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RECENT OCEANOGRAPHIC RESEARCH AT THE SCRIPPS INSTITUTION OF OCEANOGRAPHY, UNIVERSITY OF CALIFORNIA

Thomas Wayland Vaughan

To summarize, in view of the urgent need for this chart of the oceans, of the time required for the collection of the necessary data, of the demonstrated feasibility of using echo-sounding as a major method of obtaining such data, and of the extent to which world shipping is now equipped with echo-sounding devices, I believe that the time is ripe for a beginning of the project.

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The general program of research at the Scripps Institution has been presented on so many occasions that there seems to be no need to repeat it. It will be said, however, that the first endeavor in the plan of the Institution's work is to get as good a picture as is practicable of the physical and chemical features of the masses of water with which we are dealing and that the next endeavor is to relate the results of the study of other marine phenomena and processes to that general setting. The following synopsis will present the recent results of the researches under four captions: (1) Dynamical oceanography, (2) chemistry of sea-water, (3) biology of marine organisms, (4) geologic processes.

Dynamical oceanography

Publications--During the past year George F. McEwen has published three important papers. The first is "A mathematical theory of the vertical distribution of temperature and salinity in water under the action of radiation, conduction, evaporation, and mixing due to the resulting convection" (Scripps Institution of Oceanography Bull., Tech. Ser., v. 2, No. 6). This paper presents a mathematical formulation and solution of the problem of the downward diffusion of the surface cooling due to evaporation and back radiation and of the heating caused by the absorption of solar radiation. The method provides a means of estimating the rate of evaporation from the surface, the rate at which solar radiation penetrates the surface, and the rate of upwelling. The requisite observational data are air-temperature and humidity, and serial temperatures and salinities made at time-intervals of about two weeks. Formulae, tables, and numerical solutions based upon actual field data are presented to facilitate the application of the method.

The two other papers are "The water-cycle between the ocean, atmosphere, and land" (University of Southern California Short Course, Water Supply Section, School of Citizenship and Public Administration, pp. 5-17, 1929) and "A limnological study of lakes and reservoirs of San Diego County-Stagnation and overturning in relation to vertical temperature-distribution" (Water Supply Section, School of Citizenship and Public Administration, April 1930).

Computations of oceanic circulation--By arrangement with Dr. W. F. Thompson, director of the International Fisheries Commission, McEwen has made computations of the oceanic circulation relative to the bottom at a series of depths in the Gulf of Alaska. There were three sections perpendicular to the coast between Ocean Cape and Cape Chiniak averaging 400 kilometers in length. Serial observations were made at 41 stations. A prevailing westward drift of about one-half knot was thus indicated.

Lapse-rates--Evaporation-investigations at the end of the Scripps Institution's pier, made by N. W. Cummings and Burt Richardson, involved measurements of temperature, humidity, evaporation, and water-temperatures at three levels--near the water-surface, on the pier deck 30 feet above sea-level, and at a height of 50 feet. Very small differences were found in measurements made at various levels, and a very close agreement was found between the solar radiation estimated from observations at each pan and the indications of an Englehard instrument recording solar radiation at a level of 60 feet.

Chemistry of Sea-Water

The relation of diatoms to physical and chemical conditions of the water--This work was done by Moberg. From Professor Allen's diatom-counts for various levels at a station located ten miles from shore the average vertical-distribution of the diatoms during the season was calculated. This distribution was compared to the average distribution of temperature, density, salinity, pH, CO_2, NO_3, PO_4, and SiO_2 for the same period. In the case of the chemical substances there was a decided increase in quantity between 25 and 50 meters and at these depths there was also a change in the physical properties of the water. At 30 and 35 meters the maximum number of diatoms was found, whereas above 30 meters, where the concentration of the nutrient substances was low, the diatoms were very scarce. In the upper 15 meters of water nitrate was virtually absent and it is probable that lack of this substance limited the growth of diatoms. From studies made on the penetration of light in sea-water in other localities it appears probable that diatom-growth at lower levels where nutrients were abundant was prevented by insufficient illumination. These studies emphasize the importance of upwelling subsurface water, which is rich in chemicals, upon the production of phytoplankton.

Studies of vertical distribution of nutrient substances were also carried out in Monterey Bay by Miss Leslie in connection with a survey of this body of water made by Dr. H. B. Bigelow. In this case, too, it was found that the surface-layer is supplied with chemicals by upwelling subsurface water.

The oxygen-content of the water in the Pacific--At the Scripps Institution pier the quantity of oxygen in the water was determined daily for about two years by Miss Leslie. The oxygen-content was at a point of supersaturation during most of the year and showed a very close relation to the amount of temperature reduction which is correlated with the intensity of upwelling.

On board the Carnegie between San Francisco and Honolulu oxygen-determinations were made by Moberg on 190 samples collected at ten stations. At the surface the water was practically saturated with oxygen but with increasing depth the quantity decreased to a minimum at 700 meters below which there was slow but uniform increase toward the bottom. The minimum oxygen values ranged from 0.2 to 1.0 ml per liter which is considerably lower than the minimum at similar latitudes in the Atlantic. Below the minimum layer the highest quantity of oxygen found was 3.45 ml per liter whereas at corresponding depths in the Atlantic the quantity of oxygen is everywhere 5 ml per liter or more.

The calcium carbonate equilibrium in sea-water--This work is being carried out in collaboration between Moberg and Gee. They are studying the solubility of $CaCO_3$ in sea-water under various conditions of temperature, pH, and CO_2-content, with a view to determining the conditions under which it may be precipitated or dissolved in the sea. The results so far indicate that there are certain chemical factors involved which make the accepted theories of $CaCO_3$-solubility inapplicable.

Biology of Marine Organisms

Statistical methods--McEwen has published a paper "Methods of estimating the significance of differences in or probabilities of fluctuations due to random sampling" which resulted from efforts to develop and make available statistical methods for estimating the significance of differences in the abundance of marine plankton indicated by net-hauls made under different environmental conditions. It is a supplementary handbook prepared for the worker who is familiar with elementary statistical methods, but has to deal with special problems that involve small samples, high variability or skew-frequencies, and are thus outside the range covered by usual methods. Formulae, tables, and numerical problems to illustrate their use are presented to facilitate practical applications.

Another study by McEwen is that of plankton-swarming. This is a statistical study of the relation between plankton-abundance and haul-frequency or percentage of hauls containing more than a given number of organisms and was based upon a few of our records of both zooplankton and microplankton. The average values of observed abundance were found to exceed the theoretical value to be expected on the basis of probabilities assuming a uniform distribution of the organisms. The only explanation appears to be that the organisms occur in groups or swarms. Biologists working in this field had been led independently to a similar conclusion by general impressions.

McEwen has also been working on plankton-data regarded as time series. Preliminary studies of monthly averages of microplankton-counts and of corresponding physical data have been made by applying principles used in business statistics to determine the trend, typical seasonal changes, and cyclical variations. The usual methods of multiple correlation were applied to the cyclical variations or departures from the typical seasonal changes corrected for trend, a procedure justified since the time-factor is thus eliminated. The method appears to be suitable for analyzing a large mass of data corresponding to long time intervals.

Bacteriology--A. H. Gee has charge of the investigations on this subject at the Institution. According to him special mechanical equipment for the collecting and culturing of bacteria from the sea has been devised and perfected and found satisfactory on board ship. One of the devices introduced for handling bacteria in solid mediums on board ship has general application in bacteriological laboratories for some purposes for which the Petri dish has been used.

Direct cultural enumerations made at sea indicate that the water-populations in the vicinity of La Jolla are of the order of hundreds only per cc, and these are confined to the topmost 25 meters. This is an even sparser count than has been reported for samples of ocean-water elsewhere. Examination of the bottom-mud by the same method indicates, however, that there is appreciable activity on the part of readily recognized and cultured organisms. Molds, yeasts, and Actinomyces form an important part of the flora in addition to the bacteria proper. The attempt has been made to evaluate these enumerations of cultivable organisms. Direct microscopic counts of live, dead, and dormant organisms following different processes of concentration have been partially successful, and they indicate that the counts cited here and similar attempts elsewhere which are based on cultural methods, reveal only a small fraction of the bacteria actually present. Methods have yet to be devised for cultivating the organisms which are missed by conventional and special media hitherto recommended.

Phytoplankton--The work on phytoplankton has comprised the publication of papers by W. E. Allen giving the more obvious results of daily statistical records accumulated at inshore stations for five years, and a general statement of the work at such stations over a period of ten years. A report on winter collections of diatoms from surface-waters of the Gulf of Alaska and the Alexander Archipelago has been finished. Considerable progress has been made in microscopic examination of standard series of catches of phytoplankton in the Southern California region. A beginning has been made on a limited taxonomic study of diatoms of Java seas, and advance has been made in the study of kinds and degrees of variation of Pacific plankton-diatoms. Miss Easter E. Cupp is assisting Professor Allen in these investigations.

A brief study has been made of the relative dependability of filtration and concentration methods of collecting certain types of microplankton and a report published. An account of a design for a new kind of quantitative plankton closing net has also been published.

Plans have been formed for making experimental studies of diatoms. Plans for statistical treatment of the records for nearly 20,000 catches of phytoplankton taken by filtration in the last ten years have been made for the purpose of ascertaining what correlation there may be between the occurrence of the organisms and the physical and chemical features of the water from which they were taken. Most of the details of operation of these plans have been tested so that the statistical analysis can go forward as soon as the count records are completed. The statistical methods for this work were devised by McEwen and have already been mentioned in this paper.

Foraminifera--R. D. Norton has recently published (Tech. Bull. Scripps Inst., v. 2, 331-338) a paper entitled "Ecologic relations of some foraminifera." This is a study of the depth and temperature relations of about 550 species of foraminifera from the beach-line to a depth of 2,849 fathoms in the southwestern part of the North Atlantic, the Mexican Gulf, and Caribbean regions. E. M. Thorp has made estimates of the numbers of individuals of different species of foraminifera in a series of deep-sea samples collected between New London, Connecticut, and the Panama Canal Zone. G. Leslie Whipple is engaged on a study of the foraminifera associated with the marine bottom-deposits between Point Conception, California, and Panama. The three sets of studies by Norton, Whipple, and Thorp, supplement each other and are of value to geologists in that they will aid in improving the basis for inferring the physico-chemical conditions under which sedimentary rocks were deposited.

G. L. Whipple has prepared reports on larger foraminifera from the Miocene of Vitilevu, the Eocene of Eua, and the Quaternary of Vavau, to aid J. F. Hoffmeister and H. S. Ladd in their studies of the conditions under which the coral reefs of those islands have been formed. T. W. Vaughan is continuing his studies of the larger formaminfera, fossil and recent, of tropical and subtropical America, and has published twenty papers on the subject during the past few years.

Fishes--P. S. Barnhart for a number of years has made observations on the breeding seasons and spawning habits of local fishes. The species include many elasmobranchs (sharks and rays) and, among the Teleosts, the pipe-fishes, silversides, barracuda, mackerel, bonito, surf-fishes, rockfishes, cottids, and blennies.

The food of the California sardine (Sardinea coerulea) has been investigated by R. C. Lewis and the results published. The stomach contents of sam-

ples of fish taken throughout the year showed close correlation with the plankton in the water from which the fish were taken. The fish eat both phytoplankton and zooplankton, utilizing as food either both or whichever may be in the water. [A.E. Parr suggests (Ecology, v. 11, 465-468) the fish may not digest diatoms found in its stomach--they may be incidental only to catching zooplankton.] A. B. Keys has conducted investigations of the gas-exchange of fishes and the acclimation of a marine fish to fresh-water. A method, developed in the past year and a half, for measuring the gas-exchange of fishes was subjected to many tests with the result that it is now possible to use a standard technic in a wide variety of studies of the gas-exchange of aquatic animals in which a strictly physiological method for obtaining standard metabolism has been sorely needed. The paper describing the method in detail is now in manuscript and will shortly be submitted for publication. Results obtained by this method were utilized in a paper on the relation of the oxygen-consumption of fishes to the oxygen-tension of the water. It was shown that minor variations in the oxygen-tension of the water are without effect on the magnitude of the oxygen-consumption of fishes. The relation between the age of a fish and the oxygen-consumption per unit of weight was studied. It was found that the magnitude of the respiratory exchange varies inversely with the age of the fish, the younger animals having the higher rate of metabolism.

The physiological processes involved in the acclimation of the marine fish, Fundulus parvipinnis, to fresh-water were studied and the results embodied in a large paper now in press. The general problem of differences in the resistance of individuals to specific adverse situations was studied experimentally for a number of experimental conditions, and the results of the very numerous experiments analyzed statistically.

The effects of amytal anesthesia on fishes was investigated by A. B. Keys and N. A. Wells. It was found possible to induce prolonged anesthesia in fishes by means of amytal (iso-amylethyl barbituric acid) and the effects of such treatment on the respiratory processes were studied. These results are to be presented in a paper now in the course of preparation.

F. B. Sumner and A. B. Keys sought to analyze the optical stimuli responsible for changes of shade which occur in flatfishes, in response to changes in the nature of the background. It was shown, with fair conclusiveness, that the shade of the substratum (background) operates in connection with light from other parts of the visual field, and that the effective stimulus is the ratio of the light reflected from the background to the apparent source of illumination.

F. B. Sumner and Nelson A. Wells have for many months been conducting experiments with the small tropical fish, Lebistes reticulatus, with a view to ascertaining (1) the effects of the differences of temperature upon the number of vertebrae and other metameric structures and (2) the effects of differences in the shade and color of the surrounding containers upon the shade assumed by the fish--particularly upon the formation of pigment.

Besides those above listed, the results of other researches on the ecology and physiology of marine organisms are worth mentioning. One of these is a study by Prof. W. R. Coe of Yale University of the organisms that attached themselves to blocks that were suspended from the Institution's pier and allowed to remain suspended during definite times.

Geologic processes--E. M. Thorp has nearly ready for press a paper on marine bottom-deposits, already mentioned, and G. L. Whipple is studying the

bottom-deposits in the eastern Pacific between Santa Barbara, California, and Panama. Other investigations on the large number of samples at the Scripps Institution are contemplated.

T. W. Vaughan is making a quantitative investigation of the rates of cliff-recession in the vicinity of the Scripps Institution and he is trying to correlate the rates with as many factors as practicable, such as toughness and structure of material and height of cliff. Other factors, such as momentum of waves, shore and near-shore currents, and slope of bottom at and near the beaches, are being considered, but the phenomena are very complex and difficult to analyze. G. L. Whipple is assisting with the field and laboratory work. G. F. McEwen is helping with the study of water-movements and the intricate mechanics. Because of its bearing on this problem, a detailed chart, scale 1 to 10,000, of the sea-bottom off the sea-front of the Scripps Institution's property, made in cooperation between the Coast and Geodetic Survey and the Scripps Institution, is mentioned.

From foregoing statements it is obvious that to understand the geologic processes operative in the sea knowledge of all branches of oceanography, physical oceanography, the chemistry of sea-water, and marine biology, is necessary and fundamental.

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SOME PRELIMINARY RESULTS OF THE COAST GUARD'S MARION EXPEDITION TO DAVIS STRAIT

Edward H. Smith

Although it has been about two years since the Coast Guard Cutter Marion made her oceanographical survey of Davis Strait and lower Baffin Bay, the scientific report of the Expedition has not yet appeared in print. The section on oceanography and ice is being prepared by Lieutenant Commander Edward H. Smith, the leader of the Expedition. Unfortunately his whole time has not been available for the Marion Expedition report due to other pressing duties in the Coast Guard, but, nevertheless, it is hoped that the report will soon be completed and ready for distribution. In the meantime, one short notice has appeared (Science, v. 68, 469-470, 1928), giving a brief report of the area covered and the nature and number of the observations and a few of the major discoveries made. Since the appearance of this note, the oceanographical data have been subjected to Bjerknes' dynamic formulae and several interesting maps of the surface topography of Davis Strait have been constructed. We wish to describe some of the outstanding features of the circulation, which have been revealed for the first time, as they prevailed during the summer of 1928 between Greenland and North America.

First we wish to call attention to Figure 1 showing the general bathymetrical features of Davis Strait as determined by the 2,500 soundings of the Marion's fathometer, and as further supported by previous authentic wire-soundings. The number of deep soundings existing prior to the work of the Marion was very scanty and areas as extensive as 30,000 to 40,000 square miles contained not a single depth-record. The coastal shelf of west Greenland on Figure 1, it will be noticed, is much narrower and steeper than that shown on present-day maps, and the Labrador shelf is somewhat wider. It is also relieved by a depression about 40 miles out from the coast which extends as a

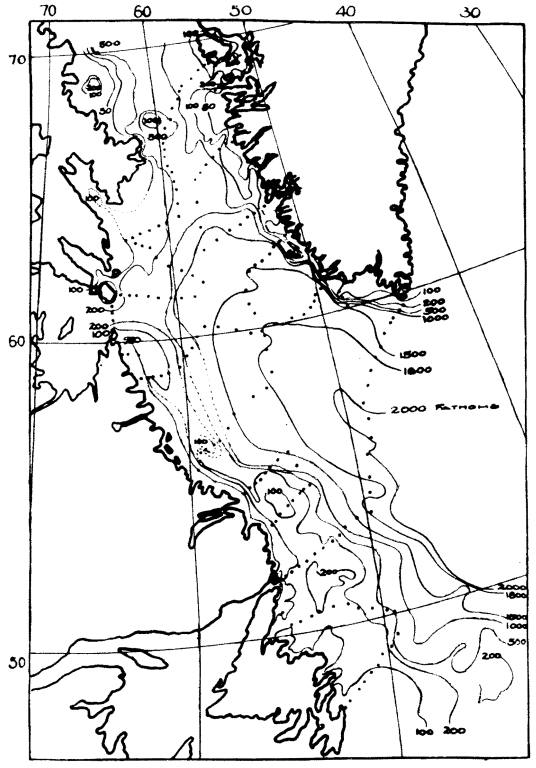

Fig. 1--Bathymetrical features of Davis Strait from soundings of Marion Expedition

trough along the entire front from Cape Chidley southward to Newfoundland. The depth-survey corroborates previous maps, namely, that the broader, shallower shelf is located on the American side of Davis Strait, and the currents, largely in consequence, are much wider and slower moving on the western side of Davis Strait than they are on the eastern side.

The dynamic topographical map of the sea-surface of Davis Strait, Figure 2, has been constructed in accordance with the methods described in Coast Guard Bulletin No. 14. In regions near the coast where depths are less than 1,500 decibars, we have followed the methods used by Jacobsen and Jensen in their paper "Examination of hydrographical measurements from the research vessels Explorer and Dana in the summer of 1924."

This is the first time that the currents over this important ice-region have ever been charted--a task that could not have been accomplished without the raw data of the sort collected by the Marion. The results of the Marion Expedition not only reveal for the first time the hydrographical circulation between Greenland and North America, but allow us to trace by logical scientific methods the movement of the ice over a major part of its northern pathway.

The lowest point in the sea-surface of Davis Strait as shown on the dynamic topographic map, Figure 2, was found at the Marion station 947, located about 130 miles seaward of Hamilton Inlet, Labrador, and in the deep water just off the continental slope. This point was called zero and used as a bench-mark above which the surface rose on all sides. This dynamic height from a point in the sea at station 947, where the pressure was 1,500 decibars, to the sea-surface was 1,454.46 dynamic meters above the 1,500-decibar plane. In this manner the particular dynamic height of the sea-surface was calculated for each of the 191 stations which the Marion took, and equal heights were connected by lines called isobaths. The dynamic isobaths in Figure 2 have been drawn for every two-dynamic-centimeter change in altitude. By obtaining these values for so many stations scattered over the Davis Strait area, it has been possible to construct a horizontal projection for Davis Strait as a whole, from Disko Bay, Greenland, to the latitude of Cape Race, Newfoundland.

In the interpretation of the motion indicated by the dynamic gradients