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CONTRIBUTIONS FROM THE LABORATORY
OF THE
MARINE BIOLOGICAL ASSOCIATION OF SAN DIEGO.

A GENERAL STATEMENT OF THE IDEAS AND THE PRESENT AIMS AND STATUS OF THE MARINE BIOLOGICAL ASSOCIATION OF SAN DIEGO.

BY

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Director of the Station.

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1.—The Idea of a Marine Biological Survey.

Volume II of the University of California Publications, Zoology, is now either published or in the Editor's hands, waiting to be put into type. It is composed exclusively of "Results from the Laboratory of the Marine Biological Association of San Diego."

The investigations on the coast of Southern California now having been in progress for several years, and their continuance being assured for a few years more at least, it seems fitting that this first volume of results should be introduced by some statement of the general ideas animating the undertaking, and of the efforts being made, and means available to realize these ideas. *Investigations in marine biology, intensive rather than extensive in character* (to borrow a useful agricultural phrase) is the key note of the idea. An immediate consequence of the adoption of such an idea as a rule of action, has been the necessity of making a clear distinction between *marine biology*, and *general biology prosecuted by researches on marine organisms.* I have elsewhere written as follows of this distinction:

"The former has for its aim, in the large, the getting of as comprehensive an understanding as possible of the life of the sea. It, of course, presents itself under a great variety of secondary questions; but the sum total of the phenomena of *marine* plants and animals will never be lost sight of as its real aim. The latter makes use of animals and plants that live in the sea in general biological researches. That these organisms happen to be marine is an incident merely. The investigator turns away from them without hesitation when others, from whatever source, come to hand that suit his purpose better. Further, the user of marine organisms in such investigations is quite indifferent to everything concerning them that does not bear upon his particular problem. He puts aside the marine animal after it has served his purpose without having even noticed, perhaps, the major part of its traits and qualities and the questions concerning it."

For this particular undertaking, I believe the ideal, broad and general as it is, is eminently useful. It is useful because it gives definiteness and coördination to action, and furnishes a commanding point of view and stimulus. It is justifiable to hold

and be guided by it, even though assurance of opportunity to carry it out fully is absent.

The aim as formulated in the articles of incorporation of the Association is, "To make a Biological Survey of the waters of the Pacific adjacent to the Coast of Southern California."

2.—The Area to be Surveyed.

The funds available being small, an important and ever-present practical question is that of fixing limits. One of the first of these was that of limiting the territory to be surveyed. The irregularly triangular area extending from Point Concepcion, Lat. 34° 27′, at the north, to a base line extending westward from the southern boundary of the United States, Lat. 32° 28′, bounded on the east by the coast line, and on the west by the meridian of Point Concepcion, Long. 120° 25′, was selected. The shore line of this area, exclusive of the islands, is about 280 miles. The length of the western side is about 120 miles, and that of its southern side about 194 miles. The area contains, therefore, over 11,600 square miles.

It is, of course, not to be supposed that a stone wall has been built about this area, and that we give no heed to anything outside of it. As a matter of fact, nothing is clearer than that complete knowledge of it is impossible without extending the explorations widely beyond it. That it makes a well defined base of operations, is about the view we take of it.

The qualifications of the region are: a position well to the south; a considerable extent of continental shelf, presenting a large diversity of bottom, with numerous islands and shoals; proximity to oceanic depths and other truly oceanic conditions; a favorable climate; a large variety of shore line; and accessibility through sea ports and railroads. Two of these advantages, that of climate and proximity to oceanic conditions, are held to be of very great importance. A fundamental element in investigations of the sort contemplated is *continuousness* of the field work. Data gathering must go on throughout the year at frequent intervals. The weather here offers little obstacle to this. Heavy storms are rare, and these are practically limited to three or four months—January, February, March, and April. For the

rest of the year there are few days on which, for a portion of the day at least, work cannot be carried on anywhere in the area with slight interference from heavy seas; and even during the months subject to storms only rarely is it interfered with. The practical importance of this can hardly be overvalued, as all experienced in this sort of work will appreciate. Not only does it make a completeness of field observations practicable, that could hardly be secured with any kind of a vessel in more storm afflicted regions; but it reduces the cost of exploration to the minimum, for the work can be done in a vessel much smaller, and hence much less expensive of operation than is ordinarily required for such work. Dredging and trawling to a depth of 500 fathoms at least from a vessel of 60 foot keel, manned by three men, is perfectly feasible; and sounding and various kinds of work on surface and intermediate waters can be done at considerably greater depths with the same equipment.

The following table, made up from data contained in the Monthly Synopses of the United State Weather Bureau, presents information concerning climatic conditions at San Diego during 1904, an entirely typical year.

TABLE OF METEOROLOGICAL CONDITIONS, 1904.

		Temperature.		Precipitation.		Wind.	
Month.	Locality.	Mean Max.	Mean Min.	Total.	Days with .01in. or more.	Total movement in miles.	Max. velocity, miles per hour.
January.							
	Nantucket	34	22	5.98	16	11,849	60
	Key West	73	82	1.42	7	7,834	31
	Farallone	54	49	.88	7	12,117	48
	San Francisco	56	45	1.05	5	4,292	26
	San Diego	65	47	.04	2	4,310	27
February.							
	Nantucket	32	19	3.86	15	11,386	47
	Key West	76	66	1.08	4	7,106	33
	Farallone	53	49	6.13	16	10,149	50
	San Francisco	55	46	5.89	16	5,561	31
	San Diego	61	48	1 50	6	3,802	36

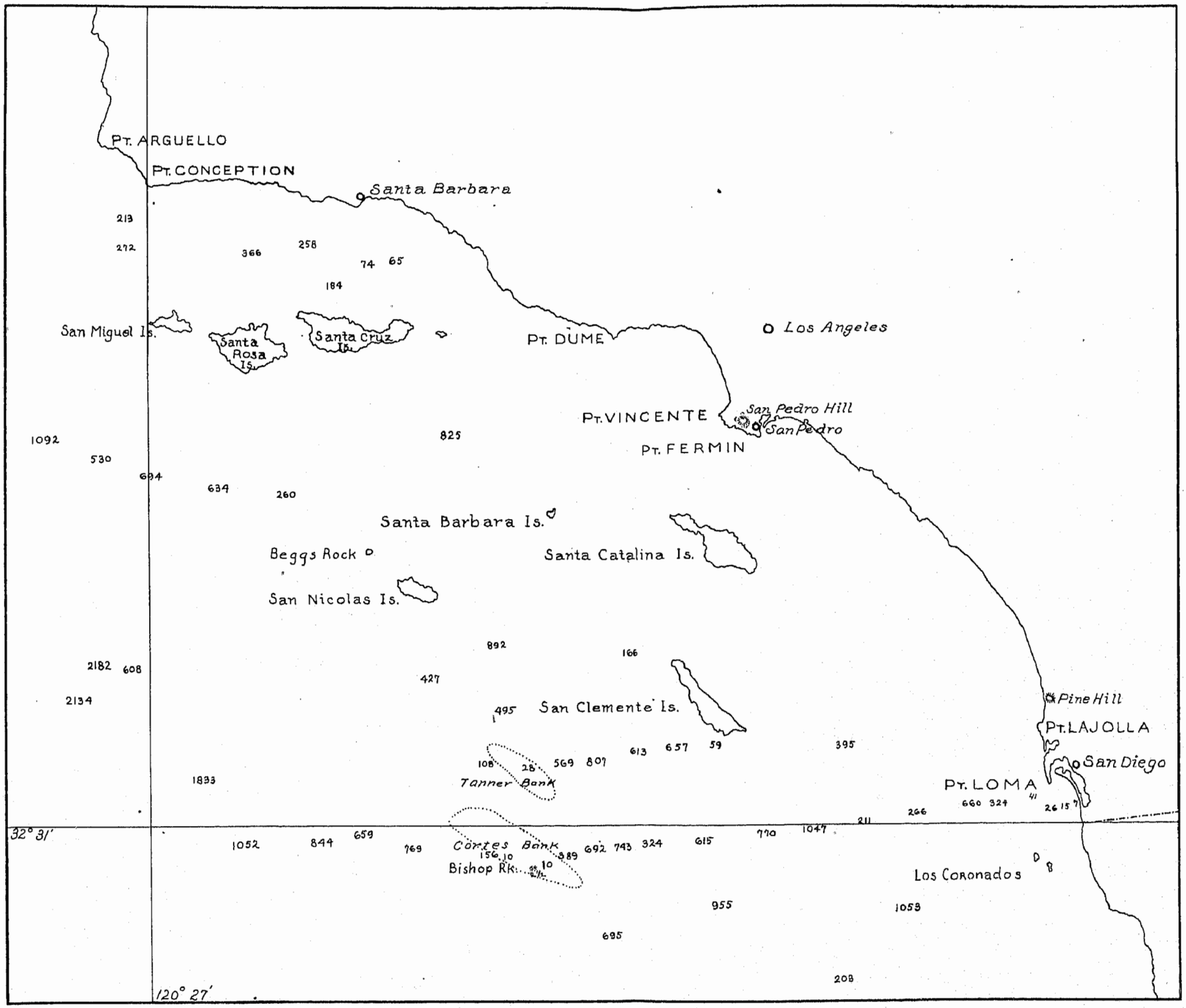
Month.	Locality.	Temperature. Mean Max.	Temperature. Mean. Min.	Precipitation. Total.	Precipitation. Days with .01 in. or more.	Wind. Total movement in miles.	Wind. Max. velocity, miles per hour.
MARCH.							
	Nantucket	39	29	2.11	10	11,294	45
	Key West	79	70	1.94	4	7,242	30
	Farallone	60	49	6.30	24	11,940	70
	San Francisco	57	47	6.01	23	7,126	48
	San Diego	**63**	**50**	**2.17**	**10**	**5,041**	**27**
APRIL.							
	Nantucket	48	38	4.08	17	10,274	42
	Key West	80	71	1.51	7	7,378	48
	Farallone	57	50	2.29	13	10,890	45
	San Francisco	63	50	1.29	8	6,544	32
	San Diego	**66**	**52**	**.15**	**3**	**4,665**	**23**
MAY.							
	Nantucket	61	50	2.39	7	9,033	36
	Key West	82	73	13.01	12	6,018	32
	Farallone	55	51	.23	1	14,993	55
	San Francisco	66	52	.30	1	8,921	42
	San Diego	**65**	**56**	**.12**	**3**	**4,153**	**27**
JUNE.							
	Nantucket	65	54	2.38	12	9,019	42
	Key West	86	77	1.70	12	6,856	28
	Farallone	55	51	.01	1	13,757	54
	San Francisco	66	52	Trace	0	9,448	36
	San Diego	**69**	**60**	**0**	**0**	**4,531**	**20**
JULY.							
	Nantucket	74	62	2.09	9	8,011	30
	Key West	87	77	1.40	11	6,750	28
	Farallone	56	52	0	0	11,974	40
	San Francisco	62	52	.02	1	10,574	38
	San Diego	**71**	**62**	**0**	**0**	**4,335**	**23**
AUGUST.							
	Nantucket	71	61	2.25	12	8,377	35
	Key West	88	77	4.24	13	6,417	31
	Farallone	56	53	Trace	0	11,066	40
	San Francisco	62	52	.06	2	9,674	36
	San Diego	**76**	**66**	**Trace**	**0**	**4,165**	**17**
SEPTEMBER.							
	Nantucket	67	56	.78	5	8,869	58
	Key West	87	77	3.55	16	6,092	27
	Farallone	No records.					
	San Francisco	71	57	5.07	5	7,141	36
	San Diego	**76**	**64**	**Trace**	**0**	**4,132**	**20**

Month.	Locality.	Temperature. Mean Max.	Temperature. Mean Min.	Precipitation. Total.	Precipitation. Days with .01in. or more.	Wind. Total movement in miles.	Wind. Max. velocity, miles per hour.
October.							
	Nantucket	57	47	1.01	8	11,700	48
	Key West	82	74	1.57	14	8,675	71
	Farallone	61	56	2.01	7	10,791	50
	San Francisco	68	56	2.37	7	5,506	32
	San Diego	**74**	**59**	**.17**	**3**	**4,171**	**20**
November.							
	Nantucket	46	35	3.29	8	11,394	60
	Key West	76	68	6.22	12	7,573	43
	Farallone	59	51	1.58	6	9,168	43
	San Francisco	63	53	1.07	5	3,851	22
	San Diego	**74**	**54**	**0**	**0**	**3,930**	**23**
December.							
	Nantucket	35	25	4.67	17	13,184	64
	Key West	74	65	.34	2	6,841	26
	Farallone	57	51	2.22	10	11,431	58
	San Francisco	55	46	1.59	10	4,876	38
	San Diego	**66**	**51**	**2.46**	**7**	**3,884**	**19**

Perhaps the most important fact, from the present point of view, exhibited by this table is that pertaining to winds. It will be noted, for San Diego, that the maximum velocity for the year was 36 miles an hour, in February. On the basis of the "Beaufort Scale" of wind velocities, this is a "Strong Breeze." February and March are the climax of the stormy season. For the months May to December, inclusive, the maximum velocities run from "Gentle Breeze" to "Fresh Breeze."

La Jolla, the suburb of San Diego at which the laboratory is located, is on a rocky point jutting into the open sea with water of 200 fathoms attainable inside of five miles; so the ecological problems of oceanic plankton, and of bottom-forms can be here attacked under peculiarly favorably conditions.

The western boundary of the area corresponds roughly to the edge of the continental shelf in this region, and immediately beyond this 2,000 to 2,300 fathoms are reached. While this extreme depth is distant about 200 miles from San Diego, by making San Nicholas Island a temporary base the 2,000 fathom



MAP 1.—Showing the Area to be surveyed. Modified from United States Coast and Geodetic Survey Chart.

curve is only 65 miles away. Within the area is a wide range of depth and great variety of bottom. A basin 40 miles off Point Loma has a depth of over 1,000 fathoms. On the other hand, the Cortes Banks, just beyond the southern boundary, carry but 15 feet of water at low tide.

There can be no doubt that deep sea and 'longshore investigations have not yet been brought together to the extent they ought to be.

3.—The Initial Step.

The first step in such a survey would obviously be to find out what plants and animals inhabit the area; to establish a speaking acquaintance, as one may say, with the organisms that are later to be more intimately known. So far this has absorbed most of the effort, and it will of necessity demand the continuance of much effort for a long time in the future. The ideal being kept always in view, the mere description of the new species for the exclusive use of expert taxonomists in the several groups, would not be sufficient. The entire fauna and flora must be recorded in such a way as to make the records a good foundation for the broader and deeper studies to follow. These considerations have determined the character of the faunistic papers now published, and that will come hereafter. The present volume contains the following contributions to a knowledge of the fauna:

No.1.—The Hydroids of the San Diego Region, by Professor H. B. Torrey.

No. 2.—The Ctenophores of the San Diego Region, by Professor H. B. Torrey.

No.3.—The Pelagic Tunicata of the San Diego Region, excepting the Larvacea, by Professor Wm. E. Ritter.

No. 4.—The Pelagic Copepoda of the San Diego Region, by C. O. Esterly.

No. 5.—The Nonencrusting cheilostomatous Bryozoa of the West Coast of North America, by Dr. Alice Robertson.

No. 6.—The Dinoflagellata of the San Diego Region, by Professor C. A. Kofoid.

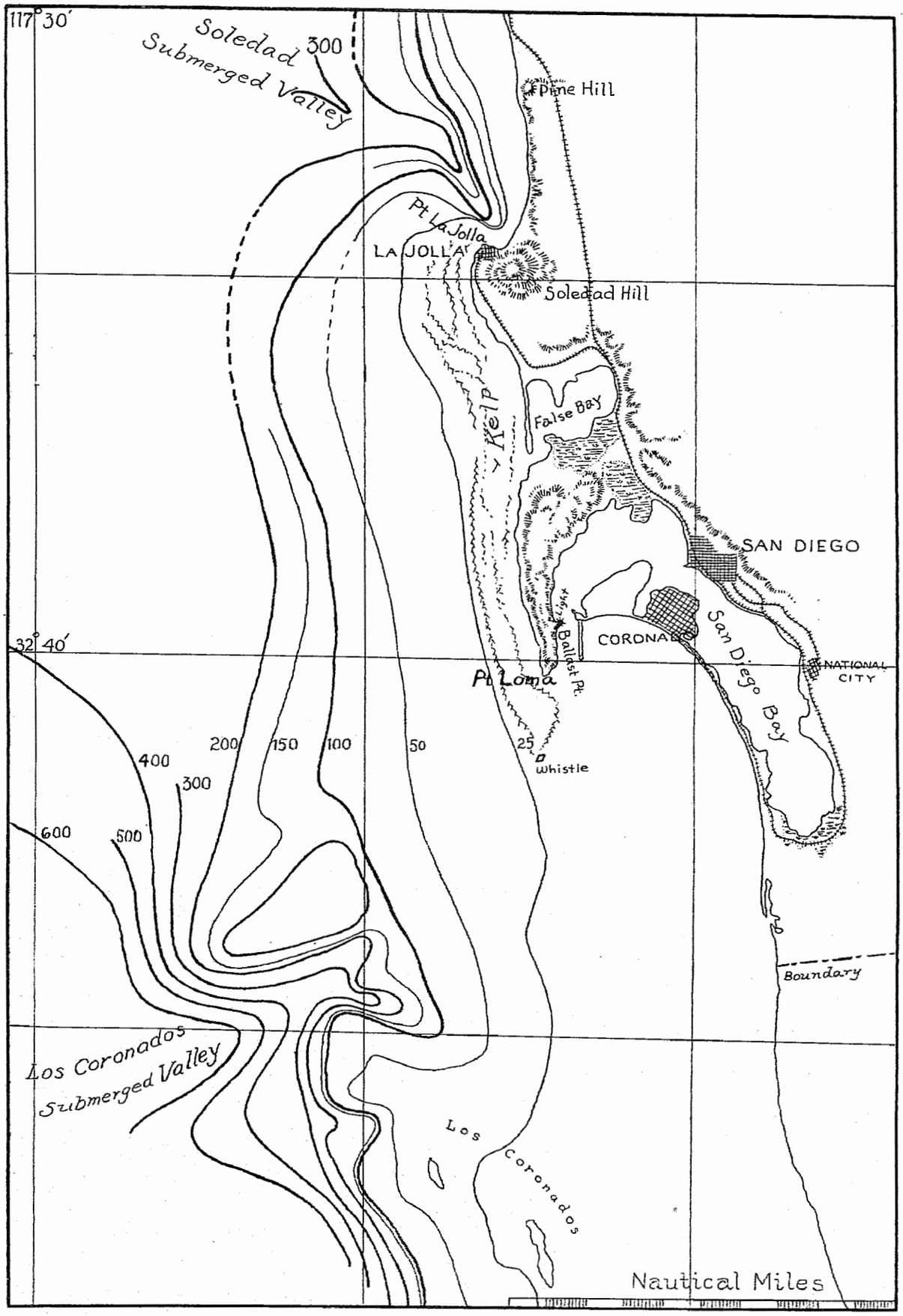
Not only are new species described, but all that have thus far been found in the area are characterized, and in most cases illustrated by figures, so that these papers will constitute a series of hand-books, as far as they go, for the identification of the species treated. It is also intended that the bibliographical lists accompanying the papers shall serve as useful guides to the literature of the several groups for those who may take them up for the study of special problems connected with them.

4.—Order of Advance on the Numerous Lines of Investigations.

While there is no reason for attempting a rigorously laid out order of attack on the numerous problems, at natural sequence, within certain limits, will establish an order; and where practical administrative conditions conveniently adapt themselves to such sequence this order will be followed. For example, the species representing a given pelagic group having been got well in hand, a natural second step would be the determination of the seasonal distribution of the group, since the study of the collections for the taxonomy would surely bring together, incidentally, considerable data on this problem. Following close upon the treatment of seasonal distribution would come that of horizontal and vertical distribution, the chorology; and inseparably linked with these would be the problems of food and reproduction; and these again would lead to problems of migration, with their intimate dependence upon temperature and other environmental factors. And here, completeness of knowledge being ever the watchword, the demand would arise for applying experimental and statistical methods in the effort to get at the deeper significance of the facts observed, and generalizations reached from the observational investigations. The chain of questions hanging one to another is endless and, of course, completeness of knowledge in a literal sense, is an unattainable ideal.

5.—Knowledge of the Physical Conditions of the Area.

It does not need to be said, in the light of general biological conceptions reigning in this day, that an aim at comprehensiveness of knowledge cannot for a moment neglect the physical conditions under which organisms live. What has to be consid-



MAP 2.—Immediate vicinity of San Diego and La Jolla, showing bottom contours in fathoms.
Modified from a map by Professor George Davidson.

ered in connection with a marine undertaking like the present, is the specific things that must be done, and the means for doing them. Oceanography is in position to hand over to the marine biologist, ready prepared, a large amount of the information he must have; and, likewise, physics and chemistry have important resources that can be drawn upon. But these general sources in nowise obviate the necessity for constant and searching studies on the sea water in connection with such a survey as that contemplated. Conditions of the water as to temperature, and currents; mineral, gaseous, and albuminoid content, etc., must be known at *the particular time and place to which the biological studies pertain,* and no general knowledge of this character can suffice. Physics, chemistry, and hydrography must, therefore, be integral parts of such a survey.

6.—Instrumentalities for Prosecuting such a Survey.

It is obvious that no small outlay of money would be essential for even a good beginning; and that considerable progress in it could be made only with large expenditures for both equipment and operation. The ideal laboratory building would not be large, but would be constructed with great care. Aquaria would constitute an important element in the plant for the work on shore. From $50,000 to $75,000 should build and equip an ample laboratory and aquaria.

Equipment for the work at sea would demand the greater portion of the capital. For the deep-water work a ship of the class of the U. S. Fisheries steamer Albatross would be essential. For less depths, say 1,000 fathoms and under, a much smaller vessel would be as efficient or even more so, since it can be handled so much more quickly. As noted above, our area is extremely favorable for this purpose. A vessel that could be built and made ready for sea (without scientific apparatus) for $10,000 or $12,000 would be ample.

Operating expenses would be considerable; and this leads me to speak of the factor most important, but least tried, for the successful carrying out of such an idea.

7.—Necessity of a Salaried Staff.

Obviously, there must be coördinated effort of numerous special investigators to make any headway. How is this to be secured? In only one way: *by paying for it.* The diversity of talent and training called for, and the prolonged period of service requisite, preclude the possibility of success on any other basis. Botanists and zoologists there are who would gladly, and without thought of money compensation, prepare reports on collections in their special groups that might be sent to them; and occasionally one would be found not only willing but able to stand the expense of a sojourn for a few days or weeks at the Station, that he might make observations in the field and participate in the collecting. But for repeated and long continued work on both living and preserved material such as is implied by the range of problems contemplated, gratuitous service of this sort cannot be counted on. And why should it be expected or asked?

So with the other lines of research; a chemist could easily be found who would be glad to examine water samples that might be sent to his own laboratory; and geologists there would be who under like conditions, from their geological interest, would willingly report on bottom deposits. But where is the chemist, or physicist, or geologist, or hydrographer, who would be willing, or could afford, to undertake such systematic studies, largely of necessity at the Station, as would meet the biological requirements? There is really little more ground for assuming that a chemist's scientific interests should be sufficient to induce him to enter upon such a task, than that they should be sufficient to induce him to do the chemical work at a sugar factory, or a gas works.

In short, the only way by which such a survey can be carried on with any considerable measure of success is through an *organized, salaried staff.* This, of course, means a large and continuous expenditure. But the size of the expenditure would be fortunately lessened by the circumstance that while the staff would be in the aggregate rather large, only a portion, and in the main a comparatively small portion, of the time of each member would be demanded. In most cases occasional visits to the Sta-

tion for brief periods, with most of the work done elsewhere, would suffice. So the chief and more permanent members could as well as not be persons in regular positions and with regular incomes in other institutions. Furthermore, the investigations are of such a nature that students in the stage of advancement of candidacy for the doctor's degree in a University could, by working under the guidance of those more experienced, be of much service.

8.—Present Status, as to Ways and Means.

An organization incorporated under the laws of California, known as the Marine Biological Association of San Diego, is at present the structural foundation upon which the survey rests; but the Association is prospectively a department of the University of California. Provision is made in the articles of incorporation that under specified conditions and at the expiration of a certain period, all the holdings and undertakings of the Association shall pass automatically and wholly into the hands and under the control of the Board of Regents of the University.

In the meantime, the University's part in the undertaking consists in a measure of coöperation through a committee of Regents, with the Managing Board of the Association, in the conduct of the business affairs of the survey; in the fact that the Director and most of the Scientific Staff are members of the University Faculty; in the granting to the Association permission to take to the Station each year a considerable amount of laboratory equipment and numerous library books; and finally, in publishing at its own expense the results of the investigations.

The assets of the Association at present are: a laboratory building at La Jolla, neither large nor of elaborate construction, but serviceable for most of the work now in progress; a schooner of nineteen tons register, with auxiliary power, and fitted with hoisting engine and gear; collecting apparatus; the nucleus of a library; and a definite guaranteed income for three years from July 1, 1904.

The present officers of the Association are:

H. H. Peters, President.

Dr. Fred Baker, Vice-president.

H. P. Wood, Secretary.

Julius Wangenheim, Treasurer.

Wm. E. Ritter, Scientific Director.

E. W. Scripps and Miss Ellen Scripps, members of the Board of Directors.

B. M. Davis, Resident Naturalist, 1904-05.

Manuel Cabral, Collector.

The permanent members of the staff since 1901 have been Wm. E. Ritter, Ph.D., Professor of Zoology in the University; C. A. Kofoid, Ph.D., Associate Professor of Histology and Embryology; H. B. Torrey, Ph.D., Assistant Professor of Zoology. In addition the following, all connected in some capacity with the University, have been members for longer or shorter times on assignment to particular pieces of work, and for the most part on the pay roll: W. J. Raymond, B.S., Assistant Professor of Physics; F. W. Bancroft, Ph.D., Instructor in Physiology; Alice Robertson, Ph.D., Assistant in Zoology; C. O. Esterly, A.B., Assistant in Zoology; John F. Bovard, B.S., Assistant in Zoology; Margaret Henderson, B.S.; H. M. Evans; L. H. Miller, M.S., Assistant in Zoology; Robert Williams, B.S.; and Effie J. Rigden.

9.—Historical Note.

Our work in this area did not begin with the San Diego Association, or even with San Diego as a base of operations. During six weeks of the summer of 1893 a party of teachers and students from the Department of Zoology of the University of California, housed in a tent laboratory at Avalon, Santa Catalina Island, made the first dip into these waters. Both the money and equipment for this piece of work were supplied by the Regents of the University. Another University party, with headquarters at San Pedro, put in several weeks of the summer of 1895. Nothing further of a formal character was attempted until 1891, though individual members of the department made repeated collecting trips to San Pedro throughout the intervening period. All this served to prove the great richness in marine life, the advantageousness as a collecting place, of the San Pedro district. When, consequently, it was resolved, in 1901, to make on effort on the

basis of ideas that had beed taking shape for several years—those, in a word, which now animate the undertaking—San Pedro was believed to be the most favorable locus for whatever might be done. For this summer it was resolved to aim particularly at dredging operations in the shallow waters, made as thorough as the time and equipment would permit, with a reconnoissance to San Diego if possible. The University being unable to supply the money for this, a successful appeal was made to friends of the University and of science in Los Angeles and elsewhere. Funds to the amount of about $1,800 were secured, with which a large though open gasoline launch was hired and fitted for the work. She was kept going almost constantly from May 20 to August 6. While the dredging and trawling were the chief occupation, other lines of work were not wholly neglected, particularly plankton collecting and temperature taking. The proposed run to San Diego was made, and from the days devoted to the work there a good impression of the biological conditions of that region was obtained.

For the work on shore on old bath house was rented and converted into a simple laboratory. The summer of 1902 was likewise spent at San Pedro, but this year nothing was done at sea, attention being restricted to the littoral fauna.

During both these seasons formal courses of instruction in Zoology were given as part of the regular University Summer Session.

Before the next summer the laboratory building and best collecting grounds within the small inner harbor at San Pedro had been destroyed by the harbor improvements being prosecuted there by the U. S. Government. Owing to this and to encouraging proposals for financial aid from San Diego, led by Dr. Fred Baker, and to the good impression made by the experiences there in 1901, it was resolved, in the early spring of 1903, to move the base of operations to San Diego. During the years 1903 and 1904 the boat house at Coronado Beach, given and in part fitted up by the Coronado Beach Company, served as a laboratory building.

The work at San Pedro was made possible largely through the interest and efforts of Mr. J. A. Graves, Mr. H. W. O'Mel-

veny, and Mr. Jacob Baruch of Los Angeles. The chief contributors of money here were: Mr. Jacob Baruch, Mrs. Phoebe A. Hearst, Mr. J. A. Graves, Mr. H. W. O'Melveny, Mr. Wm. G. Kerchoff, Mr. Wm. R. Rowland, Mr. Van Nuys, The Los Angeles Terminal Railroad, Mrs. Margaret Fette, Mr. J. H. Shankland, Mr. John E. Plater, and Mr. Charles M. Wright.

By far the largest givers to the station since its removal to San Diego have been Mr. E. W. Scripps, Miramar; Miss Ellen B. Scripps, La Jolla, and Mr. H. H. Peters, San Diego. In addition, the following have contributed substantially: Mr. Wm. Clayton, for the Coronado Beach Company; Mrs. F. L. Keating, Mr. Henry W. Putnam, Mr. G. W. Marston, and Hon. U. S. Grant.

10.—Remarks on the Present Status of Marine Biology in General.

Situated as our station is, on a biologically almost unknown part of a little known ocean, our first concern, chronologically, must be with local conditions and problems. The meagerness of knowledge, not only of the fauna and flora, but also of the oceanography of the eastern part of the North Pacific can hardly be realized except by the few specialists whose studies have led them into immediate contact with it. Sir John Murray, the acknowledged prince of oceanographers, when the science is regarded as pertaining to the earth as a whole, has recently pointed out the urgent need of further exploration of the Pacific from about 150° W. Long. to the American coast. Our information about the most general facts concerning the currents, for instance, is wholly inadequate to constitute a foundation for investigations on distribution of organisms. And as to zoology, there are whole groups of prime importance for any of the wider questions of marine biology, like the *dinoflagellata*, the *radiolaria*, and the *chaetognatha*, about which there is hardly a recorded observation. Even the better studied groups, like the fishes, the mollusks, and the crustaceans, when ecologically regarded have been hardly more than glanced at.

But, hemmed in as we are and for a long time must be by the limitations of meager local knowledge, we yet venture to look somewhat beyond these limits to see where the general idea constituting the underpinning of our enterprise stands with reference

to the present state of this domain of science; and in what particulars, if any, Nature has given us opportunities to be of special use in advancing it. Looking over the whole domain, one sees that while certain geographical regions, like the Mediterranean, the North and Baltic Seas, the environs of the British Islands, and, to a less extent, the North American half of the Atlantic, have been cultivated, intensely even, in certain particulars, when attention is directed to large problems rather than to space areas, the thoroughly subjugated portions are exceedingly small.

Let one go to the Bay of Naples, for instance, perhaps the best cultivated locality, and make inquiry about the ecology of the most familiar species found there, and see how far from satisfactory an answer can be obtained. In the realm of pelagic life, no one would contend that the great expeditions of the last half-century, even that of the Challenger, of the Blake, and the recent more concentrated and betted equipped German Plankton and Valdivia Expeditions, and those of the Albatross, have done more than to effect a reconnoissance of the field. The most general questions of seasonal, vertical, and areal distribution are still topics of widest divergence of view, and of lively discussion; and it is obvious that this diversity is in large measure due to the mere matter of dearth of readily ascertainable information. Beyond the most general truth, important is this is, that the bottom of the sea, even in its deeper parts, is inhabited by animals, how immediately one comes against a blank wall when he begins to ask questions about this life. How abundant is it? Does it actually reach into the profoundest depths? Are we to suppose it to be uniformly distributed over the entire ocean floor, modified only by local conditions, or as belonging essentially to the continental margins, with only an advance guard of stragglers, so to speak, reaching to the localities farthest removed from any land? How long, geologically, have the truly abyssal depths been inhabited, and when and how did they become inhabitable? From what source did the immigrants to these regions come? If from the littoral realms, has there been a general movement of approximately equal importance from all shores, or has it been chiefly from the polar regions? What is the significance, biologically, of the continental shelf? What of Murray's "mud line"?

When viewing this whole field of knowledge, and the means and methods of investigation, one must be struck by the prevailing uniformity and inadequacy of the existing marine stations for coping with the situation. This inadequacy is most manifest in two particulars; first, in the well nigh complete absence of endowment, which is essential for the assurance of that certainty and regularity of income by which alone continuous and long continued, definitely planned investigations can be prosecuted; and secondly, by the fundamental idea on which nearly all these institutions are based. They have been and are, with few exceptions, primarily resorts for individual investigators of specific biological problems, and not for systematically attacking the problems of marine biology proper.

I would wish to guard myself without fail against being understood as passing adverse criticism upon these laboratories. They were, most of them, brought into existence by an obvious, immediate, and pressing need. This they have met, and are meeting, magnificently. No other instrumentality has contributed so largely to the promotion of general biology. The particular need which gave them birth was not, however, that here considered. Only in the course of natural progress has this need come pressingly into existence. We are able now to formulate more definitely than has hitherto been possible, the problems in this field, and to see more clearly what methods and instruments must be used in their prosecution.

We are in position to appreciate, for example, as never before the importance of knowing the complete life-histories of animals. We are becoming ever more impressed as knowledge advances, with the truth that no segment of the phenomena presented by an animal, morphological or physiological, is fully understood until it is regarded in the light of the entire life career of that animal. We are likewise in position to see as never before what must be done to attain to this fullness of knowledge. We must, in the first place, learn by observation all the facts of the life-history of the animal. In the second place, we must make use at every point possible of a combination of observation and experimentation for the interpretation of these facts.

I verily believe the value of the experimental and statistical methods now so largely used in biology is not fully appreciated even by some of the most skilful and constant experimenters themselves, nor will it be until these methods are better coördinated with observation in Nature. The problems of animal migration, to be specific, we now know depend largely, at least so far as the simpler aquatic forms are concerned, on purely physiological reactions to temperature, light, sex relations, food, etc.; and we are already in possession of important clues to the way these questions must be studied; but we must learn, through careful and extended *observation of the animals in nature*, just what it is we have to interpret. Need for a kind of marine biological research not specially felt a few years ago is now becoming urgent.

The laboratory of the Liverpool Marine Biology Committee on the Isle of Man, under the directorship of Professor W. A. Herdman, and the proposals of the International Commission for the Investigation of the Sea, are distinctly in the direction of what the future must have for carrying on such researches.

The portions of Nature unsubjugated by science are vast—it almost seems as though they grow vaster the longer we work at them; and one of the great questions science has ever before her is that of making such effort as she is able to put forth count for the most. One way of doing this is by giving good heed, not alone to the talents and tastes of workers, and money endowments, but as well to the *opportunities* held out by Nature herself.

The conditions placed by Nature before us mark unmistakably the road we ought to take.