ACTIVITIES OF THE SCRIPPS INSTITUTION OF OCEANOGRAPHY, LA JOLLA, CALIFORNIA

By H. U. Sverdrup

On November 13, 1936, the Institution's boat, *Scripps,* which in 1934–35 had been completely overhauled and reëquipped, was lost by explosion and fire. On April 5, 1937, Mr. R. P. Scripps bought the 104-foot schooner *Serena,* which, after remodeling, he gave to the Institution. On its transfer, its name was changed to *E. W. Scripps.* In addition to the crew, the *E. W. Scripps* can accommodate a scientific party of six, contains adequate laboratory space both on deck and below deck, and carries two winches for oceanographic work, one provided with 2000 feet of $\frac{5}{32}$-inch wire rope and one provided with 2000 feet of $\frac{3}{8}$-inch wire rope. The normal cruising radius under power is 2000 miles, but this can be extended by taking fuel on deck and by using the sails.

Expeditions and oceanographic data.—From June, 1935, until November, 1936, the *Scripps* occupied a number of oceanographic stations in the waters near the coast of southern California between San Diego and Santa Barbara. In 1937, when the Institution had no vessel at its disposal, three cruises were made in coöperation with the California State Fisheries Laboratory, using their vessel, the *Bluefin.* Nearly thirty stations were occupied on each cruise along four lines running at right angles to the coast. The lines were 70 miles apart and 160–180 miles long, the northern beginning off Port San Luis and the southern off San Diego. In 1938 all these stations were occupied by the *E. W. Scripps* on six cruises in alternate months from February to December, except when, in April and October, bad weather prevented the completion of the work. On the *Bluefin* cruise, observations were made at standard intervals down to as low as 2000 meters, but on the *E. W. Scripps* cruises the work was confined to a depth of 600 meters. On the latter cruises quantitative catches of phytoplankton were made at seven depths at all stations, and vertical hauls of zoöplankton were conducted on all cruises except the first one.

In 1933, 1934, and 1935 the U. S. S. *Hannibal* occupied a large number of oceanographic stations in the Gulf of Panama and off the coast of Panama and Costa Rica. In 1933 R. H. Fleming of the Institution's staff spent about three months aboard the *Hannibal* as special observer. In 1934 the U. S. S. *Bushnell* occupied 18 stations between Adak in the Aleutian Islands and Pearl Harbor in the Hawaiian Islands. Roger Revelle of the Institution's staff accompanied the *Bushnell.* In November, 1936, 10 stations were occupied by the U. S. S. *Louisville* between San Pedro and Pearl Harbor. This work was under the charge of E. G. Moberg of the Institution's staff.

In addition, the Institution has received subsurface data from various stations close to the American coast occupied by vessels of the United States Coast and Geodetic Survey. About forty subsurface data were obtained by the *Valero III* in 1934–35 from the area off the coast of Peru in about latitude 10° S. A large number of surface data have been submitted to the Scripps Institution.

Physical oceanography.—The above-mentioned data have all been discussed and published or prepared for publication except those of 1938, which are under preparation. The *Bluefin* observations in 1937 and the observations of the *E. W. Scripps* in 1938 have shown that off the coast of southern California a big eddy appears to be present during the greater part of the year. This eddy is especially well developed during the period of upwelling when the offshore branch of the eddy carries cold upwelled water toward the south, whereas the inshore branch carries water of higher temperature toward the coast, but this inshore branch reaches only to the Channel Islands.

In order to explain the observed distribution of temperature and salinity it appeared necessary to assume that an intensive quasi-horizontal mixing takes place, at least down to a depth of 500 meters. This process of mixing can be dealt with as a process of diffusion, by introducing a coefficient of diffusion of the order of magnitude 10^6 cm^2/sec. It is probable that this mixing is maintained by eddies of dimensions up to 10 or 20 km. and that the velocities may be up to 20 or 30 cm/sec. Measurements of current by F. P. Shepard and Roger Revelle by means of a meter suspended on a tripod only 21 cm. from the bottom show that irregular currents having velocities up to 20 cm/sec. are found near the bottom at depth between 50 and 800 m. The presence of such irregular currents at these depths may be considered a confirmation of the conclusions with respect to eddy motion based on distribution of temperature and salinity.

E. C. LaFond has conducted a study of the relation between coastal surface temperatures and sea level and has shown that low surface temperature corresponds to low sea level and vice versa. By means of oceanic data off the coast it has been established that variations in sea level are closely associated with changes in the distribution of density of the coastal waters. Hence, the records of sea level can be used in the study of coastal currents.

In 1936 a series of measurements of penetration of light was made by means of a photocell, and in the summer of 1937 a Pettersson transparency meter was constructed and tried out. This instrument was used in August, 1938, for measuring at about 20 stations the transparency of water at different depths between the surface and 60 meters. This work was conducted by R. T. Young, Jr., of Worcester Polytechnic Institute.

G. F. McEwen and his associates have continued their study of forecasting seasonal air temperatures and precipitation on the basis of cycles and correlation with ocean temperatures. The public interest in these forecasts has warranted their annual publication.

Mathematical methods needed in problems of vertical flow or upwelling combined with turbulence have been further developed. Extensive quantitative applications to data on temperature and salinity in the San Diego area have been made. For convenience, each stage in the computation process was carried through for all the data, after the complete method had been tested on a few examples, and tables were prepared to facilitate the computations.

Further developments were made in methods derived earlier of calculating the velocity of horizontal currents from surface temperatures. Extensive applications of the method have been made to North Pacific Ocean data and a paper presenting these results is in preparation.

As a basis for making such calculations, a study of interrelations between processes of radiation, convection, and evaporation near the sea surface was made, which also provided theoretical values of the mean annual rate of evaporation at different latitudes.

An extensive W. P. A. project employing about twenty-five computers for compiling ocean observations reported by navigators in the Pacific, sponsored by the Scripps Institution about three years ago, is still in progress under the supervision of an officer of the United States Hydrographical Department. Thus ocean observations made since 1924 have been compiled on convenient standard forms, from which information is transferred to punched cards for use in Washington, D. C. By special arrangement with the Hydrographic Department, the compilations on these standard forms are kept on file at the Scripps Institution. These data are being averaged with respect to one-degree quadrangles and months for each year, thus providing a basis for determining changes from year to year in the Japan Current off our coast, as well as the Humboldt Current off the coast of South America.

Researches on smaller bodies of water, lakes or storage reservoirs, where relevent conditions are more completely observed, and processes are less complex than in the sea, are helpful in attacking problems of the sea. A paper presenting an extensive series of such observations and their interpretation in San Diego County was prepared by McEwen.

Daily observations of surface temperature and salinity have been continued at the following six stations:

Scripps Institution Pier	Latitude 32° 52′ N
Hueneme	Latitude 34° 9′ N
Pacific Grove	Latitude 36° 38′ N
North Farallon Island	Latitude 37° 42′ N
Blunt's Reef	Latitude 40° 27′ N
Balboa	Latitude 33° 36′ N

A study of the energy relations between the sea surface and the atmosphere has been completed, and by means of local observations of the vertical temperature gradient in the sea, together with the distribution of solar radiation and the amount of radiation penetrating the sea surface, the resulting evaporation from the sea has been computed. Methods for use in summarizing numerical field data have been critically examined.

Estimation of ocean currents from surface temperature distribution has been made. McEwen has devised formulas, based on considerations of surface energy relations, for estimating surface ocean currents from the distribution of temperatures. One such formula consists of a quotient of two quantities which in practice are subject to rather serious random errors which (ideally) are normally distributed in both numerator and denominator. Under the hypothesis of normal distribution, the probability distribution of values of the quotient has no standard deviation and its arithmetic mean is indeterminate, so that it has no "law of large numbers." A statistical estimate of the "true value" of such a quotient has been obtained which possesses a definite mean and satisfies a "law of large numbers" (how strongly is as yet not determined), although this estimate also has no standard deviation. These characteristics of an estimate are of importance for "least squares" treatment of data, and, for example, for estimating total transports of water over a period of time; it is hoped that this estimate will be found satisfactory.

Several applications of statistical methods to biological problems have been developed by McEwen and Gordon. Mr. Gordon has developed a new method for computing "most probable" bacterial populations from the results of successive tenfold dilutions of the sample. It is believed that tables based on the new formula will give better agreement with experimental results than Halvorson and Ziegler's tables, which are now in use.

Dr. C. E. ZoBell compared plate counts and successive dilution estimates taken from tables by Halvorson and Ziegler on the same material, with unsatisfactory results. The unsatisfactoriness is attributable to varying skewness of certain probability distributions, of which Halvorson and Ziegler's tables give the modes. Formulas have been devised for obtaining geometric means of these distributions, together with logarithmic standard deviations. It is expected that much better agreement with plate counts will thus be attained. Computation of tables to replace those of Halvorson and Ziegler will be necessary before this can be actually tested, also for practical use. It is hoped that funds will become available to enable this to be done. Further material is yet to be published.

Chemistry.—The work in the chemical laboratories under the charge of E. G. Moberg has for the most part dealt with routine determinations of salinity, oxygen, phosphates, and various components of the buffer mechanism. Determinations have been made on samples regularly collected at the Institution's pier as well as on samples obtained on the above-mentioned cruises.

Further investigations of the buffer system of the sea have been conducted by D. M. Greenberg of the University of California, Berkeley; Esther Allen, and Messrs. R. H. Fleming and R. Revelle, and later by Mr. John Lyman. A study of importance in comparing the results of determinations of titratable base or alkalinity obtained by different methods was carried out in coöperation with P. H. Mitchell of Brown University.

Some attention has been given to the atmospheric nitrogen content of sea water and experiments have been made to determine nitrogen by means of the Van Slyke blood-gas apparatus. It is believed that a method has been devised that will prove practicable in laboratories on shore and possibly also on board ship.

A method for detecting small differences in the carbon dioxide content of the air that may be correlated along the coast with the direction of the wind has been developed, and a rapid and scientific method for determining arsenic was applied to sea water by T. H. Winnick of the University of California, Berkeley.

With the assistance of the Works Progress Administration workers, numerous determinations of the fixed nitrogen content of bottom samples from various parts of the Pacific were made and a number of water samples were analyzed for organic and ammonia nitrogen and for calcium. Various methods for determining iodine in sea water were tried by W. L. Burdick and J. Cunningham. By means of one of these methods, accurate information regarding the iodine content of a number of samples was obtained not only from the surface but also from depths down to about 1000 meters. A study of methods for the determination of manganese and iron in sea water has also been begun. Robley D. Evans made a study of the radioactive substances in sea water, in marine plants and animals, and in the bottom deposits off the coast of southern California.

Submarine geology and marine sediments.—In 1935 F. P. Shepard of the University of Illinois undertook dredging for rocks from the walls of the submarine canyons near La Jolla, and in 1938 this work was continued and greatly extended through a grant from the Geological Society of America by means of which Mr. Shepard had the use of the *E. W. Scripps* in alternate months. Large quantities of rocks were brought up from a number of localities, cores of bottom sediments up to 12 feet in length were obtained, and detailed soundings were made in many areas. Roger Revelle of the Institution's staff took part in this work and conducted simultaneously laboratory studies of bottom sediments. A large amount of mechanical analyses of sediment samples collected by the *Scripps* off the southern California coast were completed. The results show distinct relation between the grain size of the sediments and the topography of the bottom. Similarly, the amount of organic nitrogen in the samples which were determined in the chemical laboratory showed distinct relation to the configuration of the bottom. Revelle completed his discussion of the bottom samples collected by the *Carnegie* in the course of her work in the Pacific. Together with R. H. Fleming measurements were made of the variation with depth of the currents close to the bottom. It was found that in shallow water the profile of the current near the bottom corresponded closely to the velocity profile which has been established in laboratories as characteristic for flow over a rough surface. Miss Stina Gripenberg of Helsingfors, Finland, was engaged in 1937–38 in studies of the carbon content of sediments.

Marine microbiology.—C. E. ZoBell, in charge of the bacteriological studies,

has continued his work on bacteria in sea water and in bottom deposits. Five new species have been isolated which produce ammonia from low concentrations of urea in sea water. Observations on the influence of temperature, organic matter, pH, redox potentials, and salinity on the activities of nitrifying and denitrifying bacteria indicate that in the sea the redox potential is perhaps the most important factor. Multiplication, proteolysis, carbohydrate fermentation, ammonification, and nitrification in marine bacteria have been observed at 0° to —2° C., which indicates that bacteria are functional at the low temperatures encountered in the deep sea.

With the assistance of D. Q. Anderson the vertical distribution and relative abundance of bacteria in marine sediments which activate a number of different physiological processes of oceanographic significance have been estimated. It has been shown that bacteria have a great capacity to affect in marine bottom deposits the O/R potentials which are of bacteriological, geological, and chemical significance.

Assisted by Mr. Sydney Rittenberg, a microasbestos calomel half-cell has been prepared for measuring the O/R potentials of anaerobes in oval tubes. The device makes it possible to study the influence of bacteria upon the O/R potential and also to study the influence of O/R potentials upon the activity of the bacteria.

Chitin-digesting bacteria have been found to be quite widely distributed in sea water and bottom deposits. They were found in abundance in the digestive organs of squid, thereby indicating that they may aid marine animals in the digestion of the resistant chitin which constitute the exoskeletons of most crustacea. Lipoclastic bacteria which liberate higher fatty acids from lipins and utilize the glycerol have been demonstrated in marine materials. These, together with those which create extremely reducing conditions, may account for the formation of long-chain hydrocarbons found in petroleum.

Mrs. C. B. Feltham has continued the experiments on the bacterial nutrition of marine organisms. Mussels have thrived for 14 months in the dark on a diet consisting exclusively of bacteria.

The importance of the presence of solid surfaces to which bacteria can attach themselves has been examined. It is believed that the low number of bacteria per unit volume in the ocean is associated with lack of surfaces per attachment. For further studies of the abundance of bacteria an improved bacteriological water sampling bottle has been perfected.

Phytoplankton.—W. E. Allen has continued the daily collections of phytoplankton from piers at Scripps Institution and Point Hueneme more than 100 miles farther north. The microscopic work and preliminary calculations have been completed up to 1937 and cover now a period of 18 years. A large number of surface plankton catches have been obtained from various vessels, the collections have all been examined and the results published. The surface and subsurface collections of phytoplankton which were made on the 1938 cruise of the *E. W. Scripps* have been studied and show especially that the abundance of diatoms may be as great at a distance of 180 miles from the coast as close to the coast.

Miss Easter E. Cupp has analyzed a number of phytoplankton catches by means of the centrifuge method and has spent the greater part of her time in preparing a taxonomic paper on plankton diatoms of the southern California region.

Foraminifera.—T. W. Vaughan published a number of papers on fossil foraminifera. E. H. Myers has succeeded in working out the life history of a local species of foraminifera known as *Patellina corrugata,* and has extended his studies to another form in which the cycle in all respects conforms to that of *Patellina.* M. L. Natland has continued his studies of the ecological relations of the foraminifera in the Gulf of Catalina.

Zoöplankton.—Martin W. Johnson has been engaged partly in the study of the life history of certain copepods and partly in studies of the geographic distribution of copepods and other forms of zoöplankton. Among others, the development stages of the oceanic copepods *Eucalanus elongatus* has been completely worked out and a report has been published on the distribution in the Pacific of the varieties of this form. The large accumulation of collections which were made by the *E. W. Scripps* in 1938 is being examined with the assistance of C. C. Davis. C. R. Monk has continued a systematic and distributional survey of the harpacticid copepods of the Pacific coast.

Physiology of marine organisms.—D. L. Fox, in collaboration with G. W. Marks and others, has concluded a study on the habitat and food of the California sea mussel. Further work on the mussel has been made possible by assistance from the Works Progress Administration. Experiments dealing with the biochemical effects of hypotonic and hypertonic solutions of sea water upon tissues have been conducted. It has been established that the mussel propels water through the gill chamber at an average rate of 2.5 l/hr. One of the chief lines of research has been the study of various carotenoid pigments in marine materials and marine animals, with special reference to nutrition. Part of this study, that dealing with carotenoid pigments in marine fishes, has been undertaken in coöperation with F. B. Sumner. The characteristic absorption curves of different pigments have been established spectroscopically.

Biology of Fishes.—F. B. Sumner has continued his studies of the protective value of color changes in fishes, and has experimentally established that fish-eating birds catch a much greater proportion of those fishes which do not harmonize with the background. The work of F. B. Sumner and his collaborators has, however, mainly dealt with the quantitative determination of the amount of pigments formed in fishes which have been subjected to different conditions with respect both to color of background and to incident light. It was found that the amount of melanin extracted from a given lot of fishes bears an inverse relation to the albedo of the background, probably varying inversely as the logarithm of the albedo. Intensity of incident light also played a part in determining the production or loss of melanin, but under the degrees of illumination employed so far, the influence of this factor was small in comparison with that of the albedo of the background. A series of experiments have been commenced with a view to discovering some of the physiological differences between fishes which have been acclimatized to widely different temperatures.

P. S. Barnhart has completed a monograph, *Marine Fishes of Southern California,* illustrated by 292 figures.

Studies on "fouling growth."—In 1937 coöperation was established between the United States Navy Bureau of Construction and Repair and the Scripps Institution in order to study the organisms which cause fouling growth on ships' bottoms. These studies form a continuation of work which was conducted at the Institution over a long period of years but which had to be discontinued because of other pressing demands. Mr. W. F. Whedon, who has been engaged by the Bureau of Construction and Repair to carry on these studies, has been engaged mainly in examinations of the primary film formed on submerged surfaces.

Publications.—In the years 1933–1938, 265 papers have been published. A partial list follows, which includes only those papers which deal with general aspects of oceanographic problems or with conditions in the Pacific Ocean.

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