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Photographic Systems Utilized in the Study of Sea-Bottom Populations

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INTRODUCTION

Since 1953 the Benthic Dynamics Investigation at the Woods Hole, Massachusetts, Laboratory of the Northeast Fisheries Center (NEFC), a component of the National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS), has been concerned with the distribution and abundance of sea-bottom dwelling invertebrates. This concern with the benthic fauna relates to the importance of a large number of its components in the diets of the commercially important species of groundfishes.

Initially, the principal area of investigation extended from the Bay of Fundy in the northeast to the Hudson Canyon in the southwest. Within this area intensive quantitative and qualitative sampling was conducted in the Gulf of Maine; on offshore fishing grounds such as Georges Bank, Browns Bank, and Stellwagen Bank; and on the southern New England continental shelf. Several thousand samples yielding information on surficial sediments and benthic organisms were obtained during the period from 1953 to 1963.

In 1963 the scope of the investigation broadened substantially as a result of participation in a joint program of study with the Woods Hole Oceanographic Institution (WHOI) and the U.S. Geological Survey (USGS)

(Emery and Schlee 1963). The study expanded to include the entire east coast continental shelf and slope between Nova Scotia and Key West, Florida. This program also provided several thousand quantitative and qualitative samples of sediments and their associated fauna. Up to the present, the Benthic Dynamics Investigation has garnered a total of more than 11,500 quantitative and qualitative samples from the sea bed.

The acquisition of samples during the early period (prior to 1963) was accomplished using traditional sampling devices including various bottom grabs, dredges, and trawls, all of which are relatively inefficient, tedious, and expensive to use (Wigley and Emery 1967). With the inception of the joint WHOI, USGS, and NEFC program, a different sampling strategy was initiated. In order to optimize the yield of data from grab samples, with their inherent bias of underestimating the surface-dwelling components of the epibenthic fauna (Wigley and Emery 1967), a new combination camera and bottom grab, developed at the University of Southern California (Menzies, Smith, and Emery 1963), was used to obtain quantitative samples for biological and geological analysis. Several thousand sample/photograph pairs were obtained from the study area, providing a great deal of detailed information on the distribution and relationships of the epibenthic macrofauna and sediments, hitherto unobtainable by traditional means, except at great expense with manned submersibles. Furthermore, the reluctance of biologists to identify organisms in photographs was, to some degree, overcome by the possession of sample/photograph pairs that were virtually identical in space and time (Emery and Merrill 1964; Emery *et al.* 1965).

Beginning in 1965, greater effort and emphasis was placed on obtaining information about the distribution, abundance, ecological relationships, and assemblages of the larger components of the benthos, the mega- and macrobenthos, composed of lobsters, crabs, shrimps, and other large invertebrates. Since these organisms have expansive distributions on the continental shelf and slope, obtaining the desired information would require wide ranging cruises of long duration and great expense if traditional sampling methods such as grab, dredge, trawl, or pot, were employed. To increase accuracy and efficiency, and to expedite the collection of data on the ubiquitous mega- and macrofauna—and based on the experience gained in photographic techniques and photo analysis during the course of the joint program—we began experimenting with photographic systems mounted on towed, bottom-contact sleds. The choice of bottom-contact sleds, rather than other underwater photographic systems available at the time such as pogo or towed fish configurations, was dictated by our need to maintain ground truth (a fixed distance from the bottom) in our quest for quantifiable data.

Four research cruises, specifically targeted to mega- and macrobenthic studies, were conducted between 1965 and 1974, using sled-mounted photographic systems and traditional gear, principally scallop dredges and trawls, for comparative evaluation. These studies used a total of three different photographic systems, four separate configurations of the systems, and two different sled designs as platforms. Over 34,000 photographs were obtained with these systems. The photographic systems used, and examples of the results obtained, are described and illustrated in the following sections.

COMBINATION CAMERA-GRAB

The combination camera-grab was a modified version of the Campbell grab-camera device described by Menzies *et al.* (1963). The modification, by D. M. Owen of WHOI, involved the replacement of the original Hasselblad camera-flashbulb system with one composed of two spring-driven 35-mm Robot "Star" cameras with 30-mm lenses on a stereo mount and a Honeywell Strobotron light source (Figure 1).

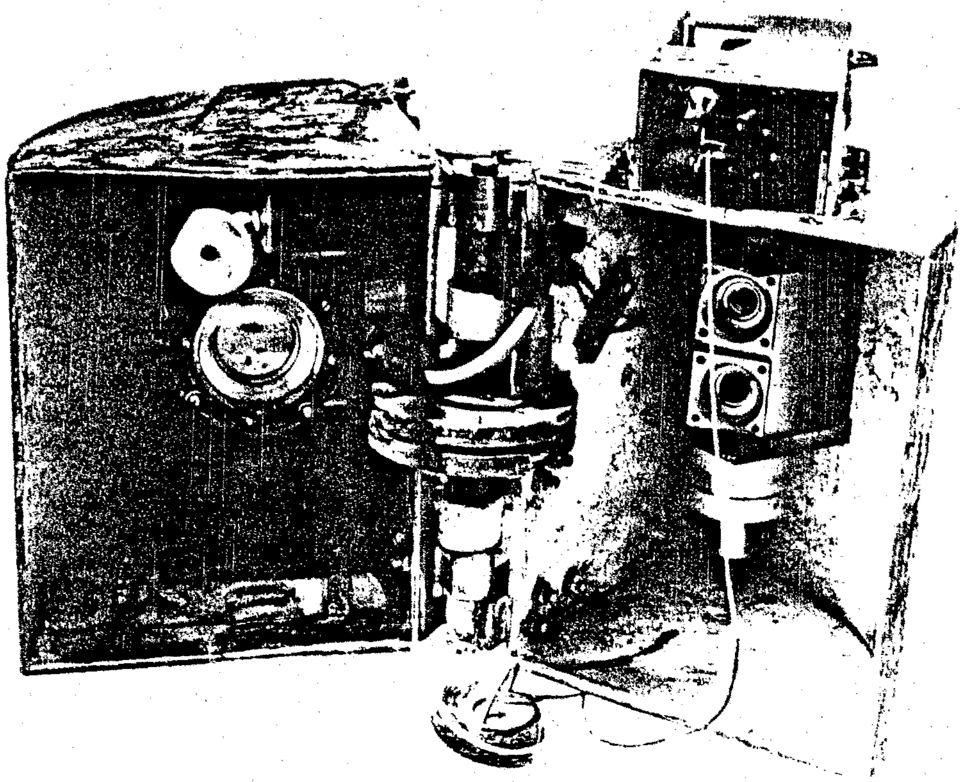

Figure 1. Combination camera-grab. Light source in left and stereo cameras in right bucket. Trip weight with compass and line are in foreground.

The grab is a heavy (250 kg (550 lb) empty air weight) clamshell type sampler whose large buckets enclose an area of 0.56 m^2 (6.03 ft^2) and are capable of containing as much as 0.2 m^3 (7.1 ft^3) of bottom material. The stainless steel housings containing the photographic system elements are mounted, one within each bucket, in such a way that when activated at a distance of 1 m from the bottom, an area of 0.48 m^2 (5.2 ft^2) is photographed, 72% of which is between the jaws of the grab (Emery and Merrill 1964; Emery *et al.* 1965).

The film load for these cameras is a standard 36-exposure magazine. One of the cameras was routinely loaded with black and white negative film (Plus X Pan rated at ASA 125) and the other with color transparency film (High Speed Ektachrome, Daylight Type, rated at ASA 160). The color photographs permitted the recognition of many organisms, especially smaller and encrusting types, whose color rendering in the black and white photos made them difficult, if not impossible, to perceive. The main advantage of black and white film was the relative ease with which it could be processed aboard ship to monitor focus, exposure, and other camera system functions.

This system provided many excellent photographs yielding valuable information on ecological and sedimentological relationships on the continental shelf and slope of the U.S. east coast. Several examples of representative photographs obtained with the camera-grab system are depicted in Figures 2, 3, 4, and 5. In addition to the works already cited, the interested reader may wish to consult the following for more information on results obtained with this system: Trumbull and Emery 1967; Wigley 1968; Wigley and Emery 1968.

TOWED SYSTEMS

Version I

The first version of a towed sled, used on the R/V *Albatross IV* in the summer of 1965, was 2.3 m (7.6 ft) long, 1.3 m (4.3 ft) high, 1.5 m (4.9 ft) wide, and weighed approximately 500 kg (1,100 lb) in air (Figure 6). The sled was of welded steel construction with flat plate steel runners 1.3 cm (0.5 in.) thick by 30.5 cm (12 in.) wide. The runners supported a framework consisting of upright triangles with reinforcing and connecting members constructed of 2.5-cm (1 in.) diameter solid bar stock steel. A 1-m diameter ring was welded between the uprights, perpendicular to the runners in the front third of the sled, and the photographic system was suspended within this ring. Two 1.9-cm (3/4 in.) thick plywood vanes fastened to the upright supports provided lateral stability during launch and retrieval, while four

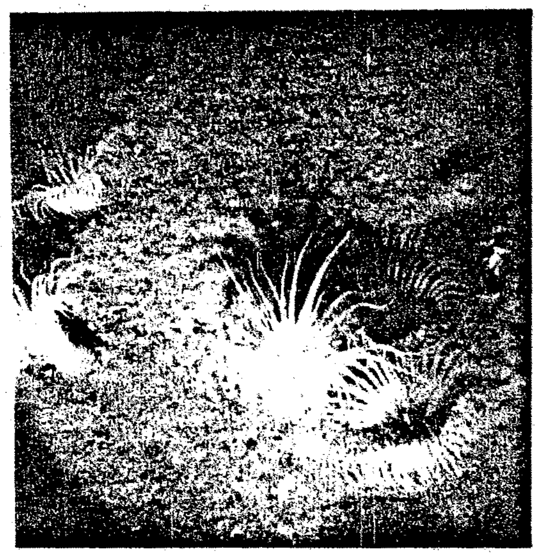

Figure 2. Seafloor at station 1052 in the southern Gulf of Maine. Cruise: *Gosnold* 12; location 42°09′ N, 69°14′ W; depth: 194 m; lithology: sand and gravel with some pebbles to 8 cm. Identifiable animals: five burrowing sea anemones, *Cerainthus borealis.* Trip weight is visible at right center.

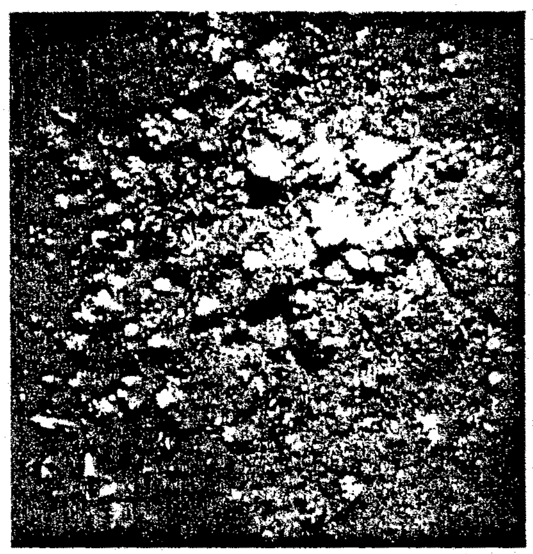

Figure 3. Seafloor at station 1158 southwest of Cape Sable. Cruise: *Gosnold* 22; location: 43°20′N, 66°13′W; depth: 61 m; lithology: mostly shell hash, with pebbles to 5 cm. Identifiable animals: northern coral, *Astrangia;* soft coral; bivalve shell remains; small starfish, and worm tubes.

hollow aluminum spheres, 16 cm (6 in.) in diameter, mounted at the top of the ring provided vertical lift and stability.

Photographic System. The photographic system consisted of a 35-mm Nikon F camera attached to a Nikon Electric Motor Drive, Model F 250. The lens was a 28-mm f/3.5 Auto Nikkor with a 74° angle of view. The camera was capable of 250 exposures from a 10-m (33 ft) film load (Kodak

Figure 4. Seafloor at station 1394 on the continental shelf south of Long Island, N.Y. Cruise: *Gosnold* 29; location: 40°44'N, 72°44'W; depth: 23 m; lithology: clean, quartzose sandy gravel, with some shell fragments. Identifiable animals: sand dollar, *Echinarachnius parma;* dead shells of northern cardita, *Cyclocardia borealis;* and surf clam, *Spisula solidissima.* Sand ripples, oriented NE-SW (note compass in trip weight) created by currents, reveal gravel fraction and shell in trough.

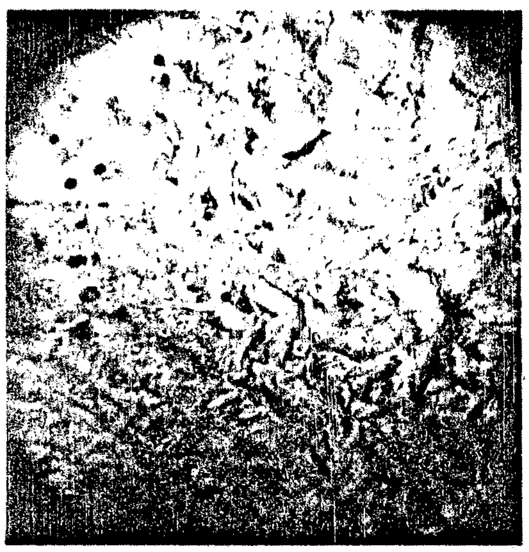

Figure 5. Sea bottom at station 1232 south of Cape Sable. Cruise: *Gosnold* 24; location: 43°10'N, 64°30'W; depth: 158 m; lithology: brown silty clay. Identifiable animals: worm tubes and holes. Sediment surface contains numerous tracks and other bioturbations.

Plus X Pan). Exposures were made at 15-second intervals once the sled reached the bottom.

The water-tight housing for the camera was a stainless steel cylinder with a viewing port of optical glass, mounted on a machined surface welded into the side of the cylinder. It was custom manufactured for us by Benthos, Inc. of North Falmouth, Massachusetts. In addition to the camera, the housing contained a 12-V power supply for the camera as well as a presetable

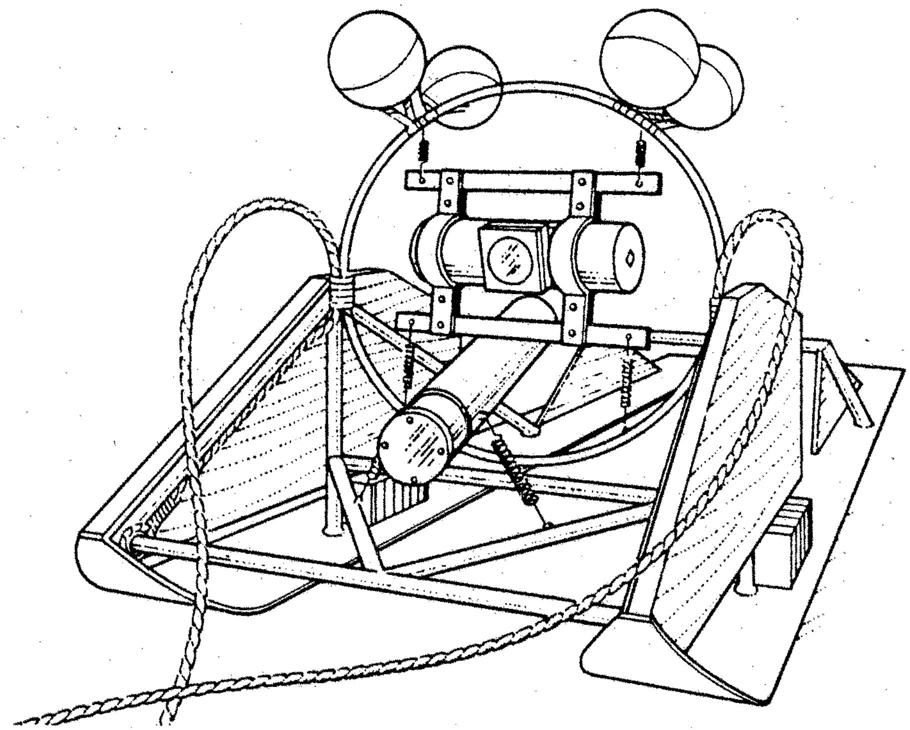

Figure 6. Towed bottom-contact camera sled, Version I.

delay timer switch designed to prevent unnecessary exposures during descent to the bottom.

The light source, also manufactured by Benthos, Inc. was a dry battery type, deep-sea electronic flash unit, of 100 watt-second output with a 12-second recycle rate. The flash tube was encased in a glass envelope to which a standard, 30.5-cm (12 in.) diameter, polished aluminum photo lamp reflector could be fastened with a worm gear type hose clamp. However, in order to reduce "hot spots" and increase light directionality, free-flooding snoots, constructed of PVC tubing, lined with reflecting aluminum foil and faced with graded neutral density filters sandwiched between clear acrylic plates were used instead of the standard reflector. The snoots were fastened to the housing over the flash tube envelope. The stainless steel cylindrical housing, with strategically placed pad eyes for ease of mounting, contained all of the strobe electronics and three 510-V batteries required to power the unit.

The camera and light source were electrically interconnected with Mecca M-16 series, #1726 female cable connectors on 18 AWG MCMB type neoprene jumper leads.

To aid in recovery, in case of loss during towing, a locating device consisting of a small, brightly colored buoy, tethered to the rear of the sled with a suitable length (2:1 scope for depth) of 0.9 cm (3/8 in) diameter polypropylene line was used.

System Configuration. The system configuration used on this sled placed the lens nodal point 1 meter above the bottom of the runners, along the central axis of the sled, facing forward at an angle of 45° from vertical. This placement resulted in a photograph covering 1.2 m^2 (13 ft^2) of bottom area. The nodal point of the light source was 30.5 cm (12 in.) from the bottom, below and slightly forward of the camera, at an angle of 60° from vertical. This placement resulted in fairly uniform and directional illumination with good modeling of the area to be photographed. Both elements of the system were shock mounted within the sled's ring by means of several heavy-duty expansion springs under moderate tension to reduce vibrations generated by the runners during towing. The shock mounting, coupled with the fast exposure time (about 1/1000 to 1/1200 sec) ensured sharp images.

Method of Operation. The sled was launched through a stern ramp on the vessel by means of a movable gantry, and was towed from a V bridle attached to a steel cable. The bridle, of 3.2-cm (1.25 in.) diameter nylon hawser 3.1 m (10 ft) long, acted as a mild shock absorber. Its ends were fastened to a horizontal cross member just behind the leading edge of each runner, then were led up and back and made captive at the midpoint of each side of the ring. This arrangement kept the bridle out of the picture area and did not affect towing stability. The bridle was fastened by a swivel shackle to a 1.3-cm (1/2 in.) diameter steel wire cable for actual towing.

Towing speed was 1.5 to 2 knots, measured by a calibrated digital speed log. Tow duration was 15 to 60 minutes at a wire vs. depth scope of 1.5:1.

This sled, used at four stations on Georges Bank at depths ranging from 48 to 329 m (157 to 1,079 ft), provided 414 usable photographs of the bottom and its associated fauna, examples of which appear in Figures 7, 8, 9, and 10. Results of studies using this photographic system were reported in Wigley and Theroux (1970 and 1971).

Version II

The second experimental towed camera system was tested in April 1967 during a short cruise by the R/V *Albatross IV* to Georges Bank. The purpose of the cruise was to test and evaluate a system for photographing

Figure 7. Mating northern starfish, *Asterias vulgaris*, at station 5 south of Martha's Vineyard. Cruise: *Albatross IV* 65-11; location: 40°71' N, 71°00'W; depth: 59 m; lithology: dark olive green sandy silt.

Figure 8. Asymmetric ripple pattern of the bottom at station 44 on southeastern Georges Bank. Cruise: *Albatross IV* 65-11; location: 41°14' N, 67°04'W; depth: 64 m; sediment: brown sand. View is facing northeast, current flow creating ripples was northwesterly unearthing small pebbles and shell fragments.

large invertebrates, and to establish the northernmost occurrence boundary of the seastar *Astropecten americanus*. The sled platform described above, with modifications to the camera mounting arrangement, was used for these trials (Figure 11). The new mounting consisted of a framework constructed of galvanized structural Flexangle that was fastened to the bars of the sled by means of U bolts. The use of this material resulted in a great deal of versatility and flexibility in camera and light placement and viewing angles.

Photographic System. The camera used in this system was an EG&G Model 200 Underwater Camera equipped with a fully corrected Hopkins 35-mm focal length, f/4.5 lens, providing a 51° horizontal and 38° vertical angle of view in water. The film load consisted of 30.48 m (100 ft) of film

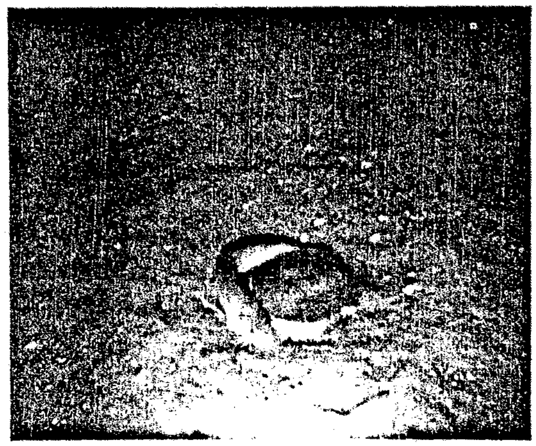

Figure 9. Red hake, *Urophycis chuss*, and sea scallop, *Placopecten magellanicus*, interrelationship. Cruise: *Albatross IV* 65-11; station 44 on southeastern Georges Bank. Environmental data same as for Figure 8.

Figure 10. Sea bottom at station 45 on southeastern Georges Bank. Cruise: *Albatross IV* 65-11; location: 41°14' N, 66°39'W; depth: 82 m; sediment: brown sand. Identifiable animals: green sea urchin, *Strongylocentrotus drohbachiensis;* Acadian hermit crab, *Pagurus acadianus;* Stimpson's distaff shell, *Colus stimpsoni;* sand dollar, *Echinarachnius parma;* ocean quahog shells, *Arctica islandica.*

capable of 500 exposures. The film used was Kodak Plus X Pan for black and white and High Speed Ektachrome for color. The camera was housed in a stainless steel tube with the lens oriented along the axis of the cylinder. Exposures on the bottom were made at 15-second intervals.

Light was provided by an EG&G Model 210 Underwater Light Source of 100 watt-second output with a 12-second recycle time. The stainless steel housing, similar to the one for the camera, contained, along with the strobe electronics, the 6-V power supply (a silver-zinc wet, four-cell, rechargeable battery) for the entire system (camera and light source), and a two-hour clock-driven mechanical time delay switch. The standard polished aluminum 30.5-cm (12 in.) diameter reflector provided with the unit was used.

A tethered buoy system, similar to that used on the first sled, served as a locating device in case of loss.

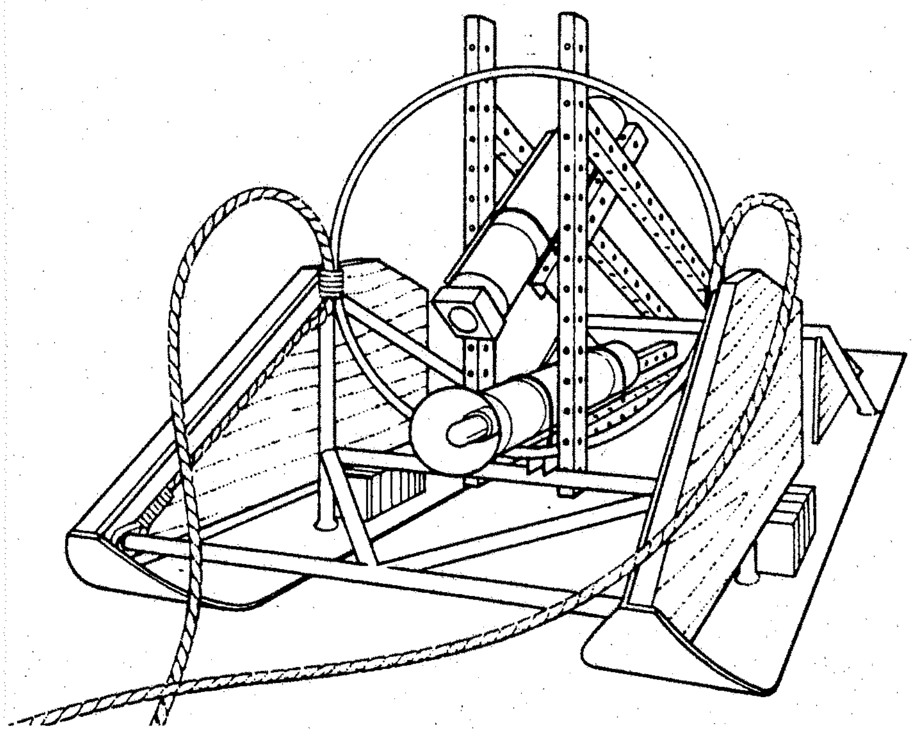

Figure 11. Towed bottom-contact camera sled, Version II.

System Configuration. Camera and light source housings were shock mounted to the Flexangle supports by means of automobile motor mounts and pipe hanger straps to prevent interference or damage caused by vibration. The nodal point of the camera lens was 1 m from the bottom, centrally located in the ring, facing forward at an angle of 60° from vertical. It photographed an area covering 8.06 m^2 (87 ft^2). The nodal point of the light was 30.5 cm (12 in.) from the bottom, directly below and slightly forward of the camera, facing forward horizontally. This placement yielded the amount of bottom modeling sought for heightened subject visibility and contrast.

Method of Operation. The same launching and towing methods described for the first sled were used with this version.

Eight tows were made with this system at four stations ranging from 51 to 101 m (167 to 331 ft) in depth on Georges Bank. Fifteen hundred usable photographs were obtained (900 in black and white, 600 in color) with this system. Examples are shown in Figures 12, 13, 14, and 15.

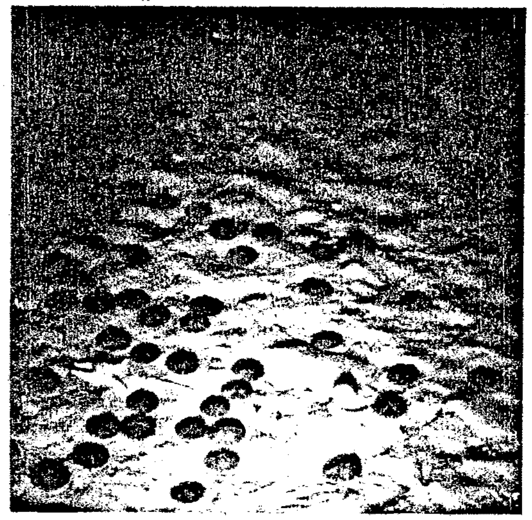

Figure 12. View of the bottom at station 1 on south-central Georges Bank. Cruise: *Albatross IV* 67-6; location: 41°07'N, 67°39'W; depth: 51 m; sediment: fine gray-white sand with shell. Identifiable animals: sand dollar, *Echinarachnius parma;* northern starfish, *Asterias vulgaris;* Acadian hermit crab, *Pagurus acadianus;* moon snail, *Lunatia heros;* New England nassa, *Nassarius trivittatus.* Bioturbations are clearly evident.

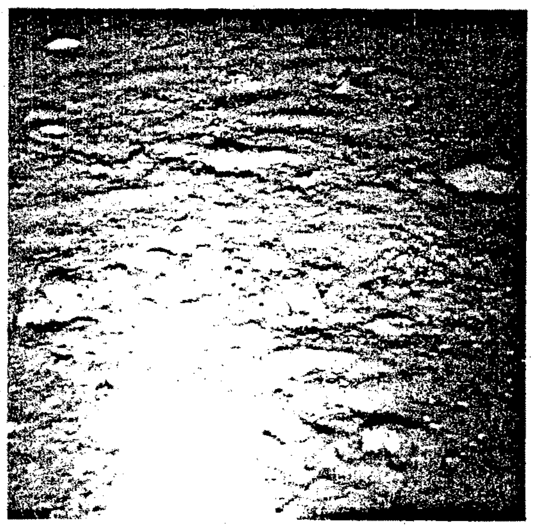

Figure 13. Sea bottom at station 4 on southeastern part of Georges Bank. Cruise: *Albatross IV* 67-6; location: 40° 41'N, 67°20'W; depth: 101 m; sediment: fine olive-green silty sand with shell. Identifiable animals: starfish, *Leptasterias;* ocean quahog, *Arctica islandica,* shells overlain with sediment; bramble shrimp, *Dichelopandalus leptocerus.* A cratered cone and animal tracks are also visible.

Version III

The third bottom-contact photographic system was used in June 1973 during a research cruise of the R/V *Delaware II.* The purpose of this Megabenthic Invertebrate Inventory cruise was to develop a methodology for a rapid, economical inventory of the offshore stocks of lobsters, crabs, and shrimps. In addition to the towed photographic system, three other methods were tested: (1) direct sampling with otter trawls; (2) direct

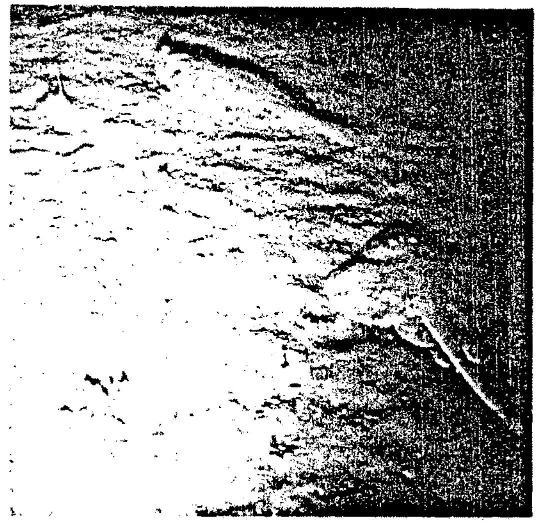

Figure 14. Bottom at station 4, southeastern part of Georges Bank. Cruise: *Albatross IV* 67-6; location: 40°41'N, 67°20'W; depth: 101 m; sediment: fine olive-green silty sand with shell. Identifiable animals: skate, *Raja* sp.; flounder; bramble shrimp, *Dichelopandalus leptocerus;* sabellid polychaete worm tubes.

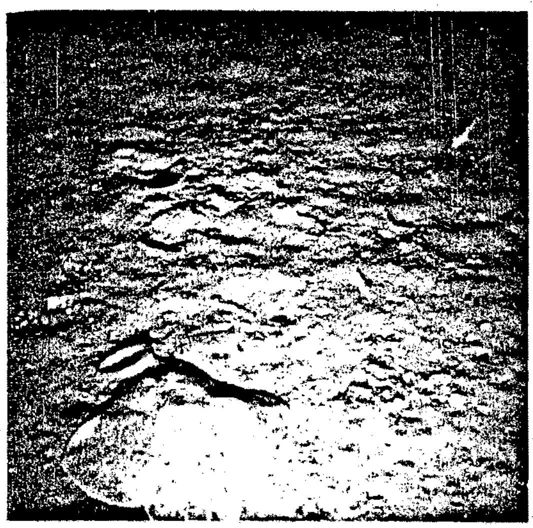

Figure 15. Another view of the sea bottom at station 4. Identifiable animals: skate, *Raja* sp.; shell of ocean quahog, *Arctica islandica;* bramble shrimp, *Dichelopandalus leptocerus.*

sampling with baited pots; and (3) visual observations from a submersible. The evaluation of the applicability of the different methods for megabenthos inventorying is reported in Uzmann *et al.* (1977).

Towed Underwater Benthic Sled (TUBS). The sled prototype, designed by the author and fisheries engineers at the NEFC, was 2.7 m (9 ft) long, 1.9 m (6 ft, 8 in.) high, 2.1 m (7 ft) wide, and weighed 1,225 kg (2,700 lb) in air (Figure 16). The superstructure was constructed of 6.4-cm (2.5 in.) diameter schedule 80 steel pipe welded to two 2.5-cm (1 in.) thick curved

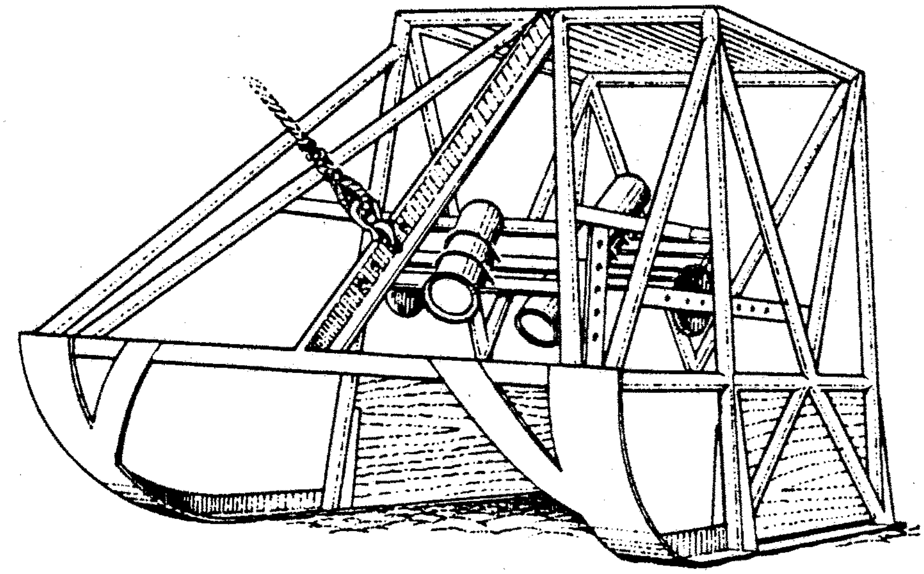

Figure 16. Towed Underwater Benthic Sled (TUBS). Bottom-contact camera sled, Version III.

steel plate runners 25.4 cm (10 in.) in width. A subframe assembly constructed of 7.6 x 7.6 cm (3 x 3 in.) by 0.95-cm (3/8 in.) thick angle iron was welded within the upper two thirds of the superstructure to provide support and variable points of attachment for rotatable camera and light mounts. The towing point, in the midline of the sled, was a reinforced flat steel bar 7.5 cm (3 in.) wide by 2.5 cm (1 in.) thick extending from the upper to the lower front support cross members. A series of 2.5-cm (1 in.) diameter holes bored into this member provided variable attachment points for fastening the towing hawser. Lateral stability, during launch and towing, was provided by two sheet steel plates, one on each side, welded to the inside lower third of the superstructure. Vertical stability, especially during launching, was provided by a perforated sheet of 1.9-cm (3/4 in.) marine plywood fastened horizontally within the uppermost structural members. Twelve (six on each side) 16-cm (6.3 in.) diameter, syntactic foam-filled, plastic, trawl headrope floats attached to the upper longitudinal structural members provided sufficient flotation to ensure an upright attitude during descent to the bottom. The center of gravity was kept low by the addition of 90.7 kg (200 lb) of lead ingots to each runner.

Photographic System. The camera of the photographic system used on TUBS was a Hydro Products deep-sea photographic camera Model PC-705 equipped with a fully-corrected Leitz water contact 43.7-mm f/2.8 lens with a viewing angle of 65° in water and a data chamber providing time of day, frame number, and station number for each exposure. Fully loaded with 30.48 m (100 ft) of 70-mm (2¼ in. square) film (Kodak Plus X Pan for black and white, or Ektachrome EF Type 5241 for color transparencies), the camera was capable of providing 400 exposures. The cylindrical housing is of hard-anodized, epoxy painted aluminum, with a certified depth rating of 9,144 m (30,000 ft), and an operating depth range to 6,096 m (20,000 ft). Exposures were made at 10-second intervals on the bottom.

Light was provided by a Hydro Products deep-sea strobe Model PF-730. The power output of the strobe was 200 watt-seconds with a recycle time of 6 seconds. The strobe had a built-in parabolic reflector providing a uniform light pattern. Housing material and configuration were the same as for the camera.

Power required by both the camera and strobe was provided by a Hydro Products Model BP-708 battery pack. This pack provides 24 V DC power from 7 ampere-hour rechargeable nickle-cadmium batteries, as well as system on-off control and a mechanical, clock-driven, timer delay switch. Batteries were recharged (approximately 14 hours) by a Model BC-605 charger. A fully charged battery pack allowed the exposure of two rolls of film, about 800 exposures. The cylindrical housing was of material similar to that for the camera and strobe.

A large, inflatable buoy fastened to the stern of the sled by means of a suitable length of 0.95-cm (⅜ in.) polypropylene line served as a locating device.

System Configuration. The housings of the camera and strobe were fastened to rotatable mounts by means of large, stainless steel U bolts affixed with vibration-proof lock nuts. The mounts were fastened to the internal mounting frame by means of 1.3-cm (½ in.) stainless steel bolts and lock nuts, in the desired location and orientation and locked into position.

The camera lens nodal point in this system was 1 m from the bottom facing forward in the central longitudinal axis of the sled, at an angle of 45° from vertical. This placement resulted in a view of 4.29 m^2 (46.2 ft^2) of bottom area between the runners from approximately the region of the forward upright support member to slightly forward of the leaning edge of the sled. The area covered was determined by mounting a frame containing a 10-cm grid equiplanar to the runners within the field of view and photographing it under water (Figure 17).

The strobe light, also along the midline, was positioned in front of the camera with its nodal point 1 m above the bottom and angled forward 60° from vertical, providing even illumination of the area viewed by the camera lens.

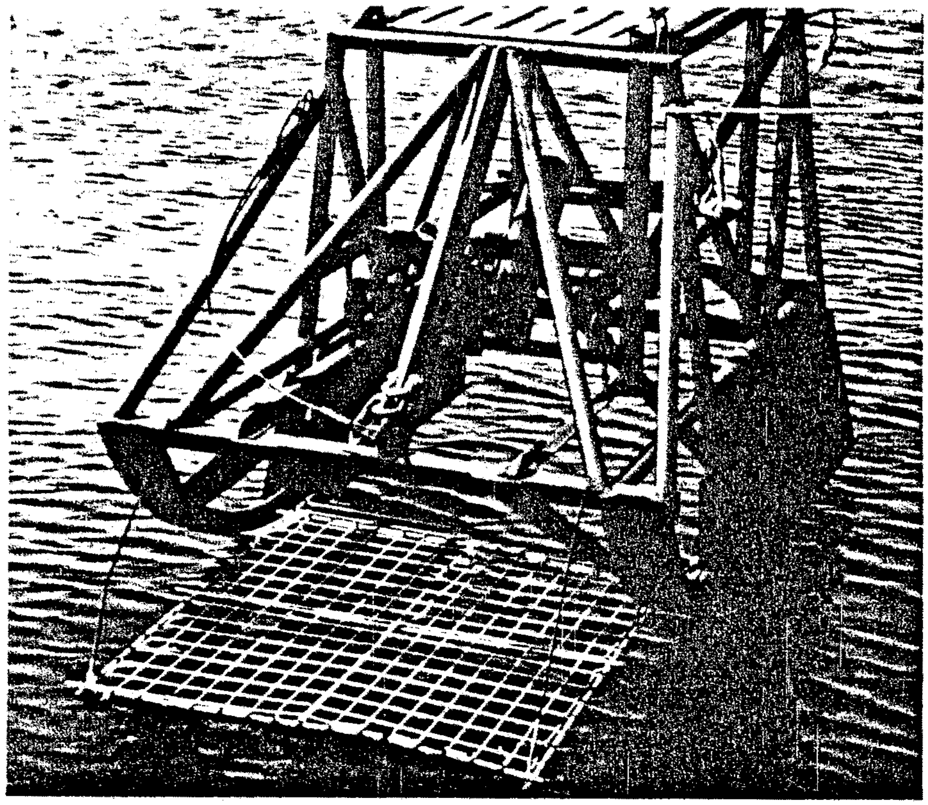

Figure 17. Preparation for calibration test of TUBS system. The calibration frame, at the focus plane, contains a 10 x 10 cm grid covering an area slightly larger than that viewed by the lens.

The battery pack was placed in the stern of the sled, for convenience in changing batteries, along the midline, on a support constructed of Flexangle.

Method of Operation. The stern of *Delaware II* is equipped with a ramp and a fixed towing gantry. The floor, or bed, of the ramp is movable, by means of hydraulic rams, from vertical (closing off the stern to the sea) to about 45° in the towing position. The gantry spans the ramp from the port to the starboard rails bisecting it at the midpoint. Variable attachment points along the gantry allow for optimum placement of towing blocks; the midline position was used for the sled. A heavy A-frame davit, fastened horizontally to the after surface of the gantry in the midline of the vessel, and extending beyond the fantail, was used in conjunction with a winch on the boat deck to position the sled in the chute prior to launch.

The sled was towed by the main winch trawl wire (2.5 cm diameter, 1 in.)

that was mated, by a swivel shackle, to 45.7 m (150 ft) of 6.4-cm (2.5 in.) diameter nylon hawser (acting as a shock absorber) that was, in turn, shackled to the towing bar of the sled. The hawser and wire passed through a large swivel block in the center of the gantry.

Launch preparations, with the vessel moving forward slowly, involved positioning the sled in the stern ramp with the rear of the runners awash (Figure 18), deploying the location buoy, and moving the vessel to the launch point. Upon arrival on station the ship's propellor was disengaged, and when it stopped, the winch brake was released launching the sled. The propeller was re-engaged after the hawser had passed through the towing block. Launching with the propeller turning often caused the sled to be overturned by turbulence striking the bottom of the runners; with the propeller stopped this problem never occurred. Tows were made at 1.5 to 2 knots, measured by a calibrated digital speed log, for from 30 to 75 minutes depending on local topography. Suitability of the bottom for

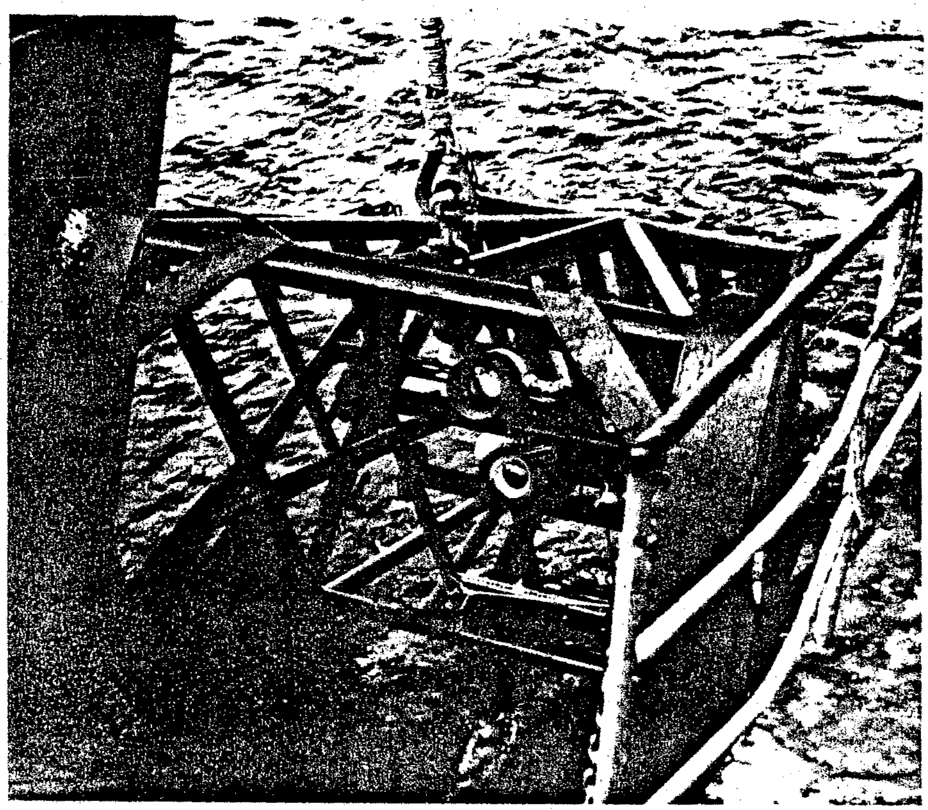

Figure 18. Position of TUBS in the stern ramp of *Delaware II* immediately prior to launch.

towing TUBS had been evaluated immediately prior to launch by means of fathometer tracings of the area. Wire scope was 1.5:1.

Retrieval of the sled was somewhat more complicated than launching since the position of the towing block on the gantry caused the sled to be suspended vertically within the ramp rather than resting on the floor of the ramp. Elevating the floor of the ramp to the vertical position allowed the sled to be stabilized on its runners within the chute. While in this position, a wire rope pennant permanently attached to the towing bar of the sled was passed over the top of the raised ramp and fastened, by means of a large jilson hook, to a hawser. The sled was dragged onto the deck by a windlass while simultaneously the ramp floor was lowered and the main wire was eased off.

The camera and battery pack were serviced on the main deck after each tow. The battery pack was replaced with a fully charged unit, the camera was reloaded with fresh film, and a short length (2 m) of exposed film was processed to monitor camera and light performance.

TUBS was towed a total of 51 times at depths ranging from 77 to 304 m (253 to 997 ft) in the Veatch Canyon area, yielding 14,000 analyzable photographs. These photographs permitted a detailed evaluation of the composition and distribution of the mega- and macrobenthos in the area as well as providing useful comparative data on the efficiency of this system versus the other survey methods used. Examples of photographs obtained are shown in Figures 19, 20, 21, and 22.

Version IV

Results obtained with TUBS in 1973 prompted us to use the sled again in 1974, this time on a cruise of R/V *Albatross IV* to survey the populations of the deep sea red crab, *Geryon quinquedens*, inhabiting the continental slope between Maryland and eastern Georges Bank. The primary purpose of this survey was to determine the distribution and abundance of the deep sea red crabs, with secondary objectives of determining the size composition of this crab stock and gathering additional biological information about the life history of this species. TUBS was used to obtain the distributional and abundance information, and a 16-foot semi-balloon otter trawl was used for direct measurements of a biological nature, such as size, weight, and sex. Results of this survey are reported in Wigley, Theroux, and Murray (1975).

Towed Underwater Benthic Sled (TUBS). The need to optimize the area viewed and covered for this survey necessitated some slight modifications

Figure 19. Bottom at station 23 in the Veatch Canyon area. Cruise: *Delaware II* 73-5; location: 39°55′ N, 69°41′ W; depth: 304 m; sediment: olive-green silty sand. Identifiable animals: burrowing sea anemone, *Cerianthus borealis;* jonah crab, *Cancer borealis;* porania starfish, *Porania insignis;* marlin-spike, *Nezumia bairdii;* sabellid polychaete worm tubes. Original in color.

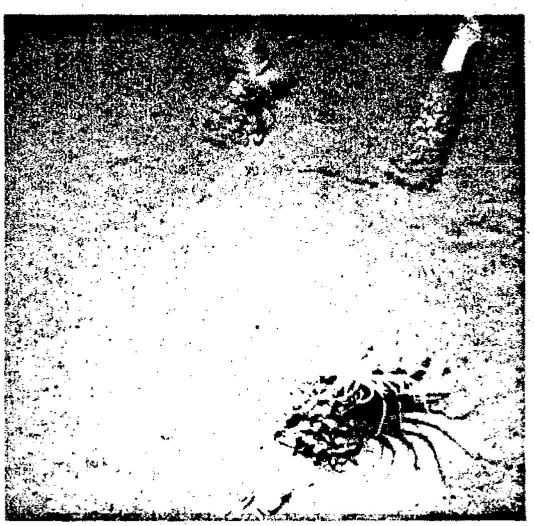

Figure 20. Another view of station 23. Identifiable animals: burrowing sea anemone, *Cerianthus borealis;* jonah crab, *Cancer borealis;* spider crab; marlin-spike, *Nezumia bairdii;* sabellid polychaete worm tubes. Original in color.

to the original sled design. The length of the towing bar and its uppermost attachment point were altered, the rotatable camera and light mounts were replaced by rigid Flexangle and steel mounts, and provisions for the inclusion of a pinger type attitude/locating device were added (Figure 23). Otherwise, the sled was unchanged from its 1973 design.

Photographic System. The photographic system was the same as the one used in 1973 with regard to the camera, light source, and battery pack

Figure 21. Bottom at station 21 in the Veatch Canyon area. Cruise: *Delaware II* 73-5; location: 39°56'N, 69°41'W; depth: 163 m; sediment: silty sand. Identifiable animals: mosaic worm, *Onuphis conchylega;* short-finned squid, *Illex illecebrosus.* Mosaic worms, which almost pave this area, are seen congregated around and preying on two dead short-finned squid.

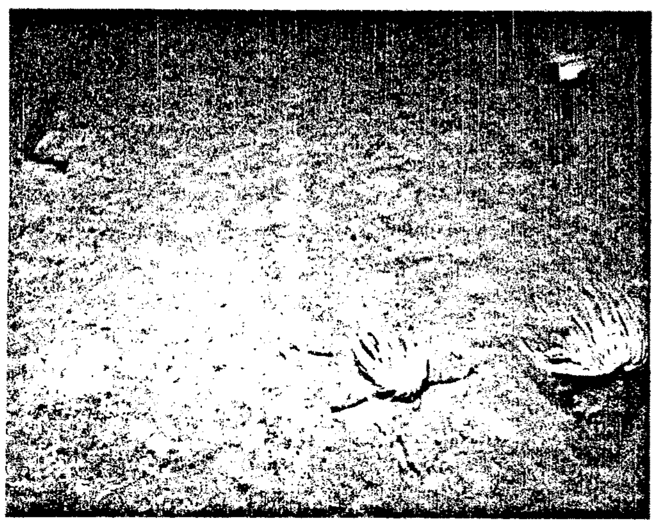

Figure 22. Bottom at station 22 in the Veatch Canyon area. Cruise: *Delaware II* 73-5; location: 39°55'N, 69°41'W; depth: 229 m; sediment: silty sand. Identifiable animals: burrowing sea anemone, *Cerianthus borealis;* bramble shrimp, *Dichelopandalus leptocerus;* munid crab, *Munida,* sp.; red hake, *Urophycis chuss.* The association of bramble shrimp and burrowing sea anemones depicted in this photograph was commonly seen in this area. Also involved in this behavior pattern were jonah crabs, munid crabs, lobsters, and fishes.

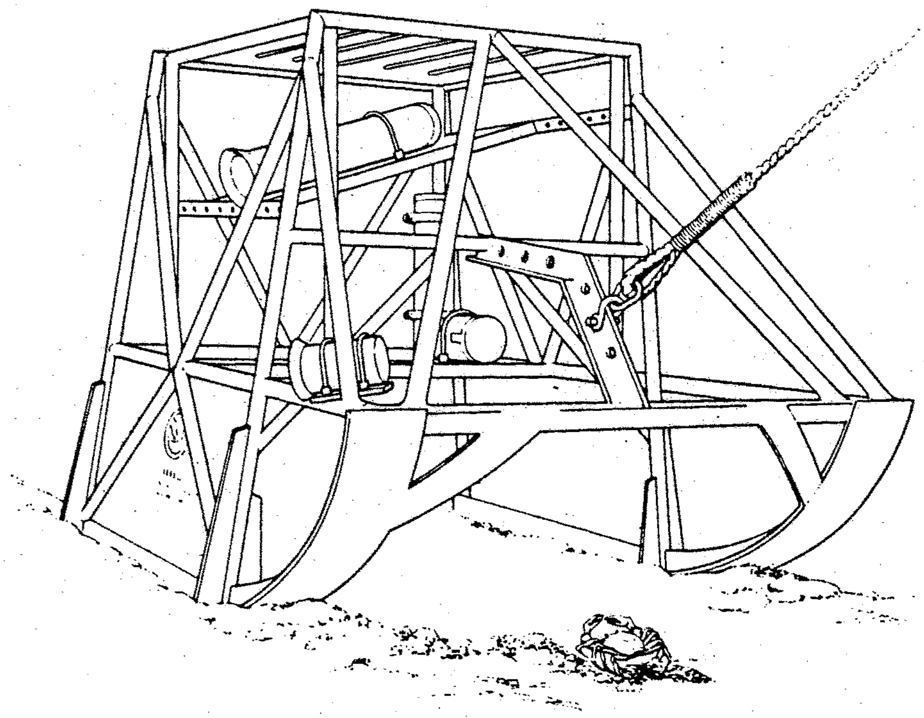

Figure 23. Towed Underwater Benthic Sled (TUBS). Bottom-contact camera sled, Version IV.

(see Version III); however, for this survey only Kodak Ektachrome EF Type 5241 color transparency film was used. The 1973 study showed that color photographs resulted in greater accuracy of identification and heightened visibility of the target organisms. Also, due to the greater depths to be sampled on this survey, the tethered buoy locating device became impractical and was replaced by a Hydro Products Model B-1055C chronometric abyssal pinger. This acoustic battery-operated pinger housed in a cylinder of hard anodized aluminum provides 12-kHz pulses with pulse lengths of 2 to 3 milliseconds at a precise pulse repetition rate of 1 per second in the vertical position and 2 pulses per second at tilts of 45° or more off axis. It is capable of operating to depths of 7,620 m (25,000 ft) for 10 days. The varying pulse rates of the pinger were useful in ascertaining the position of TUBS on the bottom after launching. Pinging rate was monitored on an EDO fathometer aboard the vessel during descent and towing. If a two-per-second pulse rate was heard, either at touchdown or during the tow, the towing wire was hauled in until the sled was righted (one-second pulse rate), then payed out again to its normal depth.

System Configuration. Camera and light placement on this version of TUBS differed significantly from the original configuration. One of the prime requirements for this survey was to survey as much area as possible within the alloted ship's time. To accomplish this, the camera was placed as high as possible on the mounting frame. A forward looking viewpoint was not possible because of the presence of the towing hawser, so a viewpoint perpendicular to the sled axis was used. The lens nodal point in this configuration was 1.75 m (69 in.) from the bottom, angled down 16° from horizontal on the right side of the sled. Thus, the area viewed by the lens was 147.3 m² (1,586 ft²) as determined by mock-up tests photographing grid patterns in the Benthos, Inc. testing pool, and by tests in Vineyard Sound.

The light source and its cradle were fastened by U bolts to the main horizontal structural member just behind its juncture with the top of the runner. The nodal point of the strobe reflector was 1 m off the bottom, angled down 10° from horizontal and about 30° aft of perpendicular.

The battery pack and its cradle were bolted to the central cross member on the right side of the sled, and the pinger was fastened vertically, by means of pipe hanger straps, to the after, left vertical support member. Placement of these elements counterbalanced the weight of the camera and light source on the opposite side.

Method of Operation. The length of TUBS and the position and size of the movable gantry at the stern of *Albatross IV* initially posed some handling problems. The gantry, although able to handle TUBS in the stern ramp, was not capable of depositing the sled completely on the main deck, which is approximately 0.75 m (30-32 in.) below the inboard portion of the stern ramp. With the gantry in the inboard, horizontal position, the rear third of the runners remained on a large steel roller at the top of the stern ramp, where it was a safety hazard and was difficult to service. The remedy was the construction of a curved steel plate (to protect the roller) conforming to the curvature of the roller, affixed to a platform constructed of heavy-gauge channel and angle iron, reminiscent of an automobile servicing ramp, parallel to the deck at the height of the stern ramp and inboard of it to house the sled. The forward portion of the platform was provided with two removable channel iron ramps for dragging the sled from the platform to the deck when necessary.

Towing was effected from the port drum of the main trawl winch with 1,190 m (650 fms) of 1.6-cm (⅝ in.) and 3.111 m (1,700 fms) of 2.2-cm (⅞ in.) diameter steel wire cable. The smaller cable mated to the larger permitted attaining the desired sampling depths and reducing the weight of the entire array; at the deepest depths sampled, 30,118 kg (13,690 lb) of sled and wire were in the water; the main trawl winch clutch has a 33,000 kg (1,000 lb) capacity. The nylon hawser shock absorber was used as before.

Launching involved positioning the sled on the stern ramp by means of the gantry, steaming slowly ahead to the launch point, then stopping the propeller and launching the sled. The propeller was re-engaged after the hawser had passed through the towing block. Towing speed, duration, and wire scope (1.5-2 knots, 75 min, and 1.5:1, respectively) were the same as for previous uses. Also, prior evaluation of topography with fathometers was routinely carried out at each sampling site.

Reversing the launch procedure was all that was required for retrieval after the tow. The entire launch/retrieve operation involved only two persons, the winch operator and the gantry operator.

Camera and battery pack were serviced after each tow, each receiving fresh film and batteries, respectively, in preparation for the next tow. As was the custom on all of our photographic missions, a short length (about 2 m) of film was processed to monitor camera and light performance. The exclusive use of color film on this cruise did not present any special problems. Although processing time was somewhat longer for color film than for black and white (Ektachrome process E-4 time is 56 minutes versus about 26 minutes for black and white), a trawl tow followed the camera tow so ample time remained, while on station, to process and examine the previously exposed film and make whatever adjustments may have been required.

During this survey TUBS was deployed 58 times at 50 sampling stations at depths ranging from 252 to 1,463 m (827 to 4,800 ft) along the east coast continental slope from Baltimore to Corsair Canyons. A total of 18,175 photographs were taken, examples of which appear in Figures 24, 25, 26, and 27.

CONCLUSIONS

The use of underwater photographic systems in the study and assessment of sea-bottom populations has finally been accepted by biologists as a sampling tool although, in some cases, somewhat reluctantly (Fell 1967; Owen, Sanders, and Hessler 1967).

Photographs supplementing samples, as is the case with the camera-grab system, yield a great deal more information about the local distribution, ecological relationships, life habits, locomotory mechanisms, and body positions of the epifauna as well as information on bioturbations and sediment topography than would be available by inference from grab samples

Figure 24. A large American lobster, *Homarus americanus*, in excavating its crater habitat unearthed what appears to be a transmission cable or large pipe. A hake, *Urophycis* sp., and blackbelly rosefish, *Helicolenus dactylopterus*, are also visible, Station 13 on the continental slope south of Hudson Canyon, Cruise: *Albatross IV* 74-7; location: 39°14′ N, 72°23′ W; depth 326 m.

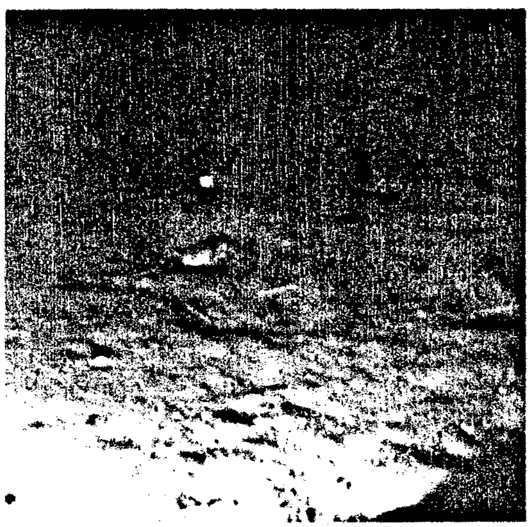

Figure 25. Sea bottom at station 14 on the continental slope south of Hudson Canyon. Cruise: *Albatross IV* 74-7; location: 39°14′N, 72°21′W; depth: 384 m. Two deep-sea red crabs, *Geryon quinquedens*, and a burrowing sea anemone, *Cerianthus*, are visible. This cratered bottom is typical of red crab habitats.

alone. Conversely, photographs alone do not allow accurate taxonomic determinations and other biological measurements (size, weight, length, sex, and maturity). In addition, photographs do not yield any information at all about buried organisms (the infauna). Ideally, then, quantitative biological samples should be supplemented by photographs of the actual site sampled, and photographs of the sea bottom should be supplemented by samples.

Underwater photography from towed systems that provide ground truth (bottom-contact devices) offers a distinct advantage, especially with regard

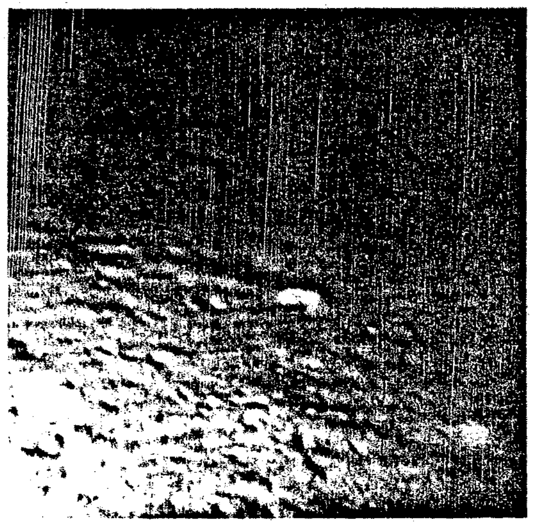

Figure 26. Example of parallel traces often seen in areas intensively fished by lobster and crab fishermen. Photo is from the area shown in Figure 24.

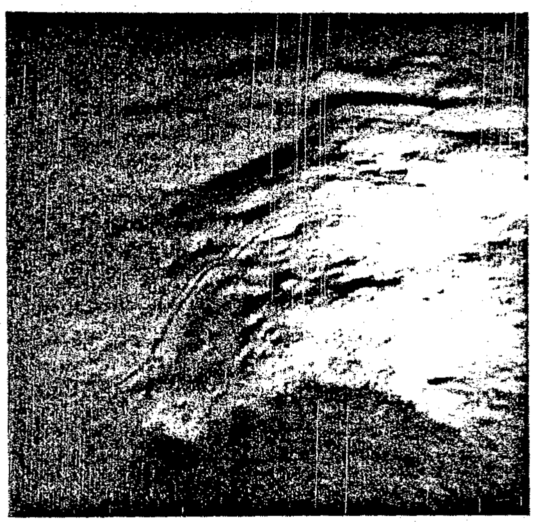

Figure 27. Evidence of bioturbations on the continental slope south of Martha's Vineyard at station 5. Cruise: *Albatross IV* 74-7; location: 39° 52' N, 70°56' W, depth: 841 M.

to areal scope, rapidity, and economy of sampling, over traditional methods for the conduct of reconnaissance surveys relating to the quantitative distribution and abundance of epibenthic mega- and macrofaunal populations.

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