Synoptic Comparison of Three Sampling Techniques for Estimating Abundance and Distribution of Selected Megafauna: Submersible VS Camera Sled VS Otter Trawl

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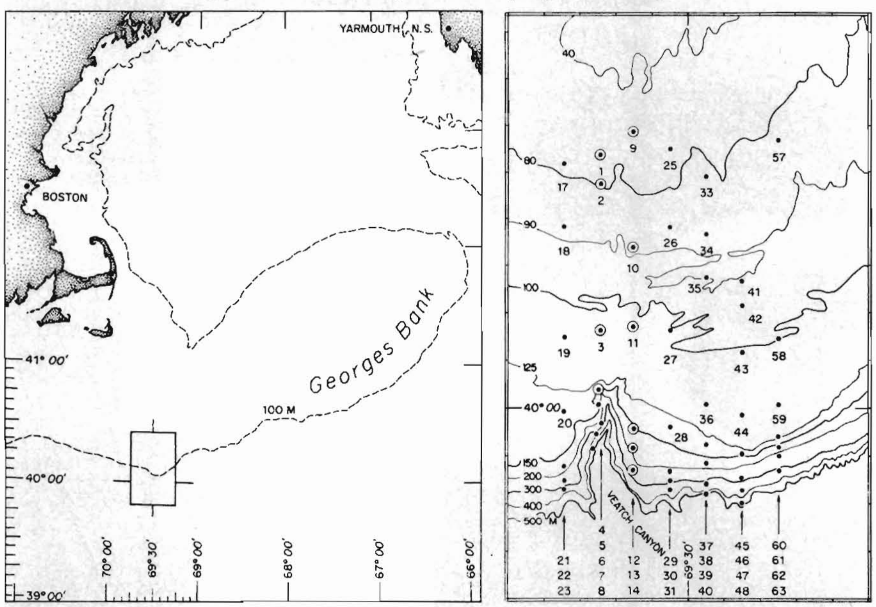
INTRODUCTION

A multiship survey of the megafauna in the Veatch Canyon region (Fig. 1) was undertaken in June 1973. The survey was designed to obtain detailed information on the distribution, abundance, and ecology of selected megafauna, particularly lobsters, *Homarus americanus;* red crabs, *Geryon quinquedens;* and jonah crabs, *Cancer borealis;* and to compare simultaneously the relative efficiency of three bottom oriented quantitative survey techniques, namely, manned submersible, towed camera sled, and a standardized otter trawl. These primary techniques were reinforced by follow-up sampling with multiple pot trawls of standard baited lobster pots. The trapping studies were conducted in collaboration with the Prelude Lobster Co. of Westport, Mass.[1], from company vessels FV *Crystal S.* and FV *Mars;* these efforts provided valuable information on distribution and apparent relative abundance of lobsters and crabs, but quantitative comparison with the primary census methods is not possible because the seabed area from which the entrapped lobsters and crabs originated cannot be estimated. The trapping results will be treated in a separate report.

[1]Reference to trade names or commercial firms does not imply endorsement by the National Marine Fisheries Service, NOAA.

Figure 1.—Veatch Canyon and sampling station array.



The Veatch Canyon area was chosen because of its background as the historical center of a commercially productive offshore lobster fishery (Schroeder, 1955, 1959; McRae, 1960; Hughes, 1963; Saila and Flowers, 1968; Skud and Perkins, 1969; Cooper and Uzmann, 1971; Uzmann et al., 1977). This fishery developed rapidly in the mid-1950's as a directed otter trawl fishery, gave way gradually to trap fishing methodology in the late 1960's, and began to decline in the early 1970's. Probable causes of declining production include overexploitation, inflationary overhead costs, and compounding of the latter by weather related gear losses, overruns, and loss of trap gear by otter trawl gear directed at lobsters and other target fish species.

In the face of this complex background, we hoped to obtain direct measures of lobster abundance from submersible and camera sled transects to compare with indirect assessments by otter trawl and trapping; within this framework we would thus compare availability and catchability while effecting intercalibration of the camera sled and trawl gear against assumed "ground truth" of submersible observations.

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Each of the primary survey techniques has readily evident advantages and disadvantages over the others in such terms as support vessel requirements, cost effectiveness, weather limitations, specialized manpower requirements, operational reliability, systems redundancy, and quantitative reliability of samples; this last characteristic was of primary interest to us because traditional assessments of benthic fishery resources, including megabenthic crustacea, are based largely on trawl net surveys of one kind or another. Despite the proven effectiveness of trawl gear for commercial harvesting of demersal fishes, lobsters, crabs, and shrimps, the absolute efficiency, hence sampling efficiency, of this gear is poorly understood with respect to any given target species, especially the lobsters and crabs of immediate interest. The operations reported here provided for the first time synoptic comparison of the three survey methods and produced a useful data base from which biological and operational inferences may be drawn.

METHODS AND MATERIALS

Sampling Design

Sampling stations were chosen according to a stratified random sampling design used at this laboratory for otter trawl assessment of demersal fish stocks (Grosslein, 1969). This scheme recognizes four ecological zones (southern New England, Georges Bank, Gulf of Maine, western Nova Scotia) within which four depth zones bounded by 30, 60, 100, and 200 fathoms are sampled randomly. Our specific study area (Fig. 1) was laid out as seven north-south transects ranging from 73 to 366 m (40-200 fathoms); the specific sampling sites chosen were selected randomly along these transects with the condition that adjacent stations be at least 1′ of latitude apart and that each of the three depth zones covered receive approximately equal attention. Of 63 stations originally designated for sampling efforts, only 51 were sampled in one way or another because of preoccupation of the remainder by commercial fishing activity.

Submersible operations were limited by time constraints to stations 1 to 6 and 9 to 14. Among these, stations 5 and 6 on the western slope of the head of Veatch Canyon were topographically unsuitable for camera sled and trawl operations. Thus the 10 stations 1 to 4 and 9 to 14 were used for quantitative comparisons. The sequence of station occupancy was: 1) submersible, 2) camera sled, 3) otter trawl, and 4) traps; at certain stations samples of the substrate and associated infauna were taken with a Dietz-Lafond grab and a Naturalist dredge; in these cases, the samples were taken after otter trawl sampling. Mean time between deployment of the submersible and otter trawl at given stations was 2.1 days (range 1-3 days). Specific strategies employed with each of the primary sampling techniques are given below with respective gear specifications.

Submersible System and Operations

The two-man submersible *Nekton Gamma* (Fig. 2) and support vessel *G. W. Pierce* were leased from General Oceanographics, Inc., Newport Beach, Calif. This submersible has the following published specifications (Shenton, 1972; General Oceanographics, Inc.[2]):

General

Crew (pilot and observer)	2
Pressure listed depth	1,500′
Certified operating depth	1,000′
Collapse depth	2,500′
Weight (pounds)	4,700
Payload (pounds)	450
Viewports	17
Length overall	15′6″
Height overall	6′0″
Pressure hull diam.	42″
Pressure hull length	96″

Systems

Propulsion —One 3.5 hp D.C. motor.

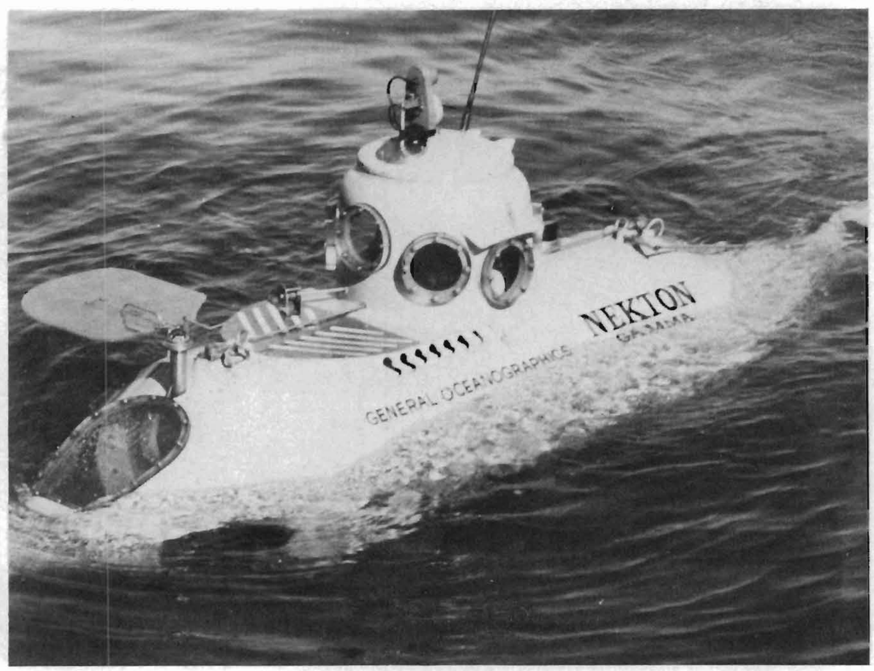
Power source—Lead acid batteries, 4.5 kwh.

Depth control—Bow plane, water ballast, drop weights.

Navigation—Magnetic compass, directional gyro, depth gauge; pinger, retractable marker buoy.

[2]General Oceanographics, Inc. Undated. Nekton submersibles. General Oceanographics, Inc., 2172 Dupont Drive, Newport Beach, CA 92664. 4 p.

Figure 2.—Research submersible *Nekton Gamma* maneuvering on surface.



- Communication—Underwater telephone, CB radio.
- Buoyancy—2 main ballast tanks, one auxiliary trim tank.
- Life support—48 man hours.
- Sampling—Mechanical arm (38″ reach), sample container.
- Photographic—exterior strobe and tungsten lamps to support interior hand held cameras and video equipment.

Cruise speed and duration of *Nekton Gamma* is reportedly 1.5 knots for 3.5 hours or 2.5 knots for 1 hour. In our operations, we limited our transect runs over the bottom to 0.3-0.5 knots; at greater speeds, apparent relative motion precludes careful assessment of details and sufficient lead time for effective photographic or video pass shots of key subject material. Within a dive time budget of 3 hours, all transects were completed with adequate time for stopping, bottom sitting, or close maneuvering about a site for such tasks as substrate sampling, bottom current measurement, temperature recording, and carefully composed photographic or video documentation of faunal behavior and species interactions.

The preselected dive sites were located by Loran A navigation and marked with an anchored buoy having an 8.8-m (20-foot) above-water mast topped with a radar reflector screen. The submersible was launched from the mothership by a deck-mounted articulating crane and lowered into the water close to the marker buoy. Just prior to launch, a so-called tether ball or tracking float was secured to the submersible's conning tower by a 50-thread braided nylon line of sufficient length and scope to trail behind on the surface as the submersible cruised just off bottom; this line was payed out as the submersible gradually descended. The transect was begun when all line was payed out, the tether ball deployed and well clear of the support vessel, and the submersible reported itself ready on bottom. The support vessel maintained a position close behind the tether ball and monitored the submersible's course by taking periodic radar ranges and bearings on the anchored marker buoy. Course corrections and distance traversed were communicated to the submersible by acoustic telephone at appropriate intervals to effect two consecutive 0.5 nautical mile transects on headings which provided the most uniform depth at a given station. All dives were made during daylight hours between 0730 and 1750.

The dive plane of the submersible was rigged with a detachable wooden yardarm to which a 3-m (9.8-foot) length of 1-inch (25.4-mm) chain was secured 2.4 m (5.5 feet) from the longitudinal axis of the craft; when cruising just off bottom, the free end of the chain tended bottom and defined a sampling path width of 2.4 m from the keel centerline within which all fish and invertebrates could be readily seen, identified, and enumerated. All observations within this sampling path were recorded on audio tape for later collation and analysis. Faunal densities (number/acre) were estimated from the number of given organisms counted within the transect path divided by the calculated acreage; the averages of replicate values were used in subsequent analyses.

Two 150-watt tungsten filament lamps were directed forward and downward on both port and starboard sides of the vehicle; these lamps provided sufficient illumination on either side for direct viewing and for monochrome video documentation up to 6 m (19.6 feet) forward and laterally. Hand held 35 mm still camera photography was fully effective through the viewing ports to maximum operating depths with an externally mounted (starboard side only) and synchronized 150-watt-second stroboscopic flash unit. Selected examples of still photographs obtained on various dives are shown in Figures 3-6.

Camera Sled System and Operations

The second survey technique permitting direct visual assessment of the megabenthos was the Towed Underwater Benthic Sled (TUBS) which is depicted in operation in Figure 7 and with calibration screen in Figure 8. This sled-mounted photographic system is a prototype designed and constructed at this laboratory specifically for assessment of megabenthic invertebrates. To date, it has been used successfully on two major expeditions—the study reported here, and an extensive red crab survey in June-July 1974 (Wigley et al., 1975).

The system consists of a 70-mm (2.75-inches) camera and stroboscopic light source mounted on a large steel sled. Dimensions of the sled are: 2.7 m (9 feet) long, 2.1 m (7 feet) wide, and 1.9 m (6 feet, 8 inches) high. It is constructed of heavy gauge 6.4-cm (2.5-inch) diameter steel pipe with runners 25.4 cm (10 inches) broad and 2.5 cm (1 inch) thick. The sled weighs 1,225 kg (2,700 pounds) in air. The camera is a Hydro-Products Deep Sea Photographic Camera, Model PC-705; the strobe unit is a Hydro-Products Deep Sea Strobe, Model PF-730. The camera unit is mounted with the lens nodal point 1 m above the bottom and centrally located between the sled runners with a 45° forward angle of view. The camera utilizes a water contact 43.7 mm, *f*/2.8 Leitz fully corrected lens with a viewing angle of 65° in water. Camera and strobe were operated in a fully automatic mode taking pictures at 10-second intervals while underway. Kodak Tri-X Pan (black and white) film and Kodak Ektachrome EF daylight (color) film were used with comparably good results. Bottom area covered in photographs was 4.29 m² as determined from underwater test photographs of a 10-cm steel grid mounted equiplanar with the upper surface of the sled runners (Fig. 8).

The camera was towed slowly, 1.5 to 2.0 knots, by the NOAA research vessel RV *Delaware II*. Transects were made only at those stations where the topography of the sea floor was suitable; high relief areas and high angle slopes were avoided; suitability of the bottom was evaluated immediately prior to launch by means of fathometer tracings. Duration of the sled tows at each station ranged from 30 to 75 minutes depending on local conditions. Upon completion of the tow, the film was removed from the camera and a

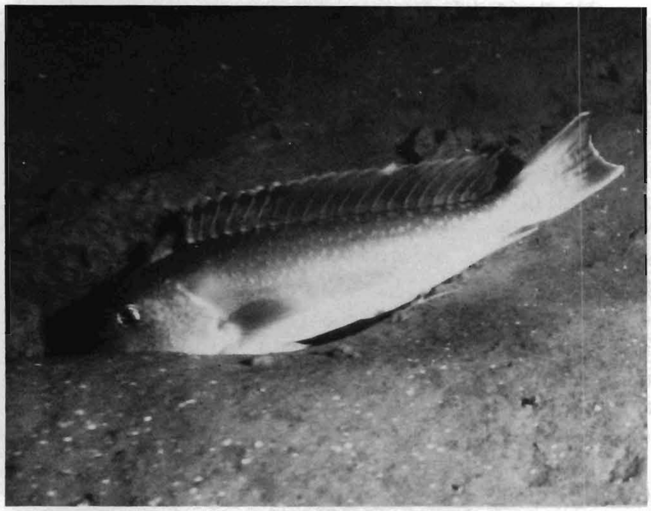


Figure 3.—Tilefish, *Lopholatilus chamaleonticeps,* about to enter burrow at base of low terrace on west flank of Veatch Canyon, depth 183 m (600′). From Ektachrome X 35 mm color transparency.

Figure 4.—Lobster, *Homarus americanus,* and black-bellied rosefish, *Helicolenus dactylopterus,* association in extensively burrowed clay outcrop on west flank of Veatch Canyon, depth 183 m (600′). From Ektachrome X 35 mm color transparency.

Figure 5.—Cusk, *Brosme brosme,* and lysmatid shrimp association in deep burrow on west wall of Veatch Canyon, depth 146 m (480′). From Ektachrome X 35 mm color transparency.

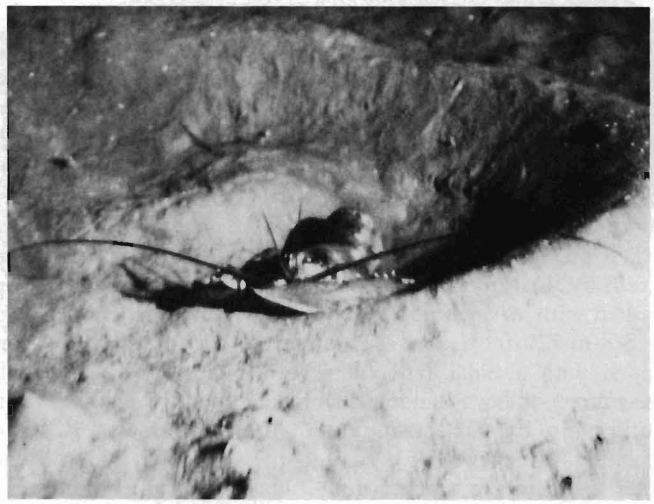


Figure 6.—Lobster, *Homarus americanus,* in characteristic excavation of level sandy silt substrates; west flank Veatch Canyon, 137 m (450′). From Ektachrome X 35 mm color transparency.

short strip developed to monitor focus, strobe light position, exposure, etc. The remainder of the film was subsequently shipped to commercial film processors for developing and printing. Selected examples of photographic results are shown in Figures 9-12.

For identification and enumeration of the megafauna recorded in the photographs, the transparencies (black and white negatives or color positives) were projected onto a large viewing screen on which was superimposed a proportionally calibrated metric grid of the seafloor area encompassed in the photographs. Faunal densities were estimated by summing the area covered by the series of transect photographs, dividing the total into the total count of each target species in the photographs, and adjusting the respective quotients to numbers per acre; density calculations from replicate tows were averaged for use in subsequent analyses.

Otter Trawl Configuration and Operations

Otter trawl operations were conducted from the RV *Delaware II* at 45 stations including 11 of the primary stations 1-14. The sampling gear was a roller rigged #41 shrimp trawl with a 36- to 38-foot spread (Fig. 13). Replicated half-hour tows at 3.5 knots were made at all stations occupied in common with submersible, camera sled,

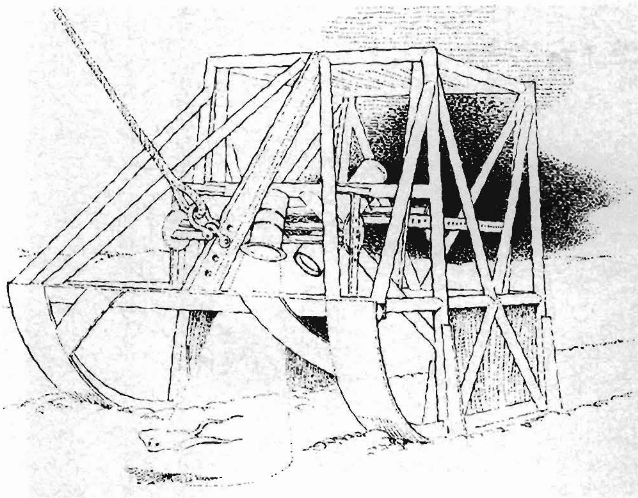


Figure 7.—Artist's rendition of Towed Underwater Benthic Sled (TUBS) photographic system in operation.

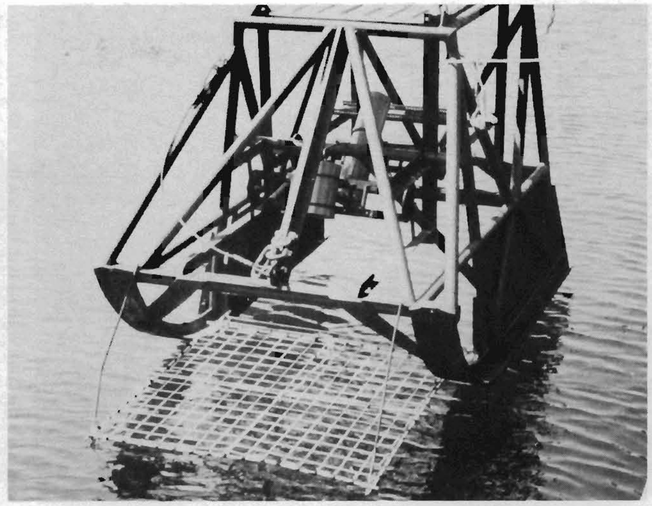


Figure 8.—TUBS being lowered into water for calibration test. Each square of calibration grid is 10 cm on a side; the grid is positioned in the plane of focus and covers slightly more than the area viewed by the lens.

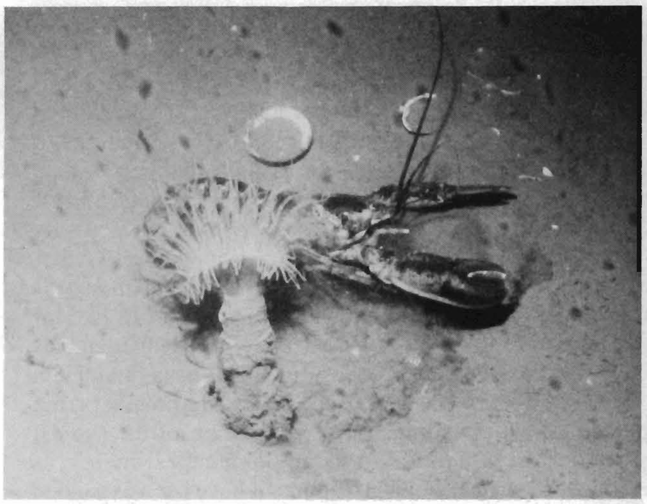


Figure 9.—American lobster, *Homarus americanus*, utilizing the ubiquitous burrowing anemone (*Cerianthus borealis*) as a haven. Also identifiable are two sand-filled valves of the ocean quahog, *Arctica islandica*, and above and to the right a partly buried starfish; at the base and to the left of the anemone are two shrimp. From Tri-X Pan 70 mm monochrome.

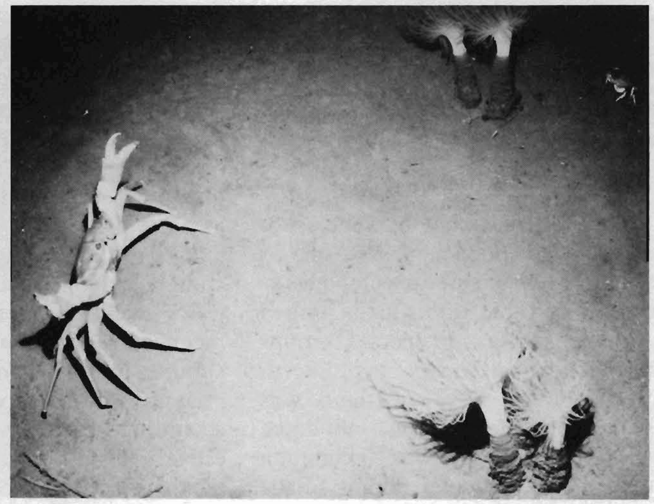


Figure 10.—Two of the target organisms; the deep sea red crab, *Geryon quinquedens*, and jonah crab, *Cancer borealis*, upper right, associated with four burrowing anemones (*Cerianthus borealis*). From 70 mm Ektachrome EF color transparency.

and trap trawls. Suitability of the bottom for trawling was determined, as with camera sled tows, from fathometer tracings of the prospective transect area. Depth and bottom temperature at the start of each tow were determined from an expendable bathythermograph cast prior to setting out the trawl.

Trawl catches were sorted and processed (identified, counted, and weighed) aboard ship; selected components of the catch were preserved and returned to the laboratory ashore for additional study. Size, weight, sex, and other biological information was recorded for individual lobsters, red crabs, and jonah crabs in each haul. Fish species taken in large numbers were weighed collectively to determine mean weight and sampled randomly to obtain mean length. Mean weights of various species obtained in trawl samples were used in calculations of biomass estimates from submersible and camera sled transects. Faunal densities were estimated from calculated acreage of trawl path divided into numbers of target organisms captured. Density calculations from replicate tows were averaged for use in tabular

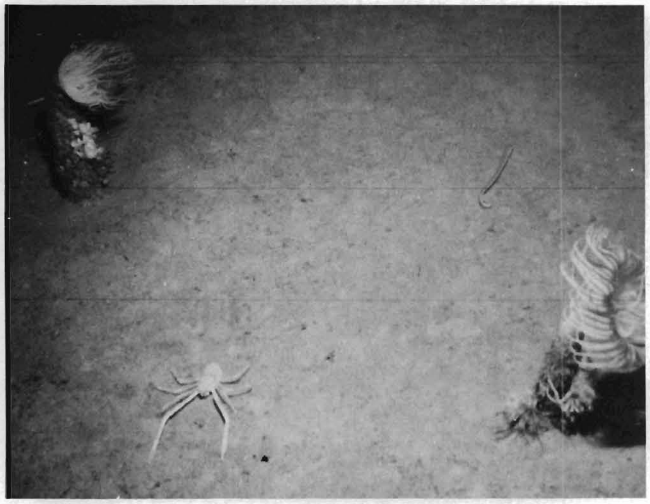


Figure 11.—The burrowing anemone (*Cerianthus borealis*) here harboring (upper left) a partially hidden galatheid crab, along with other small anemones on its tube and (lower right) another specimen with associated spider crab, small anemones, and worm tubes on its stalk; between the two large anemones are another galatheid crab and (upper right) a fawn cusk eel, *Lepophidium cervinum*. From 70 mm Ektachrome EF color transparency.

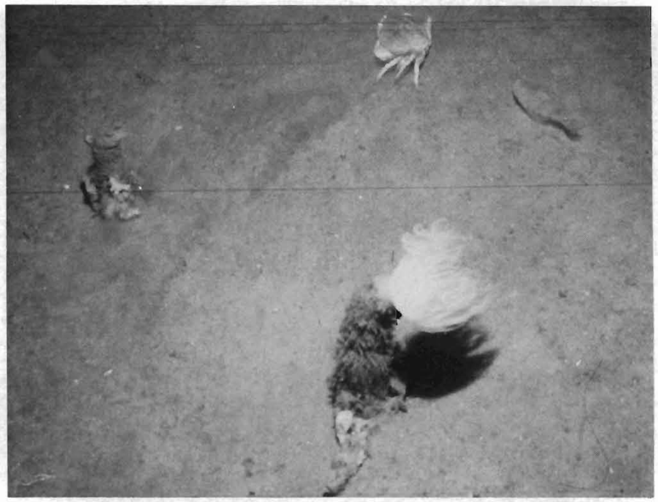


Figure 12.—Two burrowing anemones (*Cerianthus borealis*) (one retracted) and their associated attached fauna, *Cancer borealis* and a small unidentified flounder. From 70 mm Ektachrome EF color transparency.

and statistical comparisons of the three survey techniques.

RESULTS

A limited checklist of species or species groups documented by one or more of the three survey techniques is presented in Table 1; this list is limited to mobile species or species groups whose estimated density according to any one of the survey methods was equal to or greater than one individual per acre at any two of the 10 common stations. One particular finding of the overall survey was that red crabs did not occur shoaler than 150 fathoms (274.3 m); since all of the 10 common stations were shoaler, no comparison of gear efficiency can be made with respect to this species.

Table 1 provides the basis for subsequent comparison of species density estimates by gear. In order to minimize the likely bias of nonrandom distributions owing to such factors as schooling, aggregation on preferred substrates, temperature regime, depth, and the like, the species (or groups) selected for comparison were further limited to those which were documented from no less than five stations by each of at least two of the three methods; these qualified taxa, or groups, are ranked in order of decreasing abundance in Figure 14. Speciation of many forms such as shrimps, squids, hakes, flounders, and grenadiers was readily accomplished on direct examination of trawl catches, but similar diagnostic precision was not always possible from submersible sightings, or from the photographic negatives and positives; accordingly, we have pooled data on closely allied species to permit a maximum number of useful comparisons in Figure 14; density estimates were transformed as indicated to permit graphic comparisons of widely divergent values. The significance of differences between estimates by gear was examined by the Friedman two-way analysis of variance by ranks (Conover, 1971). While sampler variability, per se, and repeatability of results need be tested further before valid intercalibration terms can be inferred, we believe that the data, as analyzed, provide useful insights on the three methods.

While it was originally intended that all gear comparisons be made from daytime operations, the interactions with commercial fleet operations repeatedly forced the otter trawling schedule out of phase such that 8 of the 10 stations of common interest were occupied at night. The immediate result of this schedule alteration was to theoretically bias the catches of flounders and hakes upwards, and the catches of squids downwards (Bowman, 1974; Sissenwine and Bowman[3]). This inherent bias (i.e., overestimate) has been retained in the case of the hakes and flounders, but compensated in the case of the squids; thus squid abundance estimates as shown in Figure 14 have been expanded to theoretical daytime equivalents of Table 1 values by a factor of 18.9 (Sissenwine and Bowman, footnote 3) in order to reflect their significantly greater vulnerability to otter trawls under daytime conditions, the norm for submersible and camera sled operations.

Figure 14 shows that density estimates of the eight dominant faunal components varied widely according to assessment methodology; in general,

[3]Sissenwine, M. P., and E. W. Bowman. 1977. Relative fishing power of the Yankee No. 36 and modified Yankee No. 41 bottom trawls towed by the research vessels *Albatross IV* and *Belogorsk* during periods of light and dark. (Manuscript.)

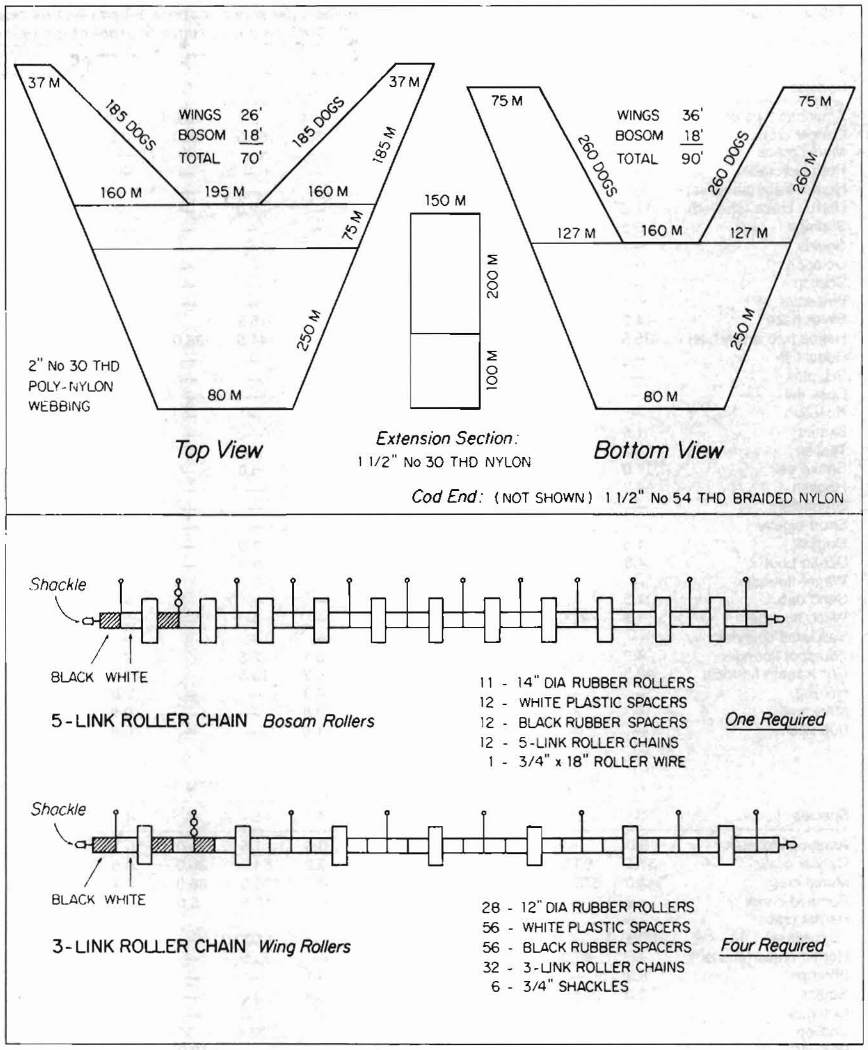


Figure 13.—No. 41 roller-rigged shrimp trawl (70′-90′).

the submersible technique yielded highest estimates followed by camera sled and trawl. Documentation of numbers of species or higher taxa (Table 1) was highest by submersible (30 taxa), followed by trawl (19 taxa), and camera sled (14 taxa). Density estimates derived by submersible were significantly higher in six of the eight comparisons with trawl-derived estimates; photo sled estimates were significantly higher than trawl estimates in five of the eight categories. Submersible counts were comparable with photosled counts in five categories, but significantly higher in three. Thus, results support the hypothesis that continuous visual assessment of the benthos provides the best approximation of species abundance and diversity.

Trawl-derived estimates of the 34 taxa listed in Table 1 were numerically superior in four cases, namely, squids, herring, mackerel, and butterfish; among these, the last three were documented only from the trawl survey. With squids occurring at all 10 stations, the four taxa occurred collectively at four stations, and in groups of two or three at four other stations. This qualitative and quantitative disparity between survey techniques is suggestive of photonegative response of these pelagic forms to the light sources common to the submersible and photo sled. Repeated studies using these diverse survey techniques should clarify this point and perhaps resolve the converse postulate that some taxa are attracted toward point sources of light and may be overcounted. It should be noted also that these four pelagic species are least constrained to the very bottom of the water column where camera sled and submersible are most effective and

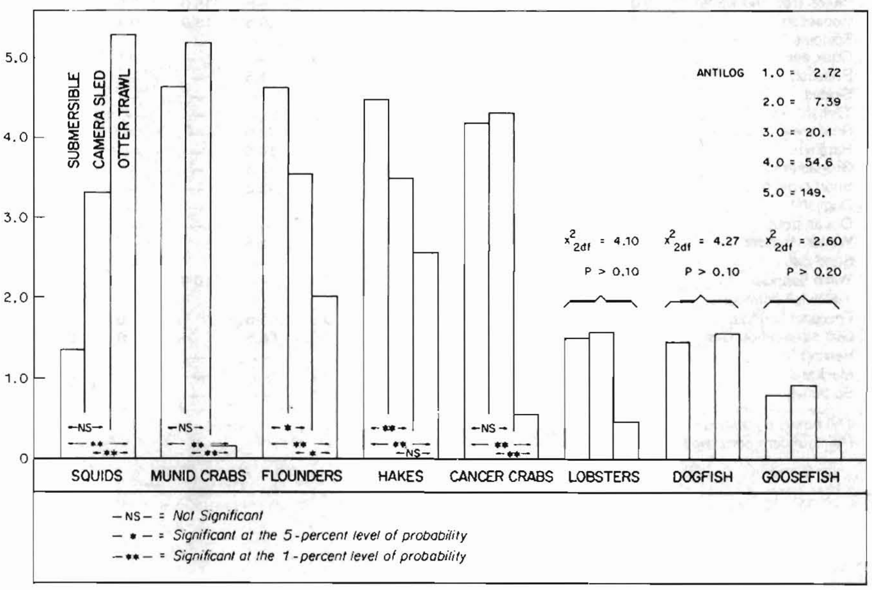


Figure 14.—Comparison of submersible, camera sled, and otter trawl in estimating abundance of dominant megafauna at 10 common stations (1-4, 9-14) in region of Veatch Canyon; Y-values are natural log $(X + 1)$ where X is estimated average abundance in numbers per acre from Table 1.

Table 1.—Estimates of standing crop of selected megafauna in numbers per acre at stations 1-4 and 9-14 as determined from surveys by submersible (S), camera sled (C), and otter trawl (T). Stations are arranged in order of increasing depth.

	STN 9			STN 1			STN 2			STN 10			STN 11			STN 3		
Species	S	C	T	S	C	T	S	C	T	S	C	T	S	C	T	S	C	T
American lobster	6.5	—	0.4	4.5	6.0	0.4	2.5	10.0	1.4	4.0	15.0	2.2	—	—	—	—	—	—
Cancer crabs	154.0	209.0	4.4	88.5	77.0	0.2	63.5	95.0	0.5	50.5	30.0	1.7	44.0	24.0	0.2	31.0	33.0	—
Munid crabs	—	9.0	—	—	—	—	—	—	—	—	—	—	144.5	24.0	—	273.5	54.0	—
Portunid crabs	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	6.5	—	—
Hermit crabs (shelless)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Hermit crabs (shelled)	11.5	9.0	—	16.0	—	—	2.0	—	—	1.5	—	—	1.5	—	—	.5	—	—
Shrimps	5.5	—	—	9.5	—	—	—	—	—	9.5	—	—	5.0	—	—	13.5	—	—
Squids	—	—	6.3	—	—	1.6	—	—	1.4	1.5	—	5.3	1.5	—	9.9	1.0	—	2.4
Octopus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Scallop	—	—	—	—	—	—	—	—	—	4.0	60.0	—	—	—	—	1.0	—	—
Brittlestar	—	—	—	—	—	—	—	—	—	—	—	—	24,265.0	—	—	—	—	—
Silver hake	14.0		3.8	6.5		8.0	15.5		29.9	5.0		5.7	16.5		—	16.5		8.6
Hakes (red and white)	135.5	[1]78.0	14.3	104.0	[1]33.0	0.7	44.5	[1]35.0	6.3	47.0	[1]30.0	6.5	44.0	[1]24.0	3.8	62.0	—	7.2
Goosefish	—	—	0.7	—	—	—	—	—	—	1.5	—	0.1	1.5	—	—	1.5	—	1.2
Sculpins	—	9.0	—	—	—	—	—	—	—	—	—	—	1.5	—	—	1.5	—	—
Cusk eel	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	67.0	0.2
Rosefish	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	11.5	—	—
Skates	1.5	—	0.3	5.0	—	—	—	—	—	—	—	0.3	—	—	—	—	3.0	—
Tilefish	—	—	—	—	—	—	—	—	—	1.5	—	—	—	—	—	—	—	—
Snake eel	14.0	—	—	10.5	—	—	5.0	—	—	9.0	—	—	25.5	—	—	2.5	—	—
Hagfish	—	—	—	—	—	—	—	—	—	—	—	—	1.5	—	—	—	—	—
Grenadiers	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Short bigeye	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dogfish	1.5	—	1.2	—	—	9.1	1.0	—	18.5	6.5	—	7.2	2.5	—	0.9	—	—	—
Ocean pout	4.0	—	0.1	3.0	—	0.1	0.5	—	0.2	—	—	—	—	—	—	—	—	—
Winter flounder	—		—	—		—	—		—	1.5		—	—		—	0.5		—
Sand dab	1.5		—	3.0		—	—		—	44.0		—	2.5		—	—		—
Witch flounder	1.5	[2]26.0	0.7	—	[2]11.0	—	—	—	0.1	—	[2]30.0	0.1	—	—	—	—	[2]26.5	—
Yellowtail flounder	—		—	—		—	—		—	—		—	—		—	0.5		—
Fourspot flounder	4.0		3.4	11.5		0.1	2.5		2.5	7.5		3.3	6.5		0.6	15.5		4.5
Gulf stream flounder	48.5		5.2	55.5		6.2	19.5		22.3	13.0		—	244.0		—	100.0		—
Herring	—	—	—	—	—	4.3	—	—	2.9	—	—	0.9	—	—	0.3	—	—	—
Mackerel	—	—	0.3	—	—	0.8	—	—	0.8	—	—	5.2	—	—	1.2	—	—	—
Butterfish	—	—	—	—	—	1.6	—	—	0.8	—	—	0.6	—	—	2.4	—	—	4.5

	STN 4			STN 12			STN 13			STN 14			Grand means		
Species	S	C	T	S	C	T	S	C	T	S	C	T	S	C	T
American lobster	9.0	—	0.6	2.5	—	0.6	1.5	5.0	0.1	4.0	—	0.5	3.5	3.6	0.6
Cancer crabs	37.5	60.0	—	42.0	42.0	0.2	54.5	26.0	0.5	27.0	76.0	0.7	59.3	67.2	0.8
Munid crabs	347.0	676.0	0.7	89.5	754.0	0.7	105.0	66.0	0.4	12.5	51.0	0.1	97.2	163.4	0.2
Portunid crabs	1.0	—	—	1.5	—	0.1	12.5	5.0	0.3	9.0	—	0.1	3.1	—	0.1
Hermit crabs (shelless)	>1,000.0	—	—	>1,000.0	—	—	>1,000.0	—	—	—	—	—	>1,000.0	—	—
Hermit crabs (shelled)	—	43.0	—	—	—	—	5.5	—	—	—	34.0	—	3.9	8.6	—
Shrimps	8.0	—	—	—	—	0.1	—	—	0.4	98.5	—	0.4	15.0	—	0.1
Squids	2.0	248.0	10.7	5.5	—	43.8	9.0	—	3.9	8.0	—	21.6	2.9	24.8	10.7
Octopus	3.5	—	—	—	—	—	3.0	—	—	—	—	—	0.7	—	—
Scallop	—	17.0	—	—	12.0	—	2,223.0	—	—	—	8.0	—	223.0	9.7	—
Brittlestar	—	2,849.0	—	28,310.0	18.0	—	—	10.0	—	—	—	—	>1,000.0	28.8	—
Silver hake	7.0		9.8	129.5		10.4	75.5		6.4	74.0		—	36.0		8.3
Hakes (red and white)	5.0	[1]17.0	1.3	—	—	1.3	6.5	[1]15.0	0.5	1.0	[1]68.0	0.2	45.0	[1]30.0	4.2
Goosefish	1.0	—	0.1	—	—	—	6.5	15.0	0.3	—	—	0.1	1.2	1.5	0.3
Sculpins	2.5	—	—	—	—	—	—	—	—	—	—	—	0.5	0.9	—
Cusk eel	—	120.0	—	—	—	0.1	—	—	0.1	—	—	—	—	18.7	—
Rosefish	55.0	—	—	—	—	0.1	1.5	—	—	15.5	—	2.1	8.4	—	0.2
Skates	—	—	—	—	—	—	—	—	—	—	—	—	0.7	0.3	0.1
Tilefish	1.0	—	—	—	—	—	—	—	—	—	—	—	0.3	—	—
Snake eel	17.0	—	—	21.5	—	—	43.0	—	—	1.0	—	—	14.9	—	—
Hagfish	3.5	—	—	—	—	—	10.5	—	—	19.0	—	—	3.5	—	—
Grenadiers	—	—	—	—	—	—	1.5	—	—	61.5	76.0	0.1	6.3	7.6	—
Short bigeye	—	—	—	1.5	—	—	43.0	—	—	—	—	—	4.4	—	—
Dogfish	—	—	—	20.5	—	—	—	—	—	—	—	—	3.2	—	3.7
Ocean pout	—	—	0.1	—	—	—	—	—	—	—	—	—	0.8	—	0.1
Winter flounder	—		—	—		—	2.5		—	—		—	0.5		—
Sand dab	—		—	2.5		—	—		—	—		—	5.4		—
Witch flounder	—	[2]180.0	—	10.0	[2]12.0	0.1	—	[2]10.0	0.4	2.5	[2]25.0	0.1	1.4	[2]32.0	0.2
Yellowtail flounder	2.5		—	9.0		—	—		—	—		—	1.2		—
Fourspot flounder	9.5		2.4	7.5		0.3	5.5		2.9	—		0.1	7.0		2.0
Gulf stream flounder	141.5		—	54.0		3.8	86.5		5.9	5.0		—	76.8		4.3
Herring	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.8
Mackerel	—	—	2.5	—	—	0.2	—	—	—	—	—	—	—	—	1.1
Butterfish	—	—	9.3	—	—	0.1	—	—	—	—	—	—	—	—	1.9

1 All hakes combined.
2 All flounders combined.

should, more likely, be more effectively sampled by the high opening trawl.

DISCUSSION

The relative merits of each of the three survey techniques must take into account a variety of practical and scientific considerations that tend to become highly subjective according to the users' experience (or inexperience) with each of the methods. It has become evident to us from this survey, and from prior and subsequent experience with each of the three methods operating independently, that apparent relative efficiency determined after the fact does not answer the practical question of which is the "method of choice" in a previously unstudied area. Those of us experienced in submersible surveys believe, cost considerations aside, that the overall advantages of direct visual assessment cannot be equalled by either of the other options taken singly. In certain situations such as rocky, precipitous bottom or submarine canyon heads and slopes, for example, there is no question that the submersible is the only effective survey strategy; conversely, over smooth bottoms, very adequate surveys can be made by photo sled at lowest cost per unit area surveyed and with fewest logistical problems.

Trawl surveys have the distinct advantage of providing not only qualitative and quantitative information on the population structure of an area, but also the inherent option of hands-on examination of catches for a great variety of other purposes within and beyond population assessment. This single advantage may, in certain kinds of surveys, outweight the evident sampling inefficiencies with respect to benthic invertebrates and bottom oriented fishes such as hakes and flounders. While it appears that bottom trawls, especially those that are roller rigged, tend to underestimate actual abundance of certain important species, this bias may also be present, to a lesser degree, with both submersible and photo sled. The distinct advantage of direct observation is that the reactions of species to the submersible can be observed and judgments made concerning the probable bias.

Further comparative studies such as this in areas with mutually amenable bottom topography should eventually provide a confident intercalibration of these methods on a species-by-species basis. The evidence at hand, nevertheless, suggests that any one method alone is unequal to the task of complete sampling efficiency.

The optimum strategy for detailed surveys of groundfish and benthic invertebrates may prove to be a combination of submersible or photo sled transects backed up with specialized trawl tows to provide specimen material for collateral studies (e.g., Wigley et al., 1975). The choice between photo sled or submersible will be dictated by cost, expected or known bottom topography, logistic capabilities of support vessel, and expected or known visibility conditions on bottom. In areas of consistent high turbidity, of course, photographic or visual assessment is virtually impossible; when such conditions prevail over untrawlable bottoms, a survey strategy will be limited to traps, gill nets, tangle-nets, line trawls, angling, or combinations of these labor intensive methods with the attendant difficulties of quantitative interpretation.

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