How the Work Is Done

THE SHIPS

Vessels belonging to three agencies regularly participate in the work at sea under the sardine research program. The ships are the *Yellowfin*, of the California Division of Fish and Game; the *Black Douglas*, of the U. S. Fish and Wildlife Service; and the *Crest* and *Horizon*, of the Scripps Institution of Oceanography. These four vessels are shown in Figures 1 and 2. The *N. B. Scofield*, of the California Division of Fish and Game, participated in some of the early cruises, and the Scripps Institution's *Paolina T* and *E. W. Scripps* occasionally have been used.

The *Yellowfin, Black Douglas, Crest,* and *Horizon* have all been acquired since the program began. They have been equipped as floating laboratories, the work being only partially done from sardine funds. Dimensions and speeds of the vessels are:

	Length (ft.)	*Tonnage*	*Speed (knots)*
Yellowfin	114	272 (gross)	10
Black Douglas	118	371 (gross)	9
Crest	136	320.27 (displacement)	10
Horizon	143	600 (displacement)	10

The cruises these ships make can be divided into three types:

(1) The routine oceanographic-biological survey cruises covering the entire area under investigation at approximately monthly intervals;

(2) Occasional cruises that are limited in scope and designed to further special studies being made under the program;

(3) Survey cruises made as part of the work on availability and young fish.

The last type of cruise is made only by the *Yellowfin*, which, as one of the research vessels of the California Division of Fish and Game, is available for sardine work during only part of the year. The other ships are available for both the routine cruises and those connected with special studies.

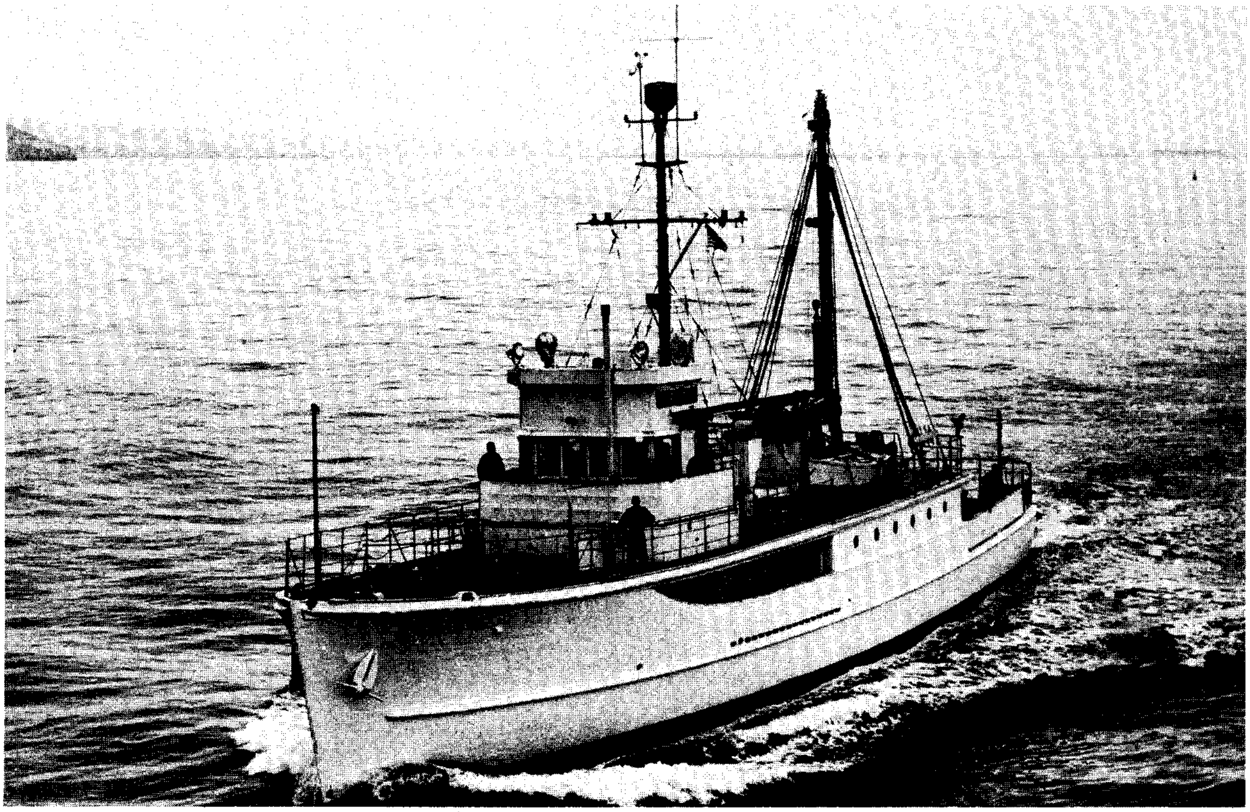
THE STATION PLAN

By far the bulk of the seagoing work consists of the occupation of the oceanographic stations—arbitrary geographic locations—which pattern the survey area. The region under survey covers approximately 670,000 square miles (Fig. 3). About 45 stations are occupied by each ship on each cruise. In density of observations, oceanography, the science of the sea, has a long way to go to catch up with the science of the air, meteorology. The area of the region surveyed is more than four times that of the State of California. The total number of stations occupied per cruise is about 140. There are 311 meteorological stations in the State of California.

The station plan now in use is a flexible one. Stations are added or dropped as the need arises. During the spawning season, for instance, several new stations are occupied in areas where spawning is most intense. However, since the whole point of the program is to gather oceanographic data by means of which average conditions in the sea can be determined, nearly the entire area is covered on almost every cruise.

The station plan was determined in this way: a line was drawn that roughly parallels the coast (true bearing 330 degrees) and the lines of stations were plotted at right angles to this base line. Most oceanographic features off the California coast, such as currents and temperature distribution, approximately parallel the coast. Having the grid oriented at right angles to the base (or coast) line allows better description than if it were along the lines of latitude and longitude. Under the system now in use (adopted early in 1950), the major station lines lie 120 miles apart and are numbered in multiples of 10. Lines can be spaced as closely as 12 miles apart and still have individual numbers. The plan also permits individual numbers to be given stations spaced only four miles apart. Most of the stations are 40 miles apart; they are numbered in multiples of 10. The numbering system would permit the survey area to be subdivided into many stations, each of which would represent an area 12 miles long by four miles wide. However, in the present plan most stations represent an area of either 40 by 40 miles or 40 by 120 miles. In referring to a station under the present plan, the line number is given, then a decimal point, then the station number. The scheme facilitates quick identification: station 120.60 is station 60 on line 120, for example.

The scheduling of new cruises is worked out at monthly meetings of representatives of the U. S. Fish and Wildlife Service and the Scripps Institution of Oceanography, and at less frequent meetings of representatives of these organizations with representatives of the California Division of Fish and Game. At these informal conferences it is decided which ships are to go where, who will be aboard each vessel, what stations will be occupied. Also at these conferences, the difficult problems of priorities are settled. They are difficult chiefly because everyone is interested in using the vessels during the same periods; when the sardines are spawning, oceanographic conditions are changing most rapidly and markedly. It must be decided whether a few stations off Northern California can be safely by-passed in the interest of adding a few more off Cedros



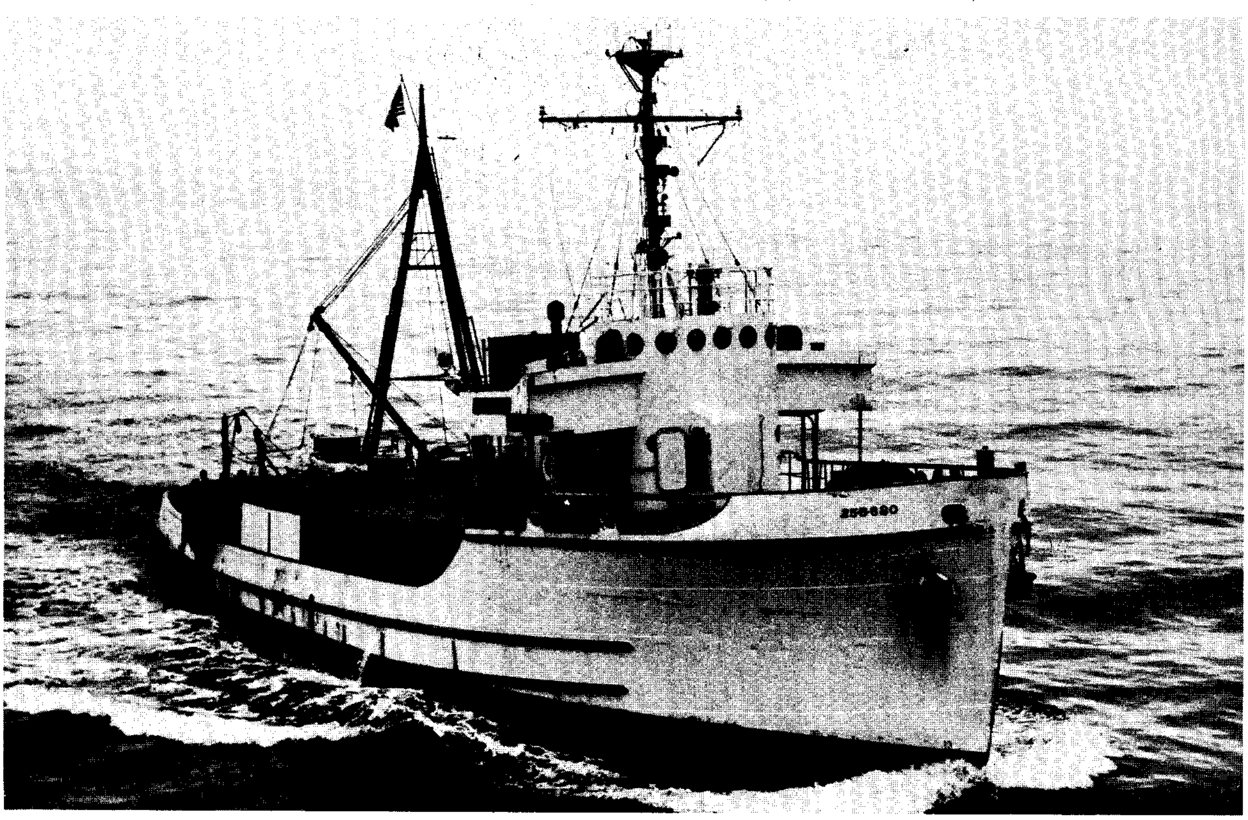


FIGURE 2. (UPPER) The *Crest,* owned by the University of California's Scripps Institution of Oceanography. (LOWER) The *Horizon,* also owned by the Scripps Institution of Oceanography. Both vessels participate in the routine survey cruises.

Island. Such decisions carry responsibility; data from those few stations off Northern California may later be badly needed to confirm variations in oceanographic conditions.

Each vessel carries a complement of scientists and marine technicians whose job it is to measure the ceaseless changes of the ocean. (Sometimes they are called upon for other sorts of work; in October, 1949, the *Black Douglas* came to the rescue of the survivors of a shipwreck off Northern California.)

COLLECTION OF DATA

"Oceanographic conditions" is a useful but rather vague phrase in which are lumped all the measurable characteristics of sea water. In any sample of water, scientists are particularly interested in the following:

(1) Temperature

(2) Salinity

(3) Amounts of dissolved oxygen and dissolved inorganic phosphorus present

(4) Transparency of the water

(5) Amounts and kind of living organisms present

Over the years instruments to get that information have slowly evolved. Some of them (trawls, for example) have been borrowed from fishermen. The search for one of the most useful instruments—a device that would entrap and allow bringing to the surface an uncontaminated sample of subsurface water—occupied scientific men for almost 300 years. It ended only in the first years of this century with the invention of the Nansen bottle, the instrument now most widely used for the purpose. When a station is occupied, a series of Nansen bottles is attached to the hydrographic wire and lowered from the ship (Figs. 4 and 5). At the desired moment, the first messenger, a small weight that slides down the wire, is let loose. It trips the first bottle and releases the next messenger. The bottles reverse and close tightly on the samples of sea water. Attached to the bottles are reversing thermometers which show the temperature at the moment of reversal.

Details of the work on station have been modified during the progress of the program, but the basic routine (which has been established by years of research in oceanography) remains unchanged. At each station, the following observations are made:

(1) Plankton tow to 75 meters. This is made with a nonclosing one-meter plankton net (Fig. 6). Fish eggs and larvae are collected in this way.

(2) Hydrographic cast to 1,200 meters (if possible) for temperature, salinity, oxygen, and phosphate data. Nansen bottles attached to the wire collect samples from 15 standard depths. The hydrographic cast takes almost an hour to complete.

(3) Bathythermograph observations. This instrument records water temperature to a depth of 137 meters (450 feet).

(4) Phytoplankton cast (again using Nansen bottles) to 70 meters.

In addition, all ships engage in dip-net fishing under a light at night, and note the occurrence and abundance of marine birds and marine mammals. Weather data are collected and transmitted to the U. S. Weather Bureau four times daily. Occasionally, deep plankton hauls are made.

As the vessel arrives on station, it is slowed; while it is losing way, the plankton net is readied and lowered into the water. The quantity of water strained during a haul is measured by a current meter fastened in the mouth of the net. The angle-of-stray of the towing wire is read at one-minute intervals during a haul. When the net tow is completed, the sample is removed, labeled, and preserved for analysis ashore. The vessel then swings into position for the hydrographic cast. The depth of the water is read from the fathometer and recorded. When the ship has lost way, the Nansen bottles and bathythermograph are attached to the hydrographic wire and lowered to an appropriate wire depth.

Four minutes are allowed after the Nansen bottles arrive down before releasing the messenger. The wire angle is measured with an inclinometer just after releasing the messenger. During the time between the cast's arriving down and starting up the weather and the state of the sea are observed and recorded. As the cast is raised, the bathythermograph and the Nansen bottles are removed from the wire. In the 15 minutes or so required for the thermometers to come into equilibrium with the air (both the air temperature and the sea temperature as recorded by the reversing thermometers are needed for computations of the true sea temperature), the phytoplankton cast is made. This completes the work on station. The entire process will be repeated at the next station, 40 miles away. Between stations, the temperatures at the 15 standard depths are read and recorded. Water samples are analyzed for their chemical constituents. Salinity (which is determined by means of chlorinity titrations) is determined ashore; the rest of the measurements are made at sea. A 250-milliliter sample from each depth is analyzed for dissolved oxygen; duplicate 100-milliliter samples for each depth are analyzed for dissolved inorganic phosphorus. During an average cruise (3 ships, 140 stations) the following number of analyses are run: 2,100 oxygen, 4,200 phosphate, and 4,200 chlorinity.

The ships keep in touch with the shore by means of radiotelephone, reporting regularly on the progress of the work.

PROCESSING OF DATA

The data collected by the techniques just described are subjected to considerable refinement. The processing of the mass of original data comprises a full-time job for 20 employees at the Scripps Institution of Oceanography and 15 employees of the U. S. Fish and Wildlife Service. Still more workers are needed. The

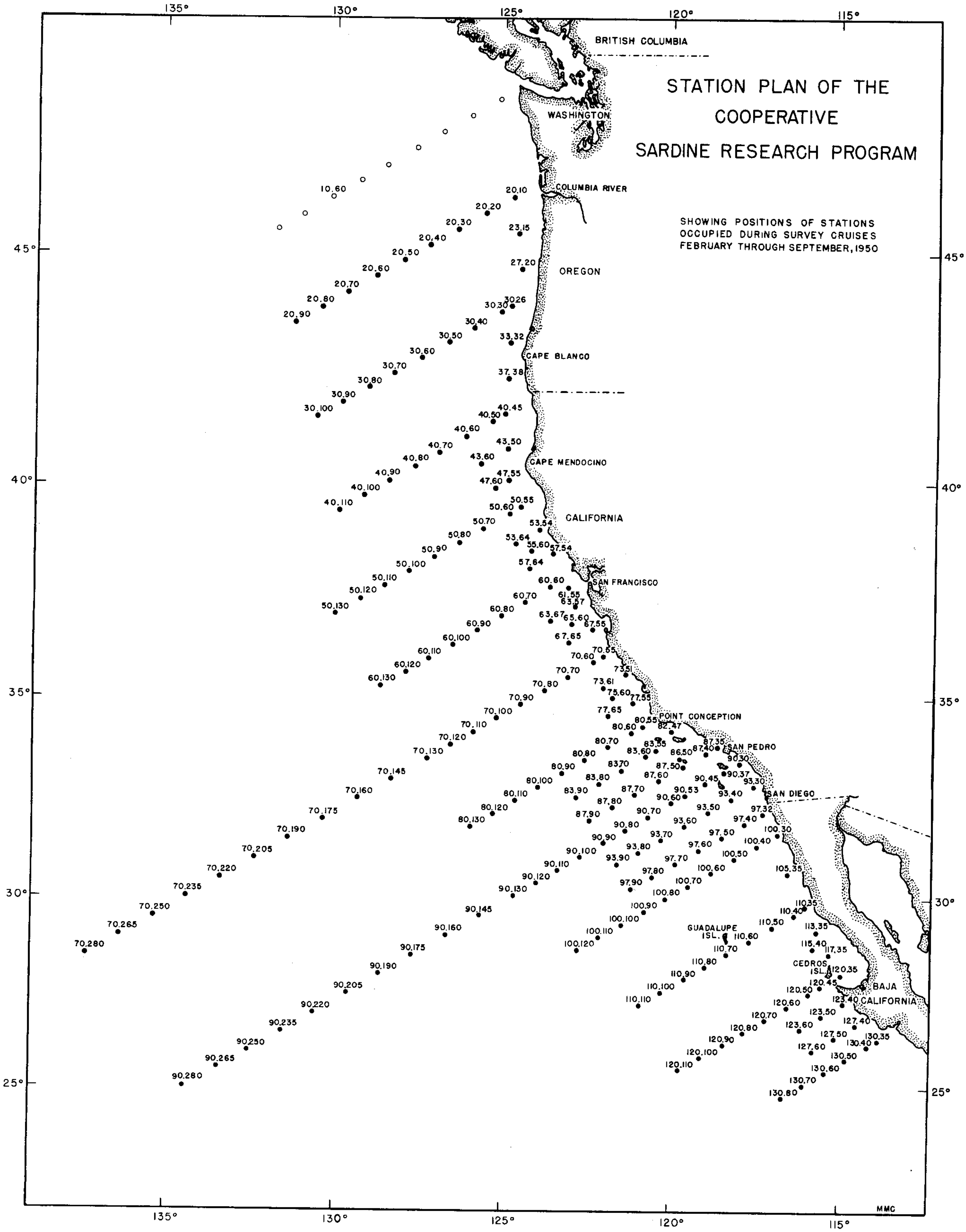


FIGURE 3. Present station plan of the California Cooperative Sardine Research Program. The numbering system, adopted early in 1950, is planned so that the station lines are 120 miles apart, individual stations 40 miles apart. Extra stations have been added in regions of particular interest in sardine work (note density of station network off Southern California).

FIGURE 5. The Nansen bottle. (UPPER) Attaching the bottle to the hydrographic wire. (LOWER) Attaching the messenger. The perforated shield encloses the three thermometers used. When a messenger strikes the tripping mechanism at the top, the bottle reverses and closes on a sample of sea water, and the messenger at the other end of the bottle is freed to slide down the wire and trip the next bottle.

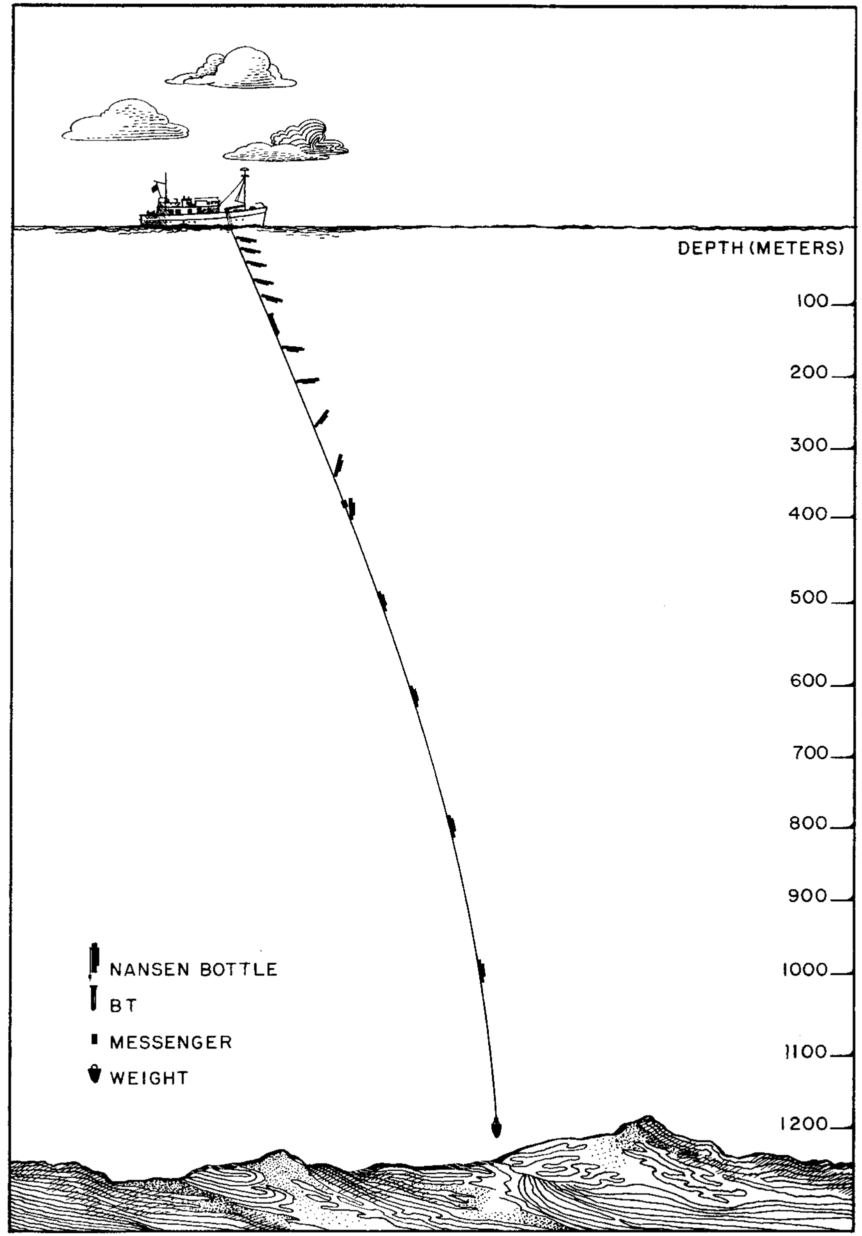


FIGURE 4. The hydrographic cast. Water samples are taken as nearly as possible from specified standard depths by means of Nansen bottles. The bathythermograph provides a continuous trace of temperature to 137 meters (450 feet). The bottles are more closely spaced near the surface because oceanographic conditions are more variable there. Making the hydrographic cast takes approximately one hour.

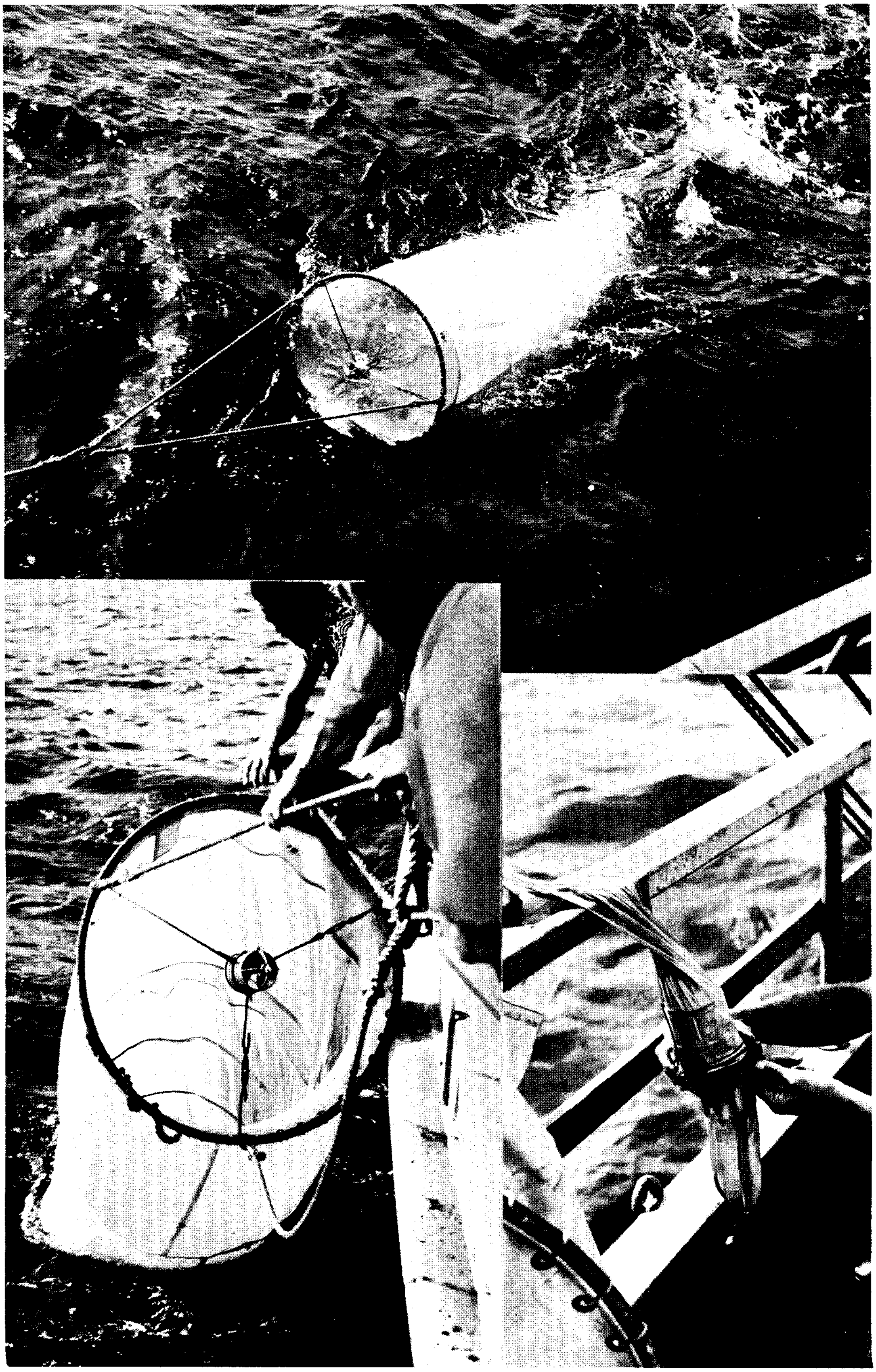


FIGURE 6. Plankton tow, using the one-meter net. As the vessel arrives on station, it is slowed; while it is losing way, the plankton net is readied and lowered into the water. The quantity of water strained during a haul is measured by the current meter fastened in the mouth of the net. When the net tow is completed, the sample, which is collected in the removable cod end (lower right) is removed, labeled, and preserved for analysis ashore.

ORIGINAL OCEANOGRAPHIC DATA

SCRIPPS INSTITUTION OF OCEANOGRAPHY — UNIVERSITY OF CALIFORNIA

11ND NEL 197 (NEW 3-49)

CAST (TIMES G.C.T.)	WIRE ANGLE	START DOWN	ARRIVE DOWN	MESS.	START UP	IN	OBSERVER	WIND	CLOUDS	LATITUDE	LONGITUDE	CRUISE	STATION
	42°	2302	2319	2323	2333	2351	SAMPSON	310° F3	2 Cu	38° 06′	127° 20′	H-8	505
CAST							RECORDER CARLSON DRUMMOND	WIND WAVES 3	SWELL 340° 6′ 8^5	SONIC DEPTH 2600 f.		VESSEL HORIZON	
BT NO. 3203 A	SLIDE NO. H-8-18	SECCHI DISK 14 m.	BOTTOM SAMPLE NO. —	WEATHER 01	WET BULB 59.6	DRY BULB 64.0	FOR THERMOMETER ARRANGEMENT SEE FORM I SHEET NO. 1					DATE X-6-49	

DESIRED DEPTH (m)	WIRE LENGTH		NANSEN BOTTLE NO.	LEFT THERMOMETER MAIN (P)	LEFT AUX.	MIDDLE THERMOMETER MAIN (P)	MIDDLE AUX.	RIGHT THERMOMETER MAIN (U)	RIGHT AUX.	Cl BOX NO.	BOTTLE NUMBERS Cl	PO_4-P	O_2	REMARKS
0	0		39A	BKT.- 17.7						2	H 599			
10	10		30	17.37 17.37	20.0 19.8					2	H 700			
20														
30	25		31	17.44 17.43	19.9 19.6					2	H 701			
50	50		32	13.90 13.89	19.5 19.3					2	H 702			
75	75		33	10.41 10.40	19.8 19.4					2	H 703			
100	100		34	9.43 9.42	19.4 19.2			10.00 10.00	18.9 18.7	2	H 704			
150	150		25	9.12 9.11	19.4 19.2	9.12 9.11	19.5 19.2			2	H 705			
200	200		26	8.16 8.15	19.5 19.0			9.45 9.45	18.6 18.4	2	H 706			
300	300		27	7.25 7.25	19.2 18.8	7.28 7.27	19.1 18.7			2	H 707			
400	400		28	6.61 6.60	19.3 18.9			9.40 9.40	18.2 17.9	2	H 708			
500														
600	600		29	5.60 5.59	19.0 18.6	5.64 5.63	19.0 18.4	9.86 9.85	18.4 18.0	2	H 709			
800	900		35	4.67 4.67	19.2 18.7			11.70 11.70	18.1 17.8	2	H 710			
1000	1325		36	3.68 3.68	19.0 18.6	3.60 3.60	19.5 18.8	13.30 13.29	18.4 18.2	2	H 711			

PROCESSED OCEANOGRAPHIC DATA

SCRIPPS INSTITUTION OF OCEANOGRAPHY — UNIVERSITY OF CALIFORNIA

11ND NEL 199 (NEW 3-49)

REMARKS	VESSEL / DATE	COMPUTERS	∡	BT SLIDE NO. / CAST	CRUISE	STATION
	VESSEL HORIZON DATE X-6-49	R.L. MARQUARDT P.S. CLARK	42°	18	H-8	505

NANSEN BOTTLE NO.	WIRE LENGTH	DESIRED DEPTH (m)	(P) THERMOMETER READINGS MAIN	AUX.	ΔT+I	T_w	I-m	AVERAGE T_w	(U) THERMOMETER READINGS MAIN	AUX.	$T_w - t_u$	$\Delta T_u + I$	$T_{w,u}$	$T_{w,u} - T_w$	COMP. THERM. DEPTH	COMP. L-Z	ACC. L-Z	ACCEPTED DEPTH	S ‰
39A	0	0						17.7									0	0	32.81
30	10	10	17.37	19.8	−.04	17.33		17.33									3	7	.88
		20																	
31	25	30	17.43	19.6	−.16	17.27		17.27									7	18	.95
32	50	50	13.89	19.3	−.08	13.81		13.81									13	37	.81
33	75	75	10.40	19.4	−.06	10.34		10.34									21	54	.84
34	100	100	9.42	19.2	−.19	9.23		9.23	10.00	18.7	−9.47	−.07	9.93	.70	81	19	28	72	.79
25	150	150	9.11 9.11	19.2 19.2	−.17 −.17	8.94 8.94	0	8.94									43	107	33.33
26	200	200	8.15	19.0	−.19	7.96		7.96	9.45	18.4	−10.44	−.14	9.31	1.35	142	58	57	143	.60
27	300	300	7.25 7.27	18.8 18.7	−.10 −.10	7.15 7.17	.02	7.16									84	216	.82
28	400	400	6.60	18.9	−.31	6.29		6.29	9.40	17.9	−11.61	−.11	9.29	3.00	289	111	111	289	.86
		500																	
29	600	600	5.59 5.63	18.6 18.4	−.28 −.37	5.31 5.26	.05	5.28	9.85	18.0	−12.72	−.14	9.71	4.43	437	163	163	437	34.11
35	900	800	4.67	18.7	−.18	4.49		4.49	11.70	17.8	−13.31	−.19	11.51	7.02	676	224	224	676	.23
36	1325	1000	3.68 3.60	18.6 18.8	−.27 −.18	3.41 3.42	.01	3.42	13.29	18.2	−14.78	−.24	13.05	9.63	1057	268	268	1057	.42

FIGURE 7. Two of the forms used in working up oceanographic data obtained on the sardine cruises. (UPPER) The original oceanographic data noted at a single station. Location, time, weather, state of sea, and depth as shown by fathometer are among the items entered. (LOWER) The processed data. Still more computations are needed, however, before the data are in their final form. Approximately 2,200 stations have been occupied since the program began; the collection and processing of the oceanographic data alone require the services of 20 full-time employees.

collection and compilation of such data forms the core of the sardine research program. Two of the forms used for original and processed oceanographic data are shown in Figure 7.

Eventually the oceanographic data from the cruises will be published in permanent form. Plans for the publication of the 1949 material are under way. Meanwhile, the results of each cruise are for convenience being mimeographed and distributed to those working on the program.

INSTRUMENTATION

During the past two years, some of the most intensive and fruitful work under the sardine research program has gone into the development and testing of a group of new instruments designed to improve methods of obtaining biological samples. This work has been done at the Scripps Institution of Oceanography.

Midwater Trawl

One of the problems of the complete investigation of any fishery is the adequate sampling of the adults of the species. Most of the data on the adults of the species from the sardine research program have come from commercial catches or from special vessels utilizing what is essentially commercial gear. The floating fish-larvae trap has to some extent approached the problem of adequately sampling the older forms of sardines, but is able to take only larvae and small juveniles. A new approach has been attempted on this problem by the development of a midwater trawl. This is a net of about the dimensions of ordinary otter bottom trawls but with a mouth made considerably higher in order to capture fishes not ordinarily found near the bottom.

Tests on a preliminary model of such a net have been extremely encouraging. A net designed on radically different principles, 10 feet wide across the mouth, 12 feet high, and about 35 feet long, has been developed. The mouth is kept open by a special beam which also acts as a depressor. The instability inherent in such a design is corrected by a small piloting depressor attached below this beam. One of the 43-pound homogeneous depressors has been used with success as the pilot. This comparatively large net has been towed at relatively high speeds and great depths. At a towing speed of about four knots a depth of 1,500 fathoms (about a mile and a half), was reached, and several heretofore unreported deep-sea forms of fishes were captured. The net has also been towed at about 60 meters depth at a speed of six knots. Fish as active as

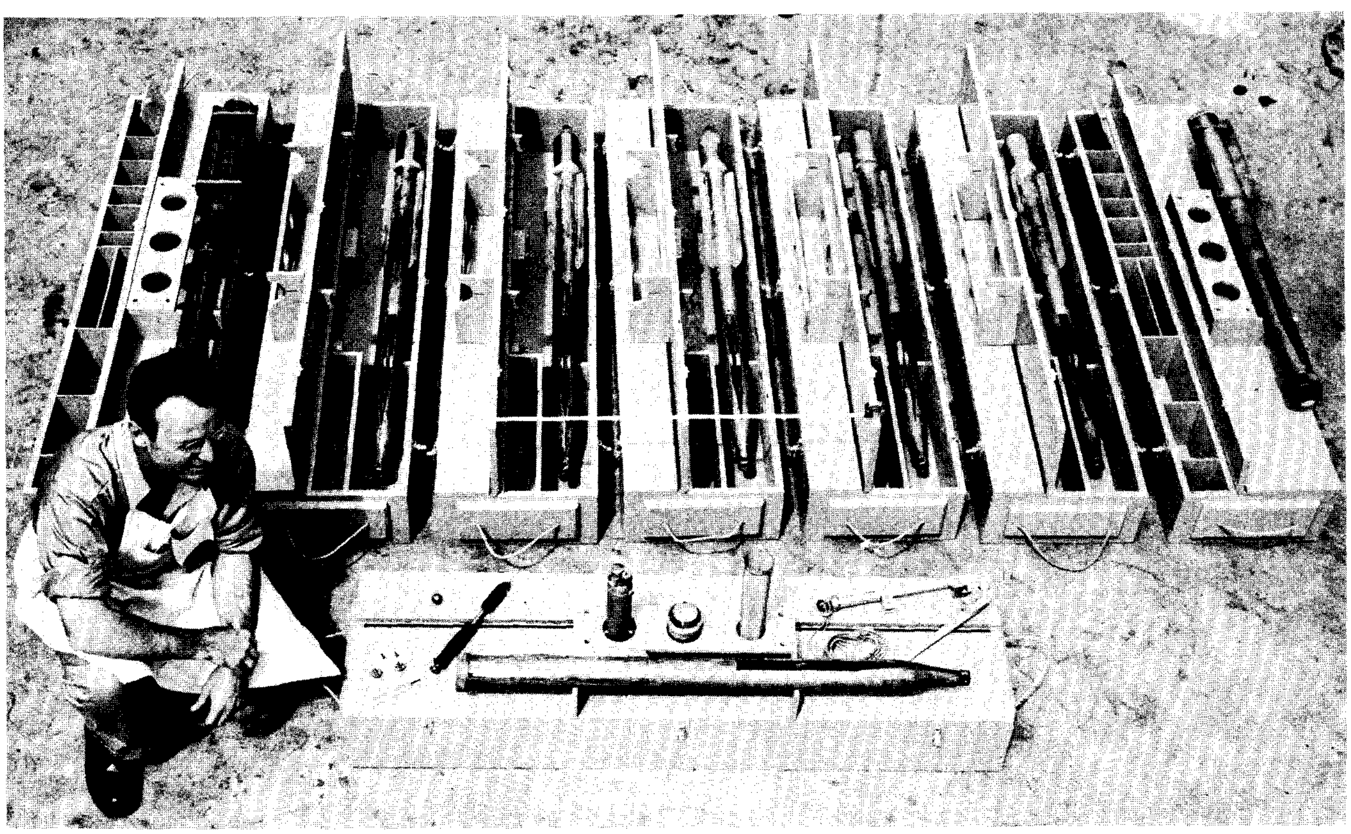


FIGURE 8. The plankton collector was developed as part of the sardine research program. Eight are shown here. The collector was designed to allow high-speed sampling. With the collector in the lower part of the picture are shown (at left and right) devices used in two methods of attaching the collector to the cable: at the left are a stainless steel ball and Allenhead screws; at the right equipment by means of which a ball made of an alloy of low melting point can be cast directly on the cable. It is melted off after use. In the center are (left to right) the recorder and bellows, propeller assembly, and collecting net. The collector at the upper right is a specially designed adaptation for low-speed work.

or more active than sardines have been captured in these few shallow tows but no adult sardines have been caught. Further tests will be made where sardines are known to be present. A larger net approximately 17 feet across the mouth and 50 feet long has been constructed, and will soon be tested at sea.

There is apparently no limitation on the size of this type of net other than the ability of the gear aboard the vessel to handle it. It is believed that a 25-foot net could be handled aboard the *Horizon,* and with the installation of special booms, nets up to perhaps 50 feet could be handled. Such nets become rapidly heavier and more unwieldy as their size is increased. To date all tows of this net have been made for the purpose of determining its hydrodynamic characteristics and ascertaining the types of fish which it can capture.

High-speed Gear

The small nets conventionally used for the collection of animal plankton have several disadvantages. One of the more serious is of course their slowness of operation. Making a net tow means that the vessel must greatly decrease its speed. Now an instrument has been developed which, although not replacing (and not intended to replace) the plankton net, allows plankton tows to be made while the ship is under way. The instrument is the high-speed plankton collector (Fig. 8). The U. S. Fish and Wildlife Service has cooperated in its development.

When a net is used to collect plankton, probably it works an area where some of the fish larvae and other nektonic creatures have been disturbed by the passage of the cable. Thus, a consideration in the design of the new collector was to have the fishing end somewhat ahead of the cable on which the collector was operated. The collector has been so constructed that it can be mounted on the cable by means of a special spherical cable clamp; this allows the cable to pass through the collector at its forward third point. The actual fishing is done some 12 or 14 inches ahead of the point of attachment.

A separable depth-flow meter is used with the collector. (Although designed primarily for that use, the depth-flow meter has a general application to all problems in which depth and distance hauled need to be known.) A continuous record is made of the depth of the meter and the flow of water past it. The fundamental components of the meter may be divided into (1) an impeller and gear train, (2) a pressure element and stylus, and (3) a recording spool and tape guides. Thirty-five-millimeter clear acetate film is used for recording tape.

The spherical cable attachment designed specifically for use with the high-speed plankton collector is also likely to have much wider applications. It was felt necessary to design such a clamp so as to permit freedom of the attached instrument with respect to the cable. Such an arrangement permits the cable to spin as loads are applied and prevents the instruments from being twisted about. The clamp, which is made of bronze, consists of two hemispheres held together by Allen-head screws.

The high-speed plankton collectors were tested on the May cruise of 1950. Four collectors were attached to a single cable, giving a simultaneous record of the distribution of plankton at several depths. The four collectors were towed about 600 miles during this cruise.

Simultaneously with the development of the high-speed collectors, it was necessary to find a method to keep the cable and collectors under the surface while they were being towed. When a ship at full speed tows an object, the forces impelling that object to the surface become enormous. The search for a device to bring about a suitable depressing force was concluded with the development of the new homogeneous depressor (Fig. 9).

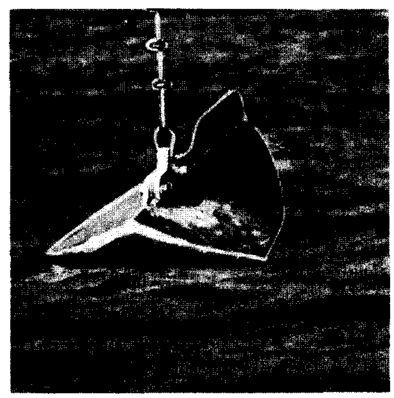


FIGURE 9. Although designed specifically for use with the high-speed plankton collector, the homegeneous depressor promises to have far wider applications in the field of oceanography. Cast of bronze, the 43-pound depressor exerts a 750-pound depressing force at 10 knots. The depressor is inexpensive, and can be made in sizes that depend upon the work to be done.

The depressor is cast from bronze. It is specifically designed so that (1) gravity orientation can be obtained with the use of a single material, and (2) the flow pattern is fixed over a large range of speeds. This permits balancing in air, eliminates the unbalancing effect of permeation by water, and permits operation at various speeds. It can be cast in several sizes, depending on the job that has to be done. A 43-pound depressor exerts a 750-pound depressing force at 10 knots. A depth of 50 meters can be obtained at that speed with $\frac{1}{4}$-inch cable. A depth of 100 meters can be attained with $\frac{5}{32}$-inch wire. The depressor is cheap; the 43-pound size should cost no more than $25 if commercially produced. The depressor has been towed at 25 knots by a destroyer without instability. It then developed a 3,000-pound depressing force.

A simple inexpensive hydraulic dynamometer has been designed for use on the cables towing depressors. This easily read indicator of cable stress is a necessity when towing plankton collectors at high speeds.

This new depressor is regarded by scientists working on the program as one of the significant recent technological advances in the science of oceanography. Apparently it is going to permit the development and use of hitherto impracticable scientific instruments, and will thus offer the opportunity for gaining important new knowledge about the ocean.

Floating Fish-larvae Trap

Another invention developed under the sardine research program is the floating fish-larvae trap (Fig. 10).

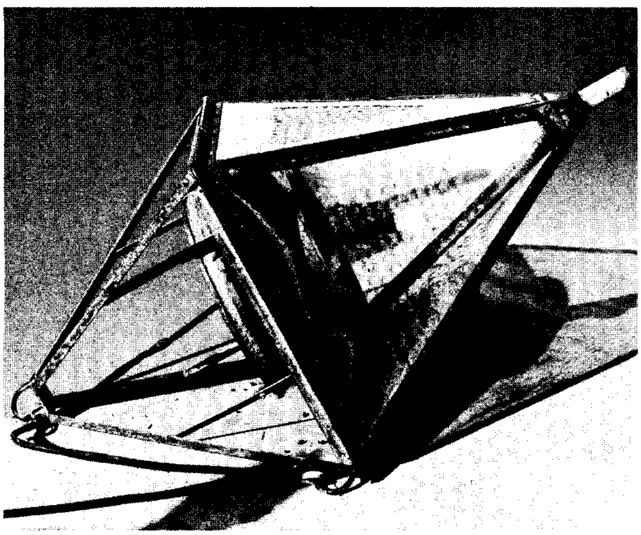


FIGURE 10. The floating fish-larvae trap is used when the ship is anchored at night. Attracted by the electric light, larval and postlarval fish enter the trap through conical holes, pointed inward, in the wire mesh sides. Flaps at the top collect fish swimming just beneath the sea surface.

Customarily fish larvae and young fish are sampled by collection with a dip net. The larvae and young are attracted by a light hung over the side of the ship at night and dipped up in the net. The floating fish-larvae trap promises to do this work more effectively. It should collect quantitative samples of the larval and postlarval forms of sardines, other surface fish, and surface invertebrates. In form, the trap is an inverted pyramid of wire mesh. The sides are pierced by a number of small conical holes. The cones have a base diameter of $1\frac{1}{4}$ inches and are directed inward $1\frac{1}{4}$ inches, terminating in a $\frac{1}{4}$-inch hole. The trap contains a float, beneath which is an electric light which attracts the fish. The trap rests with the flat base of the pyramid on or just below the surface of the water. At the surface are flap valves which seem to collect forms swimming close to the surface film. Tests have shown that the trap collects larval and postlarval fish far more efficiently than does a dip net.

Plankton-sample Splitter

The plastic plankton-sample splitter (Fig. 11) is used in the work ashore. It has been constructed to obtain aliquot divisions of a sample of plankton too bulky to handle by ordinary methods. It is in regular use in the recruitment studies.

Chlorinity Titrator

One of the immediate products of an oceanographic cruise is a large number of bottles filled with sea water, the salt content of which must be determined. In order to run these determinations more rapidly and more accurately than can be done by traditional methods, the automatic chlorinity titrator is being developed. This instrument carries out automatically a potentiometric titration of halides with silver nitrate solution, the end point being indicated by the difference in potential between a silver-silver chloride electrode in the titration vessel and a reference silver-silver ion electrode. When the titrator is in use, the operator has merely to place a sample of sea water in the titration vessel, push the appropriate buttons, and, in a few minutes, record the chlorinity.

ASOP

In the past most shipboard colorimetric analyses had been carried out with visual colorimetric instruments. Although development of the photoelectric cell has permitted the design of much more sensitive and accurate colorimeters, most instruments available commercially are ill-suited to the rigors of shipboard use.

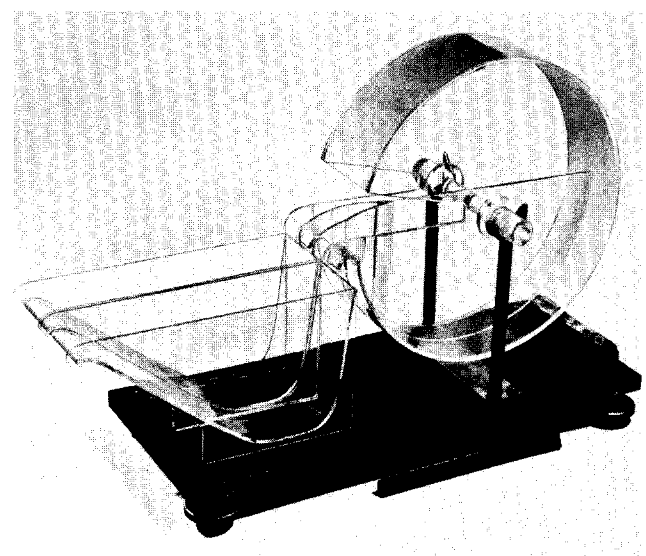


FIGURE 11. The plastic plankton-sample splitter. This instrument was constructed to obtain aliquot divisions of a sample of plankton too bulky to handle by ordinary methods. It is in regular use in the recruitment studies.

In order that colorimetric determinations of nutrients such as phosphate could be carried out as a matter of routine, it was necessary to develop a rugged seagoing instrument.

ASOP (automatic servo-operated photometer) is a double photocell instrument, in which the electrical unbalance between the two photocells is used to control a servo-motor. This in turn drives a slide wire in the proper direction to eliminate the unbalance. Essentially monochromatic light is used, resulting from a projection bulb and interference-type filters. After the instrument is balanced initially, one has only to introduce the sample and read off its transmittance.

Other Projects

The work ashore and at sea has required the frequent development and modification of equipment. Some of the other projects undertaken at the Scripps Institution include the development of shipboard filters; the production of stainless steel graduates, filter flasks and other laboratory equipment for seagoing use; the design of automatic reagent dispensers (Fig. 12) for rapid metering of small fixed fluid volumes of chemicals; the construction of equipment for the calibration of reversing thermometers; development of a slow-speed microscope stage drive; design of a non-metallic pump for the collection of uncontaminated water samples; the very successful modification of a centrifuge for use in chlorophyll analysis; design and testing of a wire drum and sheave to handle piano wire, by means of which it is hoped to reach depths of more than 200 fathoms at a speed of 10 knots; development of a deck-recording surface thermometer of great sensitivity.

Many of these devices are to be protected for scientific work by patent applications.

U. S. Fish and Wildlife Service personnel have devised an angle-of-stray indicator (Fig. 13) which consists essentially of a steel ball damped in mineral oil in a curved glass tube which is mounted on a large protractor. The instrument is suspended from the towing wire during net hauls, and provides a continuous record of the wire angle, knowledge of which is necessary in making the haul and in estimating the depths at which the net fished. A similar device has also been developed at the Scripps Institution of Oceanography.

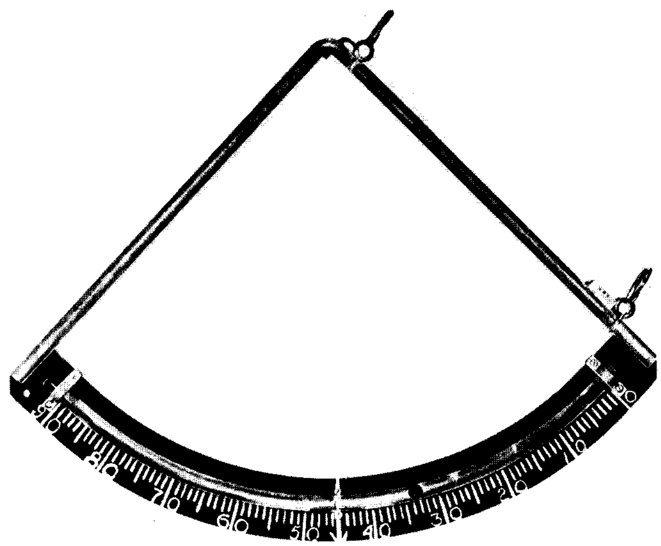


FIGURE 13. Angle-of-stray indicator. When suspended from the towing wire during net hauls, the instrument provides a continuous record of the wire angle.

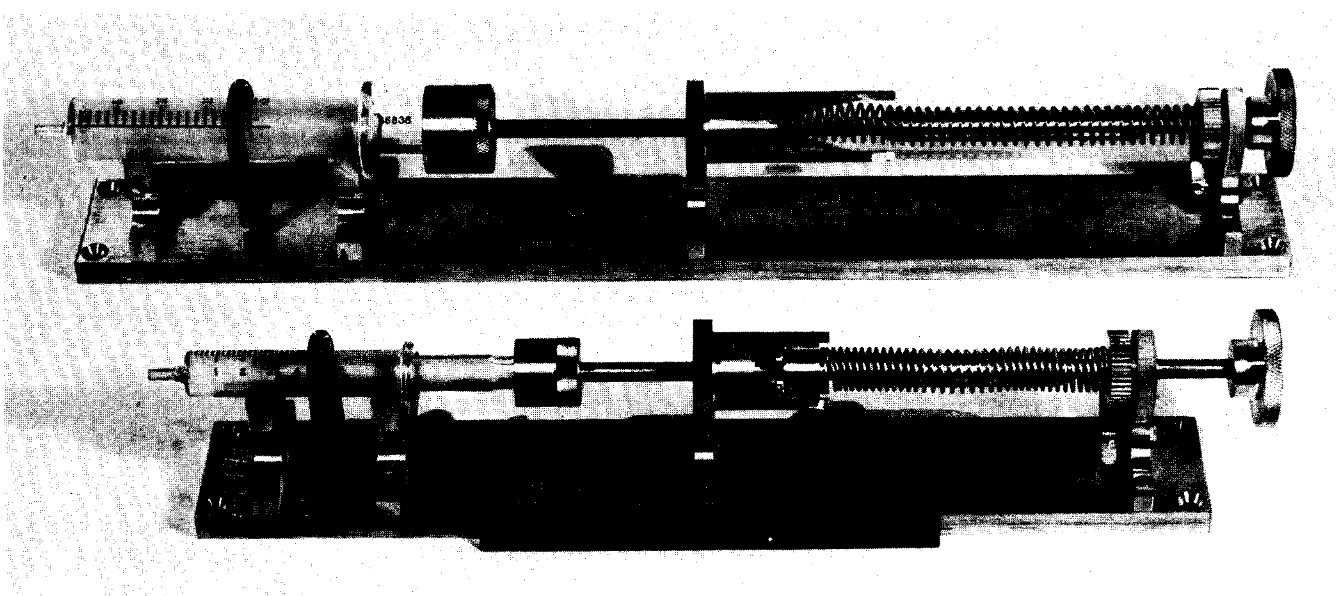


FIGURE 12. By the use of the automatic reagent dispensers, small volumes of reagents are rapidly and accurately metered by the oil displaced by the assembly. These are for laboratory use ashore and at sea.

U. S. Fish and Wildlife Service personnel have devised a wire clamp (Fig. 14) consisting of two hinged members which are clamped over the wire by means

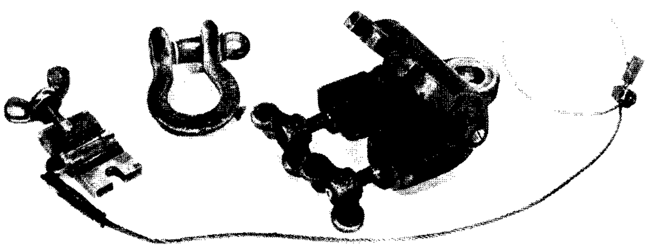


FIGURE 14. Wire clamp. A small size is used as a safety clamp for Nansen bottles, a larger size as a wire clamp for plankton nets.

of toggle bolts and butterfly nuts. A small size is used as a safety clamp for Nansen bottles, a larger size as a wire clamp for plankton nets.

Use of Soundings to Locate Sardine Schools

One important aspect of the work on instruments in the sardine research program has been the California Division of Fish and Game's testing of sonic methods for the location of fish schools. This work is now a standard technique aboard the *Yellowfin*. The vessel is equipped with a Navy surplus sonar (echo-ranging) device and with a recording echo-sounder. The work aboard the *Yellowfin* has shown:

(1) The sonar equipment installed aboard the vessel is practical for locating schools of fish up to a range of 800 yards from the vessel.

(2) The sonar equipment installed aboard the vessel is not practical for locating schools of fish in water of depths of less than 50 fathoms. The transmission angle of the projector permits return from the bottom at short ranges in shallow water, masking out any schools of fish which might be present.

(3) The recording echo-sounder installed aboard the vessel is practical for locating schools directly underneath the vessel, and for determining the vertical distribution of these schools (Fig. 15), but not for identifying their composition. As yet species of similar size and schooling habit cannot be separated by the trace on the recording echo-sounder.

The equipment aboard the *Yellowfin* is bulky, expensive, and requires the services of a trained operator. Its experimental value is considerable, but commercial exploitation is regarded, at least at present, as scarcely justified.

The methods of echo-sounding and echo-ranging are similar to those developed by the Navy for locating submarines. The sonar head is not used for active scanning; it is left at 45 degrees on either bow. When an indication of the presence of a school of fish appears, the head is rotated and the vessel maneuvered to come directly over the school. When the school appears as a trace on the recording echo-sounder, a small explosive charge is dropped and samples are collected. The method is used only as a supplement to visual location.

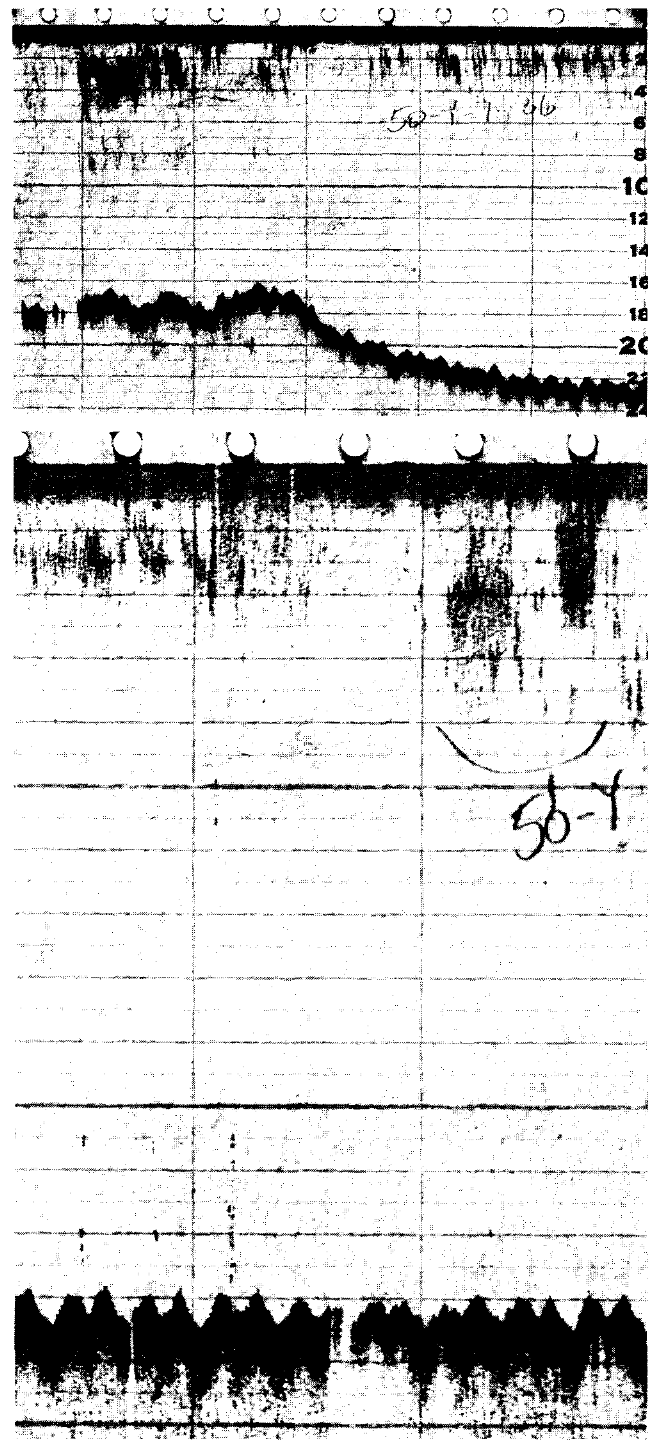


FIGURE 15. Two examples of the use of echo-sounding apparatus aboard the *Yellowfin* to help in locating sardine schools. (UPPER) On Cruise 50-Y-7-36, 23 July 1950, a school was found about one mile off Cedros Village. The light trace near this top was made by echoes from the school (the lower, darker trace is the bottom). Vertical distribution of the school was from 10 to 80 feet. The vessel probably cruised over the school. Sampling resulted in the taking of 81 sardines and 4 jack mackerel. (LOWER) This school was located visually on Cruise 50-Y-7-33. It was found 19 miles south-southeast from Morro de Santo Domingo in Sebastian Viscaino Bay. The bottom is at approximately 260 feet. The upper trace shows the vertical distribution of the school to be from 16 to 60 feet. More than 100 sardines were taken. Observers estimated that the school contained 30 tons of sardines.