightly more than one-half of the total red crab biomass. Within the estimated total biomass of nearly 53 million kg (116 million lb) of red crabs of all sizes combined, commercial size crabs made up about 27 million kg (59 million lb), a proportion of 51 percent. Both males and females are represented in this estimate of commercial size crabs, but males are by far the dominant component, contributing 97 percent; females made up only 3 percent.

The quantity of commercial size red crabs is listed in Table 12 for each water-depth class within each geographic zone. Quantities are given in terms of thousands of kilograms per unit area. Commercial size crabs ranged in quantity from zero to slightly more than 7 million kg (16 million lb) per unit area. Geographically, the largest quantities were in the northeastern areas, geographic zones C and D. Considerably smaller quantities were present in zones A and B (see totals at bottom of Table 12). Bathymetrically, there were major differences in quantity that follow the general trends described in previous sections of this report, but with one major exception. Rather small quantities were found in the shallow waters. The largest quantities occurred at intermediate depths (320-914 m; 175-500 fm). In some of the foregoing analyses that pertain to crabs of all sizes the high densities and large biomasses terminated at a depth of 640 m (350 fm), but the commercial size crabs in geographic zone D made up a relatively large biomass in somewhat deeper water (640-914 m; 350-500 fm). No commercial size crabs were present in the deep waters, greater than 914 m (500 fm), sampled in this survey. Considering all zones, by far the largest quantity of large crabs occurred in geographic zone C at water depths ranging from 320 to 412 m (175-225 fm).

Table 11.—Biomass[1] density of red crabs of all sizes, expressed in kilograms per hectare (kg/ha), listed by geographic zone and water depth class. The conversion factor to obtain pounds of crabs per acre (lb/a) is 0.89.

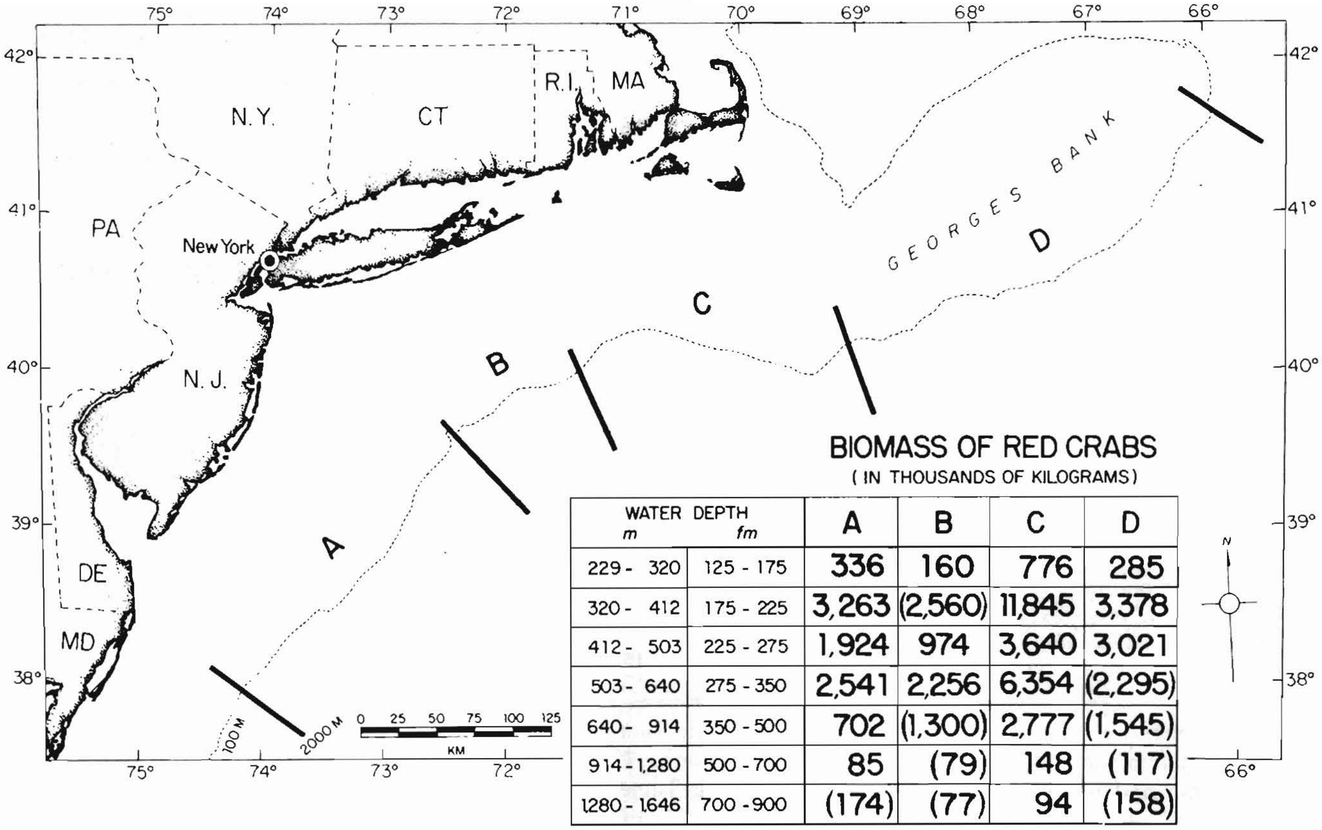
Water depth		Biomass density (kg/ha)				
		Geographic zones				
Meters	Fathoms	A	B	C	D	All[2]
229- 320	125-175	11.1	9.0	14.1	7.3	10.4
320- 412	175-225	74.5	—	157.3	52.7	94.8
412- 503	225-275	82.2	56.6	97.6	114.0	87.6
503- 640	275-350	[3](57.1)	79.7	101.5	—	79.4
640- 914	350-500	10.7	—	43.6	—	27.2
914-1,280	500-700	0.7	—	1.9	—	1.3
1,280-1,646	700-900	—	—	1.4	—	1.4

[1]Biomass values are based on photographically determined density and trawl-derived sizes.
[2]Mean of geographic zone values.
[3]This biomass value was determined by utilizing the size of crabs from the same depth class in geographic zone B.

Table 12.—Standing crop biomass[1] of red crabs of commercial size, 114 mm (4.5 in) or larger in carapace width.

Water depth		Standing crop biomass (1,000 kg)				
		Geographic zones				Total all zones
Meters	Fathoms	A	B	C	D	
229- 320	125-175	163	135	672	206	1,176
320- 412	175-225	725	510	7,290	1,160	9,685
412- 503	225-275	1,080	331	1,337	966	3,714
503- 640	275-350	[2](1,527)	1,276	2,161	3,582	8,546
640- 914	350-500	241	362	736	2,240	3,579
914-1,280	500-700	0	(0)	0	(0)	0
1,280-1,646	700-900	0	(0)	0	(0)	0
Total		3,736	2,614	12,196	8,154	26,700

[1]Biomass expressed in thousands of kilograms per unit area, i.e. geographic zone-water depth class.
[2]Values in parentheses are estimated values based on crab sizes from adjacent geographic zones.



WATER DEPTH m	fm	A	B	C	D
229 - 320	125 - 175	336	160	776	285
320 - 412	175 - 225	3,263	(2,560)	11,845	3,378
412 - 503	225 - 275	1,924	974	3,640	3,021
503 - 640	275 - 350	2,541	2,256	6,354	(2,295)
640 - 914	350 - 500	702	(1,300)	2,777	(1,545)
914 - 1,280	500 - 700	85	(79)	148	(117)
1280 - 1646	700 - 900	(174)	(77)	94	(158)

Figure 9.—Biomass of red crabs, all sizes combined, in the various geographic zones and water depth classes. Values are given in terms of thousands of kilograms per unit area. To convert kilograms to pounds, multiply by 2.2. Values in parentheses are estimated quantities based on average biomass densities within the same water depth class.

Variations Associated with Water Temperature

Red crabs were caught in the trawl or were present in in situ sea bottom photographs in waters as cold as 4.2°C (39.5°F) and as warm as 12.7°C (54.8°F) in this survey. These were the coldest and warmest waters in which our survey operations were conducted. Moreover, the density of crabs was correlated with bottom water temperatures in a rather consistent pattern. Both the numerical density and biomass of red crabs, determined from trawl-catch data and by means of the photographic method, are listed according to bottom water temperature in Tables 13, 14, and 15. These data reveal a definite trend of highest densities and largest quantities of crabs at intermediate temperatures—from 5° to 8°C (41.0°-46.4°F)—and substantially lower densities and smaller quantities at both warmer and colder temperatures. This distributional trend was apparent in each geographic zone and for all zones combined. Additionally, there was a close correlation between crab size and bottom water temperature. See page 8 for tabulations and additional information on this aspect.

Table 13.—Average number of red crabs caught per standard 30-min otter trawl haul at various water temperature classes in each geographic zone.

Temperature class		Average red crab catch (no.)				
		Geographic zones				
°C	°F	A	B	C	D	All[1]
4.0- 4.9	32.9-40.9	6	—	20	0	13.0
5.0- 5.9	41.0-42.7	36	81	45	8	42.5
6.0- 7.9	42.8-46.3	165	292	78	15	137.5
8.0- 9.9	46.4-49.9	18	—	3	6	9.0
10.0-12.9	50.0-55.4	—	2	56	0	29.0

[1]Mean of geographic zone values.

Table 14.—Mean quantity (kg) of red crabs caught per standard 30-min haul of the otter trawl at the various water temperature classes in each geographic zone.

Temperature class		Mean quantity (kg)				
		Geographic zones				
°C	°F	A	B	C	D	All[1]
4.0- 4.9	39.2-40.9	0.1	—	5.8	0	2.9
5.0- 5.9	41.0-42.7	9.8	24.0	13.0	3.1	12.5
6.0- 7.9	42.8-46.3	44.3	98.5	27.5	5.3	43.9
8.0- 9.9	46.4-49.9	7.3	—	1.7	2.2	3.7
10.0-12.9	50.0-55.4	—	1.4	25.1	0	13.3

[1]Mean of geographic zone values.

Table 15.—Density and related measures of occurrence of red crabs at different water temperatures, based on in situ photographs.

Item		Bottom water temperatures				
	°C °F	4.0- 4.9 39.2-40.9	5.0- 5.9 41.0-42.7	6.0- 7.9 42.8-46.3	8.0- 9.9 46.4-49.9	10.0-12.9 50.0-55.4
Red crab density[1]		88	248	229	68	96
Red crab occurrence[2]		34	205	218	48	73
Number of stations		5	11	8	4	5
Total number of red crabs		168	2,257	1,747	192	364

[1]Number per hectare.
[2]Number per station.

Despite this apparent relationship between crab abundance and water temperature, it is probably a secondary result of the correlation between bottom water temperature and water depth. Bottom water temperatures in the survey area were inversely related to water depth, as illustrated in Figure 10. It is this association that has confounded the analysis of the relationship between red crabs and water temperature.

Because red crabs are tolerant of a broad range in water temperature, it probably plays a secondary role in influencing their distribution. Our observed range of temperature (4.2°-12.7°C; 39.5°-54.8°F) inhabited by red crabs is intermediate between that reported in other studies. Rathbun (1937) cited numerous records of red crab catches below 4.0°C (39.2°F); minimum temperature cited is 3.1°C (37.5°F). At the other extreme, Holmsen (1968) pointed out that red crabs are tolerant of warm water. He stated that the red crab ". . .can survive for weeks in temperatures up to 70°F (21.1°C)." This information is based on aquarium studies conducted by the Rhode Island Division of Conservation. This eurythermic tolerance combined with the natural up-slope migration from deep, cold waters to shallower, warmer waters as they become larger and older, leads us to conclude that the direct effect of water temperature on crab distribution is subordinate to other environmental and biotic influences.

Variations Associated with Size and Sex

Young

Young red crabs were too rare in our samples to give definitive information about this group. Only six young were obtained; five were caught with the trawl and one with the Naturalist's dredge. The number of trawl-caught young is listed by station in Table 2. This is supplemented with the data given in Table 16, which is the station data summary and specimen measurements pertaining to young.

One important aspect of young crabs, as revealed by these samples, was that all were taken in deep water, between 741 and 1,051 m (405 and 575 fm). A comparison of water depth distribution of young with that of males and females is given in Figure 11. Young crabs were

Table 16.—Listing of the sizes and weights of young red crabs and associated environmental and collection data.

Station	Number of young	Carapace width (mm)	Weight (g)	Geo. zone	Water depth: Meters	Water depth: Fathoms	Bottom water temperature: °C	Bottom water temperature: °F	Bottom sediment
12	2	17	0.9	B	741- 765	405-418	5.0	41.0	silt-clay
		18	1.1						
[1]58	1	8.8	0.14	D	914-1,051	500-575	(4.4)	(39.9)	silt-clay
63	1	9	0.1	C	750- 768	410-420	4.8	40.6	silt-clay
64	2	8	0.1	C	1,006-1,015	550-555	5.5	41.9	silt-clay
		9	0.1						
Total or range	6	8-18	0.1-1.1	B-D	741-1,051	405-575	4.4-5.5	39.9-41.9	silt-clay

[1]Location of dredge haul, lat. 40°08'N, long. 68 19.0'W, 21 July 1974.

caught in geographic zones B, C, and D; more specifically, they were taken from just northeast of Hudson Canyon eastward to the vicinity of western Georges Bank. Bottom water temperatures at locations where young were caught were all low, ranging from 4.4° to 5.5°C (39.9°-41.9°F). Bottom sediments at all localities inhabited by young were smooth-surfaced silt-clays.

Males, Females and Young

Marked differences were observed in the depth distribution between males, females, and young. Catch records, by sex, are listed in Table 2. Size composition is illustrated in Figure 11. As mentioned above, young occurred only in deep water (741-1,051 m; 405-575 fm). Both males and females occurred at all depths sampled from 274 to 1,097-1,234 m (from 150 to 600-675 fm); however,

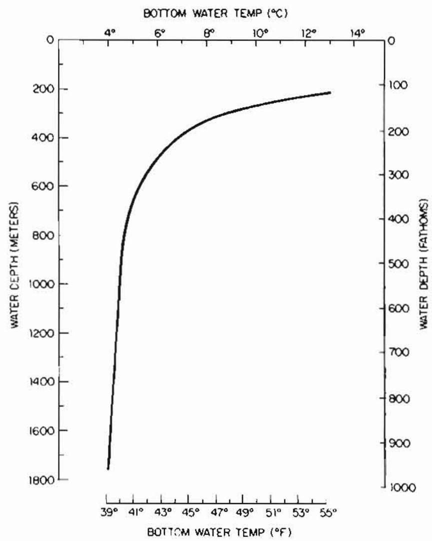


Figure 10.—Relation between bottom water temperature and water depth.

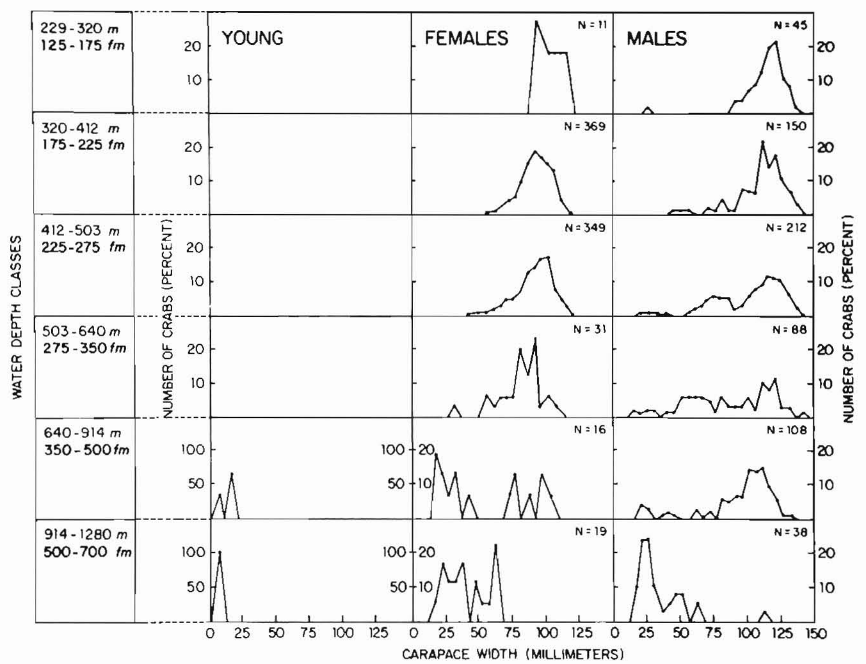


Figure 11.—Size-frequency composition of trawl-caught red crabs, expressed as a percentage and plotted separately for males, females, and young, from different water depth classes.

there were large differences in the absolute and proportional number of specimens at the various depths described below. The size-frequencies of all red crabs caught with the trawl are illustrated in Figure 11, separated according to the depth class at which they occurred. A distinctive feature of this size distribution was the large proportion of small crabs in deep water and their absence in shallow water. Furthermore, the size distribution shows the progressive diminution in modal size (carapace width) of both sexes with increased water depth. Our conclusion that red crabs undertake a long-term up-slope migration (page 7) is based in part on these trends in size and abundance as related to water depth.

A comparison of relative abundance of males versus females at various water depths revealed a striking difference between the two. Their relative abundance in each depth class is illustrated in Figure 12. This graph shows the average number of crabs, by sex, that were

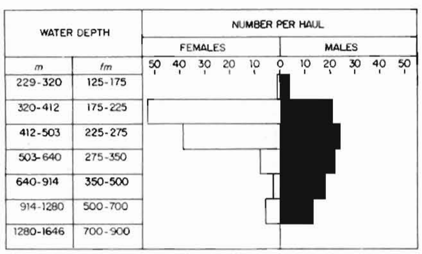


Figure 12.—Depth distribution of female and male red crabs, expressed as number caught per 30-min trawl haul.

caught per 30-min haul with the trawl at various depth intervals. Males were sparse in shallow water (less than 320 m; 175 fm), but were somewhat uniformly represented at all other depths, ranging from 320 to 1,280 m (175-700 fm), showing only a modest decrease in relative abundance associated with an increase in depth. Females, on the other hand, revealed an entirely different pattern of relative abundance. They were very common at depths between 320 and 503 m (175 and 275 fm), where they averaged 39-53 per haul, and were rather scarce at all other depths, averaging only eight per haul or less.

This pronounced difference in distribution between the sexes may be temporary (seasonal) or permanent. In the absence of distributional information by size and sex at other seasons of the year, we cannot proffer explanations for the above results in terms of a seasonal migration. For example, the tanner crab, *Chionoecetes tanneri*, in the North Pacific Ocean undertakes a seasonal migration (Pereyra, 1966) in which only males make a significant shift in water depth. Females are deep water inhabitants throughout the year. Males, however, occupy shallower water during spring, summer, and fall; only during the winter do they inhabit the same depths as the females. A migration of this type is not applicable to the red crab. Perhaps, a reversal of the tanner crab migration could be considered for the red crab whereby males would occupy deep waters during the summer and move up to shallower waters (where the females are) during the winter. Even this, we think, is unlikely. It remains for future studies to determine whether or not red crabs perform a seasonal migration, and if so, the details of the crab stock involved and the seasonal timing. Variations in the number of males and females are discussed in the following section, Sex Ratio.

NOTES ON BIOLOGY

Sex ratio

Female red crabs were substantially more numerous than males. All samples considered, there were 795 females and 641 males, a ratio of 1.24 females per male. This ratio between the sexes, however, was not constant. In fact it varied considerably, and the variations showed consistent trends associated with water depth and geographic location. The association between sex ratios and water temperature are believed to be indirect correlations caused by the water depth-water temperature relationship.

The greatest changes and most consistent trends in sex ratio were those associated with water depth. In Table 17 are listed the numbers of each sex and the sex ratio for various water depth classes and geographic zones (and for all zones combined). In the shallowest depth zone (229-320 m; 125-175 fm) males were four times as numerous as females (see right hand column, Table 17). At intermediate depths (320-503 m; 175-275 fm), however, females were dominant; approximately twice as numerous as males. In deep water (503-1,280 m; 275-700 fm) males, again, were the dominant sex; they were from 2 to 7 times more numerous than females. This same trend of male predominance at all depths except near the upper slope was clearly evident in each of the four geographic zones (Table 17). Furthermore, the ratios in the various geographic zones, within depth classes, were approximately the same magnitude as that computed for all zones combined. Even the ratios based on individual trawl samples at the same depth corresponded rather well with one another.

Table 17.—Sex ratio of red crabs listed by geographic zones and water depth classes.

Water depth		Item	Geographic zones				
Meters	Fathoms		A	B	C	D	All
229- 320	125-175	No. F	3	0	5	3	11
		No. M	25	2	18	0	45
		F:M	0.12·	—	0.28:1	—	0.24:1
320- 412	175-225	No. F	160	155	42	12	369
		No. M	31	63	41	15	150
		F:M	5.16:1	2.46:1	1.02:1	0.80:1	2.46:1
412- 503	225-275	No. F	28	170	107	44	349
		No. M	23	86	85	18	212
		F:M	1.22:1	1.98:1	1.26:1	2.44:1	1.65:1
503- 640	275-350	No. F	—	2	27	2	31
		No. M	—	31	53	4	88
		F:M	—	0.06:1	0.51:1	0.50:1	0.35:1
640- 914	350-500	No. F	9	0	7	0	16
		No. M	13	26	66	3	108
		F:M	0.69:1	—	0.11:1	—	0.15:1
914-1,280	500-700	No. F	2	—	17	—	19
		No. M	11	—	27	—	38
		F:M	0.18:1	—	0.63:1	—	0.50:1
Total		No. F	202	327	205	61	795
		No. M	103	208	290	40	641
		F:M	1.96:1	1.57:1	0.71:1	1.52:1	1.24:1

Changes in sex ratio were also associated with geographic zone. An overall, or total, sex ratio (females: males) for each geographic area, given at the bottom of Tables 17 and 18, indicates a greater proportion of females (1.96:1) in the southwestern region, geographic zone A, and a higher proportion of males to the northeast with a ratio of 0.71:1 off southern New England, geographic zone C. These overall values, obviously, were heavily influenced by the crab samples taken in upper slope waters (320-503 m) where crabs were most abundant. At these upper slope depths, when ratios were calculated separately, there was found to be a definite and rather substantial difference in sex ratio associated with geographic location that was similar in trend to the overall differences in ratio listed at the bottom of Table 17. Sex ratios (females to males) for upper slope waters at depths of 320-503 m (175-275 fm) were as follows: in the southwestern sector, geographic zone A, 3.5:1; zone B, 2.2:1; zone C, 1.2:1; and in the northwestern sector, geographic zone D, 1.7:1. Changes in these ratios were heavily influenced by the large number of females in the southwestern geographic zones.

Another method of analyzing sex ratios in relation to water depth is presented on page 14. Trawl catch data were analyzed by calculating the average number of males and females caught per trawl haul in each water depth class. These results are illustrated in Figure 12. This analysis reveals a distributional pattern for the sexes that is nearly identical to the one presented above. A predominance of females occurred at depths of 320-503 m (175-275 fm), whereas males were more uniformly distributed. Male crabs were most abundant at depths of 412-503 m (225-275 fm); however, they were nearly as common at adjacent depths and showed a moderate decline directly correlated with increased depth.

The relationship between sex ratio and water temperature appears to be an indirect correlation resulting from the water depth-water temperature relationship. Sex ratios for various temperature categories within each geographic zone are listed in Table 18. Females predominated at intermediate temperatures, 6.0 to 7.9°C, and males predominated in both warmer and colder waters.

Table 18.—Sex ratio of red crabs listed by geographic zones and water temperature classes.

Water temperature °C	Water temperature °F	Item	Geographic zones A	B	C	D	All
4.0- 4.9	39.2-40.9	No. F	2	—	18	—	20
		No. M	11	—	83	—	94
		F:M	0.18:1	—	0.22:1	—	0.21:1
5.0- 5.9	41.0-42.7	No. F	37	120	104	14	275
		No. M	36	121	118	9	284
		F:M	1.03:1	0.99:1	0.88:1	1.56:1	0.97:1
6.0- 7.9	42.8-46.3	No. F	138	207	41	38	424
		No. M	27	85	37	21	170
		F:M	5.11:1	2.44:1	1.11:1	1.81:1	2.49:1
8.0- 9.9	46.4-49.9	No. F	25	—	1	9	35
		No. M	29	—	2	10	41
		F:M	0.86:1	—	0.50:1	0.90:1	0.85:1
10.0-12.9	50.0-55.4	No. F	—	0	41	—	41
		No. M	—	2	50	—	52
		F:M	—	—	0.82:1	—	0.79:1
Total		No. F	202	327	205	61	795
		No. M	103	208	290	40	641
		F:M	1.96:1	1.57:1	0.71:1	1.52:1	1.24:1

For a discussion of the influence of water temperature with red crab distribution, see the section of this report entitled Distribution, Density, and Biomass in Relation to Geographic Area and Water Depth, subsection Variations Associated with Water Temperature.

An aspect of commercial fishing that conceivably could have some impact on the sex ratio of red crabs is the common practice of fishermen to keep only males and return females back to the sea. If a significant proportion of the crab population has been caught and the males selected out, it could account for imbalanced sex ratios, at least in heavily fished areas. Although commercial fishing has been conducted in some of the same geographical zones and water depths where females were found to predominate, it is our conclusion that fishing had little impact on the sex ratios. First, fishing effort has been relatively light and of short duration. Second, the greatest imbalances (0.12:1 and 5.16:1) that we detected in sex ratios in the shallower waters were found in geographic zone A, a population that has been subjected to little or no commercial fishing.

Seasonal migrations related to reproduction offer another possible explanation for the observed differences in sex ratios. In the absence of sufficient information on this topic we prefer to forego speculation on the possible movements that might be involved in a spawning-related migration that would result in the distribution described above.

Spawning

Very little information has been obtained concerning the spawning habits of the red crab; even the spawning season has not been clearly ascertained. A few threads of evidence pertaining to spawning were obtained during this survey and have formed the basis for tentative interpretations. Data pertaining to this topic are listed in Table 19.

Among the 795 female red crabs caught during this survey, 48 (6 percent) were carrying eggs. Their proportional distribution in regard to water depth and stage of egg maturity suggests a prolonged spawning season that extends at least from late winter through early summer. Spawning and egg maturation was strongly influenced by water depth and/or water temperature. It appears as though spawning took place only in mid- to upper-slope waters, 640 m (350 fm) or less, and that spawning began (and terminated) earlier in the year in upper slope waters and later in the year at mid-slope. It is also suggested that the egg maturation period was shorter in upper slope waters than in the lower slope. These interpretations are based on the proportion of ovigerous female crabs at various water depths and the stage of egg development as judged according to their color. As listed in Table 19, column four the proportion of females carrying eggs in July increased progressively from 9 and 2 percent in relatively shallow water to 19 percent in deep water (503-604 m; 275-350 fm). Corroborating evidence was provided by the approximate stage of egg development. Newly deposited eggs are light red or orange, and they become increasingly darker as they ripen.

A relatively large proportion of ovigerous females from deep water had egg clusters composed of newly deposited eggs, but none consisted of "mature" eggs. At intermediate depths all stages of egg maturity were represented. In shallow water only partially developed, "mid-stage" eggs were detected, represented by those having a dark brown color. The absence of newly deposited eggs at this depth can be interpreted as the result of the termination of spawning, perhaps reflecting a condition that had been reached some months or weeks previously. The absence of advance-stage mature eggs may have resulted from hatching. The ovigerous females that were caught in shallow water may signify the last remaining spawners of the season at that depth.

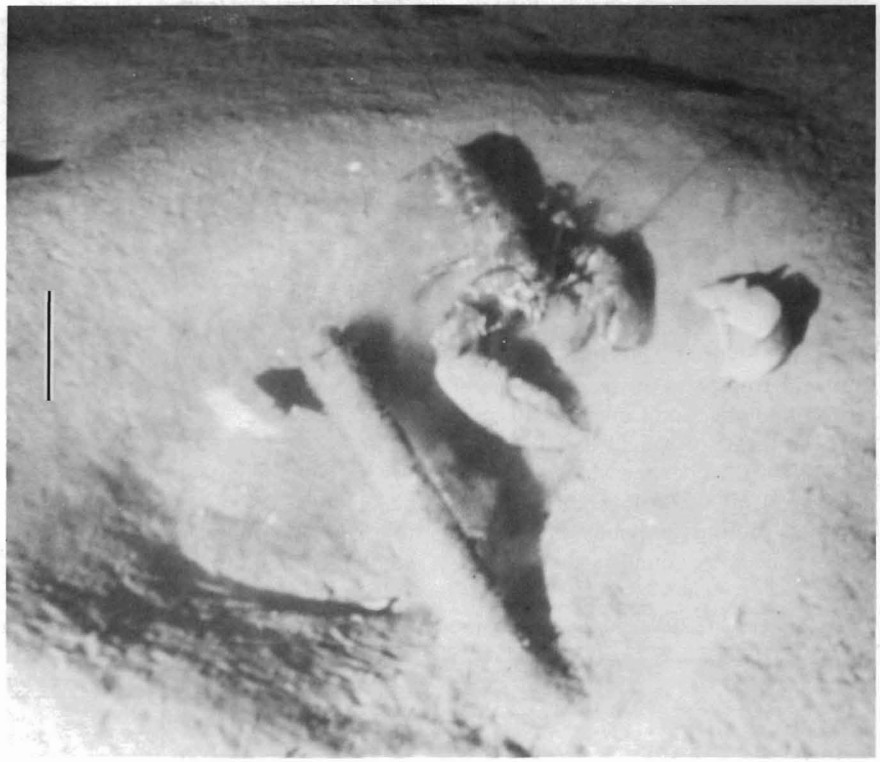


Figure 13.—A 6.8-kg (15-lb) lobster, *Homarus americanus*, within the crater it excavated unearthing what appears to be a transmission cable. Also visible are two fish; the larger is a hake and the smaller is a blackbelly rosefish. Scale bar is 0.5 m (1.6 ft).

AMERICAN LOBSTER

A total of 26 American lobsters was encountered during the survey—14 were caught in the trawl and 12 were detected in photographs. They were found at 7 (and remains of dead lobsters at 2) of the 43 stations sampled with the trawl. Of the 33 stations at which photographic data were obtained, 4 contained lobsters. Weights for trawl caught lobsters are from direct measurements; weights of photographed specimens are estimates based on their lengths and the weight of trawl caught specimens.

Lobsters were caught by trawl in all geographic zones; the greatest number and biomass (11 weighing 3.5 kg; 7.7 lb) occurred in zone C. Zones A, B, and D contained one lobster each, and they weighed 1.3, 0.4, and 6.8 kg (2.9, 0.9, and 15 lb), respectively. They were found at depths ranging from 229 to 412 m (125-225 fm). Density ranged from 1 to 6 individuals per 30-min trawl haul and weight per haul varied from 0.4 to 6.8 kg (0.8-15 lb). Lobsters were photographed in zones A and C, where they were present in equal numbers and weights—six weighing 5.2 kg (11.5 lb) in each zone. An example of a lobster and the typical basin-like depressions they excavate in the relatively smooth bottom in offshore waters is shown in Figure 13. Lobster data by haul for each station for each sampling method are listed in Table 20. Also included are estimates of density and biomass derived from photographs.

Catch rates of lobsters obtained during the survey were compared with catches made in previous years in the same region. Catch data reported by Schroeder (1959) and McRae (1960) were used for this purpose. An exact comparison was impossible because of differences in sampling gear and the locations fished. Thus, details in the comparative results are not considered significant, but the trends and general results are valid. The basic data are listed in Table 21, including: (1) number of tows upon which the samples are based; (2) total catches from each source; (3) total catch adjusted to a 30-min haul; and (4) catch/haul adjusted to a 5.8-m (19-ft) footrope trawl for purposes of comparison. Footnotes at the bottom of the table provide some additional explanations of trawl sizes. Only those data from each report that fell

Table 19.—Number and size of egg-bearing red crabs and color of eggs being brooded at each water-depth class.

Water depth		Total number of females	Ovigerous females									
			Percent of total females	Carapace width (mm)			No. eggs by color					
Meters	Fathoms			Mean	Minimum	Maximum	Red-orange	Brown	Dark brown	Purple	Black	Unknown
229- 320	125-175	1	9	105	105	105	0	0	0	0	0	1
320- 412	175-225	8	2	100	97	107	0	0	2	0	0	6
412- 503	225-275	33	9	95	68	112	4	4	2	7	4	12
503- 640	275-350	6	19	91	84	102	2	2	2	0	0	0
640- 914	350-500	0	0	—	—	—	—	—	—	—	—	—
914-1,280	500-700	0	0	—	—	—	—	—	—	—	—	—
1,280-1,646	700-900	0	—	—	—	—	—	—	—	—	—	—
Total or mean		48	6	96	68	112	6	6	6	7	4	19

within our water depth classes were included. Many catch records had to be omitted because depths sampled during the haul exceeded our established ranges.

Both the number and weight of lobsters caught during the present survey were substantially smaller than catches made in previous decades. In moderate water depths present catch rates were approximately 2-3 times lower in terms of number caught and 2-8 times lower in terms of weight at 229-320 m (125-175 fm), and from 7 to 10 times lower in terms of number and from 1 to 31 times lower in terms of weight at 340-412 m (175-225 fm). In deeper water (412-640 m; 225-350 fm), where lobsters had been obtained during previous investigations, none were found in the present survey. No comparison was possible in the shallowest water depths, since our survey was restricted to deeper regions. A notable catch during our survey was the capture of one specimen at station 37 that weighed 6.8 kg (15 lb). This was a non-berried female that was released in excellent condition.

Table 20.—Total number and weight of lobsters from each trawl haul and photographic transect. Photographic data also includes density and estimated weight per hectare.

	Trawl		Photographs				Depth by station	
Station	Total number	Total wt (kg)	Total number	Estimated total wt (kg)	Calculated no/hectare	Calculated wt/hectare	Meters	Fathoms
1	3	1.1	—	—	—	—	274-311	150-170
13	1	1.3	3	2.6	2.2	1.9	311-326	170-178
21	(1)	ripper claw remains		—	—	—	402-430	220-235
22	—	—	3	2.6	3.4	2.9	274	150
23	(1)	crusher claw remains		—	—	—	338-375	185-205
25	6	1.7	—	—	—	—	247-256	135-140
30	—	—	3	2.6	4.4	3.8	274-284	150-155
31	1	0.4	3	2.6	4.9	4.2	362-457	198-250
37	1	6.8	—	—	—	—	229-265	125-145
59	1	0.3	—	—	—	—	216-366	118-200
66	1	0.4	—	—	—	—	357-384	195-210
Total	14	12.0	12	10.4				

Table 21.—Lobster catches by trawling in 1952, 1953-56, and 1955-56 compared with trawl catches and photographic data from the present study. Trawl catches have been adjusted to 30-min hauls and to a 5.8-m (19-ft) footrope length.

Source	Water depth classes															
	91-229 m 50-125 fm		229-320 m 125-175 fm		320-412 m 175-225 fm		412-503 m 225-275 fm		503-640 m 275-350 fm		640-914 m 350-500 fm		914-1,280 m 500- 700 fm		1,280-1,646 m 700- 900 fm	
	No.	Wt[1]	No.	Wt	No.	Wt	No.	Wt	No.	Wt	No.	Wt	No.	Wt	No.	Wt
Schroeder (1959) 1952[2]																
Number of hauls	7		4		7		2		0		0		0		0	
Total catch (30-min hauls)	55	50.6	27	17.4	36	14.4	29	20.2	—	—	—	—	—	—	—	—
Catch/haul adjusted to 5.8 m trawl (factor = 2.24)	4	3.2	3	1.9	2	0.9	6	4.5	—	—	—	—	—	—	—	—
Schroeder (1959) 1953-1956[3]																
Number of hauls	28		5		1		1		0		0		0		0	
Total catch (30-min hauls)	506	407.8	31	25.6	9	9.0	1	1.4	—	—	—	—	—	—	—	—
Catch/haul adjusted to 5.8 m trawl (factor = 2.90)	6	5.0	2	1.8	3	3.1	0.3	0.5	—	—	—	—	—	—	—	—
McRae (1960)[4]																
Number of hauls	43		35		19		9		1		0		0		0	
Total catch (30-120 min)	187	359.3	1297	3771.2	683	2065.7	442	1134.0	4	11.3	—	—	—	—	—	—
Total catch adjusted to 30 min haul	77	180.9	467	1386.6	301	79.5	183	459.5	2	5.7	—	—	—	—	—	—
Catch/haul adjusted to 5.8 m trawl (factor = 5.26)	0.4	0.8	2	7.5	3	0.8	4	9.7	0.4	1.1	—	—	—	—	—	—
Present study[5]																
Number of hauls	0		11		7		9		4		6		3		3	
Total catch (30 min haul)	—	—	12	11.2	2	0.8	0	0	0	0	0	0	0	0	0	0
Catch/haul	—	—	1.1	1.0	0.3	0.1										
Photo Sled[6]																
Geographic Zone			No./ha	kg/ha	No./ha	kg/ha										
A	—	—	2.7	2.3	0	0	0	0	0	0	0	0	0	0	0	0
B	—	—	0	0	—	—	0	0	0	0	—	—	—	—	—	—
C	—	—	1.7	1.5	2.6	2.2	0	0	0	0	0	0	0	0	0	0
D	—	—	0	0	0	0	0	0	—	—	—	—	—	—	—	—
All zones combined			1.6	1.4	0.6	0.5										

[1]Weight is listed in kilograms.
[2]Schroeder's haul duration 30-40 min, considered as 30 min here. Trawl sizes: footrope lengths of 10.7 and 15.2 m (35 and 50 ft).
[3]Trawl sizes: footrope lengths of 15.2 and 18.3 m (50 and 60 ft).
[4]McRae's haul duration 30 to 120 min, adjusted to 30 min here. Trawl size: footrope length of 30.5 m (100 ft) with 40.6-45.7 cm (16-18 in) rollers.
[5]Trawl size: footrope length of 5.8 m (19 ft).
[6]Density and biomass of lobsters per hectare in each water depth class within each geographic zone based on photographic data.

BOTTOM SEDIMENTS AND TOPOGRAPHY

Sediment Composition

Information about the composition of bottom sediments was obtained from two sources: (1) photographs and (2) trawl. Since the majority of photographs were made on color film, we were readily able to determine sediment color. The type and softness of the sediments was deduced from samples collected with the trawl and the action of the photo sled and animal behavior as recorded in the photographs.

Bottom sediments throughout the entire survey area were composed primarily of a soft, olive-green, silt-clay mixture. Detailed data are listed in Table 22. This sediment type was present in all geographic areas and at all water depths. Furthermore, silt-clays were the overwhelmingly predominant component at all sampling locations, with only a few exceptions in the Georges Bank region—geographic zone D. Here, in addition to silts and clays, gravels of various sizes constituted major components at a few stations (see Figure 14 A and B). Gravels in the Georges Bank region ranged in size from granules (2-4 mm; 0.08-0.16 in) to large boulders (up to 1.5 m; 60 in). The distribution of the various coarse components are illustrated in Figure 15. Smaller gravels, such as granules, pebbles, and cobbles were present at all sampling stations on the continental slope in the Georges Bank region. Boulders were encountered at only five stations, and were most numerous at stations 38 and 46. At station 38 the gravels were the most widely distributed and contained the greatest range in size, from granules to large boulders (as large as 1.5 m; 60 in). At station 39 the gravels consisted mainly of pebbles and cobbles in the 5- to 15-cm (2- to 6-in) size range. At station 40, 5-10 cm (2-4 in) pebbles were the major coarse component, with a few boulders as large as 86 cm (34 in). At station 41 the gravels were made up largely of pebbles and a single boulder of 86 cm (34 in). At station 45 the gravels ranged from granules to cobbles, but all were limited in distribution to a small portion of the station area. At station 46 the gravels varied in size from granules to boulders, the latter ranged from 15 to 112 cm (6-44 in) and were widely distributed geographically.

Table 22.—Bottom type at sampling stations based on in situ sea bottom photographs and materials collected in the trawl.

Station	Bottom type from photographs	Coarse components from trawl and photographs: Type[1]	Gear	No.	Weight (g)	Size (cm): Average	Range
2	Silt-clay						
3	—	Very coarse granule	Trawl	2	300	5.5	—
		Cinders	Trawl	3	500	7.0	—
5	Silt-clay						
6	Silt-clay						
7	Silt-clay						
8	Silt-clay						
10	Silt-clay						
11	Silt-clay						
12	—	Coarse pebbles	Trawl	7	100	2.9	2.1-4.0
		Cinders	Trawl	7	200	3.5	2.1-7.7
13	Silt-clay	Very coarse granule	Trawl	3	50	3.5	—
14	Silt-clay						
15	Silt-clay	Small cobbles	Trawl	11	907	6.5	—
16	Silt-clay						
17	Silt-clay	Med. to coarse pebbles	Trawl	55	350	2.4	1.3-5.0
		Cinders	Trawl	1	4.0	3.1	—
18	Silt-clay						
21	Silt-clay						
22	Silt-clay						
23	—	Small cobbles	Trawl	1	280	7.0	—
24	—	Pebbles	Trawl	6	—	—	—
27	Silt-clay	Med. to coarse pebbles	Trawl	53)		3.0	1.3-5.0
				)	800		
		Cinders	Trawl	13)		2.6	1.8-5.1
28	Silt-clay						
29	Silt-clay	Coarse pebbles	Trawl	3	15	2.5	2.3-2.7
30	Silt-clay						
31	Silt-clay						
32	Silt-clay						
33	Silt-clay						
35	—	Med. to coarse pebbles	Trawl	21)		2.3	1.2-4.0
				)	130		
		Cinders	Trawl	8)		2.1	1.6-2.8
36	—	Pebbles	Trawl	6	—	—	—
37	—	Small cobbles	Trawl	3	1,000	12.0	—
38	Silt-clay and scattered gravel	Granule to lg. boulders	Photo				<0.5-152
39	Silt-clay and scattered gravel	Granule to med. boulders	Photo				≃5.0-51
40	Silt-clay and scattered gravel	Granule to med. boulders	Photo				≃5.0-91
		Large cobbles	Trawl	8	3,000	13.5	—
41	Silt-clay and scattered gravel	Granule to med. boulders	Photo				≃5.0-86
44	—	Very coarse granule	Trawl	55	1,360	4.0	—
45	Silt-clay and scattered gravel	Granule to sm. cobbles	Photo				≃5.0-10
46	Silt-clay and scattered gravel	Granule to lg. boulders	Photo				≃5.0-112
47	—	Coarse pebbles	Trawl	5	280	4.3	3.4-5.5
		Cinders	Trawl	1	—	7.9	—
48	—	Coarse pebbles to small cobbles	Trawl	9	—	4.7	2.5-7.2
59	Silt-clay						
60	Silt-clay						
62	Silt-clay						
63	Silt-clay	Coarse pebbles	Trawl	12	155	3.3	2.1-4.9
		Cinders	Trawl	25	907	—	—
64	—	Med. and coarse pebbles	Trawl	11	85	2.5	1.5-3.0
		Cinders	Trawl	2	—	2.8	2.3-3.2
67	Silt-clay						

[1]Wentworth classification.

On the continental slope westward and southward of Georges Bank small quantities of cinders and small gravels were commonly present in the silt-clay sediments. However, in all cases the coarse components were not visible in the photographs. Thus we concluded that they were buried under the fine sediments and consequently were detected only when taken in the trawl.

Some of the differences between photographic and trawl-derived sediment information may be explained by comparing the two sampling methods. Trawls often dig into the bottom while being towed and actually sift the sediments, retaining only those components too large to pass through the meshes; or, if small enough to pass through, may be inadvertently retained by a codend filled or partially filled with animals. The photographic system, on the other hand, records the sediment surface; therefore, only the larger or prominent

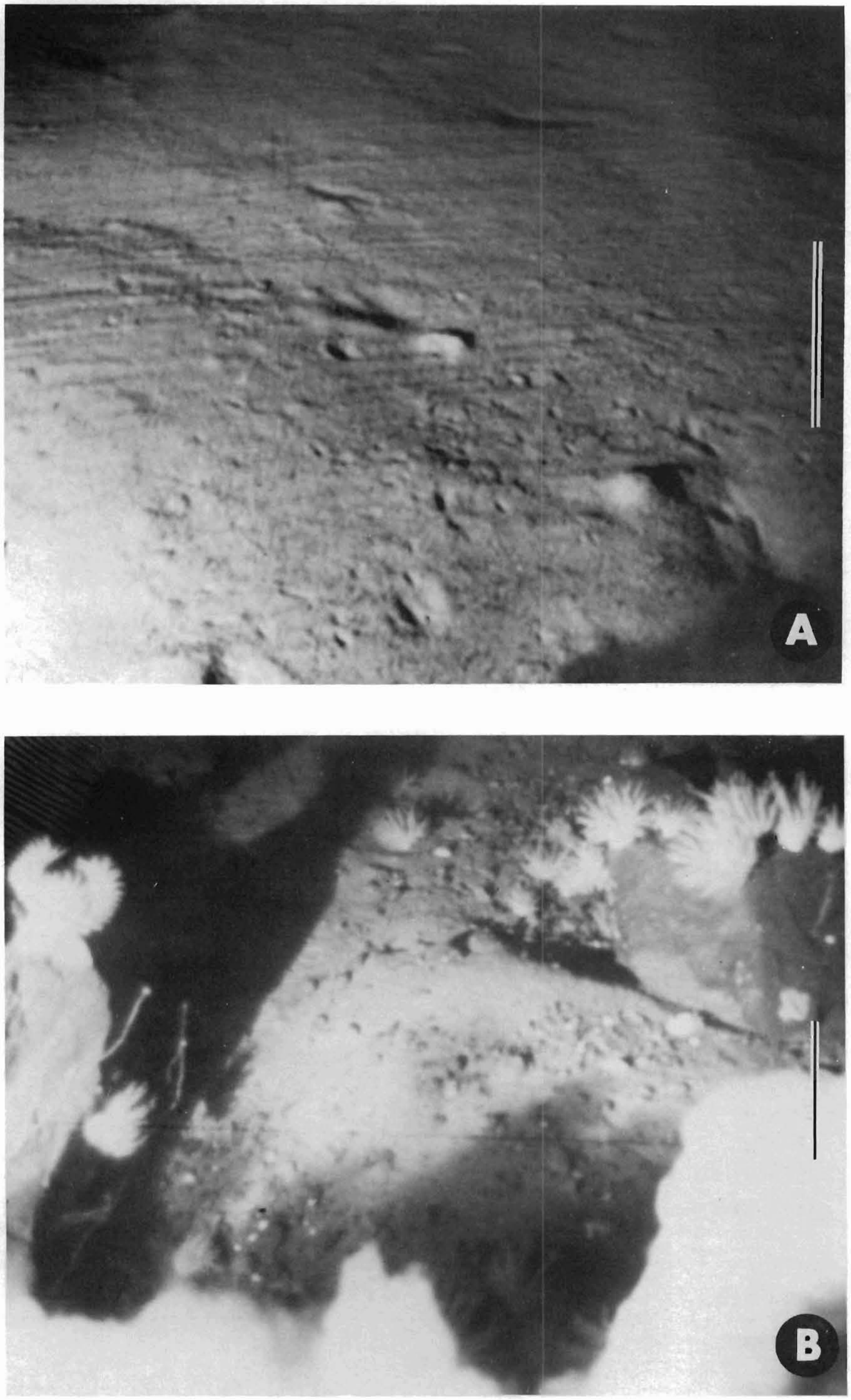


Figure 14.—Photographs of the sea floor that illustrate topographic and sediment anomalies. (A) A soft, silt-clay sediment with parallel lineations that appear to have been man-made, perhaps by a trawl. Scale bar is 1 m (3.3 ft). (B) Large boulders with sea anemones and soft-corals attached. Light areas in foreground are sediment clouds produced by the sled runners. This photograph was taken at station 38, located off Georges Bank at a depth of 348-439 m (190-240 fm). Scale bar is 1 m (3.3 ft).

coarse components, which are not buried, are observed.

Bottom topography

Topographic information at each sampling site was obtained from the analysis of photographs. Although time limitations precluded a comprehensive evaluation, a generalized analysis was made and summarized in this section.

Small-scale topography of the sea bottom at nearly all sampling sites was relatively flat and smooth. Minor departures from the norm occurred at five stations where undulations of the bottom were present, and at only three stations was the bottom sufficiently irregular to be categorized as rough. The most common difference in surface irregularities between sampling sites was the degree of bioturbations present in the form of cones, craters, holes, burrows, and mounds of reworked sediments. Additionally, some areas contained disturbances in the form of single and multiple, parallel lineations, gullies, and furrows, many of which appear to be the result of fishing activities. Major variations to the dominant flat and smooth bottom regime were found in the Georges Bank sector, geographic zone D. Here, in part but not entirely, the generally flat and smooth condition was modified by the superimposition of gravels ranging from granules to large boulders.

Georges Bank region

This was the only region where major modifications to the basic sediment regime of soft, unconsolidated silt-clays was found. Here, at all photographic sampling sites, at all depths, surface topography was altered by the presence of gravels, some of which may have been ice-rafted to this area. Details pertaining to these gravels are contained in the previous section on sediments. The distribution and quantity of coarse components in this area was not uniform. Figure 15 illustrates the distribution and relative abundance of the coarse gravel components for each photographic transect within this sector. The topography was generally flat and smooth. Some gentle undulations were detected only in the deeper portions of this region (430-448 m; 235-245 fm). Topographic relief, with the exception of those areas within each photographic transect modified by coarse rubble, was composed of occasional small, low, regular mounds and small to medium sized cones. Craters were the dominant relief form occurring at all depths. They ranged from few to moderate in number and from small (2 cm; 0.8 in) to large (75 cm; 30 in) in size. A few small holes were observed along with some apparently man-made parallel furrows at depths of from 210 to 293 m (115-160 fm), and from 357 to 512 m (195-280 fm).

Southwestern region

The general small-scale topography throughout this region was flat and smooth with undulations and large irregular mounds occurring only occasionally and restricted to some of the deeper areas (823-1,097 m; 450-600 fm). Circumscribed topographic relief was composed of cones, craters, crater rows, holes, furrows, burrows, and man-made perturbations in the form of parallel furrows, gullies and lineations. The extent and degree of the small-scale relief varied randomly throughout the area and appeared to be due primarily to the amount of local biological activity. One interesting observation in this region was the presence of a large crater at a depth of about 311 m (170 fm) occupied by a large lobster (Fig. 13), who, in digging the crater, excavated what appears to be a telephone transmission cable.

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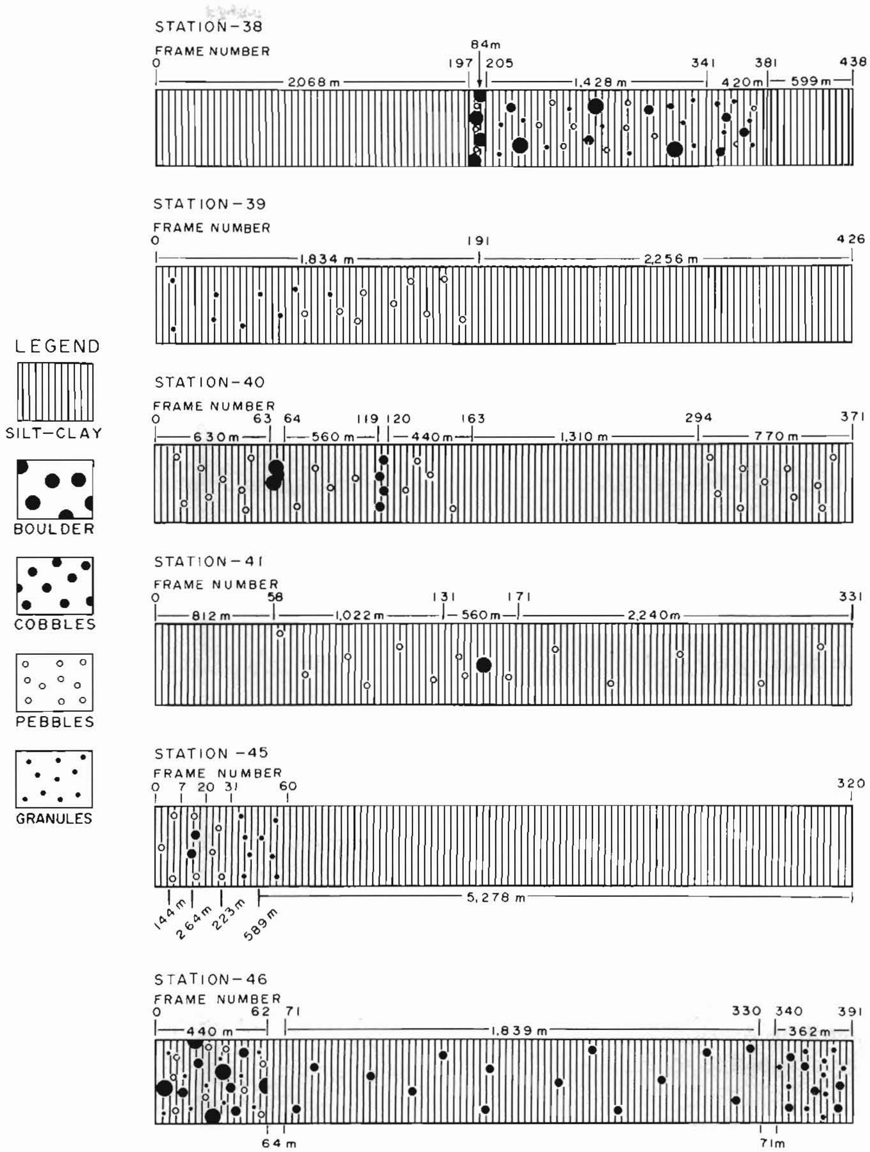

Figure 15.—Graph illustrating the distribution, extent, and relative abundance of the coarse components in bottom sediments at six stations in geographic zone D, the Georges Bank region.

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