OCEANOGRAPHIC OBSERVATIONS ON THE "E.W. SCRIPPS" CRUISES OF 1938

BY

H. U. SVERDRUP AND THE STAFF

OF THE

SCRIPPS INSTITUTION OF OCEANOGRAPHY

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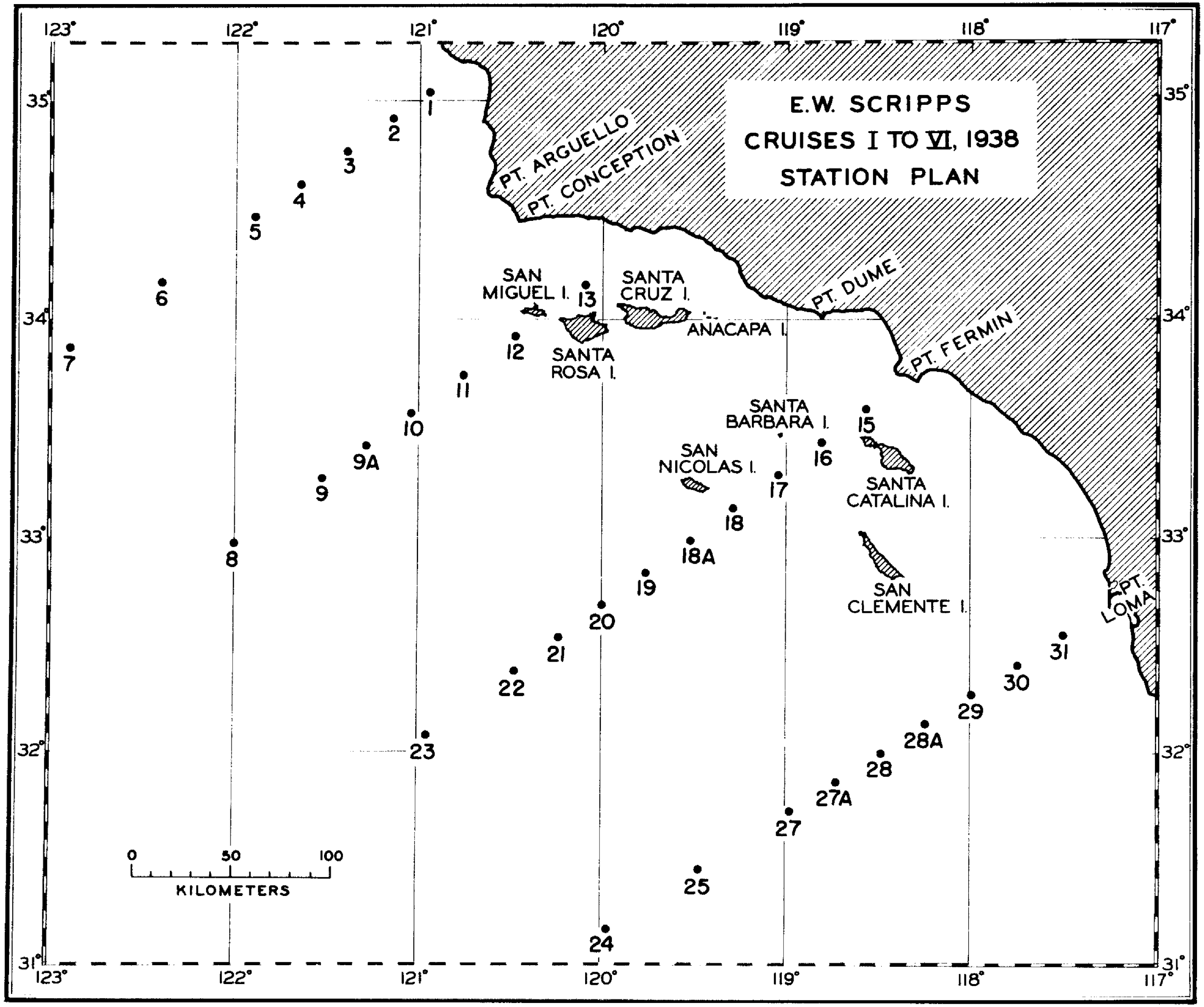

Fig. 1. Station plan of the "E. W. Scripps" cruises, 1938.

OCEANOGRAPHIC OBSERVATIONS ON THE "E. W. SCRIPPS" CRUISES OF 1938

INTRODUCTION

THE CRUISES OF 1938

By
H. U. SVERDRUP

The new vessel of the Scripps Institution of Oceanography, the "E. W. Scripps," was placed in commission at the end of December, 1937, after having been remodeled and equipped for oceanographic work. A description of the vessel is included in this report, giving its dimensions and its facilities for oceanographic work.

In 1937 a coöperation had been established with Dr. F. P. Shepard who, through a grant from the Geological Society of America, was to have the vessel at his disposal for investigation in submarine geology every second month of 1938, beginning in January. Thus the Scripps Institution would have the vessel available for its particular purposes only during every other month of the year. The most advantageous plan therefore seemed to be to continue the type of survey which had been conducted in 1937 in coöperation with the California Division of Fish and Game making use of the patrol vessel, the "Bluefin."

Figure 1 shows the area off the coast of southern California which was studied in 1937 and 1938. On the chart are indicated the locations of the stations which were to be occupied in 1938, with the station numbers. Owing to weather conditions not all the stations were occupied on certain cruises. Also, the exact locations vary slightly from those shown in this chart, but in the maps showing the results of the different cruises the actual positions are indicated by dots.

The work was planned to comprise observations of temperature, salinity, and oxygen within the layers where significant differences could be expected, determinations of phosphate phosphorus if possible, and collection of phytoplankton at seven different levels at and below the surface. Except on Cruise I vertical net hauls for zoöplankton between 200 meters and the surface were part of the routine program.

The "Bluefin" cruises[1] had shown that great contrasts in the hydrographic conditions exist off the coast of southern California and had indicated that marked changes in the character of the currents took place during the early part of the year. The "Bluefin" cruises had also shown that significant differences in the character of the waters occurred mainly above a depth of 500 meters, for which reason the hydrographic work of the "E. W. Scripps" was limited to this depth. Observations for temperature and water samples were collected between the surface and a depth great enough to insure that the deepest samples were from a depth somewhat greater than 500 meters, except on Cruise I when most stations were worked to a depth of 1000 meters and one to a depth of 3900 meters. Water samples were obtained by Nansen reversing water bottles. Temperatures were measured by means of standard reversing thermometers, using unprotected thermometers on every third water bottle in order to determine the depth at which the bottles reversed. The salinity was determined by chloride titration, three or more titrations being made on each sample if the difference between the first two titrations exceeded 0.04 $^{0}/_{00}$ in salinity. The oxygen content was determined on board by means of the Winkler method. On the first three cruises phosphate was determined by the method of Denigès, using 1 ml. of acid-molybdate reagent to 100 ml. of sea-water sample and direct visual comparison. Results were calculated using the salt-error factor of 1.12 reported by Cooper[2] for these conditions.

Table 1 shows the dates of the different cruises, the number of stations occupied on each cruise, the number of temperature, salinity, oxygen, and phosphorus-content determinations, the number of samples for study of phytoplankton, and the number of vertical net hauls for zoöplankton.

On the cruises the stations were occupied in numerical order with the following exceptions: On Cruise III stations 31-15 were first occupied, then station 13, and finally stations 1-12. On Cruises IV and V station 13 was first occupied and the other stations in numerical order, and on Cruise VI the sequence was stations 13, 1-12, 23-15, and 24-31. Cruises I, II, and V could not be completed, owing to storms. Generally a somewhat rough sea was encountered to the north of

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[1] H. U. Sverdrup and R. H. Fleming, "The Waters off the Coast of Southern California, March to July, 1937." Bull. Scripps Inst. Oceanog. (1941), vol. 4, no. 10, pp. 261-378.

[2] Jour. Mar. Biol. Assoc., 23 (1938): 171-78.

TABLE 1

Summary of Observations on the "E. W. Scripps" Cruises, 1938

Cruises	Number of Stations	Number of Observations					
		Temperature	Salinity	Oxygen content	PO_4 determinations	Phytoplankton samples	Vertical net hauls for zoöplankton
I, Feb. 15-25	30	437	440	439	440	189	0
II, April 8-12	14	172	172	170	168	85	10
III, June 7-16	33	428	430	429	423	192	25
IV, Aug. 16-25	34	441	441	440	0	238	34
V, Oct. 26 - Nov. 5	29	362	359	359	0	203	28
VI, Dec. 9-18	33	434	434	432	0	238	27
Total.	173	2274	2276	2269	1031	1145	124

Point Conception and outside a line from Point Conception passing west of San Nicolas Island. The greatest difficulties were encountered during Cruise II when, in ten days, only two lines of stations could be completed owing to bad weather and when the time available was too short to make it possible to continue the program.

Four or five of the staff members or assistants at the Scripps Institution took part in each of the cruises. These men and four of the ship's crew divided the day into six-hour watches. The stations were therefore occupied all day and night, and work went on continually during the cruise.

Dr. R. T. Young, Jr., of Worcester Polytechnic Institute, took part in Cruise IV, during which he made measurements of the transparency of the water between the surface and 60 meters at twenty stations. The results of this work have been reported in the Journal of Marine Research.[3]

Table A contains interpolated values of temperature, salinity, and oxygen content at standard depths. These values have been read off from curves showing the vertical distribution of the different properties; but prior to constructing these vertical curves, T-S curves and, usually, $T\text{-}O_2$ curves were constructed in order to discover possible errors. The last three columns of the table of results contain the values of σ_t as derived from McEwen's tables of 1929, anomalies of specific volume, δ, and the anomalies of the dynamic depth ΔD of the standard isobaric surfaces indicated by the argument in the first column of the table. These anomalies have been computed from Sverdrup's tables of 1934. A separate table, Table B, contains interpolated values of the phosphate-phosphorus content at standard depths. For financial reasons it was impossible to follow the recommendation adopted by the International Association of Oceanography at its meeting in Edinburgh in 1936 that both observed and interpolated values be published. The observed values can be obtained in manuscript form from the Scripps Institution of Oceanography.

Charts have been prepared in order to show the essential results from the cruises. A very brief description of these by R. H. Fleming is included in this report, but a detailed discussion will be postponed because it has been considered essential to present the observations at the earliest possible time.

Table C shows the number of diatoms found in the different catches and the percentage of the total number which appeared to be in poor condition. The phytoplankton collections were made by means of the Allen closing bottle which has a capacity of five liters. The water sample brought up from the desired depth was filtered through a net of number-25 bolting silk. A brief summary of the more outstanding results by W. E. Allen is included elsewhere in this report.

I take great pleasure in acknowledging the enthusiastic coöperation of the crew of the "E. W. Scripps." The staff members and assistants of the Institution who took part in the cruises and in the working up of the data deserve special credit. These are Messrs. W. E. Allen, C. Davis, R. H. Fleming, C. Heusner, M. W. Johnson, E. C. La Fond, J. Lyman, E. G. Moberg, S. Rittenberg, L. Simpson, H. U. Sverdrup, R. B. Tibby.

Assistance in the preparation of these materials was given by the personnel of Works Progress Administration, Official Project No. 665-07-3-141.

[3]Jour. Mar. Research, vol. 2, no. 2, 1939.

THE "E. W. SCRIPPS"

By

E. G. MOBERG AND J. LYMAN

A wooden auxiliary-motor vessel of the Gloucester-schooner type, the "E. W. Scripps" was built at Sausalito, California, in 1924 by J. H. Madden and Son from designs by Lee, Brinton, and Wayland, Inc., of San Francisco. She was intended as a yacht for ocean racing and extended cruising and originally carried a gaff-headed two-masted schooner rig with fidded topmasts. "Aurora" was her original name, which was changed to "Serena" under a later ownership. As the "Serena" the vessel was purchased at Los Angeles in April, 1937, by the late Robert P. Scripps for donation to the Scripps Institution of Oceanography to replace the motor vessel "Scripps" destroyed by explosion and fire at San Diego in November, 1936. The work of converting the "Serena" for scientific purposes was undertaken by the San Diego Marine Construction Company. On December 1, 1937, permission was received from the Director of the Bureau of Marine Inspection and Navigation to change her name to "E. W. Scripps," in honor of Edward Wyllis Scripps, father of Robert P. Scripps and one of the founders of the Scripps Institution of Oceanography. The vessel was formally transferred to the Regents of the University of California later in December and was ready for use in January, 1938.

Construction and design. - The registered particulars of the "E. W. Scripps" are as follows:

Tonnage, gross	108
Tonnage, net	59
Length, feet	93.7
Beam, feet	21.1
Depth, feet	11.9
Official number	224055
Signal letters	KLNT

On a draft of 12 ft. 3 in. her waterline length is 86 ft. 2 in. and corresponding displacement tonnage 135. The overall deck length is 104 ft.

Figure 2 gives the hull lines of the vessel to the outside of the planking. They show the hollow bilges, cut-away forefoot and raking keel of the Gloucester-fisherman model, which is characteristic of most large American schooner yachts.

The following table gives details of her scantlings:

Position	Dimensions	Timber
Keel and forefoot	18" x 20"	Oregon pine
Stem	12" sided	Apitong
Propeller and rudder posts	12" x 14"	Apitong
Frames	3-3/4" sided	Apitong
Clamp	3-3/4" x 9-3/4"	Oregon pine
Shelf	3-3/4" x 22"	Oregon pine
Ceiling	2-1/2"	Oregon pine
Ceiling, 6 bilge strakes	3-3/4" x 7-3/4"	Oregon pine
Deck beams	3-3/4" x 6"	Oregon pine
Beams at deck openings	5-3/4" x 6"	Oregon pine
Deck	2-3/4" x 2-3/4"	Oregon pine
Covering board	3-3/4" x 10"	Teak
Bulwarks	12" high	Teak
Outside planking	2-3/4"	Port Orford cedar

The frames are double, spaced 16 in., and mold from 8 in. at the heels to 4 in. at the heads. Every fourth frame is double-sawed; the rest are steam bent in one piece. Floors of sawed frames are of apitong, 6 in. x 8 in. Floors of bent frames are wrought iron, 1/4 in. x 4 in. at ends to 1-1/2 in. x 4 in. on keel, and running up 18 in. on the frames. They were galvanized after fitting. The stern transom is framed with Port Orford cedar and sheathed with teak. The ceiling is fastened with two 1/2-in. screw bolts in each frame and edge-bolted between frames. The outside planking ranges from 14-in. width at the garboards to 6-in. in the topsides and is fastened with 3/8-in. x 5-in. spikes. All fastenings are galvanized iron.

The vessel has 30 tons of cast-iron ballast consisting of two sections bolted to the underside of the keel with twelve 1-3/8-in. bolts passing through the metal floors and set up with nuts.

Eight hanging knees, 3 ft. 6-in.- x 4-in.-sided, are worked in each side, and lodging knees 2 ft. 8 in. x 4 in. at all deck openings. The joiner work is teak above deck and teak, mahogany, and pine plywood below.

Rigging. - Figure 3 on page 5, gives the sail plan of the vessel. The headsails are the original rig, the mainsail has been made smaller by eliminating the gaff and shortening and raising the boom, and the foresail has been reduced in hoist. The topmasts and all their gear have been removed. The trysail shown in the plan is generally set when hove to for work at a station in any kind of breeze, since it aids in keeping the vessel broadside to and also contributes to an easier motion.

Mainsail and foresail use wooden mast hoops, rather than the more modern travelers and track. The standing rigging is 7/8-in. wire rope, set up to chain plates with rigging screws. The spars are all solid sticks of Oregon pine, the mainmast

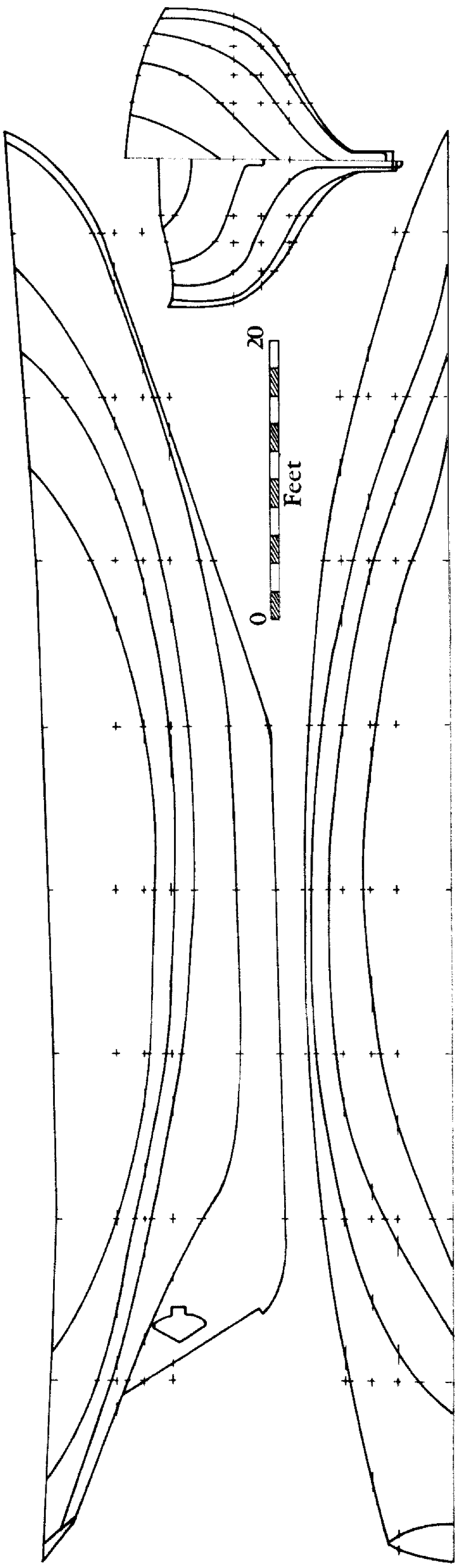


Fig. 2, A, B. Hull lines of the "E. W. Scripps."

being 74 ft. long from deck to truck and 15-1/4 in. in diameter at the deck, and the foremast 66 ft. and 14-3/4 in., respectively. In addition to the mainsail boom two working booms are fitted on the mainmast: an 18-ft. boom to starboard for the hydrographic winch and a 20-ft. boom to port for the trawling winch.

Deck fittings. - The deck layout of the vessel is shown in figure 4. She is entirely flush-decked fore and aft. There is a 12-in. bulwark all the way around, while a 3-ft. rail with removable sections in the wake of the working booms is fitted abaft the main rigging and across the stern. The anchors, consisting of a 521-lb. Baldt navy-type stockless anchor, a 400-lb. old-style anchor with shipping stock, and a 600-lb. sand anchor, are carried on deck forward. There is a total of 140 fathoms of 3/4-in. galvanized chain, which stows in the chain locker. The anchor windlass has electric drive and an anchor davit is provided for getting the ground tackle on deck. Between the windlass and the foremast are a hatch and a skylight to the forecastle. The foremast has a pinrail, and at port and starboard are skylights to the galley. Abaft the foremast is the dredging winch, and then a long skylight divided into three sections. In the forward third the batteries are stowed; the second ventilates the engine-room, and the after third the saloon.

The lifeboat, a standard metal boat, 18 x 6.5 x 2.8 feet, weighing 1300 lbs., is carried to starboard of the skylight; and to port, the work boat, a 14-ft. wooden skiff with an outboard motor. Abaft the skylight are the mainmast and pinrail. On each side of and slightly abaft the mainmast there is an electrically driven gypsy-head to which all the halyards can be led. The deck pump is directly abaft the mainmast; then follows the main companion trunk on which are mounted the pelorus and radio direction-finder.

On deck to starboard of this trunk is the hydrographic winch. The section of rail opposite the winch is removable and a sounding platform, a teakwood grating measuring 20 in. x 60 in., is hinged to the gunwale in such a way that it can be stowed flat against the main rail when not in use. Another removable section of rail fits into sockets on the outboard side of the platform while lanyards between it and the main rail enclose the fore and after sides.

Abaft the companion is the deckhouse, of which the forward part is the pilothouse and the after-part the deck laboratory with an open hatchway leading to the laboratories below. Abaft the deckhouse is the manhole to the lazarette, the standard compass, spare wheel, and stearing-gear box.

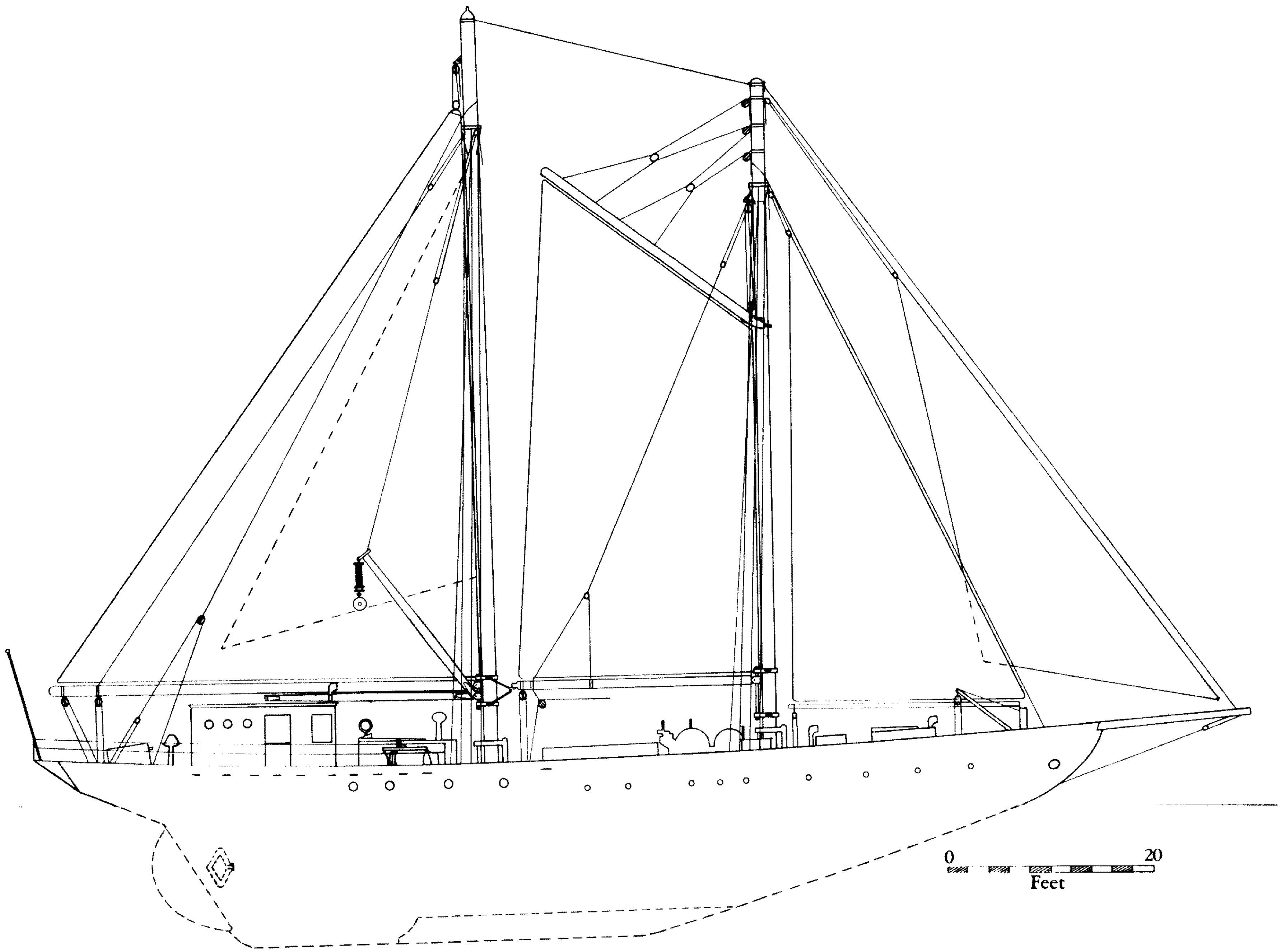


Fig. 3. Sail plan of the "E. W. Scripps."

Accommodations. - Figure 5 gives the below-deck layout of the "E. W. Scripps." In the fore-peak is the chain locker, with a passage to the forecastle. There are two built-in and five pipe berths in the forecastle. The crew's lavatory, the captain's room with single berth, and a locker containing carbon-dioxide tanks for the fire-extinguishing system open into the fore-castle. Abaft, the galley runs across the entire width of the vessel. On the foreside of the galley to port stands a Ray diesel oil-burning range and a water heater and, to starboard, a 10-cu.-ft. electric refrigerator. On the starboard side there are a sink with running hot-and-cold fresh water and a hand pump supplying sea water. Tables, shelves, and cupboards occupy the port and after sides. From the galley a passage leads to the saloon. On the starboard side of this passage are two berths, and on the portside is the engine room.

In the saloon is a mess table measuring 3 ft. 4 in. x 6 ft. 6 in. with a settee on the starboard and after sides and folding chairs for the other two sides. Opening off the saloon is a stateroom with two berths, and a passage leading aft. On the portside of this passage are situated a lavatory, a single-berth stateroom, and finally a stateroom with three berths; on the starboard side are the door to the laboratories and the companionway to the deck.

Tanks. - A bulkhead separates the after stateroom and laboratory from the lazarette in which are two 650-gallon fuel-oil tanks. The rest of the fuel tanks are in the engine room, making a total capacity of 2000 gallons of fuel oil. Lubricating oil is carried in a 50-gallon tank in the engine room and in an 80-gallon tank built under a sideboard in the saloon.

A total of 635 gallons of fresh water is carried in five tanks under the saloon, four to starboard and one to port. Distilled water is carried in a 55-gallon tin-lined copper tank in the after laboratory. Two septic tanks are located abaft the fresh-water tanks, port and starboard. These take the drains from the lavatories and sinks, discharging to the outside through the bilge pump.

Machinery. - When built, the vessel was equipped with an 80-HP diesel engine, but this was replaced in 1929 by the present engine, a six-cylinder, four-cycle, direct reversing Winton diesel, rated at 175 HP at 450 revolutions, giving a normal cruising speed of eight or nine knots under power. Originally this engine had an air-injection system, which in 1937 was replaced with a Bosch solid-injection system. Circulating water for the engine is supplied by a 1-HP Fairbanks-Morse electrically driven 1-in. centrifugal pump, mounted on the forward end of the main engine, with intake direct from the sea. An air compressor, a 3-HP electric Winton unit, stands on the forward portside of the engine room. Arranged in a tier on the starboard bulkhead of the engine room are eight compressed-air tanks, five of which will carry air at a pressure of 650 lbs. and three at 1000 lbs. for starting the main engine. The engine exhaust leads under the counter and discharges below the waterline at the stern.

A 3-in. centrifugal pump powered by a 3-HP Westinghouse motor placed under the starboard side of the galley serves for fire, bilges and drainage. Fresh-water pressure is maintained by another 1-1/2-HP electric pump also under the starboard floor of the galley. Fire protection is provided by a "CO-Two" system, with both manual and thermostat controls for engine room and bilges. There are also a number of portable fire extinguishers of various types in strategic positions.

Electrical equipment. - Electric current is supplied by an engine-generator unit mounted on Korfund shock-absorbing springs to port of the main engine. The engine is a model GA-2, two-cylinder, four-cycle Superior diesel engine direct-connected to a Westinghouse generator and booster generator. This engine is rated at 21 HP at 1200 r.p.m. The main generator is a single-bearing type, with compound-series field winding, and is rated at 115 volts and 15 kilowatts at 1200 r.p.m. A special-series field winding is provided for cranking the engine from the battery. The function of the booster generator is to provide the extra voltage needed for charging the batteries as a unit without raising the line potential above the usual 115 volts. The booster generator has a differential-series winding limiting the battery-charging current to 40 amperes at 10-volt boost and giving a maximum boost of 25 volts at no charging current. This differential winding carries the booster-armature current only; the main field has a constant potential 115-volt winding. This method of battery charging also tends to maintain a constant line voltage, since the batteries assist through the booster generator in smoothing out voltage changes caused by sudden load changes. The batteries are Exide Ironclad, type MVA 9-plate lead cells; fourteen 8-volt units in series with a capacity of 137 ampere-hours.

The speed of the winch motors is regulated by controlling the voltage of the main generator through variation of its field voltage. In this manner a maximum of from 175 to 185 volts may be produced. While this control is being used, the rest of the ship's load is taken directly from the batteries; consequently the main electrical system always has a constant potential of about 115 volts, for which most of the equipment is designed. When the extra voltage connection for maximum hoisting speed is not required, the generator will connect to the line automatically whenever its voltage is normal and will disconnect when the voltage is reduced. Figure 6 is a diagram of the electrical connections. The Westinghouse switchboard is hinged for rear accessibility and has heavy-duty contactors and relays for all automatic hoist-motor connecting functions. Feeder and transfer switches are standard navy-type knife switches.

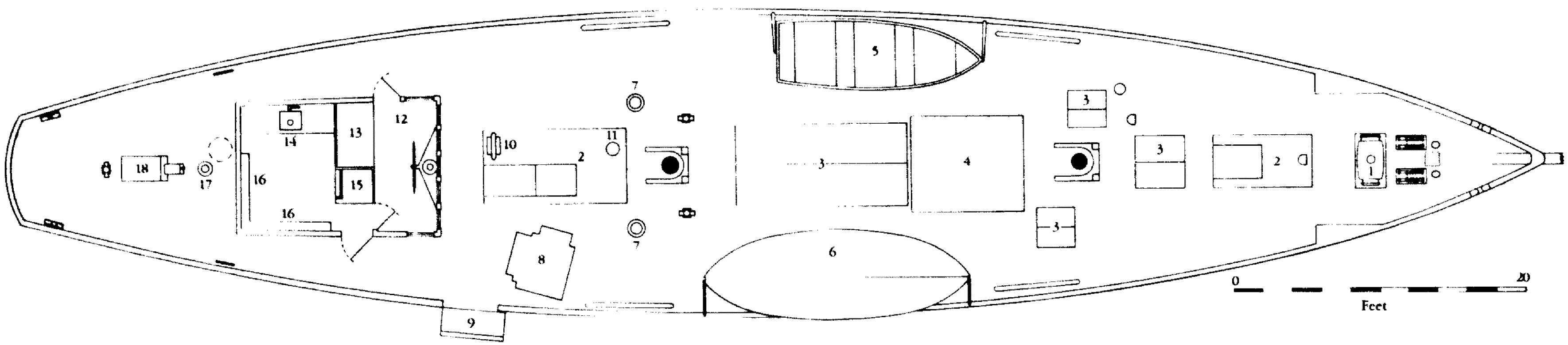


Fig. 4. Deck plan of the "E. W. Scripps": (1) anchor windless; (2) companionway trunk; (3) skylight; (4) dredging winch; (5) workboat; (6) lifeboat; (7) sail hoist; (8) hydrographic winch; (9) working platform; (10) radio direction-finger; (11) pelorus; (12) pilothouse; (13) chart table; (14) deck laboratory; (15) hatch to below-deck laboratories; (16) Nansen bottle rack; (17) standard compass; (18) steering-gear box.

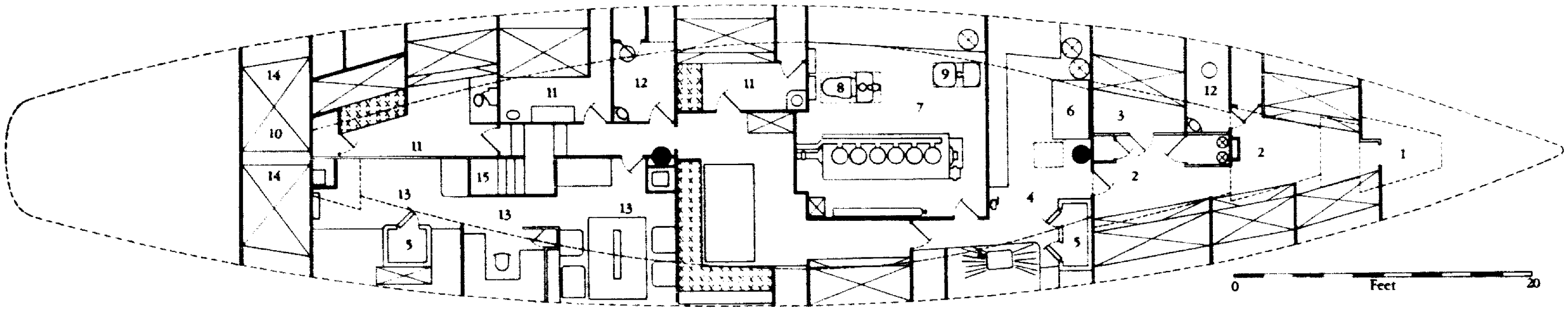


Fig. 5. Accommodation plan of the "E. W. Scripps": (1) chain locker; (2) forecastle; (3) captain's stateroom; (4) galley; (5) electric refrigerator; (6) galley range; (7) engine room; (8) auxiliary and generator; (9) air compressor; (10) saloon; (11) stateroom; (12) lavatory; (13) laboratories; (14) fuel-oil tanks; (15) companionway to deck.

Navigation equipment. - Most of the navigation equipment is in the pilothouse. In the after port corner is a 3- x 4-1/2-ft. chart table with drawers underneath in which most charts can be stowed without folding. The standard compass is an 8-in. liquid compass by Ritchie of Boston, mounted in a standard binnacle aft of the deckhouse. A 7-in. Ritchie compass mounted in the pilothouse serves as steering compass. A hand telegraph connects pilothouse and engine room. Also in the pilothouse is the recording log, connected to a small propeller mounted on the starboard side of the hull near the stern, which indicates on separate dials speed and distance run.

There is an electric siren mounted on the main masthead. A standard U.S. navy-type pelorus with illuminated dial is mounted on the portside of the companionway trunk. Also mounted on this trunk is a radio direction-finder, a Bludworth "Mariner" model with fixed loop. A sonic depth finder, Submarine Signal Company "Fathometer" model 710, is situated over the chart table in the pilothouse. In this model the shoal-water or visual-signal method is designed for depths to 250 fathoms, and the acoustic method for depths to 1000 fathoms. In actual practice either method can be used for taking soundings successfully in depths two or three times as great, depending upon the nature of the sea bottom and the condition of the sea.

An ordinary short-wave radio receiving set in the pilothouse, together with a single chronometer, provides adequate timekeeping. A 100-watt Sound Products radio-telephone installation in the saloon provides communication with other vessels so equipped, as well as with shore stations.

Hydrographic winch. - The hydrographic winch (fig. 7) was built in 1934 by Allan Cunningham of Seattle for the "Scripps," and, salvaged from the wreck in 1936, was rebuilt in 1937 for the "E. W. Scripps." It originally had two drums--one for hydrographic work and one for dredging--but since a separate and more powerful winch was obtained for the heavier work, the dredging section of the old winch was removed. The drum is of the double-cone friction type, the friction being applied by means of a double-helix mechanism operated by a hand lever. Braking is provided by an asbestos-lined brake band, also operated by a hand lever. The drum carries 20,000 feet of 5/32-in., 7 x 7-construction, galvanized plow-steel wire rope. The rope is laid evenly in close layers on the drum by means of an automatic spooling mechanism consisting of a carriage fitted with two vertical rollers which guide the wire. The rope is moved the length of this drum along guides by means of a diamond screw driven by gearing-and-sprocket chain from the drum. To the carriage of the spooling mechanism is attached a wire-metering device consisting of a sheave and a recorder with four dials indicating 10 to 10,000 meters, respectively.

The winch is driven by a reversing compound-wound Westinghouse motor (Type 33 SK), rated at 5 HP and 1150 r.p.m. at 115 volts; however, with the excess voltage obtainable from the generator and by using outside cooling the actual maximum continuous output is at least 7-1/2 HP and 1450 r.p.m. The motor is cooled by forced ventilation from an electric blower attached to the motor housing. The speed of the winch is regulated by a special portable rheostat which controls the generator-field voltage. This rheostat has over 60 control steps, special waterproof protection, and 15 feet of heavy-duty extension cord. When the winch is used, the rheostat is attached to the blower housing, where it is readily accessible to the operator. This motor can exert full torque continuously at any speed from 0 to 150 per cent of rated speed, and the rheostat gives very fine speed control at any load and speed. A starting and reversing switch is mounted on the side of the companionway trunk directly behind the operator.

From the drum the wire rope leads between the rollers of the spooling mechanism, under the metering sheave, which is mounted immediately back of the rollers, then through a sheave at the outer end of the starboard work boom and into the water at a convenient distance from the working platform. Between the boom and the sheave is an accumulator consisting of a double-compression spring which will sustain an outboard load of about 1500 lbs. before becoming totally compressed. The wire rope has a tensile strength of about 2600 lbs.

Dredging winch. - This winch (fig. 8) was built by the Stephens Adamson Company of Los Angeles. The drum carries 20,000 feet of 3/8-in. plow-steel wire rope constructed of six 19-wire strands and a wire-rope center. The breaking strength of this rope is approximately 26,000 lbs. The winch is powered with a totally enclosed Westinghouse (Type 103 SK) 115-volt electric motor. This non-reversing, compound-wound motor is rated at 15 HP at a speed of 1150 r.p.m. The motor is connected to a Ford-truck transmission having a clutch and gearshift with four forward speeds ranging from 6.4:1 to 1:1 and one reverse speed. The speed is further geared down through a 7:1 reducing-gear box and is then transmitted by chain drive to the drum with another reduction of 45:16. The drum is equipped with a friction brake and a ratchet gear with pawl. Brake and pawl are operated with hand levers, and the clutch with a foot lever. In addition to the gearshift the portable rheostat described under "Hydrographic winch" controls the motor speed. For starting and stopping the motor a push-button switch is installed in a convenient position. The wire rope is spooled and metered by a device similar to that on the hydrographic winch. From the spooling-metering device the wire rope leads through a snatchblock on the mainmast and then through a sheave slung by a heavy-duty compression spring from the end of the port working boom. On hauling in at normal motor speed the wire speed can be varied by shifting gears

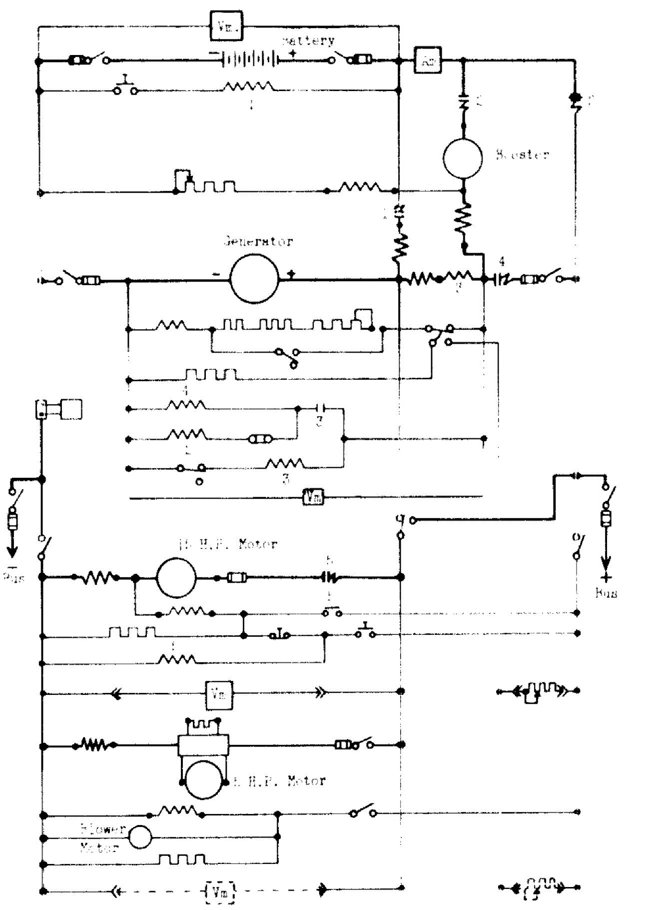


Fig. 6. Electric wiring diagram of the generator, battery, and winch motor circuits. The light system and the other motors are taken off the bus circuit, which is maintained at a constant potential of 115 volts, as described in the text. Coils represented by right angles are resistances; those by acute angles are magnets. The numbers connect the respective parts of relays.

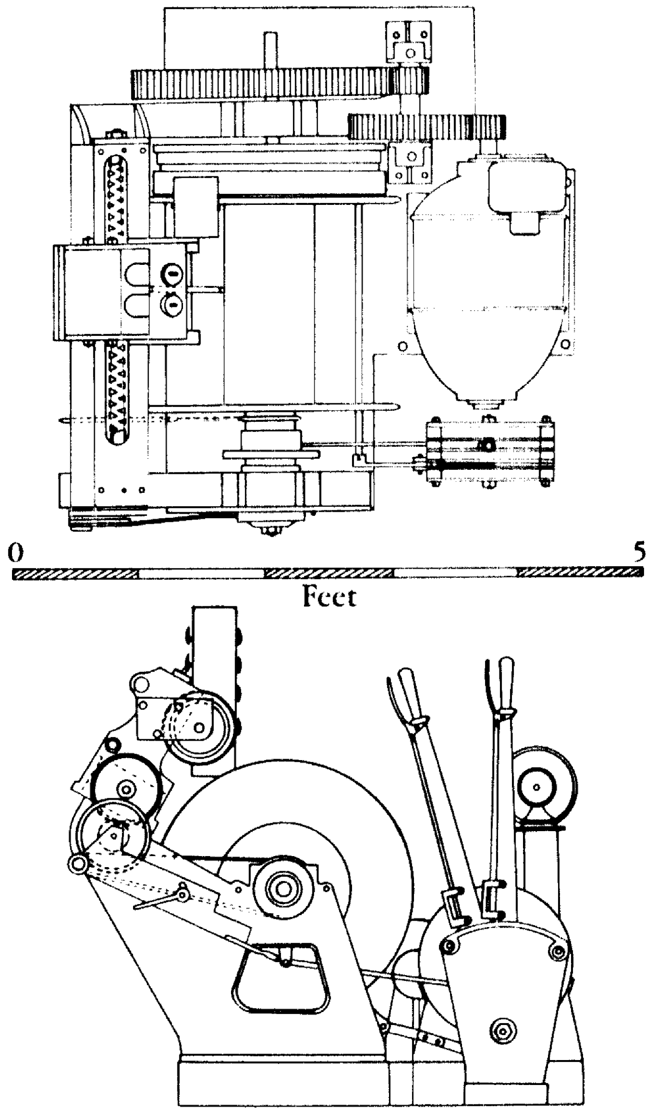


Fig. 7. Hydrographic winch.

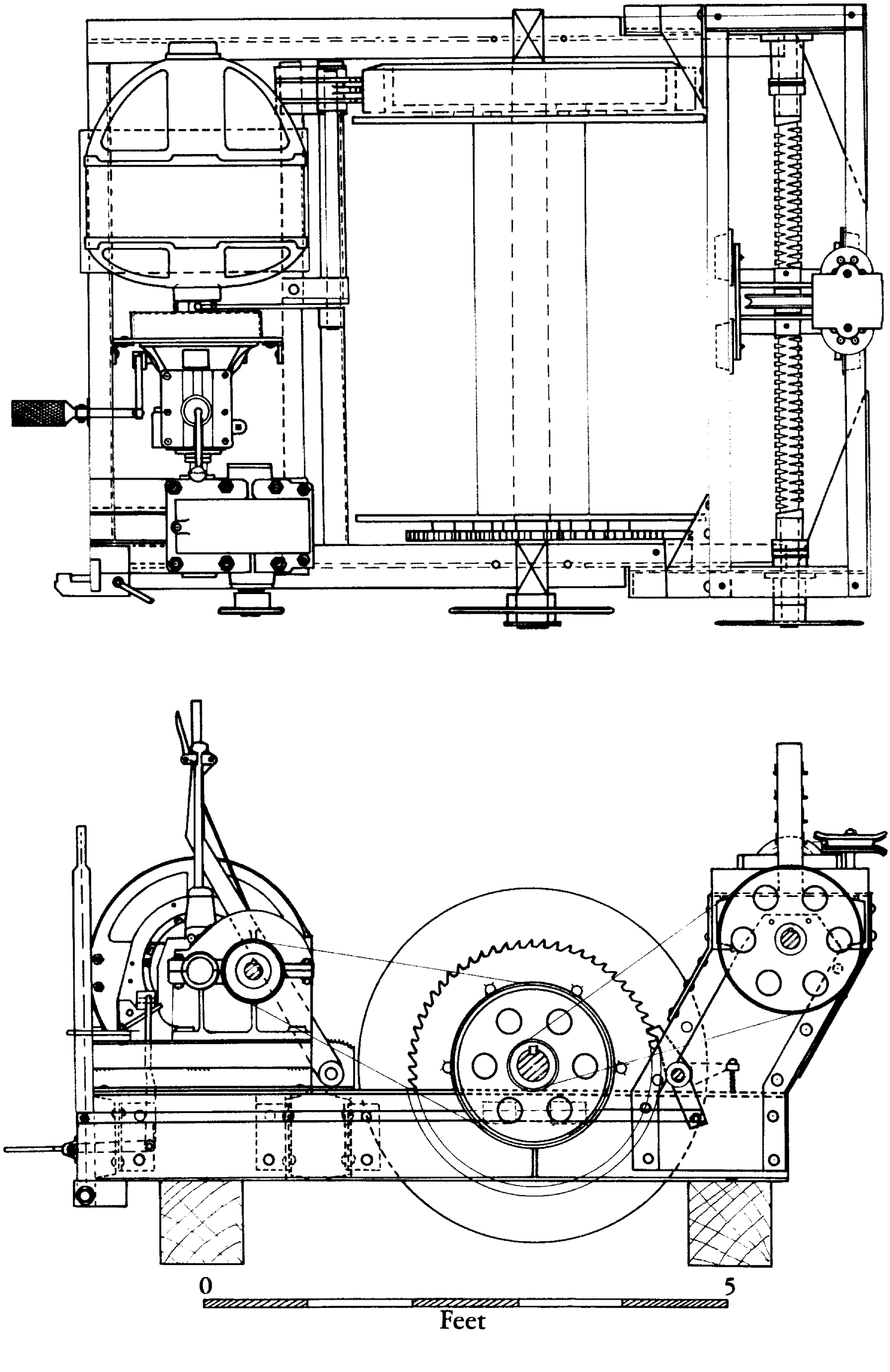


Fig. 8. Dredging winch.

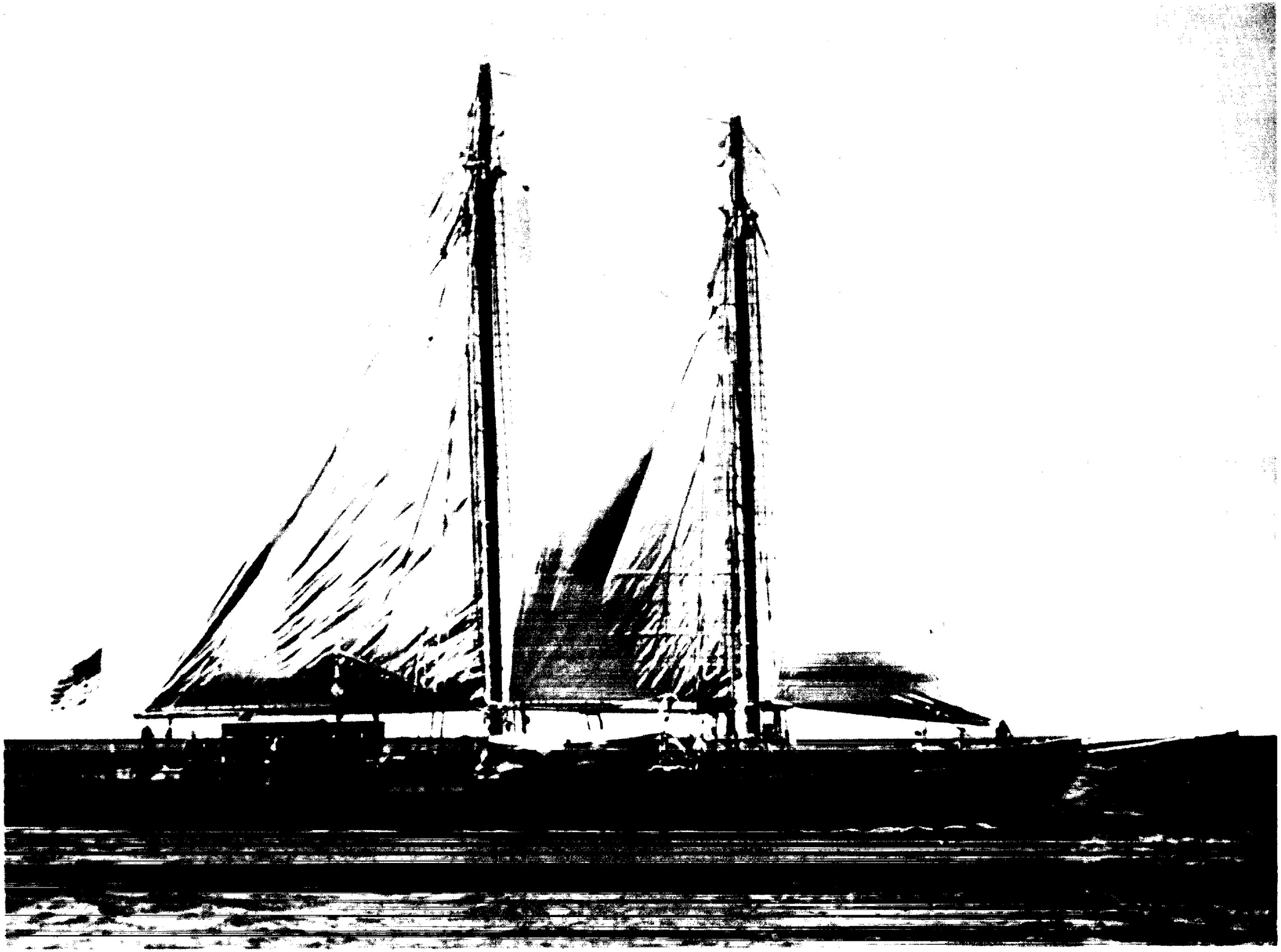


Fig. 9. "E. W. Scripps" off La Jolla, May, 1939.

from an average of about 40 feet per minute to about 300 feet per minute with a load of about 7,000 lbs.; in any gear the motor can be varied by the rheostat from almost nothing up to 150 per cent of rated speed.

Laboratories. - As shown in figures 4 and 5, there is a laboratory in the afterpart of the deckhouse and three others below deck. Athwart ship the deck laboratory measures approximately 9 feet, its port half being 7 feet long and its starboard half 10 feet. Forward on the starboard side a door leads to the deck, a second door to the pilothouse, and a hatch to the laboratories below. On the starboard-deck laboratory wall, aft of the door to the deck, and on most of the after wall there are racks for about twenty Nansen reversing water-collecting bottles. Under the Nansen bottle racks are racks for various types of bottles for water samples. Along the entire portside there is a laboratory bench with an acidproof sink and a salt-water hand pump. Under the bench are drawers and lockers.

The below-deck laboratories (fig. 5) occupy all the space to starboard of the center line and between the saloon and lazarette bulkheads. These laboratories are arranged in three sections. The after section, which connects directly with the deck laboratory, has shelves for storing water samples, an electric refrigerator, and a small laboratory bench. The center section at table height measures only about 6 ft. x 6 ft., but it has convenient working benches on three sides and can be darkened whenever necessary for colorimetric and similar work requiring reduced light. The forward laboratory section, measuring 8 ft. x 10 ft., has a typical chemical laboratory bench about 6 ft. long, with a central drain trough above which are shelves for apparatus and reagent bottles. At the end of the trough is a rack for holding chemical-proof buckets, into which can be discharged solutions that may damage the ship's drainage system. This room also contains a sink with fresh-water taps for washing glassware, lockers and shelves, and another laboratory bench situated under a section of the main companionway trunk where apparatus up to 6 ft. in height may be installed. All the laboratories are equipped with an adequate number of 115-volt, D.C. electric outlets. On each side of the bench in the forward laboratory there are two folding seats surfaced with mason-

Figure 9 gives a picture of the "E. W. Scripps" off La Jolla in May, 1939.

Since the above description was prepared, the following changes have been made:

Construction and Design. - In the fall of 1939 the bowsprit was cut off and the forward rail was built up to approximately 18 inches higher at the stem and tapering back to 6 1/2 inches higher at the forerigging.

Rigging. - In the fall of 1939 the foregaff was removed and the foresail was cut to a leg-of-mutton sail.

Deck Fittings. - In July, 1941 the skylight aft of the dredging winch was replaced by a solid trunk. In the forward third of the trunk where the batteries are stowed, small ventilators were placed on top of the trunk. In the after two-thirds of the trunk were placed ventilators for the engine room and saloon. The skylights over the galley were replaced by solid trunks with portholes.

Machinery. - In August, 1940 the Winton diesel engine was replaced by a 170-HP Gray marine diesel engine, the exhaust of which discharges through a short straight pipe passing through the engine-room trunk. Engine-room controls were installed in the wheelhouse.

PRELIMINARY DISCUSSIONS

RESULTS IN PHYSICAL OCEANOGRAPHY

By

RICHARD H. FLEMING

Tables A and B, contained elsewhere in this report, give interpolated values based on the physical and chemical observations obtained by the "E. W. Scripps" on six cruises off the coast of southern California in 1938. Charts show for each cruise the topography of the 0- and 200-decibar surfaces relative to the 500-decibar surface and the distribution of temperature and salinity at the surface and at depths of 50 and 200 meters. Additional charts show the dissolved-oxygen content at 200 meters and, for Cruises I, II, and III, the phosphate-phosphorus distribution at 50 meters. These charts will be briefly discussed, but a detailed examination of the observations will be postponed. Since the chief purpose of this investigation was to determine the nature of the annual cycle, the charts for the six cruises dealing with the same observations will be discussed together.

Surface currents. - The dynamic height anomalies of the surface relative to the 500-decibar surface are shown for the six cruises in charts 1 to 6. The contours have been drawn for intervals of one dynamic centimeter and the arrows indicate the direction of flow. The inset diagrams show the theoretical relation of the distance between the contours to the velocity.

The results of the "Bluefin" investigations in the spring and early summer of 1937[1] showed that the current in the offshore area was directed to the southeast. This current had a tendency to flow in the direction of the coastline to the north of Point Conception and then to deviate from the coast to the south of this point. Inside of the flow to the southeast, which can be considered as part of the California Current, was found a flow in the opposite direction which was called the Southern California Counter Current. In March, May, and June, 1937, this Counter Current reached only as far north as the Channel Islands. There, or to the southeast of the Channel Islands, the Counter Current turned around and followed the coast as an inshore current to the southeast. The Counter Current may be considered as part of two eddies, one cyclonic eddy which was usually centered near San Nicolas Island, and one anticyclonic eddy with its center near San Clemente Island.

Examination of charts 1 to 6 will show that in 1938 the currents had the same general character as in 1937, but in several instances the Counter Current continued north past Point Conception and usually the pattern of flow was complicated by the presence of eddies of different sizes, particularly in the offshore area.

During Cruise I, February 15 to 25 (chart 1), the California Current was broken up by a series of large eddies. The topography indicates a general transport toward the southeast and an appreciable influx of water from offshore in the southwestern part of the area. A well-developed trough separated the offshore flow and the Counter Current, which at this time extended northward beyond Point Conception as a clearly defined current. The anticyclonic eddy southeast of San Clemente Island was also fairly conspicuous.

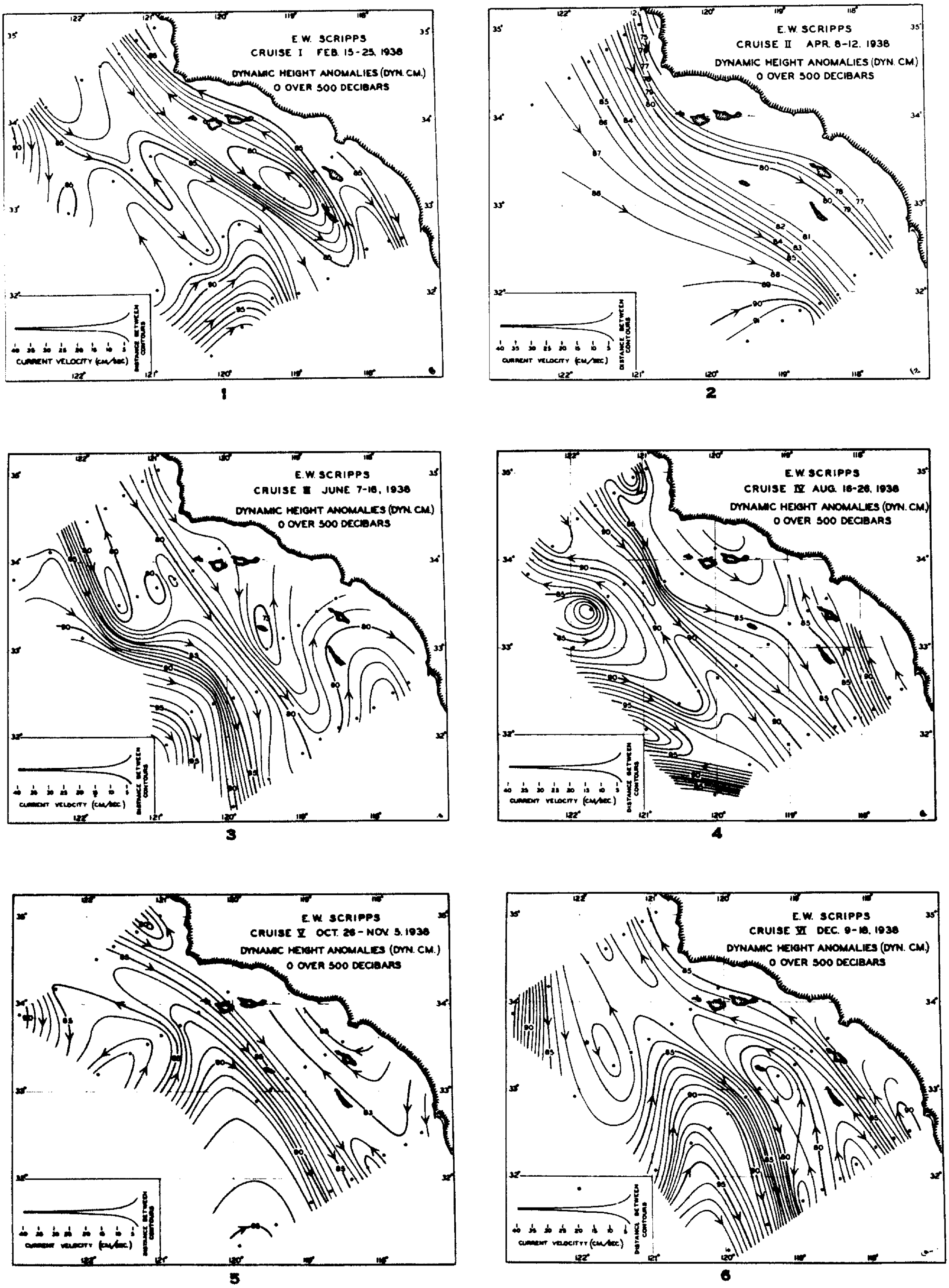
In comparison with the other charts, that for Cruise II, April 8 to 12 (chart 2), appears extremely simple, but this may be because of the fact that the representation is based on observations from only the northern and southern lines. However, the observations show no indication of the Counter Current, which on Cruise I was clearly demonstrated by the data from these two lines. There was a general flow toward the southeast covering the whole area, with some inflow from the west in the southwestern part.

The surface topography for Cruise III, June 7 to 16 (chart 3), shows that the California Current had increased in velocity and that the Counter Current was again present, but only in the southeastern part of the area. A trough extended southward from Point Conception but there was no indication of a flow to the north past Point Conception. The band of high velocities in the California Current is comparable to similar bands found on the second and third "Bluefin" cruises in May and June, 1937[2] and can, like these, probably be ascribed to the effect of transport of light surface water away from the coast by the prevailing northwesterly winds. The band of high velocity occurred along the boundary separating the warm and light offshore water from the colder and heavier upwelled water.

The surface topography for Cruise IV, August 16 to 26 (chart 4), shows an extremely irregular pattern of flow in the offshore area. There was no net transport of water to the southeast and the high velocities appear to be associated with large eddies. It is also interesting to note that instead of inflow from the west in the southwestern part of the area, there was at this

[1]H. U. Sverdrup and R. H. Fleming, "The Waters off the Coast of Southern California, March to July, 1937," Bull. Scripps Inst. Oceanog. (1941), vol. 4, no. 10, pp. 261-378.

[2]Ibid.



Charts 1-6.--Dynamic height anomalies, 0 over 500 decibars.

time a current in the opposite direction. The Counter Current was well developed, but from our observations it is not possible to decide whether this flow extended northward all along the coast or whether it turned southward again to form an anticyclonic eddy.

The surface topography for Cruise V, October 26 to November 5 (chart 5), is based upon an incomplete series of observations, since the third section was not finished. The general flow toward the south and east offshore was again modified by the inflow of water from the west. Although this water was ultimately carried away to the southeast, there is some indication of a northerly branch. Near shore there are several eddies which indicate a flow toward the northwest, but the flow has not the character of the fully developed Counter Current shown in the other charts.

The surface topography for Cruise VI, December 9 to 18 (chart 6), bears a striking resemblance to the data obtained on Cruise I, which indicates that there may be a rather clearly defined pattern in the annual cycle. Once again there was a general southeasterly flow offshore separated from the Counter Current by a trough line. The Counter Current extended northward beyond Point Conception as a well-defined flow. There was inflow from the west in the southwestern part similar to that encountered on most of the cruises.

From the results of these six cruises the variations in the surface circulation during 1938 may be described as follows: The pattern of flow is dominated by two currents flowing in opposite directions, namely, the California Current toward the southeast and the Counter Current toward the northwest. The nature of the circulation in the area covered by these investigations depends upon the relative development of these two currents. The presence of eddies of different sizes and probably of little permanency adds to the complexity of the pattern of flow as found on each cruise. During the winter months (charts 1 and 6) the Counter Current has its maximum development with the northward flow extending alongshore as far north as observations were made. During the winter months the part of the California Current represented by the southeasterly flow offshore is poorly developed, except in the southern part of the area where it is augmented by an inflow from the west. This inflow is greatest during the winter months. With the greater development of the northwest winds during the spring months the California Current increases in extent and velocity. As a result, the Counter Current is reduced or disappears entirely (chart 2). Following the period of maximum development of the California Current during the spring, there is a progressive breakdown of the southeasterly flow and a reestablishment of the Counter Current. The presence of numerous eddies in the offshore area indicates that the flow must be extremely unstable. The Counter Current has its greatest development during the winter months when it extends northward beyond Point Conception. Frequently a part of the Counter Current turns inshore and the flow is again to the south near the coast of southern California, as shown in charts 3 and 6.

The California Current and the Counter Current are separated by a trough line which extends southeastward from the vicinity of Point Conception. During the winter this runs some distance to the west of Point Conception but with the onset of the northwest winds in the spring it moves in toward the coast. During the spring and summer this trough line represents a divergence and is the zone of active upwelling, particularly near the coast.[3]

Currents at 200 meters. - For each of the six cruises the detailed topography of the 200-decibar surface relative to the 500-decibar surface is shown in charts 7 to 12. Even at this depth the pattern of flow is complicated and subject to variation. The southeasterly offshore current is not clearly defined or may be entirely absent, but there is always some transport to the north near shore. It is this northerly flow, termed the Coastal Deep Current,[4] which brings in southern water of a higher salinity and a lower oxygen content than those of the water found in the offshore area. The trough line has been shown to be a zone of active mixing. There is some similarity between the flow at the surface and at 200 decibars, but even on Cruise II, when there was no indication of the Counter Current at the surface, there was a northerly flow at this lower level. No annual cycle could be detected in the currents at this level.

Temperature and salinity distribution at the surface. - The distribution of temperature and salinity at the surface for each of the six cruises is shown in charts 13 to 18. The temperature distribution is always characterized by a tongue of relatively cold water extending south and east from the coastal area to the north of Point Conception. The extent and location of this tongue varies during the course of the year and in general corresponds to the trough separating the flow to the south from the Counter Current system. On all cruises the lowest temperatures were found near Point Conception and the highest temperatures in the offshore water and in the Counter Current off San Diego. The maximum and minimum temperatures encountered on each cruise and the stations at which they occurred are given in table 2. The location of the stations may be obtained by referring to figure 1 in the introduction to this report. During the spring and summer months the highest temperatures occurred off San Diego, but during the remainder of the year they were found in the southwestern part of the offshore area.

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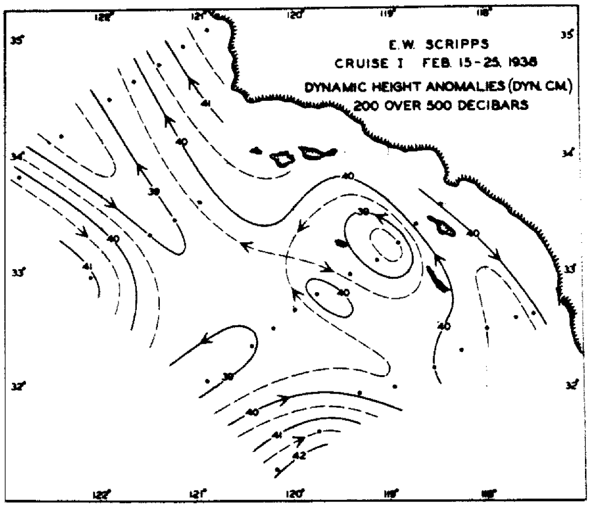
[3] Ibid.

[4] Ibid.



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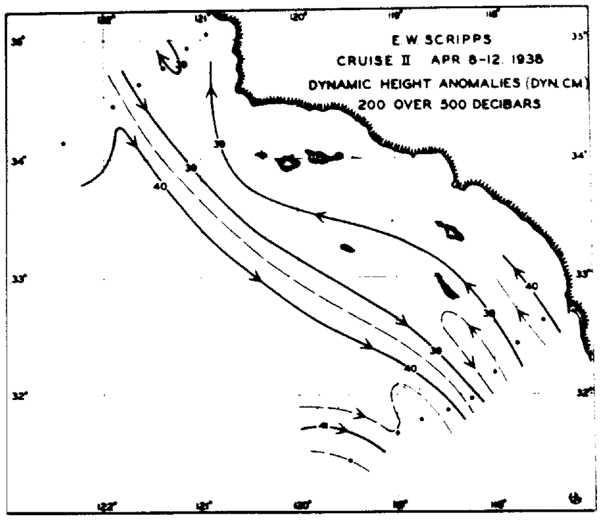

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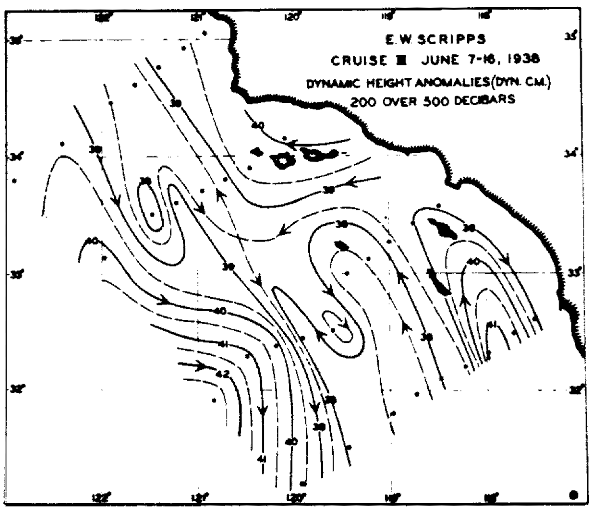

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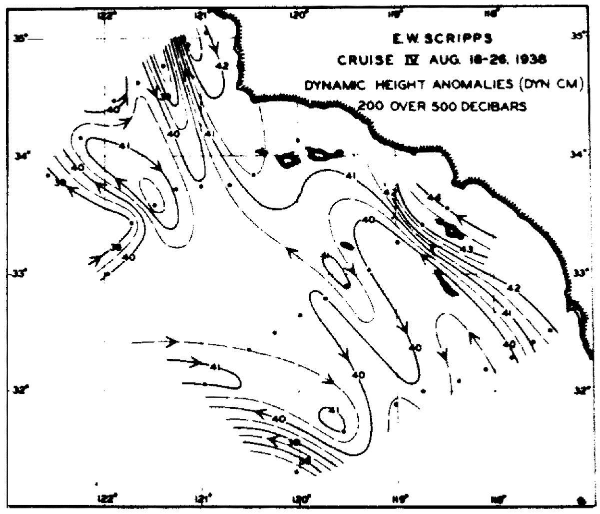

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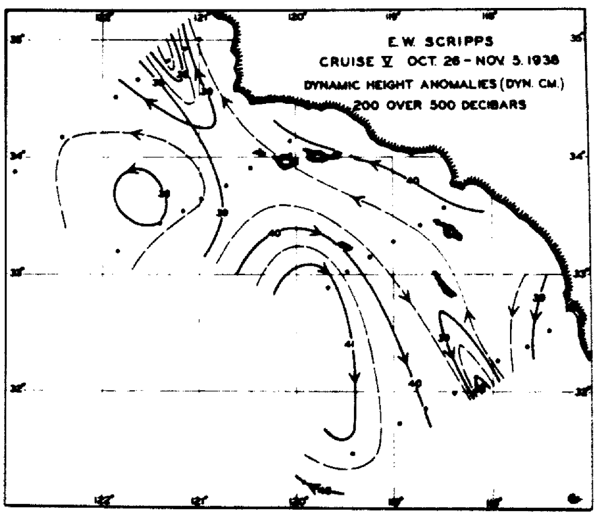

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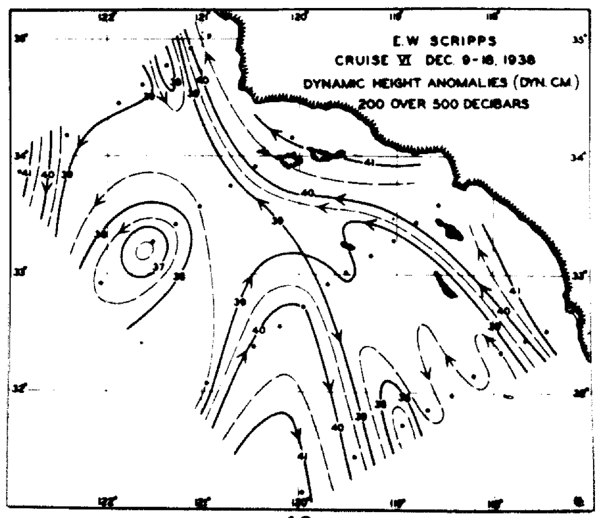

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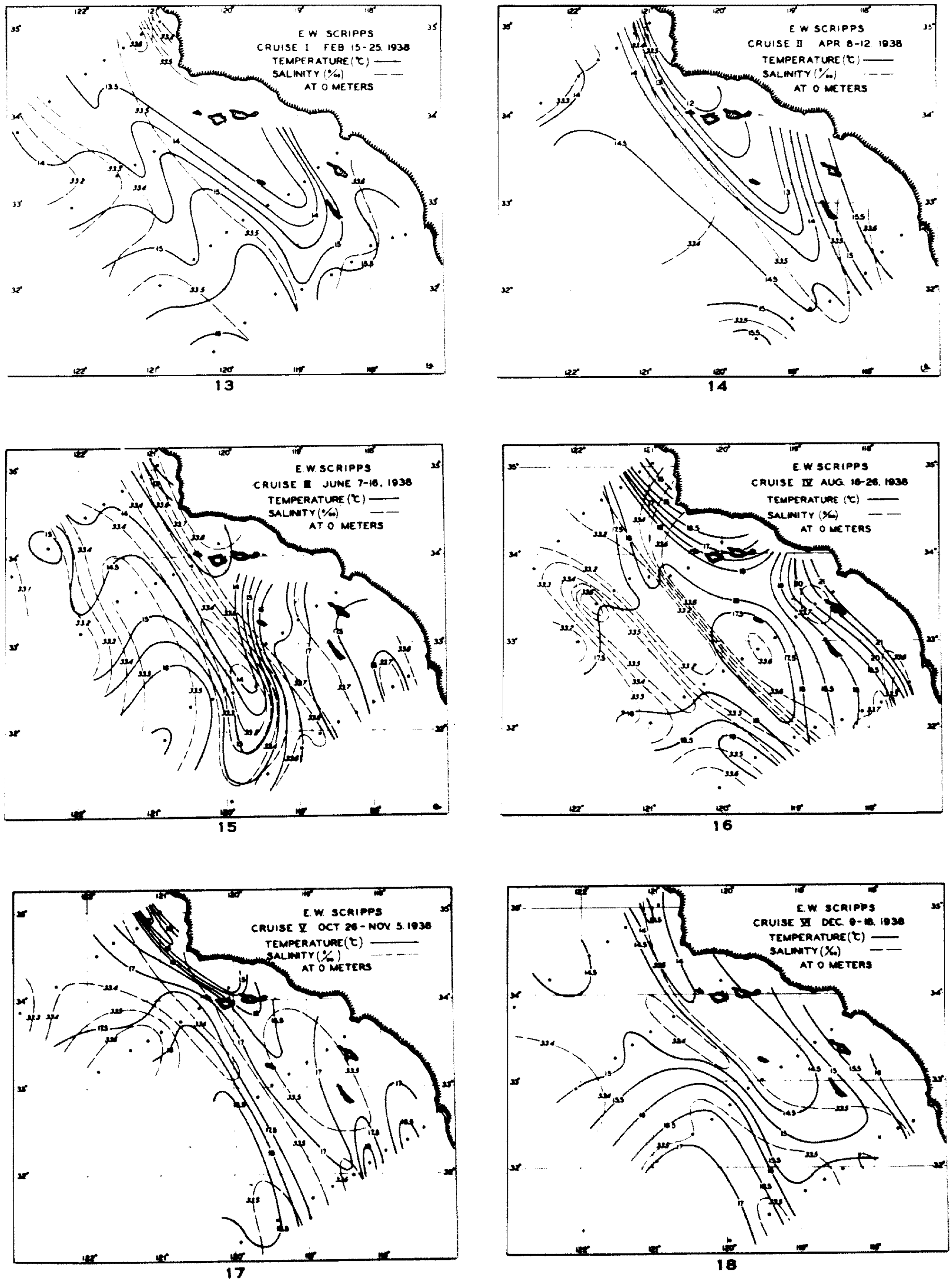
Charts 7-12.--Dynamic height anomalies, 200 over 500 decibars.



Charts 13-18.--Temperature-salinity at surface.

TABLE 2

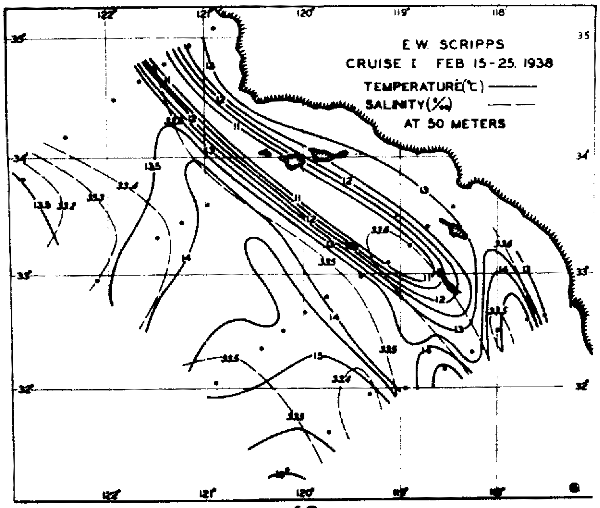
MAXIMUM AND MINIMUM TEMPERATURE AND SALINITY AT 0, 50, AND 200 METERS AND DISSOLVED OXYGEN AT 200 METERS

Depth (m.)	Values	Cruise I (30 stations)		Cruise II (14 stations)		Cruise III (33 stations)		Cruise IV (34 stations)		Cruise V (29 stations)		Cruise VI (33 stations)	
						TEMPERATURE (deg. C.)							
0 m...	Max.	16.47	(24)*	15.80	(31)	18.39	(30)	21.26	(31)	18.40	(24)	17.30	(24)
	Min.	13.17	(1)	11.30	(1)	12.35	(1)	14.75	(1)	13.93	(2)	13.50	(2)
	Range	3.30		4.50		6.04		6.51		4.47		3.80	
50 m...	Max.	15.90	(24)	14.40	(25)	15.35	(23)	16.67	(23)	18.35	(25)	17.17	(24)
	Min.	10.50	(23)	9.70	(1)	9.88	(13)	10.91	(15)	10.87	(3)	10.15	(18)
	Range	5.40		4.70		5.47		5.76		7.48		7.02	
200 m...	Max.	9.40	(31)	9.02	(30)	9.25	(29)	9.37	(31)	8.77	(25)	9.13	(31)
	Min.	7.75	(23)	7.73	(6)	7.43	(25)	7.53	(24)	7.45	(4)	7.48	(27)
	Range	1.65		1.29		1.82		1.84		1.32		1.65	
						SALINITY (°/oo)							
0 m...	Max.	33.64	(15)	33.68	(31)	33.82	(13)	33.74	(9)	33.65	(9A)	33.59	(27)
	Min.	33.16	(7)†	33.29	(6)	33.09	(7)	33.13	(6,10)	33.23	(7)	33.38	(8)
	Range	0.48		0.39		0.73		0.61		0.42		0.21	
50 m...	Max.	33.66	(18)	33.88	(31)	33.86	(13)	33.69	(13)	33.68	(28A)	33.74	(27)
	Min.	33.17	(7)	33.30	(5)	33.09	(8)	33.01	(5)	33.11	(11)	33.22	(11)
	Range	0.49		0.58		0.77		0.68		0.57		0.52	
200 m...	Max.	34.30	(31)	34.28	(31)	34.30	(18)	34.24	(9)	34.13	(28A)	34.15	(11)
	Min.	33.86	(24)	33.86	(25,27)	33.76	(23)	33.89	(6)	33.93	(24)	33.84	(24)
	Range	0.44		0.42		0.54		0.35		0.20		0.31	
						DISSOLVED OXYGEN (ml/L)							
200 m...	Max.	3.15	(20,24)	3.26	(25)	4.04	(23)	3.25	(5,23)	3.56	(24)	3.63	(24)
	Min.	1.12	(31)	0.87	(31)	0.87	(18)	1.10	(12,9A)	1.40	(12)	1.62	(27A)
	Range	2.03		2.39		3.17		2.15		2.16		2.01	

*Figures in parentheses indicate stations.
†Salinity at station 1, 33.10 °/oo.

The maximum and minimum salinity for each cruise is given in table 2, from which it is seen that the variation is rather small. Minimum values were always encountered in the offshore water with the exception of Cruise I, when water of low salinity, apparently diluted by rainfall and runoff, was found to the north of Point Conception. The maximum salinities were usually associated with low temperatures and were located in or near the trough. The surface salinity in the Counter Current was generally intermediate between that of the offshore water and that of the upwelling water. The pattern of distribution on any one cruise was frequently complicated by the presence of eddies which had transported water of one type into that of a different character. The latter statement applies to the conditions at other levels as well as at the surface.

Temperature and salinity at 50 meters. - The distribution of temperature and salinity at 50 meters for each of the six cruises is shown in charts 19 to 24. The extreme values and the ranges in conditions are given in table 2. At this level the distribution of conditions is more complicated than that at the surface, owing to the greater range in temperature and salinity. The greater range may be attributed to the fact that the convection layer varied from depths considerably less than 50 meters to more than 100 meters. The convection layer was generally thickest in the offshore area, within which the temperatures at 50 meters were therefore similar to those at the surface. Near shore the convection layer was thin and, consequently, low temperatures were found at 50 meters. Lowest temperatures and highest salinities were usually found in or near the tongue extending south and east



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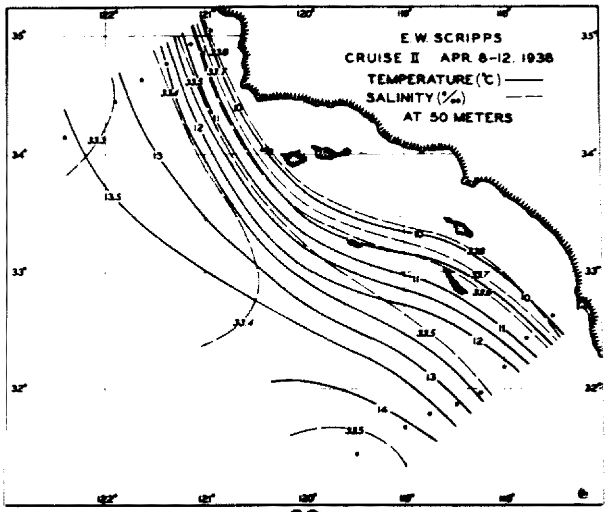

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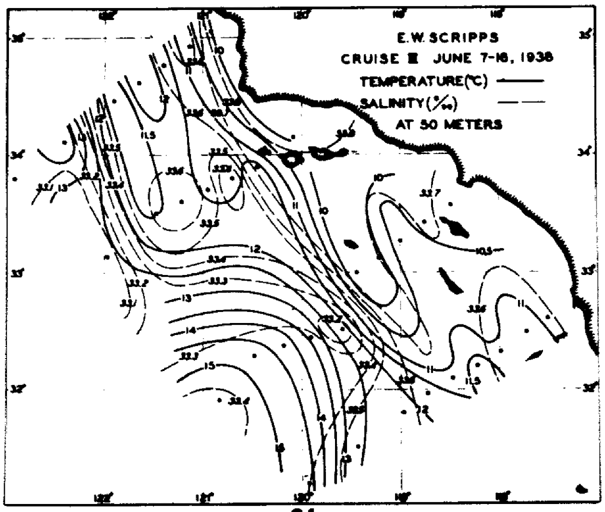

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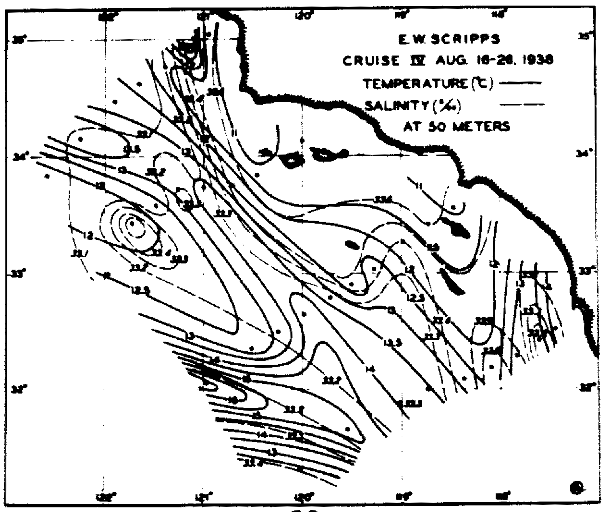

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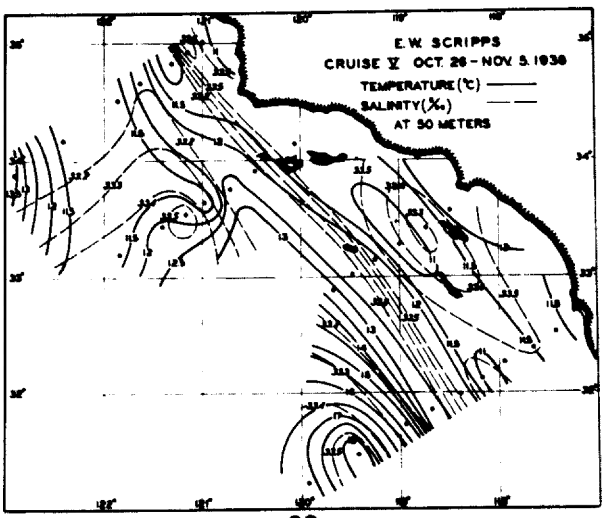

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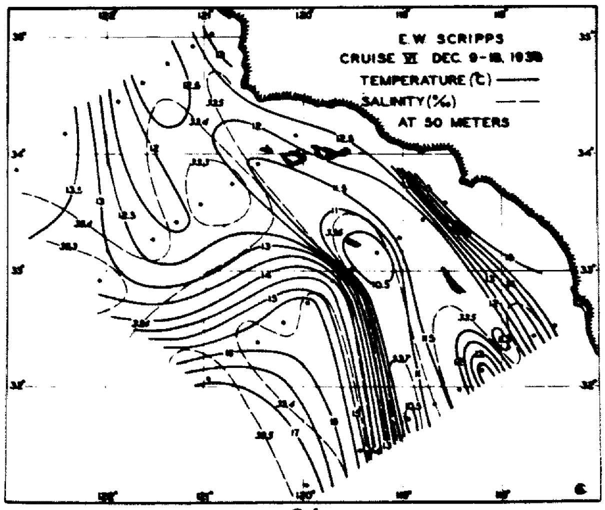

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Charts 19-24.--Temperature-salinity at 50 meters.

from Point Conception and corresponding to the trough line. Maximum temperatures and minimum salinities were always located in the offshore area and a secondary temperature maximum occurred off San Diego.

Temperature and salinity distribution at 200 meters. - The temperature and salinity distribution at 200 meters for each of the six cruises is shown in charts 25 to 30. The extreme values and the ranges in conditions are given in table 2. The pattern of distribution in each instance is rather complicated but the range in temperature and salinity is much less than at the higher levels. The most marked difference at this level is that the minimum temperatures are now associated with minimum salinities, usually in the offshore area, whereas maximum temperatures and salinities always occur in the Counter Current system. Sometimes this generalization does not hold, because of the transport of water of one character into that of another type. Since the seasonal climatic cycle cannot be directly effective at this depth, the fluctuating conditions must be ascribed to the shifting currents.

Dissolved oxygen content at 200 meters. - The distribution of dissolved oxygen at a depth of 200 meters for each cruise is shown in charts 31 to 36. The extreme values and the range encountered on each cruise are given in table 2. The minimum values were always found in the Counter Current or in the trough. Occasionally isolated minima, associated with eddies, occurred in the offshore water. The low oxygen content inshore is a characteristic of the water of the Coastal Deep Current, as shown by Sverdrup and Fleming.[5] The maximum values for dissolved-oxygen content always occurred in the offshore water and generally in the southwestern part of the area examined.

Phosphate content at 50 meters. - The dissolved-inorganic-phosphate content found on Cruises I, II, and III, at a depth of 50 meters is shown in charts 37 to 39. The values are given as microgram-atoms per kilogram. The pattern of distribution in general follows that of the temperature, indicating that upwelling is the chief process bringing phosphate to the surface layers. Maximum values were always found north of Point Conception and in the trough line extending south and east. Minimum values always occurred in the offshore water and generally in the southwestern part of the area examined. The highest value was found off Point Conception on Cruise III, showing that the upwelling provided a plentiful supply of nutrients during the vegetative season.

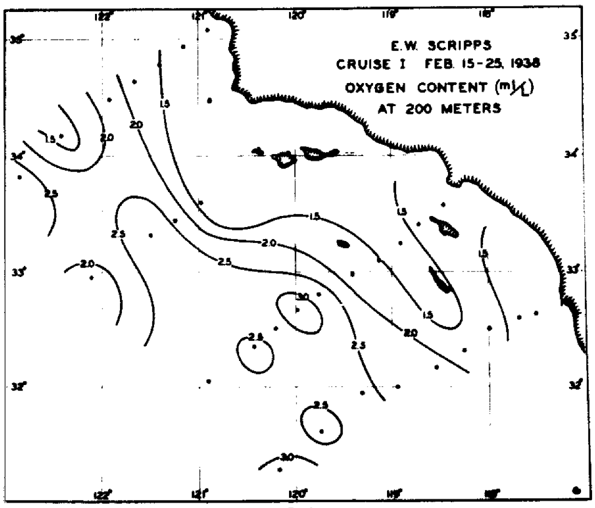
Currents and the distribution of properties. - Since the dynamic topography depends upon the distribution of density, one must expect a parallelism between the streamlines and the horizontal distribution of the isotherms and isohalines, especially of the former. That such an agreement exists may be seen when the surface topography for any cruise is compared with the corresponding temperature distribution at 50 meters. Changes in the pattern of flow between cruises are similar to the changes in the distribution of temperature and salinity. Since fluctuations occurred at depths below the zone of direct influence of the local external climatic factors, it seems reasonable to attribute the major part of the changes in conditions to variations in the pattern of flow rather than vice versa. Parts of the changes in the currents may be due to local factors such as the winds, but others are probably brought about by agencies operating beyond the area covered by our investigations.

The cyclic changes in conditions which might be expected to occur during the course of the year are obscured and complicated by a number of factors. The area covered by these investigations is one of large variations in the lateral distribution of temperature, salinity, oxygen, and probably other components. This is due partly to the gradients associated with the flow, but chiefly to the effect of upwelling and to the different character of the subsurface water in the offshore area and in the Coastal Deep Current near the coast. Consequently, the changing currents carry with them water of widely differing character and, in addition to the changes caused by the shifts in the circulation, lateral mixing and the breaking away of eddies lead to a very complicated pattern which to a great degree obscures any annual cycle.

Near the coast upwelling tends to reduce the temperature and to increase the salinity in the surface layers. The upwelling is most active during the spring and early summer months and tends at that time to lower the temperatures when normally there should be warming of the surface layers. From the data in table 2 it is seen that at 0 and 50 meters minimum temperatures always occurred near Point Conception and in or near the trough, and that the annual range of the minima was much less than the range of the maxima. That is to say, in the area off Point Conception and toward the southeast, the upwelling tends to maintain low and rather uniform temperatures whereas the temperature in the offshore area and in the Counter Current system are rising.

Part of the complexity of the distribution of properties is due to eddies which transport water of one type into that of another type. These eddies are apparently associated with the shifting currents or result from the instability of the current system. These eddies are frequently of such small dimensions that they were only detected at single stations. Consequently the complexity of the distribution shown in the charts depends to an appreciable degree upon the fact that the observations were obtained at a relatively large number of closely spaced stations.

[5] Ibid.



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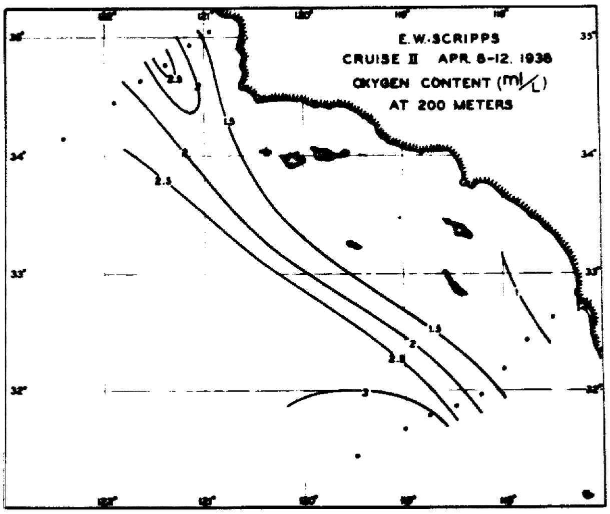

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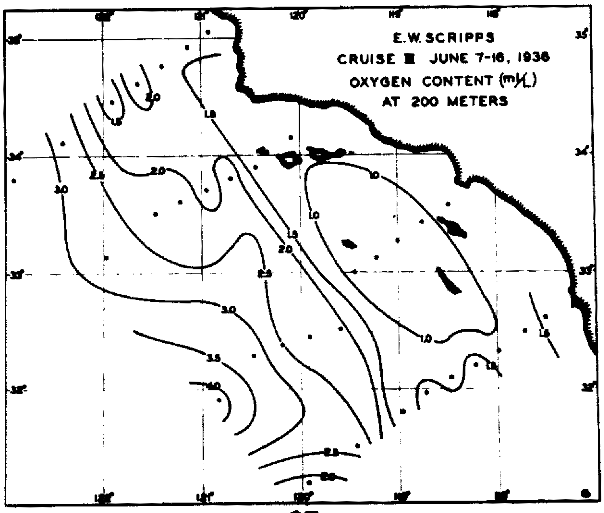

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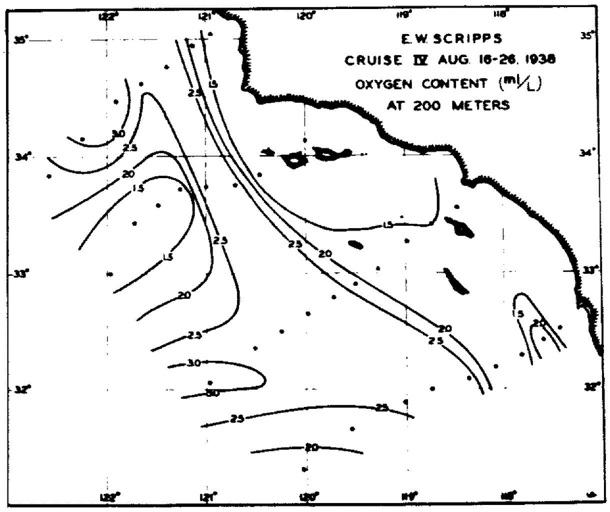

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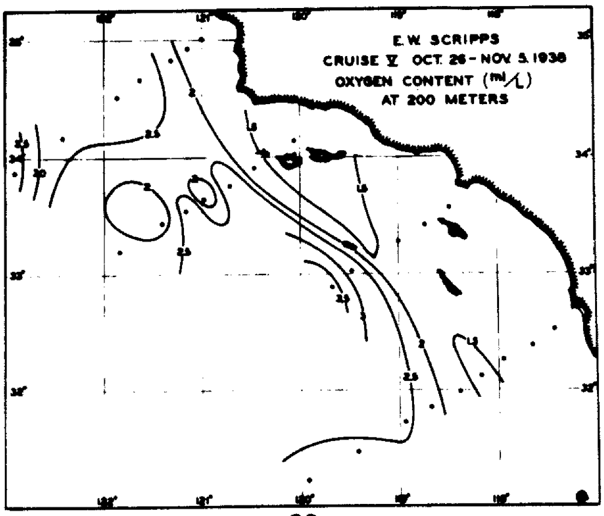

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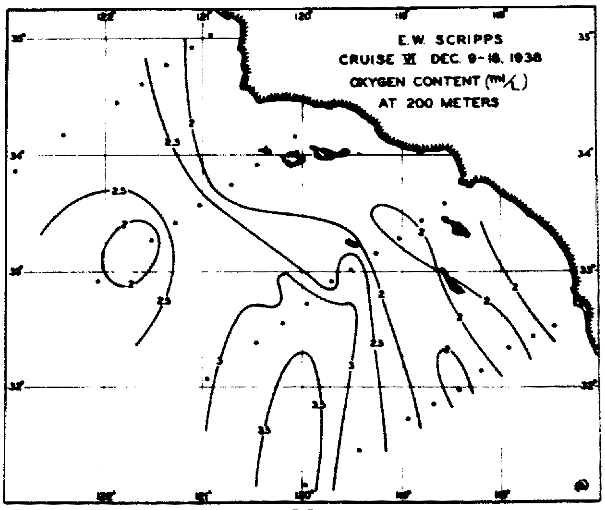

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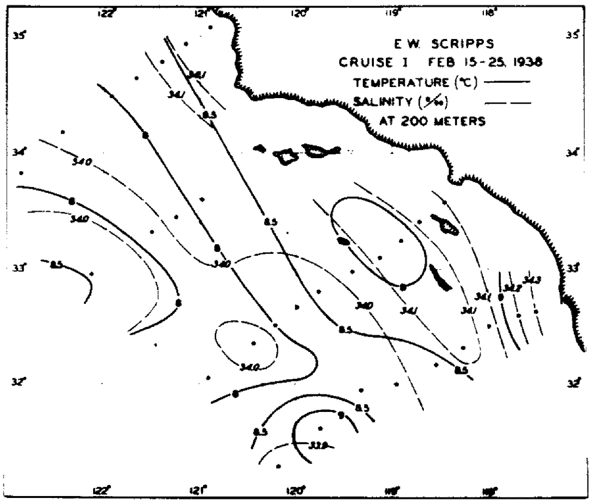
Charts 25-30.--Temperature-salinity at 200 meters.



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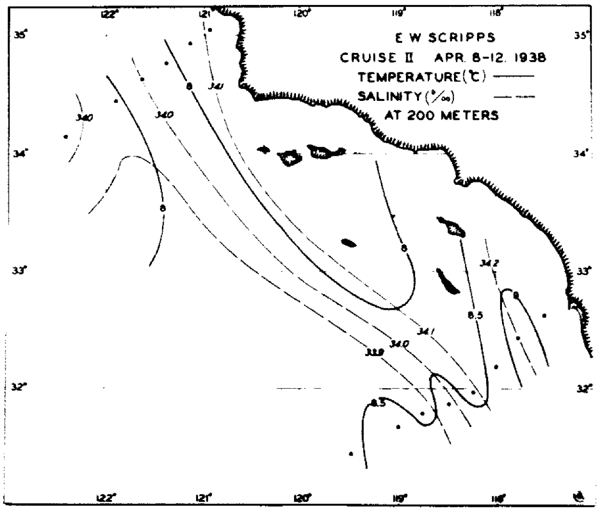

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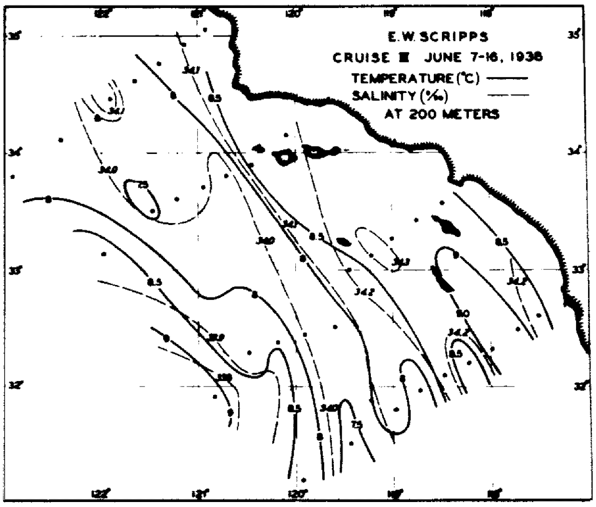

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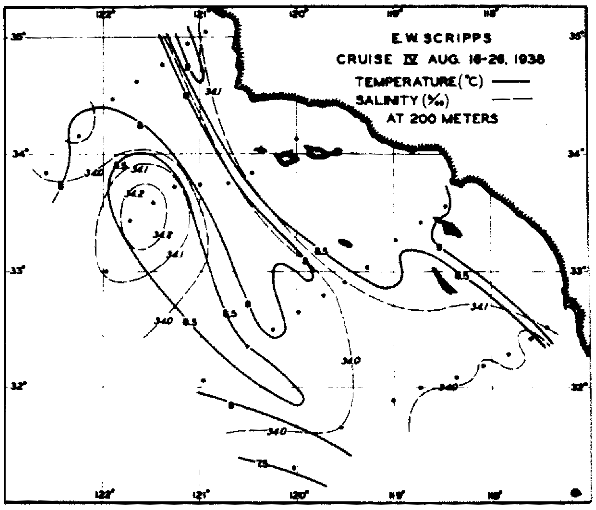

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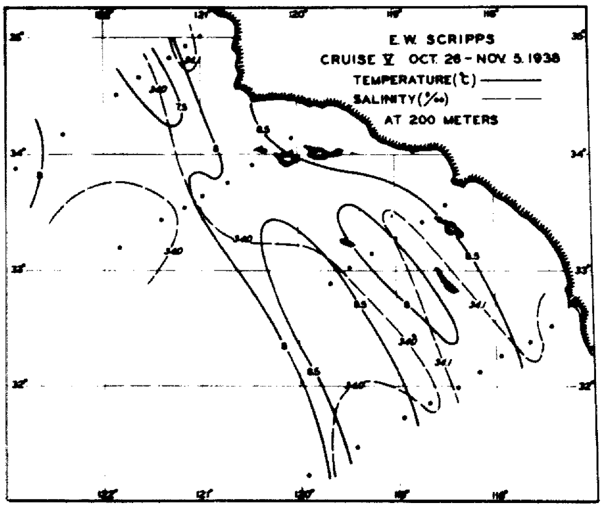

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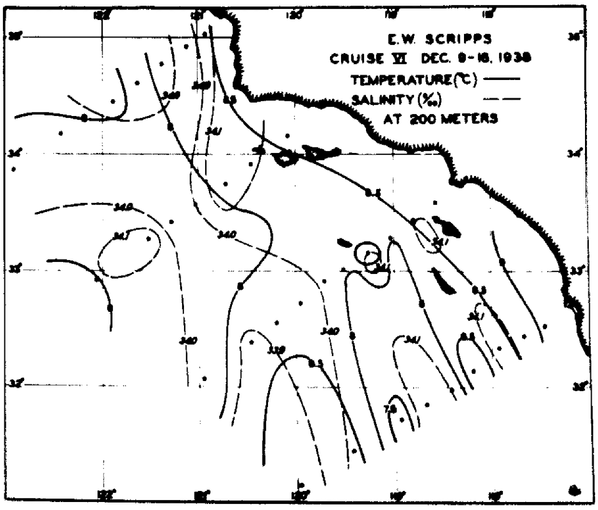

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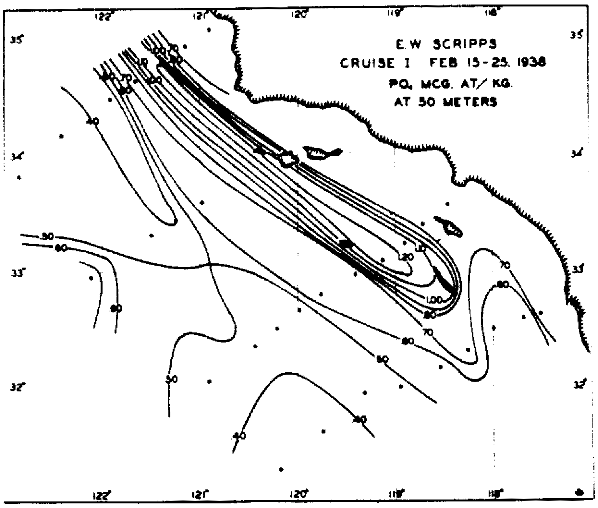
Charts 31-36.--Oxygen content at 200 meters.



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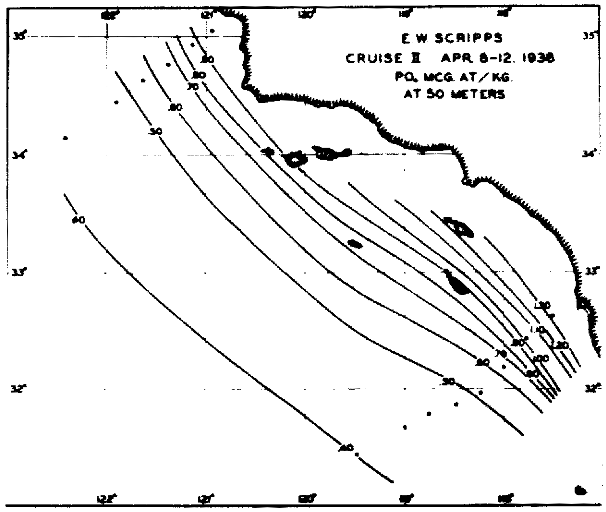

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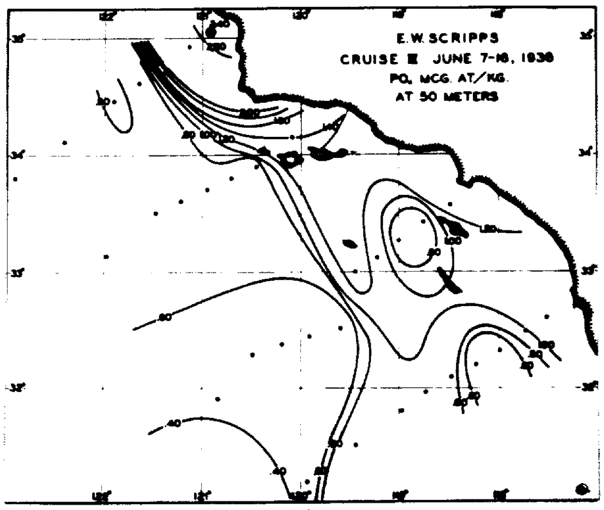

39

Charts 37-39.--Phosphate phosphorus at 50 meters.

Owing to the complexity of the pattern one can evidently not expect to find a repetition of identical conditions each year. Examination of the charts of the distribution of temperature and salinity at the surface, at 50, and 200 meters, and of the dissolved oxygen at 200 meters shows, however, that the general pattern is the same for all cruises although the absolute values vary. Therefore, emphasis can be placed on the maximum and minimum values contained in table 2. The location of the stations indicated in this table can be found in figure 1 in the introduction to this report (facing page 1).

It follows from the foregoing discussion that the area covered by these investigations may be roughly divided into three zones: First, the Offshore Zone, where there is generally a flow toward the south or southeast. In this area the surface temperatures are, as a rule, relatively high and the salinities low, and the convection layer is thick. Second, the Trough Zone, extending south and east from the area north of Point Conception. This represents the zone separating the southeasterly flow from the Counter Current flowing toward the north. Within this zone upwelling, particularly during the spring and summer months, maintains low temperatures and relatively high salinities in the surface layers, and the convection layer is thin. Third, the Counter Current or Coastal Zone, where there is flow either toward the north or, close to the shore, toward the south. Except in winter this zone does not extend farther north than Point Conception and in spring it may be entirely lacking. In this zone the surface temperatures are again relatively high and the salinities are intermediate between those of the other two zones. The convection layer is usually rather thin.

It will be seen that these zones are not geographical but that they depend upon the pattern of flow. Consequently, individual locations may be under the regime of different zones at different times of the year. However, on the basis of this division into zones, a fair estimate of the distribution of conditions can be derived from the pattern of flow. On the other hand, if the temperature distribution in the upper layers, say, down to a depth of 100 meters, is known, a very good idea of the pattern of circulation can be obtained.

In conclusion, some suggestions are presented with respect to the possible character of the annual changes of the currents off the coast. The fact that the Counter Current is most conspicuous in winter when the winds are variable indicates perhaps that the inshore flow to the north represents a "normal" state which is developed in the absence of strong external influences. Perhaps the Counter Current, which, in winter, can be traced all along the coast of California, represents a counterpart to the inshore flow to the southeast along the east coast of the United States, on the left-hand side of the Gulf Stream. If this assumption is correct, the prevailing northwest winds in spring and early summer bring about "abnormal" conditions which are caused by the upwelling along the coast. When the external influence of the wind decreases, large eddies develop (fig. 4), but gradually the "normal" state is reëstablished.

The fact that below 200 meters the Counter Current appears to be equally well developed in all seasons perhaps supports the conclusion that the Counter Current represents a "normal" feature which in the upper layer is disturbed by the prevailing winds of the spring and early summer.

DIATOMS

By

W. E. ALLEN

Throughout the six cruises of 1938 (February, April, June, August, October, December) not only was the group of diatoms far the most prominent in catches of phytoplankton, but the representation of other groups was negligible to about the same degree. Even though such forms as coccolithophores and smaller dinoflagellates may have been lost excessively through the meshes of the filtration net (200 meshes to linear inch), their presence should have been observable if their abundance had been great at any time. Therefore, it appears reasonable to assume that attention to diatoms is sufficient for present purposes and that other groups represented in the phytoplankton may be neglected.

After microscopic examination of the 1130 catches of phytoplankton I felt most impressed with the fact that diatoms were represented in all sections at all seasons. Even in those catches yielding numbers too small for statistical significance there were enough specimens to constitute an important source of supply for production or renewal of large populations under favorable conditions. In the region investigated, taken as a whole, nearly two-thirds of the catches showed numbers of 500 diatom cells per liter, or more. The line about one hundred and forty miles southwest from the vicinity of Santa Barbara showed greatest consistency in producing significant numbers, more than two-thirds of the catches yielding 500 cells or more; but the northern line was nearly as good, with almost exactly two-thirds containing such numbers. The poorest line was the one southwest from Los Angeles Harbor, only a few more than one-third of the catches reaching or exceeding the 500 mark.

There is no possibility of determining from existing data the true relationships between alongshore and offshore populations, but it is natural (and reasonable) to suppose that there is a fairly close correspondence of periods of increase and decrease in abundance. Uncompleted manuscript records of surface catches made daily at two shoreline stations (Point Hueneme near Santa Barbara and La Jolla near San Diego) indicate that all but one (November) of the six cruises of 1938 were made in periods of decline of abundance or of a minimum abundance at these two stations. Obviously, the noteworthy or large numbers found in many catches offshore may have been remnants of still larger numbers in process of reduction, or they may have been derivatives of inshore populations in process of increase, or they may have been entirely independent in origin. In consideration of such wide differences in possibilities no positive conclusion can be completely acceptable at present. However, a tentative suggestion may be made that constancy of representation of diatom populations is to be more generally expected offshore throughout the whole year, irrespective of seasons.

At most offshore stations the abundance at the surface level was closely indicative of the size of the population total at any particular station. Therefore, comparison with shoreline surface catches is surely permissible. But, in any event, the clear showing of declining production at two stations inshore at the time of five out of six cruises constitutes warning that the problems of the range of either actual or potential annual productivity of offshore areas are still open questions. Nevertheless, the records do show that a number of offshore stations may yield phytoplankton abundantly.

As far as the data for these cruises are concerned, there is strong evidence that certain offshore areas are more productive, certainly more consistently productive than those near shore. An exception exists in the two stations near Santa Rosa and San Miguel Islands. Still, these two stations lack consistency, one showing extreme abundance in only one of the four times sampled, and the other showing insignificant numbers in one of the four times sampled. Of other stations within twenty-five miles offshore the two on the northern line showed numbers greater than those at stations more than fifty miles from shore in one out of six times sampled. Nearly the same statement applies to the stations near Los Angeles Harbor and to the two stations near San Diego.

As far as seasonal differences in production of diatoms is concerned, the evidence from the six cruises seems fairly clear and corresponds very well with the data obtained in most years from daily catches at shore stations. Thus the largest abundance for the year was in April or June at most stations of the cruises. However, station 30 (near San Diego) showed largest numbers in October, and it is possible that certain other stations would have shown different times of maxima if they had been sampled on all six cruises. Such exceptions are sufficient to show that biological sequences through a year cannot be determined positively without a high degree of continuity of observation.

As has been suggested in a preceding paragraph, the surface level usually indicates fairly well conditions of abundance or lack of abundance of plankton diatoms at individual stations. However, data from this level are not fully reliable as indicators of greater or lesser abundance; they may be widely misleading if accepted as indicators of total numbers for the station or for particular levels below the surface. These facts are well illustrated by the northern line where, in twenty-eight yields of significant numbers, there were only seven at which the surface numbers were as large as those at certain lower levels. In a few instances the numbers at a level below the surface were more than four times as large as those at the surface. Still it is true that the surface level held the lead in abundance a little more often than any other. The thirty-, forty-, and fifty-meter levels led in abundance almost as often. Large abundance at any level was nearly always accompanied by abundances nearly as large at two neighboring levels.

At some time in the year more than thirty different species of diatoms, representing fourteen genera, were sufficiently prominent to rank among the leading five at one or more stations. There was no significant difference in the lists of names from different parts of the area surveyed, and the prominent forms were all well known from daily catches at shore stations.

NOTES ON ZOÖPLANKTON

By

MARTIN W. JOHNSON

Together with other oceanographic observations taken during the 1938 regular cruises (Cruises II to VI of the "E. W. Scripps" off the southern California coast), there were included also net collections for the animal plankton. These collections were taken with a regular Nansen closing net 3 meters long with an opening of 70 centimeters. The bolting cloth used in construction of the net was Nos. 000, 0, and 8.

It was originally planned to take vertical net hauls from 500 to 200 meters and from 200 to 0 meters at each station. However, as indicated below, this plan was carried out at only three stations of Cruise II. Because of the amount of time needed for the joint observations, it was necessary to eliminate the lower-depth hauls. Though collections from depths greater than 200 meters are highly desirable, it was deemed that most of the zoöplankton population would be sampled in the 200- to 0-meter hauls. Study of the bathypelagic population is, therefore, deferred for the time being.

A summary follows of the number of stations occupied for each cruise at which net collections were made. Occasionally the wind was too strong to operate the net at all of the scheduled stations, but for each cruise the stations were usually well distributed over the area included.

Cruise II, April 8-12...3 stations: 500-200 m. and 200-0 m.
4 stations: 200-0 m.
(This cruise was not completed owing to storms.)

Cruise III, June 7-16...25 stations: 200-0 m.
Cruise IV, Aug. 16-25...34 stations: 200-0 m.
Cruise V, Oct. 26-Nov. 5...28 stations: 200-0 m.
Cruise VI, Dec. 9-18....27 stations: 200-0 m.

In addition to the above regular collections, some twenty surface hauls were made with small nets for collection of material for life-history studies.

Up to this time the collections have been only partially analyzed, and it is possible here to indicate only a few of the outstanding characteristics of the population as shown thus far.

Volumes. - In general, it may be said that the total volumes (when free from diatoms) of plankton caught at each station are characterized by being only moderately rich and rather uniform, especially for adjacent stations. The anomalies are not as a rule haphazard in appearance (fig. 10), but they indicate that extensive, sufficiently large, patches or streaks of zoöplankton exist in such a way that several stations may come to fall within a patch. It is difficult to relate the volumes to the hydrographic features, though there is some indication that these general patches are perhaps drawn out in a general north-south direction more or less following the main contour of the currents.

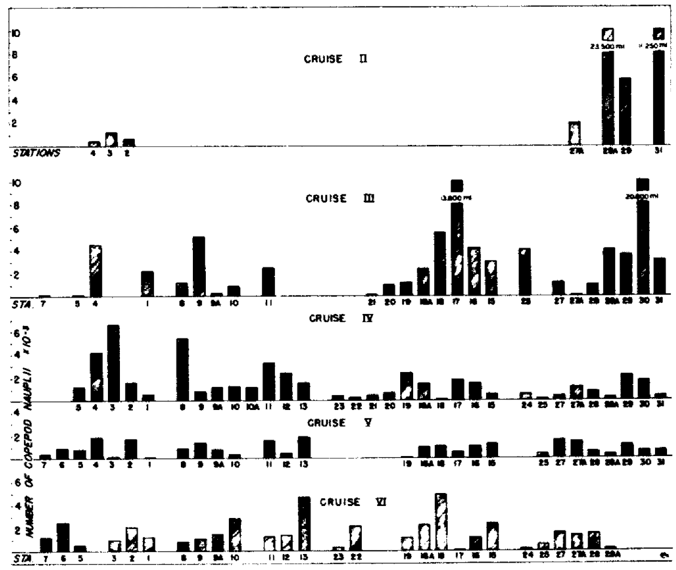

Fig. 10. Zoöplankton. Net haul volumes (displacement). Volumes higher than 15 ml. result from mixture of diatoms except at stations 28A, 29, and 31 of Cruise II, where zoöplankton constituted about 25.20 and 18 ml., respectively. Only the stations at which plankton samples were taken are shown.

During the April cruise only a few stations were occupied, but it will be seen that total volumes were high in the southern line. At station 28A this is chiefly owing to a mixture of diatoms which formed about half of the volume, as shown by laboriously separating them from the animals. At station 29 the volume is also influenced by diatoms but to a much lesser degree. The other stations had nearly clean zoöplankton.

The volumes of the June cruise are also conspicuously influenced by diatoms caught together with the animals. No attempt was made to separate the two in order to obtain a true volume of the animals. Where smaller volumes were taken, the catches were nearly pure zoöplankton. It may be stated here that, in making net collections, a dilemma is presented in deciding the appropriate mesh aperture to use in nets for general zoöplankton catches during periods of diatom outbursts. If apertures are sufficiently large to allow escape of diatoms, especially larger and filamentous forms, the smaller copepods and nauplii also escape, and the first of these may at times bulk rather large. Also, the relative numbers of nauplii are important indications of the productive periods in the area (fig. 11).

In the remainder of the cruises diatoms occurred only in moderation and enter seriously into the bulk only where volumes are over 15 milliliters as measured by displacement.

The phytoplankton population will be more fully discussed in separate reports, but a few remarks should be made in passing. In general, the net catches support the findings on distribution and abundance as indicated by special study of diatoms. Three factors are brought out rather clearly. (1) The main diatom outbursts are indicated in April and June. During the remainder of the cruises only moderate numbers were taken in the net. (2) During the maximum "flowering" of diatoms, the phenomenon is not localized but occurs over nearly the whole area (except as indicated below), as shown by the June cruise. It would appear that the impulse had moved from south in April to the more northerly sections in the later cruises. (3) Only the stations situated inside the main southerly flow of water are productive, that is, the stations characterized by more or less mixed waters.

Composition of zoöplankton. - The zoöplankton is qualitatively very heterogeneous, with euphausiids, radiolaria, chaetognaths, Appendicularia, and various invertebrate larvae as important constituents. The animal plankton is, however, dominated by the copepods and the present report will be limited mainly to this group, of which at least 91 species in 45 genera were taken. Species not yet determined are counted as one, though in several instances the genus concerned is known to be made up of several local species, namely the genera Corycaeus, Oithona, and Oncea, together with a few microcalanids. Many, but not all, of the copepods have previously been recorded from this area by Esterly, but the following list, compiled only in the course of general plankton analysis, gives twenty-six species not previously found in this area (starred). At least seven of these are in genera not previously found off this coast.

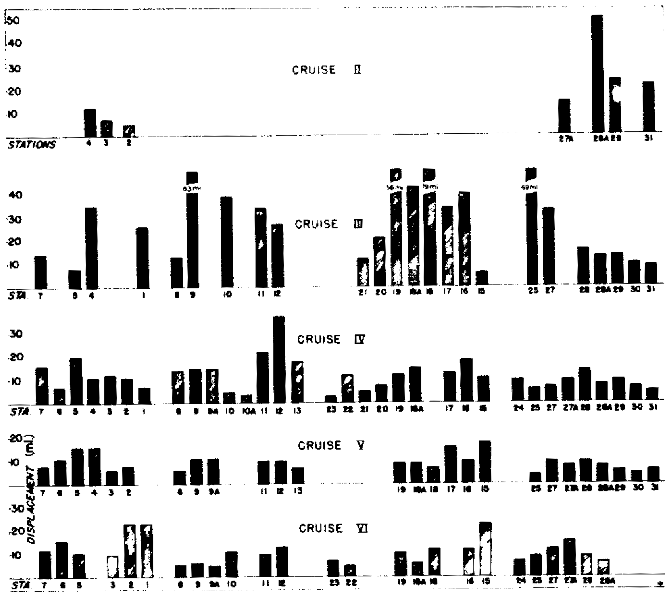

Fig. 11. Numbers of Copepod nauplii, 200- to 0-meter hauls. "E. W. Scripps" Cruises II-VI. Only the stations at which plankton samples were taken are shown.

- Acartia
  - clausi
  - danae*
  - tonsa
- Aegisthus mucronatus*
- Aetideus giesbrechti*
- Arietellus setosus
- Calanus
  - finmarchicus
  - tenuicornis
- Calocalanus
  - pavo*
  - tenuis*
- Candacia
  - aethiopica
  - bipinnata
  - bispinosa*
  - curta
  - simplex*
  - tenuimana*
  - varicans*
- Centraugaptilus
  - lucidus
  - porcillus*
- Centropages
  - bradyi
  - violaceus*
- Chirundina streetsi
- Clausocalanus arcuicornis
- Clytemnestra rostrata
- Ctenocalanus vanus*
- Copilia mirabilis*
- Copilia sp.
- Corycaeus
  - furcifer*
  - spp.
- Euaugaptilus sp.*
- Eucalanus
  - attenuatus
  - bungii californicus
  - crassus
  - elongatus
  - subtenuis
- Euchaeta
  - acuta
  - elongata
  - media
  - propinqua
  - spinifera
  - spinosa

Euchirella { curticauda, galeata, messinensis, propria*, pulchra, rostrata }
Euterpina acutifrons
Gaetanus { secundus, unicornis }
Gaidius pungens
Haloptilus { acutifrons*, longicornis*, ornatus*, spiniceps* }
Heterorhabdus { clausi, longicornis, papilliger }
Labidocera { jollae, trispinosa }
Lophothrix frontalis
Lubbockia (aculeata?)*
Lucicutia flavicornis
Macrosetella sp.*
Metridia { atra, boecki, lucens }
Microsetella rosea
Mormonilla { minor*, phasma* }
Oithona plumifera
Oithonina nana
Oncea conifera
Oncea spp.
Pleuromamma { abdominalis, gracilis, xiphias }
Pontellopsis occidentalis
Rhincalanus nasutus
Sapphirina { angusta, iris, scarlata }
Scolecithricella subdentata
Scolecithrix danae
Scottocalanus persecans
Tortanus discaudatus*
Undeuchaeta { bispinosa, major, minor }
Vettoria granulosa*

Most of the species were represented at all stations on one or more cruises. A few were always widely distributed and were rarely absent from any station, though varying in numbers. Among these may be mentioned Eucalanus bungii californicus and Calanus finmarchicus and some unidentified microcalanids. Of the species most closely bound to the immediate coast may be mentioned Tortanus discaudatus, Oithonina nana, Acartia clausi, and A. tonsa. The more typically oceanic forms are Corissa parva, Acartia danae, Copilia mirabilis and Eucalanus elongatus. A few normally deep-water species came within reach of the net, for example, Aegisthus mucronatus. At no time was there evidence of any one species dominating markedly in numbers over all others, as is so characteristic at times in boreal waters. Calanus finmarchicus, the most important of the boreal Atlantic species, was only moderately numerous, competing with Eucalanus bungii californicus for first place numerically among the larger copepods. This was perhaps to be expected, since it appears that in the open waters of the Northwest Pacific from the Bering Sea southward, C. finmarchicus has also for the most part relinquished its place to other members of the same genus, namely, C. tonsa and C. cristatus, and to the two varieties of Eucalanus bungii. A heterogeneous group of small copepods lumped as "microcalanids" and Oithona spp. were numerically most abundant of all the copepods. Unidentifiable immature calanoids were also very abundant.

In general, the stations situated about midway between the outer and inner ends of the sections, that is, the stations falling within the zone generally characterized by mixed water, show the greatest numbers of individuals of the numerically important species such as C. finmarchicus, E. bungii californicus, and the "microcalanids."

There is marked evidence of copepod reproduction throughout the period investigated (April to December), but the greatest number of nauplius larvae were taken in April and June at stations along the southern sections. In August the greatest numbers occurred along the northern sections. In October the numbers had fallen off but some increase was again indicated for December at some stations.