THOSE WERE THE DAYS: THESE ARE THE PEOPLE

Oceanographic Medley

In joining some of my "old time" colleagues in recalling early experiences and involvements during some of the formative days of Scripps Institution of Oceanography, it is useful to consider, as a background, a bit of the yet earlier past. But emphasis will fall mainly on the thirties and forties when special effort was being made to direct research more towards the open sea. The intention is not to write a supplement to the institution's history,* although it must necessarily include some, it is rather an abridged memoir of sorts dealing with topics leading to and involving mainly my own research at SIO and including, in much less detail, that of my students on biological projects in what was first known as the "Zooplankton Division"; then the "Marine Invertebrate Division"; and finally, in the general growth and reorganization, a part of the "Marine Life Research Group".

On coming to Scripps: —In retrospect of days before and after coming to SIO, a number of questions seem to be posed relative to my participation in the oceanographic program following its transition. Among these questions are: what was the status of SIO with respect to the marine discipline that I expected to be concerned with, and what could I bring to the Institution by way of ideas and experiences that might be helpful towards advancing seaward certain biological studies, especially zooplankton, that had in the

* Helen Raitt and Beatrice Maulton 1967 Scripps Institution of Oceanography: First Fifty Years.

Elisabeth Noble Shor 1978. Scripps Institution of Oceanography: Probing the Oceans 1936-1976.

earlier days been mainly in coastal waters; how was SIO prepared to carry on a high-sea work; and finally, what did I, as a faculty member, contribute to SIO's scientific and educational output.

In the early planning of the San Diego Marine Biological Station, the policy of its first director, Dr. W.E. Ritter, was to do intensive local surveys as a basis for further offshore work after the fauna had become adequately known. This was no small task in view of the complexity of marine life. It is, indeed, this complexity and abundance that led to the establishment of biological stations at the coast where the greatest abundance of life is available for comparative purposes in the many specialties that make up Marine Biology. This is so since it is in the sea that we find the greatest array of major divisions of the animal kingdom. The seventeen phyla, as generally recognized, occur in the sea, and five of these are exclusively marine. Over 40% of the classes are exclusively marine, whereas only about 7% are exclusively non-marine.

But with these coastal efforts, there was obviously a feeling of need to extend the studies further seaward to include the entire environment. This is expressed also by Dr. C.A. Kofoid, coworker with Ritter in establishing the Biological Station: "...and the plan further contemplates maintaining a vessel large enough to sound, fish and dredge any portion of the Pacific Ocean." It is not surprising then, that a transition finally occurred, culminating in Oceanography, a harmonious composition of various disciplines including the physical, chemical, geological and biological aspects.

The Marine Biological station undertook to grow in that direction in 1923, but not without some growing pains associated with recruitment of personnel, lack of adequate sea-going facilities, and with an unexpected austerity program necessitated by the economic depression of the thirties. Although SIO was the first Institution of Oceanography established in the United States, it appears that in the twenties there was a general increase in awareness of a need for more emphasis on Oceanography, either by expansion of established biological stations, or by establishing independent institutions for this specific purpose. As a result, Woods Hole Oceanographic Institute came into being in 1930; the University of Washington, Department of Oceanography in Seattle in 1932; and at Friday Harbor, Washington by taking over the 29 year old Puget Sound Biological Station. However, unlike the SIO's experience, this conversion at Friday Harbor did not persist and the laboratories there reverted largely to multidepartmental use as the Friday Harbor Laboratories.

Enroute to Scripps: —Certain chronological events which, seen in retrospect, provide some insight into experiences that have been very useful to me at Scripps in both laboratory and field work.

In 1903 when Dr. Ritter was busy laying plans that eventually led to the establishment of SIO, I was a farm boy in Saskatchewan, Canada and North Dakota, riding herd on grazing cattle and learning first hand the natural history of the great plains. There was little thought of the Pacific Ocean or of its contribution to summer showers or the roof-high winter snow drifts. The only sea to behold was one of waving prairie grass, a classical example of fundamental ecology and economy that shows in contrasts— a real basic

difference between the terrestrial and marine biocycles with regard to the type of pasturage and resultant type of grazers of each; a contrast as great as the difference between cows and copepods. All this, of course, had to be learned later. But it was here that I saw my first living marine-related animal, namely the California sea gull following the plow in search of tid-bits exposed in furrows of freshly borken prairie sod.

All this prairie-land natural history was relegated to memory in 1909 upon moving to Washington state, where, in the Pacific northwest, a new wonderland of giant forests, mountains and arms of the sea suddenly appeared, each with a new type of natural history.

Here at Everett, I experienced the first taste of seawater and watched the ships come and go while dreaming of going to sea some day.

The forests, too, had their special appeal and, while working at logging, I acquired an injury that provided one of the links in events that led towards the sea by way of the salmon fishing industry. Here, in the industry, I found certain types of work at which a convalescing borken leg was not too great a handicap while tending and guarding fish traps or patrolling by boat against fish pirates who operated in the area.

So now I had finally come to the sea in a meaningful way. It was here at the Alaska Packers Association field camp at Point Roberts, Washington and at the San Juan Islands that I was really introduced to the inspiring world of abundant and diverse marine life and to one of its mysteries, the migrations of salmon.

Subsequently, for several years, during summer vacations from highschool and the University of Washington, I was engaged by the A.P.A. in various aspects of fishing.

Upon graduation from the University in 1923 with a B.S. in zoology, I taught general science in West Seattle High School until June 1924 when Dr.T.C. Fry, director of the university's Biological Station at Friday Harbor, Washington, asked me to return to the university as curator at the station. Needless to say, I accepted the position which offered an excellent opportunity to study marine biology in a practical way through collecting and preparing biological material, and as time allowed, to carry on personal investigations that resulted in ~~four~~ six publications that Dr. T.G. Thompson called bootleg research, part of which served as my Ph D dissertation at the University of Washington in 1931.

The next adventures in marine biology was as a west-coast member of the scientific staff of the Passamaquoddy International Fisheries Commission working out of the Woods Hole Oceanographic Institute and the Atlantic Biolgical Station at St. Andrews, N.B., Canada. Using a Canadian and a U.S. vessel, cruises were made locally in Passamaquoddy Bay, the Bay of Fundy and the Gulf of Maine, involving hydrography, biology and chemistry. This experience in practical application of Biological oceanography provided a better understanding of the factors to be considered in any study of the economy of the sea.

The depression of the thirties was in full swing and when the commission was disbanded in 1933 I returned to Friday Harbor as honorary Research Associate at the Biological Station, which in the interim, had become the University of Washington Oceanographic Laboratories with Dr. T.G. Thompson as director.

The following narration carries the memoir forward into some years critical to Scripps Institution.

At SIO: - In June 1934 Dr. T.Wayland Vaughan, Director of Scripps Institution, offered me a position as Research Associate in Marine zooplankton, acknowledging the inadequacy of the low salary of $100.00 per month. In further correspondence, however, he raised the offer to $120.00 the $20.00 to pay for rental of one of the campus' cottages. I accepted the position, and if needs be, would have done so even at the lower rate, in view of the then nation-wide depression, and in view of the potential Scripps seemed to offer as a part of the University of California and despite the austerity budget it was operating with at the time.

In his correspondence of June 9, 1934, Dr. Vaughan made it clear that he was making special efforts to get research headed towards the open sea saying, "We have on the Institution's staff a few people who are not sea-going. I do not intend to add to the staff anybody else who will not work on water". This was not a deterrant to me because I had already wanted to get out on the Pacific with some of my research, and the plankton program to be worked out was left entirely to me.

Upon my arrival July 1, Dr. Vaughan was ill with tuberculosis and during my bedside visit with him the next day he thoughtfully insisted, for my benefit, that we not shake hands. But we had a good conversation covering the state of affairs at SIO. He suggested that I consult especially with Dr. Eric Moberg and the graduate students Richard H. Fleming, chemist, and Roger R. Revelle, geologist, regarding sea-going facilities and what cruises, if any, were pending. This I did and although somewhat dissapointed in regards to plankton facilities, I was pleased to find a good deal of enthusiasm and sympathetic attitude towards plankton research, as an essential

part of oceanography.

This was also the attitude of others on the staff that made up the small but good nucleus for marine research, including the newly added faculty members Dr. Denis L. Fox, biochemist, who was engaged in studies of comparative metabolism of caratonoid pigments of marine animals; and Dr. Claude E. ZoBell, microbiologist, whose research delt with biochemical reactions of bacteria in diverse environments of the ocean.

Joining the biological faculty some years later was Dr. Carl L. Hubbs, ichthyologist, who with his ever present helpmate Laura Hubbs, carried on research projects from fish to whales.

The only staff members actively engaged in plankton studies at the time were Professor W. E. Allen and Ester E. Cupp, phytoplanktonologists. I made it a point to visit Allen shortly after my arrival. In the course of our conversation I mentioned that Vaughan's expectation was that my work would involve study of the zooplankton. To this he approved but remarked, "Nobody talked with me about it". This being the case, I could not but have some sympathy with his remark in view of the fact that in line with my experience it seemed that there should always be a rather close understanding between phyto- and zooplankton -ologists in planning, collecting and evaluating results. So adding a new worker in plankton might, indeed, have some bearing on his work.

Insert no. 1 —

Dr. Francis P. Sumner, another of the original Biological Station staff, had terminated his critical study on the genetics of mice in order to be more in keeping with the newer emphasis on marine research. He was, however, no stranger to marine research in which he had engaged in years earlier. His newer projects dealt with the ecology and physiology of fishes to which he contributed much with regards to the influence that the albido of the

background played in pigmentation of the animals.

Although he obviously enjoyed his newer projects, he apparently retained some mixed feelings towards the shift away from the mice; but, as I learned later, he was good humored about it and even tolerated some disparaging remarks in jest at the shift. I recall once at a party, playing parlor games, I was assigned to make a sketch of him captioned with an appropriate verse. Knowing him rather slightly at the time, there was some doubt as to what his reactions might be upon reading the doggerel:

"I doubt you knew you look like this

But you got that way studying fish.

Now if you'd kept on studying mice

You'd still be looking very nice"

All went well, and he and Mrs. Sumner insisted upon taking the, not too flattering, sketch home with them.

Dr. George McEwen, physical oceanographer and mathematician, was concerned especially with upwelling of cold water along the coast and with oceanic temperatures, etc. and related meterology. He was, as I also found later, always glad to join biologists in solution of projects needing mathematical analysis. In his department was Stanley W. Chambers who kept temperature and tide records at the pier

Percy Barnhart, curator of the museum and aquarium, had a major interest in taxonomy of local fishes. The aquarium was kept open day and night and together with the pier, which was open to the public for fishing over the railing, were the main public attractions.

Dr. Vaughan, whose personal research interest dealt with living corals, and thus contributed towards his appreciation of the place of marine biology in the overall oceanographic program.

As mentioned earlier, the thirties were austerity years and this was much in evidence at SIO in all aspects, including the Administrative,

Academic and Physical facilities. Prospective purchases of equipment, etc. kept to a minimum and inconveniences were tolerated. On the first floor of Ritter Hall only one telephone was available, placed in the hallway, to serve three faculty members. Travel funds were short. I recall Vaughan one year called Fox, ZoBell and me to his office to explain that he had only about $75.00 to spend on us for a trip to Seattle to present papers at the AAAS meeting there; we could divide it between us or let one have the whole sum. We decided to use it jointly driving to Seattle in ZoBell's car and sharing the driving expenses.

But so far as I know everyone on the SIO payroll received their monthly pay check promptly. It was hand delivered by Tillie Genter who made the rounds and if no one was present to receive the check it was left face down on some laboratory or office table. Tillie was inspiration to everyone's honesty and good will.

Conspicuous at SIO during the depression was the U.S. Works Progress Administration (W.P.A.) which provided some hiring relief for assistants, etc.,some professional in nature others for routine menial tasks. Although the program was intended mainly as a stop-gap relief for people caught without employment, most workers that I knew of were conscientious and anxious to learn. In applying, a few had overestimated their training or ability for a specific job.

A most notable WPA helper in my division was Mrs. C. Painter, who helped translate Sven Ekman's 1935 "Tiergeographie des Meeres".

Zooplankton at SIO: - The importance of zooplankton to a study of marine biology and oceanography has long been recognized and from the early founding of the Biological Station it was given major attention. By 1923 when SIO was established, a good deal of pioneering research in

zooplankton had been done, especially by Dr. Calvin O. Esterly, a non-resident on the staff from Occidental College. His publications dealing with taxonomy, coastal distribution, seasonal occurrence and diurnal vertical migrations of copepods, the commonly major component of plankton, were of great aid to me before and after joining Scripps. His investigations, including copepods from San Francisco Bay, spanned about two decades during which he listed 48 genera and 147 species, 56 of which were new to science. Included in his surveys were also euphausiids and ctenophores.

Ellis L. Michael, a resident on the staff for about sixteen years, worked mainly on chaetognaths, the arrow worms that are sometimes dominant in the plankton. His most significant contributions deal with the vertical migrations that the animals undergo in relation to environmental conditions.

Dr. Ritter's interest, as one might expect in view of his concern with biological philosophy, was with protochordates such as Entropenusta with a planktonic tornaria larva that suggests an evolutionary relationship to echinoderms by way of some of their similar appearing larvae. Included also in his research were studies of the planktonic Larvacea.

Although Dr. C. A. Kofoid became head of the Department of Zoology at Berkely in 1910, he continued contact with the Biological Station and continued with plankton work started there. This culminated in two monographs, one on the "Unarmored Dinoflagellates" with Olive Swezy and one with A. S. Campbell entitled "A Conspectus of the Marine and Fresh-water Ciliata Belonging to the Suborder Tintinnoinea, with Descriptions of New Species Principally from the Agassiz Expedition to the Eastern Tropical Pacific 1904-1905".

Regarding this work Kofoid states it to be, "fairly representative

of the North Temperate, Tropical and South Temperate Pacific from the Arctic Circle to the Tropic of Capricorn, especially in the Eastern part of the ocean".

In the work of the Biological Station, rather little attention was given to life histories of invertebrates with planktonic larvae. Only one copepod larval development was worked out by H.E. Murphy and although Dr. B. M. Allen carried on some excellent fundamental ecological studies on the adult of the commercially important California spiny lobster, the ecology of the planktonic larval stage was not considered; most likely because of lack of adequate collecting facilities.

Beginning a few years before SIO was established and about up to 1934 there was a lull in active zooplankton research. This no doubt resulted in part by the selling of the Biological Station's boat the "Alexander Agassiz" in 1917, leaving mainly the pier for what collecting could be done there. The "Scripps" was acquired September 1925 and was used to some extent for collecting at the five and ten mile stations, but the samples were apparently not used for population studies.

space —

On the coming of a new Director: - Some time before Dr. Vaughan's retirement in September 1936 he called a staff meeting to announce the appointment of Dr. Harold U. Sverdrup, of the Geophysical Institute at Bergen, Norway, as his replacement as Director. Although the staff had not been consulted beforehand, no voices were raised in either objection or approval. Personally I had a feeling of both surprise and elation. Firstly because I had heard much about him, through news reports, as an Arctic explorer associated with the ice-locked drift of the "Maud", but had not the least thought that he might be a candidate. Secondly, it was a

forceful reminder to me of my attempt fourteen years earlier in 1922 to visit the "Maud" while she was docked in Seattle's Lake Union for repairs after having been freed from the ice and proceded south through the Bering Strait. I was attending the University at the time and it seemed a rare opportunity to see the ship and if possible to talk with Dr. Sverdrup or members of his party. But from the dock I was unable to arouse anyone on the ship and was further frustrated by a dog aboard that paced me from bow to stern as I walked the dock. Although I failed in my main objective, there was at least some satisfaction in having seen the "Maud".

In relating all this to Dr. Sverdrup at SIO, he kindly presented me with a photograph of himself, some crew members and the dog aboard ship.

The choice of the new director was timely for Scripps during its transition to an oceanographic institution. His oceanic experiences and personal participation in cruises after he came here was a good stimulus to traditional oceanographic research. He made it a high priority concern to obtain a good seaworthy vessel to replace the "Scripps" that was destroyed in 1936 by a tragic explosion while at dock. Dr. Fleming participated actively in this search for a new ship and I recall taking a cruise with Sverdrup and Dick to try out the "Novia Del Mar" owned by Robert P. Scripps. She had no oceanographic gear aboard but I brought a net along and made a good routine plankton haul to have something to show for the day.

The outcome of the search resulted in purchase of a sailing yacht owned by the movie actor Lewis Stone. Renamed the "E. W. Scripps" and converted for oceanographic work, she was a good ship but with a low free-

board and with a heavy winch placed forward she was sometimes pretty wet until the bow was built higher.

This serves to recall a stormy night while running a line of stations about 125 miles off Point Conception. Scientists on board consisted of Sverdrup, Fleming and myself. As usual, we took turns at watch, six hours off, six hours on except where sampling operations demanded more time on. My turn to stand watch between stations that night with Herb Mann included the small dark hours of the night when the wind freshened and occasional waves began breaking over the bow. In tending a forward hatch I did a sort of momentarily thrilling body-surfing act along the deck to the piolet house. This was not too bad, but our troubles for the night were not yet over. There was a good deal more plunging through unexpectedly high waves when suddenly we heard, above the water noise, a siron as if a ship was bearing down on us, probably a coast guard cutter coming up astern. However, we could see no ship lights anywhere and finally realized that it was our own siron that had been shorted and kept screetching until Herb, after some time below deck, could find the short and make corrections. So far as I recall, neither Sverdrup or Dick was awakened by all this, which shows how sea-hardened they were. It also illustrates a type of routine not too uncommon in oceanography.

Education at SIO: - When I came to Scripps there were only a few graduate students engaged in research towards a higher degree under the guidance of a faculty member to whom they served, largely nominally, as assistants. No regular formal lecture courses were given on the campus at the time. Degrees other than oceanography could be granted by departments on other campuses to which Scripps could contribute.

In 1936 the faculty initiated a course in general oceanography in which several of us participated with lectures. It was customary for those giving lectures to join the students as auditors in a following lecture given by some other faculty member in his oceanographic specialty. This was useful mainly during the first flush of enthusiasm. Lack of an integrated text in Oceanography was a serious handicap. This led Dr. Sverdrup, Dr. Fleming and me to write such a text after having abandoned an earlier idea of preparing only a syllabus for class use.

To write such a text was, of course, an ardous task with much burning of midnight oil while at the same time caring for other duties. In contracting with Prentis-Hall we had at first envisaged a book of five or six hundred pages, but it soon became evident that Oceanography is too large a subject to be presented so briefly. This increase in length led to some grumbling by the publishers but they relented and agreed to publish at a loss if necessary. It came off the press in 1942 with 1087 pages and, after a period of U.S. restrictions on some foreign sales, received worldwide acceptance. In recalling the satisfying toil involved in writing my portion of "The Oceans", there is always brought to mind also the hours spent by Miss Ruth Ragan, librarian, who expertly typed what we brought to her.

sketch?

As the curriculum for teaching Oceanography became better organized, all students irrespective of their major background were expected to have a good smattering of knowledge of the four disciplines, Marine Biology, Marine Chemistry, Marine Geology and Marine Physics. These were considered most useful for a good oceanographer to function happily and with training sufficient to mutually draw upon or to contribute to marine disciplines

other than his own specialty. It was my responsiblity to lecture in Marine Biology.

Over the years the teaching and research led to my serving on a total of 214 student guidance, departmental, M.S., and Ph.D. committees; 57 of which were for final doctoral examinations mostly at SIO; two were for D.Sc. as foreign judicator.

In the early days at SIO, and even into the fifties, the faculty was so relatively small that there was always a heavy demand for members to serve on standing or ad hoc committees. These time consuming necessities were often a drain on research and teaching time, but there was also a complementary gain in keeping aware of academic and institutional business. No attempt will be made here to discuss or enumerate these extracurricular activities or those associated with scientific societies, etc.

Teaching at UCLA: - During the fall semesters, beginning in 1937, I taught a course in Invertebrate Zoology and a seminar in Marine Biology on two successive days weekly at UCLA for four different years, making the trip up and back by automobile over the then two-lane highway. This commuting was finally stopped after the 1941-2 semester because of the war-time gas rationing that went into effect, and the pressure of work at SIO.

During this involvement in teaching, most of the field trips were to sea shore areas, but arrangements were made for my use of the "E. W. Scripps" on some class cruises. Both bottom dredge and plankton net hauls were made and enthusiastically participated in by the students. There were a few seasick casualties, but it is interesting to note that after

returning to shore, even these appreciated having been along. They had gained a conversation subject, but more important they had learned a characteristic attribute of the sea. Everyone tries to deny this malady as long as possible, but the sea will often have its way as shown by the student who came to me ashen faced and confidently asked in a faltering voice: "Dr. Johnson, what does one do when one gets seasick?" Having experienced this handicap on stormy seas, I knew just how she felt and could with all my sympathy tell her what to do.

Supplimental to SIO and UCLA teaching, mention should be made of teaching and research done during four summer sessions at the University of Washington Friday Harbor Laboratories and one session at the Marine Biological Laboratory at Woods Hole, Massachusetts.

~~Zooplankton~~ 1934-1940: - As mentioned earlier, Dr. Vaughan anticipated that my research would be concerned mostly with zooplankton in an effort to get this type of research going again. However, there have been some major deviations into teaching or other aspects of marine biology as well, including marine fouling and wood boring organisms, and bio-acoustics mentioned later.

But most of my studies have dealt with some aspect of zooplankton which comprises a whole spectrum of animals including the planktonic larvae of both benthic and nektonic life. A few of these studies will be mentioned here because of the special use they served in proposing projects to students and in planning further work on oceanic plankton that might be carried out in the Pacific either personally as mentioned below or by interested graduate students with plans of their own involving zooplankton.

The following open-sea plankton collections were eye-openers to me suggesting the most promising organisms or oceanic areas for surveys: 1, a pioneering net collection taken by the U.S. Coast Guard cutter "Chelan" in 1934 through the Bering Sea into the Chukchi Sea; 2, a collection I made at 150 miles intervals from water pumped to the cooling system of the freighter "Harpoon" of the Shepard Line while enroute from San Francisco to the Panama Canal in January 1932; 3, a series of net samples I collected aboard the Coast and Geodetic Survey ship "Guide" off Cape Mendocino in 1936; 4, net samples taken by Eugene La Fond and Robert Dietz on a line north from the Hawaiian Islands through the Bering Sea into the Chukchi Sea in 1947; and 5, general plankton surveys in the San Juan Archipelago, Washington.

All these samples studied together with Esterlie's and Michael's reports from the San Diego Region and with Mildred Campbell's report on Copepods of the Vancouver I. region provided some solutions to certain taxonomic and geographic range problems. This was especially well illustrated by the copepod Eucalanus elongatus and its three varieties with a total range extending from the Chukchi Sea southward to tropical waters. Each variety (now considered separate species) evidently has ~~their~~ its separate preference and numerical dominance in hydrographically recognizable water masses or water currents of the North Pacific where they live and find conditions favorable for reproduction, as indicated by the presence of their larval stages that were identified earlier in separate life history studies for this and a number of other genera and species while at SIO and Friday Harbor.

Plankton studies based on regular cruise collections made by the "E. W. Scripps" in the California current from Point Conception south before the second World War provided information on the vertical diurnal migrations of the general plankton. This later proved very useful in 1945 in suggesting that if the "deep scattering layer" is biological, it should undergo diurnal migration.

The distribution of the planktonic zoeal stages of the intertidal sand crab Emerita found off shore in the 1938 "E. W. Scripps" cruises gave evidence that packets of inshore water shifted with the larvae to far offshore positions through coastal turbulance along the coast of Southern California.

During part of this period of time, four graduate students were at SIO working on zooplankton for higher degrees: Weldon M. Lewis, from Pomona College, M.S.; Cecil Monk, UCLA, Ph.D.; Beatrice La Rue, UCLA, and Charles C. Davis, University of Washington, Ph.D.

UCDWAR: - Much of the work planned or in progress at SIO was abandoned or slowed to snail's pace in the later thirties because of the Second World War. Some members of the SIO staff were given leave to work with the University of California Division of War Research at the Navy Electronics Laboratory at Point Loma. I was asked to join the UCDWR in 1942 in its effort to identify certain ambiant underwater noises that interfered with or disabled underwater listening and other sonar operations carried on by the Navy. Although the headquarters of the Listening Section to which I was assigned was on Point Loma, much of my research was carried out at SIO, in the field aboard the "E. W. Scripps", or on sound scouting surveys along the

East and West coasts on navy vessels, assignment on which was facilitated by Dr. Roger Revell of the Oceanographic Section under the Navy's Bureau of ships. For these personal surveys the physicists at NEL provided me with portable hand-carried sound gear. Because of the uniqueness of the problems involved, they will be covered here in some detail.

A very critical acoustical problem that at the time needed clarification was a mysterious high frequency static-like crackling of such intensity and persistance that it masked out the wanted signals in listening or echo ranging operations designed to detect the sounds from ships or submarines.

Needless to say, at first I was as mystified as anyone else and it was several months before a breakthrough appeared. In the meantime I was offered a goodly number of suggestions, both physical and biological, as to the cause. For example, among these were "terrestrial" noise; clapping of clam shells; breaking of shells by strong clawed crustacea; rheumatic-like crackling of crustacean many jointed legs; feeding noises of fish; expansion and contraction of ships timbers or boring of shipworms; and by some submarine operators as "new fangled gadgets" dropped by the enemy. In testing with the portable gear in many situations and places, I felt that causes of these types were eliminated. The areas that I found to be affected by this kind of noise further suggested that the type of habitats and the animals (if animals be the cause) confined to them ecologically, must eventually provide the answer. Tests in fresh water lakes indicated the phenomenon must be marine in nature. Its geographic range suggested tropical or subtropical nature.

With these leads, animals that might be suspect were collected and tested in aquaria. Early suspects included snapping shrimp but, although

they seemed to fit habitat and geographic distribution requirements, their rarity in areas available to collecting, and the infrequency of individuals to snap cast doubt of their likelyhood of producing such a bedlam of noise as could be heard over some rocky reefs and coral bottoms.

There were also some serious conflicting aspects in any hypothesis that demanded only a rocky or coral bottom. Severe crackling was also found in some shallow water areas where the bottom was muddy, and some deep water areas with bottoms similar to noisy areas were silent. These anomalies later served to indicate that depth of water must be a critical environmental factor to be considered, and also that muddy, sandy bottoms with eel grass, etc., may support snapping shrimp, and that harbors littered by debris or having biologically fouled structures may be noisy.

Finally, after weeks of frustration, I happened to observe a small group of marines at rifle practise at the Camp Callan rifle range, now part of the upper UCSD campus. The overall sound produced in rapid gunfire by 10-15 marines closely similated the mysterious underwater crackling that needed identification. This led me to realize that it would not take an overwhelming number of snapping shrimp within hearing range to produce the type of crackling that in nature had an overall sound pressure of 30 or more decibels above "sea state 1" water noise. With this information as a stimulus, I managed to collect about a hundred specimens for testing as a population in an aquarium. It was soon learned that the animals are very difficult to collect because of their secretive habits of living in ready-made burrows in heavy shell incrustations, fouling, etc., from about zero tide level to about 30 ~~meter~~ fathom depths. Individuals snap when in any way disturbed.

In the aquarium tank the population collected produced a good number

of isolated snaps, so, with this encouragement, my next step was to predict locally and elsewhere where the crackling would or would not likely be found in nature. These predictions proved highly successful when they were based on (1) identification of the cause of the noise, (2) the animal's habitat requirements, (3) the geographic range of over 350 known species of snapping shrimp and (4) reference to hydrographic charts giving type of bottom and water depths. In distant Asiatic areas, Dr. Francis P. Shepard aided by compiling bottom charts where the predictions would most likely apply.

As to the reliability of the persistance and of the seasonal and diurnal characteristics of crackling, studies were made of the behavior and life history of the animals involved.

Shrimp crackle was not the only noise observed. Sound recording equipment was installed at the end of Scripps pier for a number of purposes. From these we obtained information on the continuity and diurnal changes of intensity of crackle and on noises produced by fishes. In order to monitor incoming noises, I spent a number of 24 hour periods during which a "croker chorus" was discovered in April 1943 and that continued regularly for about three months. It began about sunset and prevailed for about three hours. In isolated tests the most likely members of this chorus seemed to be the spotfin and black crokers and the midshipman Porychtes.

When the mystery of the underwater crackling was resolved to the point of predictability for naval use, I opted to return to my more routine peacetime work at SIO. But Drs. C. F. Eyring, R. J. Christensen and R. W. Raitt had discovered quite a different troublesome acoustical mystery of the sea. This was a sound reflecting layer called the "deep scattering

layer" (D.S.L.) that on the fathometer tended to record false bottoms at depth levels well above the real bottom.

After Dr. Christensen, Chairman of the Echo-Ranging Section, briefed me on what was then known about the layer, it sounded more like a physical than biological phenomenon. But I agreed to have a try at it hoping to arrive at some workable hypothesis to test at sea. It occurred to me that if the layer was composed of organisms, it should behave as many marine animals do, especially the plankton, and undergo diurnal migrations rising towards the surface in the evening and returning again to depth in the morning. No such behavior had been observed for the layer. For a test trial I requested the use of the "E. W. Scripps" for a 24 hour run June 26-27, 1945 to test the hypothesis, asking for someone to attend the ship's fathometer while I operated the plankton net for a series of hauls. The helpers assigned to me in the test were R. Ely and G. Duvall.

The results showed that like the well known behavior of plankton, the layer also underwent an upward movement in the evening and returned to a daytime depth the next morning. In some reviews of the observation of the migration of the layer it has been erroneously stated that since the layer was known to migrate diurnally, it was later assumed by me to be composed of organisms.

The solutions proposed for these two acoustical problems may be thought of as biology having scooped physics in two sea mysteries, but it is more to the point to think of it as showing the need and advantage of cooperation in solving marine problems.

Crossroads: - Some time after finishing the above mentioned UCDWR work, I was asked to participate in the Navy's "Operation Crossroads", March 10 to August 8, 1946 in the Marshall Islands during the atomic bomb tests in Bikini Lagoon.

In this assignment, I was concerned with the composition and retention of the plankton within the lagoon as a possible indicator of the extent of lagoonal flushing by water currents, and also to note what if any immediate effect the blasts might have on the plankton and on the bottom-living snapping shrimp.

Briefly stated, no appreciative effect could be noted on the abundance of plankton, and the shrimp were silenced only in the immediate area beneath the underwater explosion.

Because of the historic interest in this unique operation, it is useful to include here the following description that I wrote shortly after the aerial test over the lagoon.

"We left Rongelap Atoll Sunday afternoon June 30 and on July 1st arrived at a point about 18 miles north east of Bikini Atoll where we witnessed the blast together with a goodly number of other ships attached to the project and carrying personnel of the Crossroads Project and other observers.

The time of dropping the bomb had been changed from 0830 to 0900. The sun shone brightly and there were scattered clouds along the horizon. The scientists of our party were grouped at a vantage point on the main deck of the U. S. S. Bowditch. We were provided with heavy, dark goggles to protect our eyes from the initial intense light of the blast, and were anxiously waiting the signal to put them on at 2 min. before 9. None of the officers or men on this deck were observed to have goggles, hence they

were ordered to turn their backs to Bikini, close their eyes, face the deck, and cover their eyes with their arms. Presently, the signal "Bomb Away" came in over the radio and the bomb was dropped about one min. after 9. Since the atoll could not be seen at this distance, some of us were looking a little too much to the south, but still the blast was well within the field of vision. The actual blast was so short that it was hardly noticed, and it changed almost instantly into a most beautiful orange-red (through our goggles) ball of fire that glowed brightly for what seemed to be about 2 or 3 seconds. It appeared to be about 1-1/2 to 2 times the size of the sun, but this was very hard to judge at the instant. Then it quickly changed so that by the time I had removed my goggles there was a billowing white cloud of hot vapor partly concealed by the natural clouds at the horizon. Fortunately, the clouds were quite open and none covered the initial blast and ball of fire.

The billowing cloud of incandescent vapor rose rapidly in great tumbling wreathing masses that formed a top-heavy mushroom-like form that grew constantly larger from within as if it were boiling over in ever increasing quantity and flowing out from the top. The curling overflowing masses appeared to be persistently tumbling downwards like new snow down a mountain side but again entering the bottom and sides of the mushroom cap, and suggesting that they would presently emerge once more at the top mueh as the rolling of a smoke ring filled to the core. Suddenly, there appeared a thin wisp of white vapor immediately over the top of the cap. This vapor, like a narrow cloud over a snow-capped mountain, rapidly increased in size and cascaded downward over the sides of the turbulent cap so that it covered about two-thirds of it with a smooth, white silken

veil. A second similar wisp of vapor appeared only to vanish or merge with the first. The whole veil soon disappeared or was consumed by the rolling billows that came out more beautiful and impressive than ever. It has been suggested that this veil was a localized snow storm. Though fleecy and cloudlike, the whole column gave the impression of something more substantial than ordinary clouds.

From our distance, the color was a beautiful pastel duotone with amber and faint rose passing imperceptibly from pure white highlights on the outer edges of the billows to faint amber and finally darkening to amber-rose in the deeper cavernous recesses where the billows rushed inward to the hot core of the column.

The sound that accompanied the explosion was, of course, delayed in reaching us. It was quite loud and much like any-other heavy distant explosion, but, perhaps, with more rumbling than one would expect in an area where there is little obstruction to cause reverberation.

We could see smoke rising from the target area and this served to indicate that the lower part of the column was drifting westward with the trade winds. The cap, however, seemed to be practically stationary at about 30,000 feet. Before we saw the target smoke to orient us, the cap seemed to be drifting eastward. This caused some momentary concern because if true we might be in danger of rain carrying down radioactive material in our otherwise safe area.

It was not possible to see for sure if there was a mushroom cap below the top one. There appeared to be a thickening of the column, but at no time, from our point of view, was the whole structure completely free from intervening clouds. But at any rate the topmost cap became separated and

gradually dispersed into non-billowing stratus clouds of amber-like color that streaked for considerable distance across the western sky. A similar streak represented the lower part of the column. I watched it dissipate for an hour and then when finally returning again after a time away listening to radio reports from observation planes, I could not be sure of distinguishing the bomb cloud from the natural clouds. ---So ended this unique show of man's uncertain steps into the atomic age.

To say the least, it was an interesting and impressive show. But this was not so much because of its magnitude from this distance as because of the awe inspiring potentialities that it suggests in one's mind. In witnessing these tests one cannot but be left with a deep and abiding feeling that humanity must assume a heavy responsibility for the use of this power that has been unlocked.

Immediately after the blast, we started (in a long convoy of ships) slowly back to Bikini and entered the lagoon just before sundown and proceeded to our anchorage which we reached at the edge of the target area just at dusk".

The SIO Community: - An important adjunct to the scientific and educational functions of SIO in the early days was the community of staff members living in cottages on the campus. A number of the houses still exist converted to scientific use. My family and I lived in cottage No. 29 which, with a good deal of renovation by myself and more later by SIO, provided good living for twenty years. It has now been much further modified to serve as a special SIO conference room.

Dr. Vaughan had a deep interest in landscaping of the campus and while

still convalescing from his illness proudly took me on a personally conducted tour to much of the gardening he had promoted. But the gardening around the cottages was left to the tenants. The modest rental income probably spent over the whole campus, was not enough to do much upkeep on the cottages, the care of which was doubtless a function of the Superintendent of Buildings and Grounds, James Ross, who often disappeared around a corner (probably for good budgetary reasons) when he saw a tenant approaching and not wanting to disappoint anyone.

Although rather formal in his ways, Vaughan was always friendly and prudently tolerant and kept a good social contact with community members. He had a reserved sense of humor which at times broke out into merriment as illustrated at one of his rather frequent dinner parties for staff and community members. He had a German Shepard dog named Spook who sometimes attended these dinners to get a handout of meat balls that the Philippine house boy brought to Vaughan for the routine feeding of Spooks, trained to beg on command by stretching out his front feet and lowering his head. I don't know what the usual command was, but this time, no doubt inspired by my presence as a past associate of Dr. T. G. Thompson, Director of the University of Washington Oceanographic Laboratories, the command given was "Pray for Tommy Thompson", to which Spooks properly responded.

These two Oceanographic directors were sometimes given the appelations: Emperor of the Pacific and King Fish of the Pacific respectively. These were no doubt terms of endearment suggested by the deep enthusiastic concern each had for the Pacific as a world for oceanographic research.

World War II brought important changes to the scientific aspects of

SIO and to living habits of the community. Some of us established "victory gardens" in the area now partly excavated for the Geophysics parking lot. To make the rural atmosphere even more complete and to circumvent the patriotic "meatless day", some rabbit hutches were also maintained hidden behind shrubbery, and there were also a few penned up egg-laying chickens. All this farming proceeded harmoniously with few exceptions.

Status of Post-war Zooplankton Research at SIO: - Following the second world war, SIO experienced marked growth in both research and educational activity. Especially important was the increase in post graduate students, including biologists, some of whom undertook research projects in marine zooplankton which had been at a low ebb especially during most of the war years.

The increase in post-war oceanic research involving zooplankton has been nearly world-wide, probably inspired in part by an awareness of the need to know more about the sea as a source of food for the fast growing human population. Interesting too is the fact that more attention than previously is concerned with the life history of individual species to ascertain the living requirements of the critical larval stages. Widespread interest in the deep scattering layer was a further impetus to zooplankton study. The present brief review will, however, be limited mainly to work in which SIO took a conspicuous part or in which staff or students have participated. It suffices also to show that the original intent of extending the marine studies seaward has been realized, probably beyond the fondest hopes of Dr. Ritter and others when establishing the Biological Station in 1903 and in later proposing its transition to a

full-fledged
~~fulfledged~~ Oceanographic Institution.

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It is gratifying to note that at SIO this open sea research on both phyto- and zooplankton has had a sustained growth in the past three decades, and that there has been a pertinant integration of effort, in the physical and biological aspects on the various cruises by staff and students. Summary review of some these efforts will be found in the various SIO Annual Reports. For plankton studies see especially the sections on the Marine Life Research Group.

In this acceleration of oceanographic research, Scripps has provided leadership in the formation and direction of certain cooperative oceanic and biological surveys in which zooplankton collecting and analysis has been a major part.

A primary purpose of some of these surveys has been to seek information essential to management of fisheries resources to assure maximum returns to the industry. In this effort, the collections have provided useful knowledge as to the composition of the total plankton community that is so important to the survival and growth of all stages of development from the planktonic eggs and larvae to the swimming adult fish.

Outstanding of these cooperative enterprises in which SIO was and still is a part, is the "California Cooperative Fisheries Investigation" (CalCOFI). At SIO the University of California component part of this enterprise is known as the "Marine Life Research Group" (MLR) composed of biologists (some distinguished as Biological Oceanographers) and non-biologists with biological leanings such as Professor John D. Isaacs who with his diversity of knack, experience, and interest was for several years the director of the group. The present director Joseph L. Reid,

physical oceanographer, is also deeply interested in the biological findings. The multiship operations of CalCOFI extended over a large segment of the California Current from about the latitude of the Columbia River to below Cape San Lucas, Baja California, and seaward to 300 or more miles.

The seven years of year-around collecting, 1949-1955, provided an abundance of material pertinent to the study of coastal fisheries and of zooplankton in general.

The fish eggs and larvae obtained in this regional survey were studied by Dr. Elbert H. Ahlstrom and his collaborators at the National Marine Fisheries service laboratories on the campus. The net collections have been further drawn upon for other coastal plankton organisms or as supplementary and comparative material for collections made on special expeditions planned and carried out by certain SIO staff members and students having ocanographic projects covering vast oceanic areas in determining the composition and ecology of plankton that characterizes the different water masses and currents of the Pacific Ocean.

In addition to my previously mentioned students working on plankton in the SIO invertebrate Division, there were the following eleven who, for the period 1950 to 1965, were granted Ph.D. degrees based on dissertations dealing with zooplankton ecology, geographic distribution and taxonomy:

David K. Arthur - food of herring larvae.

Leo D. Berner - salps.

Robert Bieri - chaetognaths.

Brian P. Boden - euphausiids.

Thomas E. Bowman - amphipods and copepods.

Carl M. Boyd - galatheid shrimp.

John S. Bradshaw - living foraminifera.

Edward Brinton - euphausiids.

William D. Clarke - deep sea mysids.

John A. McGowan - Pelagic molluscs.

Bui-Thi Lang - calanoid copepods.

J. Bennet Olson - Cyclopoid copepods.

The students who left upon receiving the degree and who continue in research or teaching in marine biology are widespread in the U.S., from Washington, D.C. to San Diego and from Halifax, Nova Scotia to Australia and Vietnam.

Dr. McGowan and Dr. Brinton continue their plankton studies as SIO staff members. Margaret Knight, who has assisted and collaborated in various plankton projects, continues as a staff member with her own studies on life histories of planktonic crustacea.

More recently added staff members whose biological research is much concerned with zooplankton are Dr. Abraham Fleminger in the Marine Life Research Group and Dr. Michael M. Mullin in the Food Chain Research Group.

Visiting biologists and former staff members who published on zooplankton research done at SIO include Dr. Angeles Alverino - chaetognaths and siphonophores; Dr. R. Phillips Dales (Bedford College, University of London) - polychaetes; Dr. Charles C. Davis (University of Washington) - copepods; Dr. Norman Tebble (British Museum, London) - polychaetes; Dr. Takasi Tokioka (Seto Marine Biology Laboratory, Japan) - larvaceans and ~~molluscans~~ chaetognaths.

My own research in post-war years has continued with general zooplankton, a part of which will be mentioned for the Arctic, but particularly

with the identification, production and dispersal of phyllosoma larvae in the Eastern Pacific. From these studies we can now identify the larval stages of all the known species of both the palinurid and scyllarid lobsters along the west coast of North and Central America from Point Conception to Peru, South America; and, especially for the California spiny lobster, we have a good picture of the duration of the phyllosoma larval life and the degree of dispersal by hydrographic conditions along the coast based on extensive collections made by CalCOFI and the Inter-American Tuna Commission cruises.

In the tropics the westward flowing South Equatorial Current may carry the larvae a distance of 2,000 nautical miles from the Galapagos Islands into the area of the extensive deepwater East Pacific Barrier.

Along the California coast, the main spawning areas are shown for the California spiny lobster (Panulirus interruptus) and the dispersal pattern of the larvae indicates that, although there is a loss by adverse currents, still there is a good retention of larvae by the various large eddies and counter currents that retard outflow from the area. During the course of this study much aid has been given in plankton sorting and in other aids by members of MLR Group.

Additional studies were also carried out on phyllosoma larvae from plankton samples taken by Brinton and others on the "Naga Expedition" in the South China Sea, and on the lobster larvae form the Hawaiian Archipelago held in collections at the Commercial Fisheries Laboratories at Honolulu.

General zooplankton analysis were made on personally collected material in the Beaufort and Chukchi Seas; and from samples collected by

Dr. T. Saunders English on ice islands in the Polar Basin 1957-58; and on collections made by the scientists aboard the ice breaker U.S.S. "Burton Island" in the Beaufort Sea 1950 and 1951.

These zooplankton surveys especially when integrated provide corroborative information on the type of oceanic circulation from the Aleutian Islands northward through the eastern part of the Bering and Chukchi Seas into the Arctic Ocean. The geographic range of several copepod species is greatly increased and shows a marked drift of plankton from the Chukchi Sea eastward along the Alaskan coast past Point Barrow. Here some reproduction of subarctic species may occur. This is indicated especially by Tortanus discaudatus, a common copepod species off the west coast and that occurs also in southern Hudson Bay and along the subarctic coast of eastern Canada and USA, suggesting a possible intermittant dispersal route between the Pacific and Atlantic Oceans.

There is also shown drift of expatriates from the Chukchi Sea directly northward into the Arctic Ocean. Most of these copepod species succumb before reaching far into the high Polar Basin but a few survive as shown by Eucalanus bungii found in adult stage at 83°41'N. and 85°6'N.

Other areas of personal collecting and analysis of zooplankton include: the Marshall Islands; Caprecorn Expedition across the tropical Pacific; and in the San Juan Islands of Washington.

Under the curatorship of Dr. Abraham Fleminger and H. George Snyder, there are now about 60,000 plankton samples from all sources in the SIO collection. Most of these samples have been examined in part by various workers for specific types of animals used in their special studies.

The foregoing references to plankton research has been oriented towards the studies of certain zooplankton populations per se and to their environments. But this is only a part of the interest and concern the organisms, individually or as populations may have to other fields or projects of research at SIO by biologists or nonbiologists. Among these may be mentioned as examples the Food Chain Research Group or Dr. A. Benson's study of conversion and storage of phytoplankton fats as liquid wax by grazing copepods. The plankton, being an ubiquitous factor of sea water, is of direct concern in sedimentation; penetration of light and behavior of sound in water; and in the distribution, concentration and renewal of the nonconservative chemical elements in the sea.