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ABSTRACT

Epibenthic invertebrate animals were sampled with a large scallop dredge and photographed with a sled-mounted camera at four locations on the Continental Shelf off Massachusetts in August 1965.

Sea-bottom photographs taken at a station south of Martha's Vineyard, Mass., at a depth of 59 m. revealed a sandy silt sediment with a slightly uneven microtopography. At three stations on southeastern Georges Bank, at 64 to 82 m., sediments were predominantly sand with small proportions of shell fragments and silt. The microtopography was generally rough and irregular, largely caused by feeding of fish and other biological activity. Sand ripples were common; some apparently formed by wave action and others by tidal currents.

Species composition of the large epibenthic invertebrates was similar at the three localities on Georges Bank but differed markedly from that south of Martha's Vineyard. Also, the number of specimens were substantially higher on Georges Bank than south of Martha's Vineyard. The densities of invertebrates estimated from photographs (0.7, 1.7, 1.8, and 8.6 individuals per square meter) at the four stations were substantially higher than estimates based on the dredge collections (0.02, 0.16, 0.3, and 3.3 individuals per square meter).

INTRODUCTION

Undersea photography has proved exceedingly useful in recent years for determining geological features and biological components (Ewing, Vine, and Worzel, 1946; Vevers, 1952; Laughton, 1957; Thorndike, 1959; McIntyre, 1956; Shipek, 1960; Menzies, Smith, and Emery, 1963; Barham, Ayer, and Boyce, 1967; Hersey, 1967; Wigley and Emery, 1967; and others). Even in great oceanic depths of the bathyal and abyssal zones, the animal life, bottom sediments, and similar subjects have been documented by photographs (Laughton, 1959; Shipek, 1960). Of particular interest to us are the studies that demonstrated the possibility of using sea-bottom photographs to obtain quantitative evaluations of epibenthic animals (McIntyre, 1956; Menzies, Smith, and Emery, 1963; Barham, Ayer, and Boyce, 1967; Wigley and Emery, 1967).

Because of the urgent need for more accurate and economical methods of measuring the density distribution of benthic animals, we took a series of photographs at the same stations where samples were collected with a dredge. This report describes the photographic method and presents the results, including a comparison of the two methods of estimating densities of the macrobenthic fauna.

MATERIALS AND METHODS

Sea-bottom photographs and dredge samples were collected from aboard the research vessel Albatross IV in August 1965 at four stations on the Continental Shelf south and southeast of Massachusetts at water depths between 59 and 82 m. (table 1, fig. 1). At each station a sample of benthic animals was collected with a large scallop dredge and a series of photographs was taken with an underwater camera.

Photographs were obtained with a camera and light unit mounted on a heavy steel sled (fig. 2) that was towed along the ocean bottom. Basic features of the sled are generally similar to Costeau's "Troika" (Gaston Fredj,[1] personal communication) and the submarine plow developed by Bell Telephone Company (Robert Allen,[2] personal communication). A

[1] Gaston Fredj, Biologist, Musée Océanographic, Monaco.

[2] Robert Allen, Scientist, Bell Telephone Research Laboratory, Chester, N.J.

Table 1.--Station location, depth of water, and related information concerning the photographic and dredge-collection stations occupied by R.V. Albatross IV, August 1965

Station	General locality	Latitude (North)	Longitude (West)	Water depth	Date (August)	Time	Sediment[1]	
							Type	Color
				m.				
5	South of Martha's Vineyard	40°41'	71°00'	59	18	0800	Sandy silt	Dark olive green
42	Southeastern Georges Bank	41°01'	67°31'	66	22	0900	Sand	Gray-brown
44	Southeastern Georges Bank	41°14'	67°04'	64	22	1600	Sand	Brown
45	Southeastern Georges Bank	41°14'	66°39'	82	22	2000	Sand	Brown

[1] Based on laboratory analyses of samples collected with a Smith-McIntyre grab sampler.

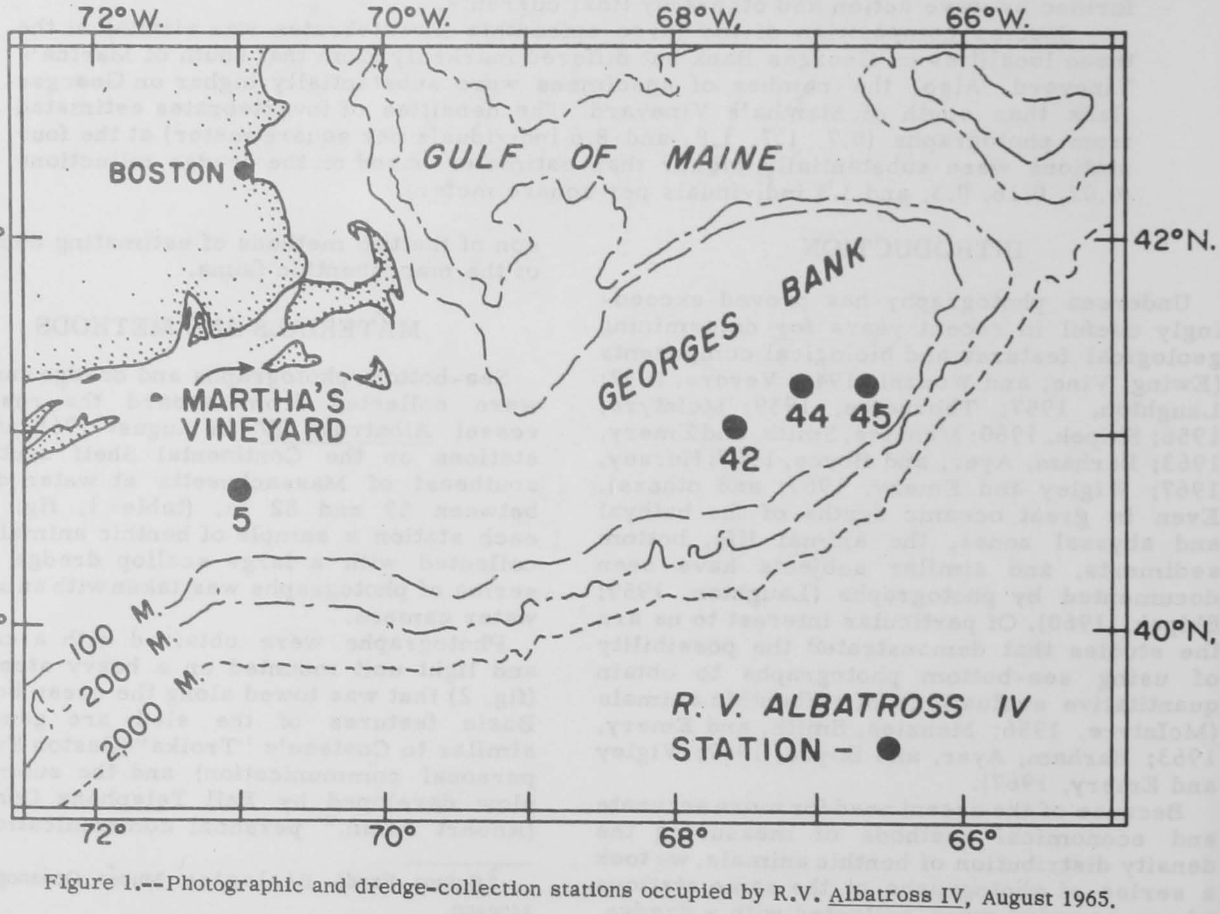

Figure 1.--Photographic and dredge-collection stations occupied by R.V. Albatross IV, August 1965.

Nikon F[3] camera (35-mm. film) equipped with a Nikon Electric Motor Drive, model F 250, and a timer were coupled to a 100 watt-second electronic flash tube. Camera and light were enclosed in separate watertight metal housings and shock-mounted on the sled. The sled was 2.3 m. long, 1.3 m. high, and 1.5 m. wide, and weighed about 500 kg. Four hollow aluminum spheres, 16-cm. diameter, were tied to

[3] Reference to commercial products does not imply endorsement by the Bureau of Commercial Fisheries.

the highest part of the sled frame to aid in keeping the sled upright. The camera was positioned on the sled 1 m. above the runners, and aimed forward 45° from vertical. The large-capacity film magazine (250 frames) and rapid recycling time (12 seconds) of the capacitor for the light permitted up to 250 photographs to be taken at 15-second intervals on one film load. The sled was towed at 1-1/2 to 2 knots for 15 to 60 minutes at each station. Thus the linear distance along the sea bottom between photographs was 12 to 17 m. The 28-mm. lens gave a photograph of 1.2 square meters of bottom area in each frame.

The numbers of photographs taken at stations 5, 42, 44, and 45, respectively, were 212, 70, 112, and 20 (total, 414). The film was black-and-white panchromatic that has a speed rating of ASA 125.

A photographic print, 7-1/2 by 11-3/4 cm., was made from each negative. Only a portion of each print was used for counting and measuring animals. A template was placed over each print that blocked off all except 0.46 square meter of foreground area. Animals larger than 5 cm. were identified and counted. Table 2 is a summation of the counts.

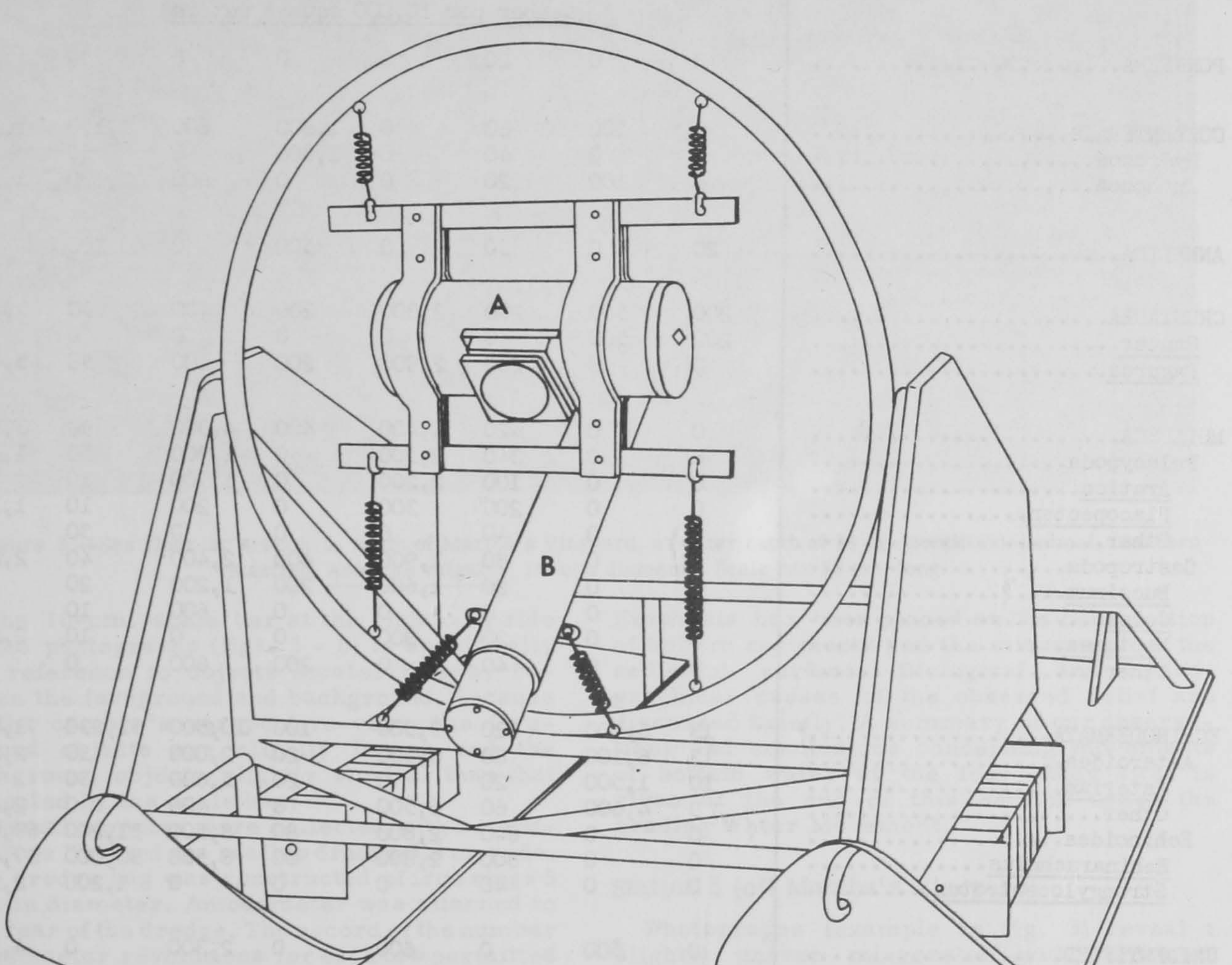

Figure 2.--Front-oblique view of sled-mounted photographic unit. Camera (A) is mounted above the electronic flash tube (B) in the circular portion of sled frame.

Table 2.--Density estimates of benthic invertebrates larger than 5 cm. at four stations on the Continental Shelf off Massachusetts in August 1965. [Values are based on scallop dredge samples and bottom photographs; all densities are expressed as the number of individuals per 10,000 square meters of sea bottom.]

Taxonomic group	Station							
	Martha's Vineyard		Georges Bank					
	5		42		44		45	
	Dredge	Photo	Dredge	Photo	Dredge	Photo	Dredge	Photo
	Number per 10,000 square meters							
PORIFERA	3	0	20	0	0	0	50	0
COELENTERATA	5	100	60	0	1,800	600	1,150	1,100
Hydrozoa	5	0	40	0	1,800	0	50	0
Anthozoa	0	100	20	0	0	600	1,100	1,100
ANNELIDA	20	0	30	0	500	0	100	0
CRUSTACEA	200	500	200	2,800	200	400	50	5,400
Cancer	200	500	0	0	0	0	0	0
Pagurus	0	0	200	2,800	200	400	50	5,400
MOLLUSCA	0	0	420	4,400	400	4,300	90	3,300
Pelecypoda	0	0	340	2,500	0	1,900	50	1,100
Arctica	0	0	100	2,200	0	1,700	10	0
Placopecten	0	0	200	300	0	200	10	1,100
Other	0	0	40	0	0	0	30	0
Gastropoda	0	0	80	1,900	400	2,400	40	2,200
Buccinum	0	0	20	1,600	200	1,200	20	0
Colus	0	0	0	0	0	600	10	0
Neptunea	0	0	20	300	0	0	10	2,200
Other	0	0	40	0	200	600	0	0
ECHINODERMATA	13	6,100	920	9,300	100	10,500	31,230	71,800
Asteroidea	13	6,100	80	6,500	20	2,000	30	2,200
Asterias	10	1,500	20	0	20	1,600	30	0
Other	3	4,600	60	6,500	0	400	0	2,200
Echinoidea	0	0	840	2,800	80	8,500	31,200	69,600
Echinarachnius	0	0	800	2,800	80	8,500	30,000	67,400
Strongylocentrotus	0	0	40	0	0	0	1,200	2,200
UNIDENTIFIED	0	500	0	600	0	2,300	0	4,300
TOTAL	241	7,200	1,650	17,100	3,000	18,100	32,670	85,900

Figure 3.--Sea floor at station 5, south of Martha's Vineyard, at water depth of 59 m. Identifiable animal: northern starfish, Asterias vulgaris, 16-cm. diameter. Scale bar 10 cm. long.

The 10-cm. scale bar at the righthand side of the photographs (figs. 3 - 8) is specifically for reference to objects located midway between the foreground and background. Because of the camera's perspective view, the foreground objects are slightly larger and the background objects slightly smaller than that indicated by the scale bar.

Faunal samples were collected with a standard New Bedford sea scallop dredge 3.3 m. wide. The dredge bag was constructed of iron rings 5 cm. in diameter. An odometer was attached to the rear of the dredge. The record of the number of odometer revolutions for each tow permitted a rather accurate measure of distance the dredge was towed. The number of specimens in the dredge samples were counted; table 2 shows the calculated number of individuals, prorated to 10,000 square meters of bottom area.

DESCRIPTIONS OF BIOTOPES FROM PHOTOGRAPHS

This section gives a description of the physical environment, as deduced from photographs, at each of the four stations studied. Emphasis has been placed on the composition of bottom sediments and the microrelief of the sediment surface. Biological and hydrographical causes of the observed relief are discussed briefly. A summary of our observations and conclusions concerning movements of bottom water at the four study sites is given at the end of this section under the heading Water Movement.

Station 5 (off Martha's Vineyard)

Photographs (example in fig. 3) reveal a slightly uneven microrelief with somewhat smooth, gently rounded irregularities. Small indistinct animal tracks are superimposed on low mounds, ridges, and pockets. The rounded contours of nearly all irregularities indicate a rather high silt-clay content of the sediment. Tracks and trails of crabs, gastropods, starfish, and other motile invertebrates are common. These imprints are not clearly discernible and rarely extend more than 1/2 cm. deep into the sediment, presumably because of the large proportion of fine particles and the soft texture of the sediment. Burrows made by polychaete worms, heart urchins, and other burrowing creatures are evident from holes of various sizes that extend through the surface of the sediment. The number of holes (average density 20 per square meter) at this station is less than at Georges Bank stations.

The sediment, as judged from the photographs, appears to be predominantly silt and of moderately dark color. This evaluation corresponds closely with determinations based on sediments collected with a Smith-McIntyre bottom sampler. Sediments are sandy silt, dark olive green without visible shell fragments.

Water movements are judged to be exceedingly weak or absent. (See section on Water Movement.)

Station 42 (Georges Bank)

Sea bottom topography is slightly undulatory with low ridges at intervals of 100 to 300 m. The microtopography is disarranged and uneven (fig. 4). Numerous small pockets, ridges, hillocks, and other irregularities occur throughout the area photographed. Tracks and trails of motile benthic animals are present but are relatively inconspicuous owing to numerous other irregularities on the sediment surface. Although water movement and animal tracks contributed to the uneven and disorderly sea floor surface, we believe that a major cause of this disturbance was the feeding and hiding activities of bottom-dwelling fishes, such as skates, flatfishes, haddock, and others. The photographs, plus observations of aquarium-held specimens of some of these fishes, particularly the skates and flatfishes, have shown that they habitually excavate shallow pockets and hide in the sediment with only eyes or other body parts exposed.

Burrow openings in the sediment surface are common; they average 33 per square meter.

Sediment appears to be chiefly sand of moderately dark color. Sediment in grab-sampler collections is gray-brown sand. Fragments of mollusk shells are common and rather evenly distributed. The size of these

Figure 4.--Sea floor at station 42, southeastern Georges Bank, water depth 66 m. Identifiable animals: A. posterior end of skate, Raja; B. sand dollar, Echinarachnius parma; C. ocean quahog; D. hermit crab, Pagurus. Scale bar is 10 cm. long.

fragments ranges from nearly entire shells (10 cm.) of ocean quahog, Arctica islandica, to pieces only slightly larger than sand grains.

About 50 percent of the sea bottom is sculptured with a ripple pattern that appears to have resulted from wave action (see section on Water Movement).

Station 44 (Georges Bank)

Large-scale topography is slightly undulatory with low, irregularly spaced elevations. The microtopography is uneven (fig. 5) because of small pockets, ridges, and mounds of various shapes. Some of these surface markings are uniformly spaced and of equal size, whereas others are irregularly spaced and uneven in size. This combination suggests that water movement and biological agents are both active in reworking surface sediments at this locality. Fish feeding, hiding, and escape activities undoubtedly contribute to the irregular and disorderly surface sculpturing, which covers about 60 percent of the bottom area. Tracks and trails are uncommon, burrow openings average five per square meter, and tubes of polychaete worms and amphipods are moderately numerous.

The photographs indicate that the sediment is predominantly sand of relatively light color.

Mollusk shells are fairly common and somewhat evenly distributed. Their size ranges from large (14 cm.) intact shells of surf clams, Spisula, to specimens or fragments less than 1 cm.

Samples of the bottom sediment collected with a Smith-McIntyre sampler are predominantly medium and coarse sands of light brown color, with a small proportion of shell matter.

Roughly 40 percent of the bottom area at this station contains ripples of asymmetrical shape that are believed to have been created by a rather strong water current. The direction of the ripple marks indicates that the water flowed from southeast to northwest (see section on Water Movement).

Figure 5.--Sea floor at station 44, southeastern Georges Bank, water depth 64 m. Identifiable animals: A. burrowing sea anemone, Cerianthus borealis; B. waved whelk, Buccinum undatum; C. surf clam, Spisula solidissima; plus numerous tubes of polychaetes and amphipods. Scale bar is 10 cm. long.

Station 45 (Georges Bank)

Sediment surface is uneven with numerous small pocket-like depressions, ridges, and mounds (fig. 6). A varied and unkempt appearance of the sea floor results not only from microtopographic irregularities but also from the patchy distribution of large mollusk shells and several groups of living animals. Tracks and trails are present but are not particularly noticeable because of the generally disturbed surface. Among the more distinctive trails evident in the photographs from this station are those of the sand dollar. This species crawls on or through the sediment with the aid of tube feet and the movement of spines. Its progression along the ocean bottom leaves a smooth flattened path with low rounded ridge on each side (fig. 6, upper left). Width of the path equals the body diameter. Other common tracks are those of hermit crabs and gastropods.

The sediment appears to be primarily sand containing a small amount of silt. Color ranges from dark to moderately light. Mollusk shells are common; the small fragments are rather uniformly distributed, in contrast to localized aggregations of the large shells. The ocean quahog and northern cardita, Venericardia borealis, are the principal species whose shell remains are identifiable. About half the large pelecypod shells have the convex (outside) face downward on the sediment, and the other half have the concave (inside) face downward. Shells with the convex face downward are partially or completely filled with sand.

Sediment taken with a grab sampler was coarse to medium brown sand.

Ripples in the sediment are relatively uncommon, but their conformation suggests they are formed by the oscillatory action of waves (see following section on Water Movement).

Water Movement

Evidence of water movement is revealed by sand ripples sculptured in the sea floor sediments in photographs at the three locations

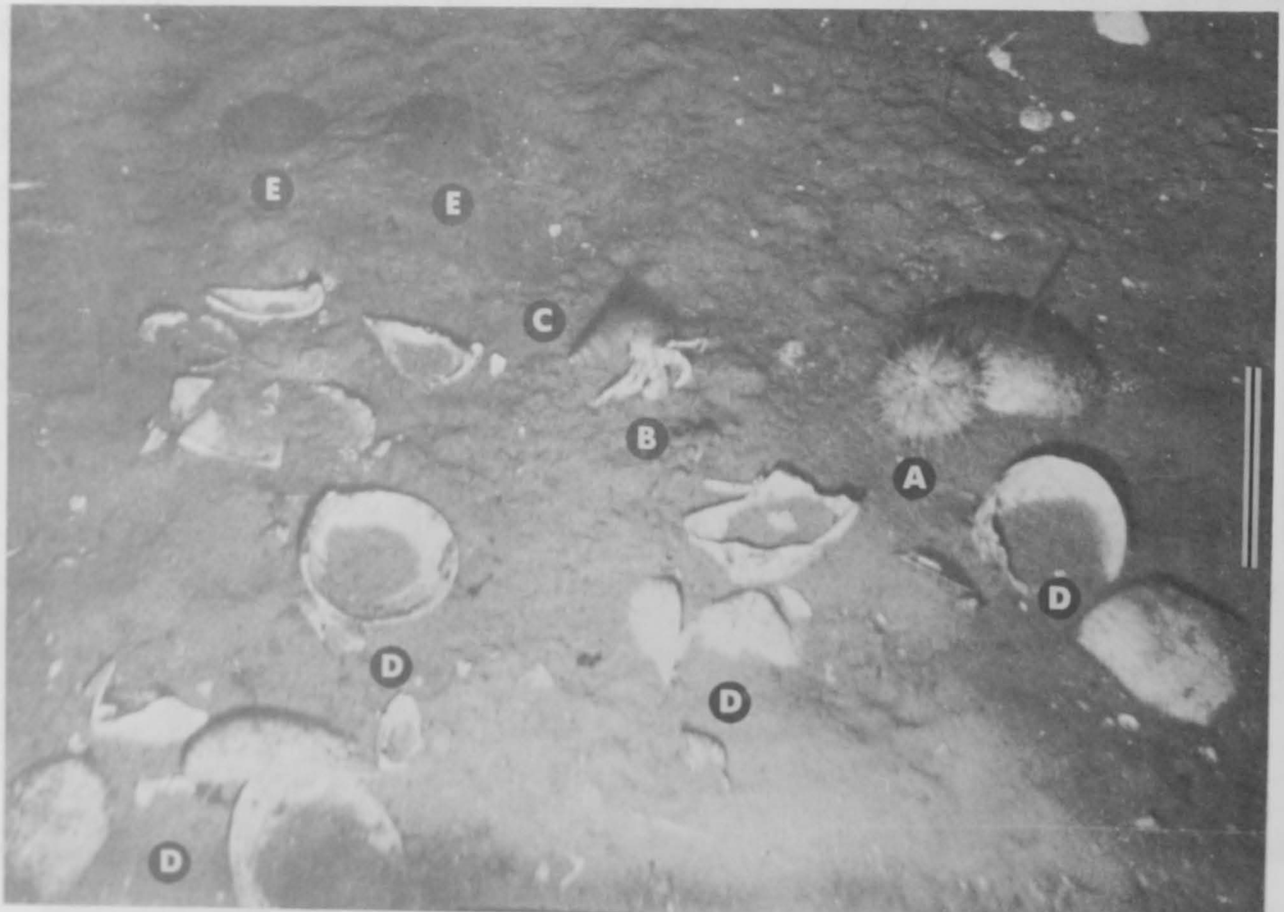

Figure 6.--Sea floor at station 45, southeastern Georges Bank, water depth 82 m. Identifiable animals: A. green sea urchin, Strongylocentrotus drobachiensis; B. Acadian hermit crab, Pagurus acadianus; C. Stimpson's distaff shell, Colus stimpsoni; D. ocean quahog; E. sand dollar. Scale bar is 10 cm. long.

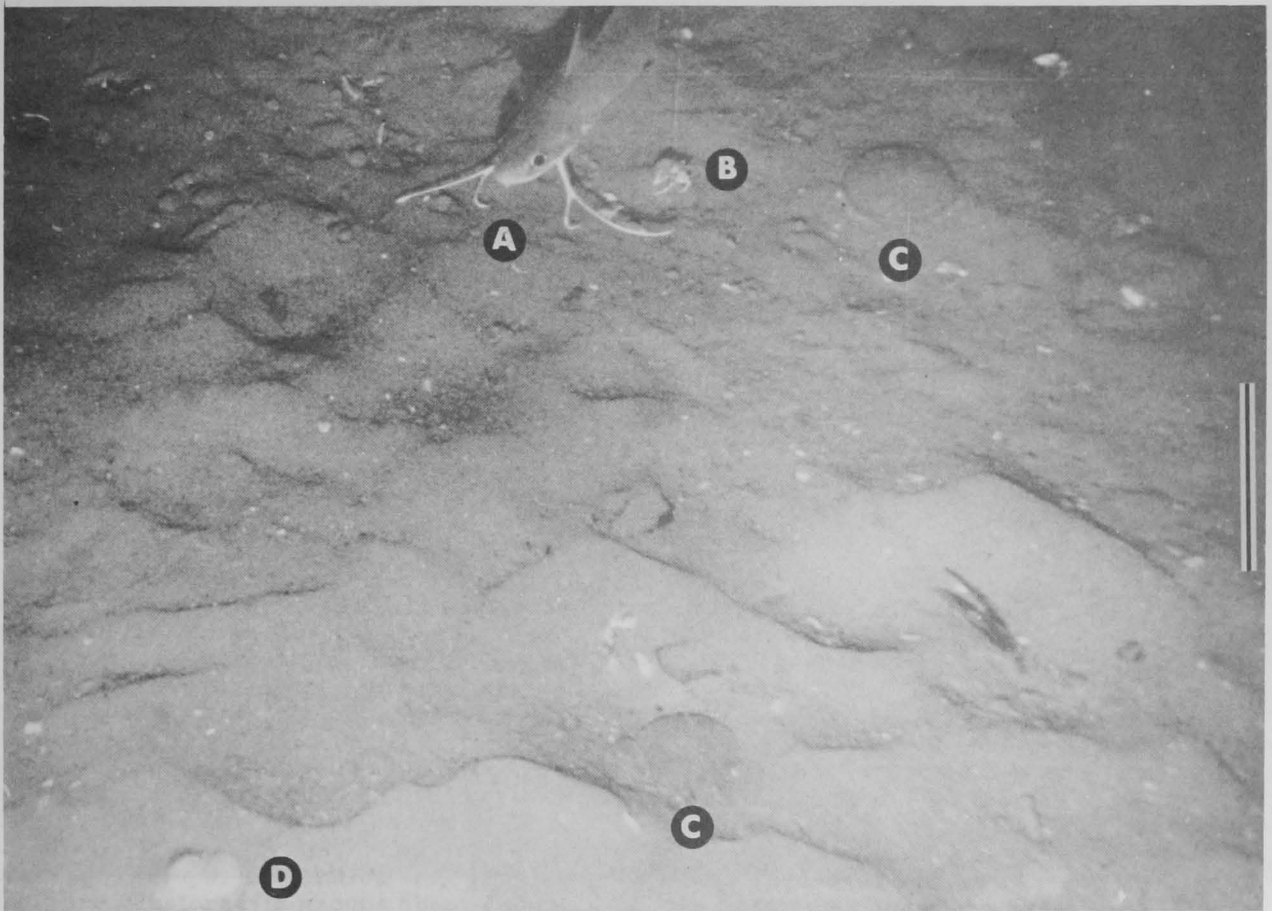

Figure 7.--Symmetrical ripple marks on the sea bottom at station 45. Identifiable animals: A. red hake, Urophycis chuss; B. hermit crab; C. sand dollar; D. common northern moon-shell, Lunatia heros. Scale bar is 10 cm. long.

on Georges Bank. Symmetrical sediment ripples having crests spaced at roughly 10-cm. intervals are present in photographs taken at 66 m. (station 42) and at 82 m. (station 45), see figure 7; they are interpreted as having been formed by wave action. A large series of pronounced asymmetrical sand ripples at 64 m. (station 44; illustrated in fig. 8) indicates a moderately strong water current flowing from southeast to northwest (340°). Bottom water currents judged from similar data from the Continental Shelf off northeastern United States were reported by Emery, Merrill, and Trumbull (1965). They reported the currents on southeastern Georges Bank to be flowing from the northeast and northwest, rather than from the southeast. This diversity of direction suggests that tidal current is the principal force producing these ripple marks.

No sequential sediment markings indicative of water movement are apparent in the photographs from the sampling station south of Martha's Vineyard. Deformations in the sediment are irregularly spaced and of different sizes and shapes. They appear to have resulted from animal activities.

COMPARATIVE ESTIMATES OF FAUNA DENSITY FROM DREDGE COLLECTIONS AND SEA-BOTTOM PHOTOGRAPHS

This section deals with the kinds of animals and the numerical density of each kind as detected in the photographs and caught in the dredge. The two major faunal categories are treated separately under the headings "Epibenthic Invertebrates" and "Fishes." Emphasis is given to the relative accuracy of the two methods (dredging and photography) used in estimating the density of benthic animals.

Epibenthic Invertebrates

Accurate and economical methods for obtaining quantitative estimates of epibenthic invertebrate animals in sublittoral and deep-sea environments have yet to be developed. Older techniques for determining relative densities or approximate quantities are dredging (collecting samples with an oyster dredge, scallop dredge, or similar device towed along the sea bottom) and trawling (towing a net such as an otter or shrimp trawl). More

Figure 8.--Asymmetric ripple marks on the sea bottom at station 44. Direction of view is northeast, and the water current that formed the ripples flowed toward the northwest. Identifiable animals: A. burrowing sea anemone; B. hermit crab. Scale bar is 10 cm. long.

recently, grab-type bottom samplers and photography have been used successfully (Vevers, 1952; McIntyre, 1956; Emery, Merrill, and Trumbull, 1965; Wigley and Emery, 1967; and others). From results of the above-mentioned studies, the photographic method appears promising for many purposes, even through it may also be the most inadequate for identifying the animals and determining their exact size.

Our results substantiate conclusions from other studies that revealed that photographic techniques are superior to dredging methods for obtaining quantitative measures of the large epibenthic species and determining local distribution (dispersion) of animals and sediment features. Estimates of density of epibenthic invertebrates derived from bottom photographs and from scallop-dredge samples at the four stations (fig. 1) off Massachusetts are listed in table 2. Densities based on an analysis of photographs were substantially higher than those based on dredge collections. This difference held true for every taxonomic group (as well as for all taxonomic groups combined) except the Porifera and Annelida. Only a few Porifera and Annelida were collected in the dredge hauls; none was observed in the photographs.

Species compositions of animals at the Georges Bank stations (42, 44, and 45) were generally similar but differed markedly from the fauna south of Martha's Vineyard (station 5). On Georges Bank the dominant species were: Echinarachnius parma, Strongylocentrotus drobachiensis, Buccinum undatum, Colus stimpsoni, Neptunea decemcostata, Arctica islandica, Placopecten magellanicus, and Pagurus acadianus. Principal species south of Martha's Vineyard (station 5) were: Asterias vulgaris, Leptasterias tenera, and Cancer borealis.

Echinoderms were, by far, the most abundant major taxonomic group sampled. Echinoids, a principal subgroup, were represented chiefly by the sand dollar and the green sea urchin. Sand dollars were particularly numerous (6.7 per square meter) at 82 m. on Georges Bank (station 45). They were less common at shallower depths on Georges Bank (stations 42 and 44) and were absent at 59 m. south of Martha's Vineyard (station 5). Asteroids were another major subgroup. They were very common south of Martha's Vineyard but less plertiful at the more easterly stations.

Representatives of several other phyla were quantitatively important. Mollusks were moderately common at the Georges Bank stations. Gastropods, the most abundant molluscan group, were represented chiefly by Buccinum, Neptunea, and Colus. Pelecypods were the only other molluscan group; the principal species were the ocean quahog and the sea scallop. Nearly all crustaceans in the samples were decapods, mainly rock crabs (Cancer) and hermit crabs. Coelenterates were rather sparse and were represented by Hydrozoa and Anthozoa. Porifera were very sparse in the dredge samples (maximum density 0.005 per square meter) and were not detected in the photographs.

Fauna revealed by photographs was generally the same throughout the entire strip sampled at each station. Local variation, inferred from changes from one frame to another, was more pronounced for some species than others. Starfishes, for example, were rather uniformly distributed, whereas sand dollars and hermit crabs tended to occur in groups. Large numbers of sand dollars at stations on Georges Bank were frequently concentrated in patches 10 to 20 m. in diameter spaced at intervals of 50 to 75 m. Mollusk shells, both the intact shells and shell fragments, also were distributed in groups. At station 42, Arctica shells were clustered in groups about 200 m. apart, but shell fragments were rather evenly distributed. At station 44, where water currents appeared to be strong, both the large intact shells and shell fragments occurred separately in groups. Smaller pieces were commonly found in troughs of sediment ripples.

For all taxonomic groups combined, the number of individual animals per unit area calculated from photographs was substantially higher at all four stations than estimates made from the dredge hauls. Dredge data yielded estimates of faunal density of 0.02, 0.16, 0.3, and 3.3 per square meter at stations 5, 42, 44, and 45, respectively, whereas the photographic analyses for these stations yielded estimates of 0.7, 1.7, 1.8, and 8.6 per square meter. Intrastation disparity (dredge versus photographs) in density estimates ranged from as much as 1:30 at station 5 to as little as 1:2.6 at station 45.

The interstation density of species, genera, and higher taxonomic groups varied in much the same manner described above for all groups combined. Substantial interstation density differences were expected, but the pronounced differences in density estimates from the two sampling methods were unexpected.

Quantitative results from the photographic method are judged to be substantially more accurate than those from dredge-collection data in this situation. Greater accuracy in measuring the density of large epibenthic invertebrates by analysing sea-bottom photographs, as opposed to dredging, is in keeping with known inadequacies in the latter method. Some of the principal deficiencies in dredging are: (1) insufficient accuracy in measuring the bottom area sampled; (2) inefficiency in capturing specimens that lie in pockets, plus the loss of animals that come in contact with the dredge ground-chain and are pushed aside or below (outside) the dredge bag; and (3) noise or shock waves that may alert motile animals and permit them to avoid capture. Only the last of these is believed to have a detrimental effect on the photographic method; apparently the effect is not excessive.

Fish

Although the scallop dredge and photographic system were not designed for capturing fish or measuring fish abundance, a brief summary of results concerning this subject may be of interest. The number of fish caught in the scallop dredge averaged 30 specimens per 10,000 square meters per station; all were bottom-dwelling species. In contrast to this apparent low abundance, the estimated density based on photographic analyses were 690 specimens per 10,000 square meters per station. The more common species represented in these samples and photographs were: goosefish, Lophius americanus; red hake; yellowtail flounder, Limanda ferruginea; and several species of skates, Raja. Although the evidence is meager, these results suggest the superiority of photographic methods over the scallop dredge for judging the abundance of bottom-dwelling fishes.

Accuracy of quantitative information, plus the capability of sampling large areas quickly and relatively inexpensively, are features of the photographic method that are particularly desirable for certain types of survey and inventory.

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LITERATURE CITED

BARHAM, E. G., N. J. AYER, JR., and R. E. BOYCE.
1967. Macrobenthos of the San Diego Trough: photographic census and observations from bathyscaphe, Trieste. Deep-Sea Res. 14: 773-784.

EMERY, K. O., ARTHUR S. MERRILL, and JAMES V. A. TRUMBULL.
1965. Geology and biology of the sea floor as deduced from simultaneous photographs and samples. Limnol. Oceanog. 10: 1-21.

EWING, MAURICE, ALLYN VINE, and J. L. WORZEL.
1946. Photography of the ocean bottom. J. Opt. Soc. Am. 36: 307-321.

HERSEY, JOHN BRACKETT (editor).
1967. Deep-sea photography. Johns Hopkins Oceanogr. Stud. 3: 1-310.

LAUGHTON, A. S.
1957. A new deep-sea underwater camera. Deep-Sea Res. 4: 120-125.
1959. Photography of the ocean floor. Endeavour 18: 178-185.

McINTYRE, A. D.
1956. The use of trawl, grab and camera in estimating marine benthos. J. Mar. Biol. Ass. U.K. 35: 419-429.

MENZIES, ROBERT JAMES, LOGAN SMITH, and K. O. EMERY.
1963. A combined underwater camera and bottom grab: a new tool for investigation of deep-sea benthos. Int. Rev. Hydrobiol. 48: 529-545.

SHIPEK, C. J.
1960. Photographic study of some deep-sea floor environments in the eastern Pacific. Bull. Geol. Soc. Amer. 71: 1067-1074.

THORNDIKE, E. M.
1959. Deep-sea cameras of the Lamont Observatory. Deep-Sea Res. 5: 234-237.

VEVERS, H. G.
1952. A photographic survey of certain areas of sea floor near Plymouth. J. Mar. Biol. Ass. U.K. 31: 215-221.

WIGLEY, ROLAND L., and K. O. EMERY.
1967. Benthic animals, particularly Hyalinoecia (Annelida) and Ophiomusium (Echinodermata), in sea-bottom photographs from the continental slope. In John Brackett Hersey (editor), Deep-sea photography, pp. 235-249. John Hopkins Oceanogr. Stud. 3.

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