

SEA GRANT REPORT

1970 - 1971

University of California, San Diego
and
San Diego State College

Institute of Marine Resources
P. O. Box 109
La Jolla, California 92037

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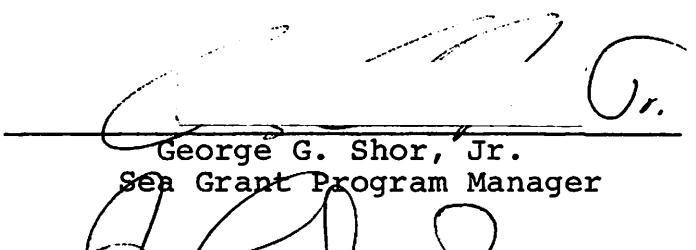
October 1971

**University of California at San Diego
La Jolla, California 92037**

and

**San Diego State College
San Diego, California 92115**

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**George G. Shor, Jr.
Sea Grant Program Manager**

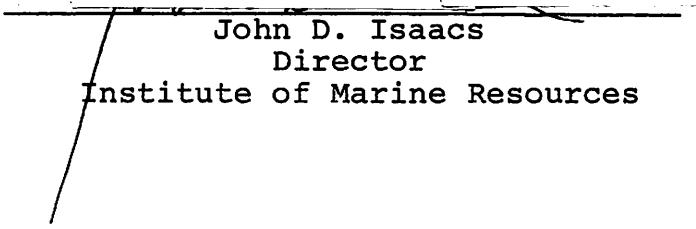

**John D. Isaacs
Director
Institute of Marine Resources**

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INTRODUCTION

In this first annual report on activities carried out under the University of California Sea Grant Institutional Program, we have presented the reports of individual project leaders in the same format and the same order as they appeared in the original proposal. In each case, therefore, an extract from the original summary of the project is given, followed by a report on the progress achieved to date, and the abstracts of any papers that have been published or presented on the work of that project.

The grant was received on 1 October, 1970, and, thus this reports work completed over an eleven-month period. Expectedly, some projects have had the normal delays in recruiting personnel and purchasing equipment. Most of the projects continue into the present grant year; the work is therefore not yet completed and these should be considered only as what they, indeed, are - reports of progress.

ADMINISTRATION

George G. Shor, Jr.

During the past year the administrative structure of the University of California Sea Grant Institutional Program has been subject to steady change to prepare itself for the statewide program that began 1 September, 1971. A statewide University of California Sea Grant Coordinating Council (consisting of one representative from each UC campus and five public members) was formed in the Fall of 1970, to prepare plans for 1971-1972. The membership of the committee is as follows:

W. A. Nierenberg	Chairman
George W. Brown	UC Irvine
John D. Isaacs	IMR Director
Robert Featherstone	UC San Francisco
Robert Garrison	UC Santa Cruz
James O. Hewitt	Public Member
Robert W. Holmes	UC Santa Barbara
John D. Mackenzie	UC Los Angeles
John E. Robb	Public Member
Bernard Schweigert	UC Davis
Irwin W. Sherman	UC Riverside
Gustaf Arrhenius	UC San Diego
Robert L. Weigel	UC Berkeley
Elmer Wheaton	Public Member
Charles D. Wheelock	Public Member
John Peterson	Public Member

George Shor was designated to continue as acting statewide coordinator, and an ad hoc committee to assist him in planning work was designated: Robert Holmes (UC Santa Barbara), Bernard Schweigert (UC Davis), and Robert Weigel (UC Berkeley). Statewide liaison throughout the year was carried out by the staff of the Institute of Marine Resources; local administration of the UC San Diego program was carried out by Shor and that of the San Diego State College program by Glenn Flittner.

During the summer of 1971 the entire program was transferred to administration by the Institute of Marine Resources (John D. Isaacs, Director) with Shor continuing as Sea Grant Program Manager and principal investigator under Isaacs' direction. Local activities at the San Diego State College campus are directed by the Bureau of Marine Sciences (Glenn Flittner, Director), at Santa Barbara by the Institute of Marine Science (Robert Holmes, Director), and at Davis by the Department of Food Technology (Bernard Schweigert, Chairman). Elsewhere project leaders report directly to the Institute of Marine Resources office at UC San Diego.

To facilitate planning of research and advisory activities in a state as large and diverse as California, the Sea Grant Coordinating Council requested that a study be made of the needs of the state of California, as related to

the ocean and the coast line. A preliminary study was made during the summer of 1971 by James Sullivan (Economics Department, UC Santa Barbara) who has taken the coastal planning aspects of the study, and Marston Sargent (Coordinator of the California Cooperative Oceanic Fisheries Investigations - CalCOFI) who has taken on the fisheries side. This work was supported out of administrative funds.

A beginning has been made on the revision and reissue of the Marine Technicians Handbook; the first three chapters are now completed and available to users, other chapters are in press. The SIO Diving Manual has been revised and it also is in press, again for general distribution. These publications are being handled through the IMR publications sales system, so that free copies are mailed to the distribution list for Sea Grant, and additional copies are available for sale. The most widely distributed publication through the sales system has been the chart of the North Pacific which was prepared by the Geological Data Center (see project UCSD-13). A second version of the chart, in reduced size suitable for school use, has been prepared with assistance from the Sea Grant program.

GRADUATE EDUCATION IN APPLIED OCEAN SCIENCES

Victor C. Anderson

Summary of Proposed Work

The program of advanced study and research in the Applied Ocean Sciences, started under grant GH-24, has become a fully organized curriculum with 12 graduate students working toward Ph.D. degrees. These students are enrolled in the SIO Department, the Department of Aerospace and Mechanical Engineering Sciences, and the Department of Applied Physics and Information Science. Curricula for these students are adjusted to their individual goals. The program has developed in a manner that reflects the current interests of both the participating staff and students; as a result, the emphasis is heavily placed on the applied aspects of fluid dynamics and electronic instrumentation in the marine environment.

We hope to see a considerable expansion of work in the fields related to beach formation and erosion to match the developing need and student interest. Because of the newness of the curriculum, no degrees have been awarded as yet. It is expected that registration of new students in the Applied Ocean Science option will be considerably increased this fall as the existence of the program becomes more widely known. Under present university limitations in funding, building space, and teaching appointments, the total registration at Scripps cannot exceed about 200 graduate students (approximately 40 Ph.D. awards per year); the proportion in the Applied Ocean Science curriculum should stabilize at about 30 students in residence, or about 6 graduates per year. Requests have been made to the University administration for increases in space and teaching appointments; if granted these will make it possible to reach a plateau of students in residence considerably in excess of the pessimistic figures listed above.

Report of Work Accomplished

At the midpoint of the graduate education project in Applied Ocean Science, the impact of the program on curricula at UCSD is becoming evident. The effects are in courses offered, new students enrolled in applied programs, new faculty appointments, and student guidance, as well as the encouragement of new research programs. There has been a steady growth in enrollment in the AOS curriculum. During the first year two students were enrolled; in the second year 12, and the third year 23 students. One student has been advanced to candidacy, and several more will be ready to do so this year. Several new courses have been started as a direct result of the Sea Grant sponsored project. Victor Anderson has established an acoustics teaching laboratory with Muir College building equipment funds. This laboratory is heavily oriented towards underwater acoustics.

Carl Gibson, another of the Sea Grant faculty, has introduced a course in turbulent mixing and transport which is oriented towards the needs of AOS students, dealing with phenomena important in any studies of the disposal of wastes into the ocean.

George Shor has instituted a course in marine geo-physical exploration dealing with the tools and techniques

used in exploring the ocean for minerals, for studies of geological structure, and for surveys in general.

An outstanding example of the impact of the project on the curriculum is one course that was given by Frank LaQue on marine corrosion. LaQue has given his course both for enrolled students at UCSD and for practicing engineers through the University Extension.

The weekly AOS seminar, under John Mudie, has been a highly effective information exchange medium, providing an interplay between the AOS students, other students, local staff members, visiting professors, and representatives of industry.

During the year the rather informal curriculum became more clearly defined and this has resulted in specifying areas in which new courses are needed.

Douglas Inman and Tony Bowen have expanded the coverage of the existing course in Near-Shore Processes, and a large number of the AOS students are enrolled. This is a field in which more work needs to be done.

Physical facilities are limited by the delays in building construction on the campus. In order to provide office space for new AOS students and a laboratory for Bowen, we have used departmental (university) support funds to purchase two trailers. Although space still will be limited in the coming year, we have been able to admit new students in

number similar to last year, eventually reaching a steady-state of 30 to 40 students in residence.

Action has been taken to reinvigorate the relationship with the Ocean Engineering curriculum at the Berkeley campus, to provide the opportunity for AOS students to take needed ocean engineering courses at Berkeley, and for Berkeley engineering students to take desired ocean-related courses at San Diego. We hope to be able to provide facilities for these interchanges in the future.

Another area of less tangible progress is in the participation by AOS students, including those in AMES and APIS departments, in seagoing activities of the Scripps Institution.

GRADUATE STUDENT RESEARCH ACTIVITIES

Summary of Proposed Work

In 1969-1970 we obtained support for assistantships and student research funds to support student research in the Applied Ocean Science program, Marine Biology, and Biological Oceanography. There is an increased interest on the part of graduate students in all oceanographic programs in doing research that has a direct practical value in increasing utilization of resources and protecting the marine environment. The assistantships and research funds were therefore used primarily for support of advanced graduate students who are carrying out projects of practical importance. These included studies of the salinity tolerance of nearshore fishes; the use of juvenile mussels as biological assayers of water productivity *in situ*; studies of the temperature tolerance of eastern Pacific fishes; the growth and change of the assemblage of sessile organisms in southern California waters when it is heated above the ambient temperature (as in thermal discharge from power plants); possible uses of the artificial upwelling in a coral lagoon; determination of the permeability of atoll limestone; the energy expenditure involved in swimming for marine crustacean Labidocera trispinosa; distribution and ecology of Acanthaster; study of salt and water balance in fishes; speciation studies of sergestid shrimp; study of the reproduction and life of the abalones (a prospect for aquaculture); the ecology of Sumner Branch of Scripps Submarine Canyon; overpressure on submerged instruments during earthquakes; and in underwater optical and acoustics research.

We expect to continue to support student-generated practical projects, and also encourage student research of specific listed projects in fisheries development and management of the coastal zone.

The following are reports by two students on independent projects (Arthur Wolfson and Vance Holliday). A third student (Ted Tutschulte) on an independent project has transferred to the UC Santa Barbara campus to complete his work on abalone culture. His report will be included in the UCSB report on work performed under Joseph Connell.

Part 1: The Effects of Increased Temperature on a Marine Community (Wolfson).

During the first six months a temperature controlled seawater system was built which simulated the thermal regime created by the tidal diversion of power plant effluent. Two tanks were not heated and these ambient temperature tanks served as the experimental control.

Settling plates were suspended in the system for controlled periods, then removed and analyzed. Individuals or colonies present were classified, measured, and reproductive conditions determined. A statistical analysis of these data indicated that during the late winter months thermal elevation of the marine environment did not affect the settlement or survival of the members of the fouling community, but did

significantly increase growth rates.

The data for the months of June, July, and August have not been statistically analyzed yet, but a cursory look suggests that heating during the summer may retard the settlement and growth of a wide spectrum of the species comprising the marine fouling community.

Part 2: Research into Techniques for the Remote Acoustic Classification of Fish (Holliday).

The results of initial testing of techniques for the remote acoustic classification of fish indicate that 1) a positive test for swimbladder presence has been developed, 2) the test can be used to determine swimbladder size and subsequent fish size, and 3) a new tool is available for the study of schools consisting of mixed species, and 4) further refinement of the technique could result in intra-specific size distributions for application as inputs to fisheries population dynamics models.

Much of this work was done in cooperation with the National Marine Fisheries Service using the R/V DAVID STARR JORDAN.

A paper describing the acoustic technique and initial testing has been prepared and submitted for publication. An abstract accompanies this report.

Publications

Holliday, D.V. Resonant structure in echoes from schooled pelagic fish. (Submitted to J. Acoustical Soc. of Amer.)

Abstract

Explosive acoustic sources were used to obtain echoes from aggregations and schools of commercially important marine fish. Narrowband spectral analysis of the echoes from these targets revealed significant structure in the frequency range from 200 Hz to 5 kHz. The targets were partially captured after the acoustic tests; three yielded northern anchovy (Engraulis mordax), one consisted of a mix of anchovy and jack mackerel (Trachurus symmetricus) and the last sample contained an aggregation of seven species of rockfish (Sebastes), a whitefish (Caulolatilus princeps) and a striped perch (Embiotica lateralis).

The results of the direct biological sampling were combined with theoretical predictions for the resonant swimbladder response and compared with the experimentally observed resonances.

DIVING PHYSIOLOGY AND DIVER TRAINER TRAINING

Robert W. Elsner and James R. Stewart

Summary of Proposed Work

It was proposed to add another faculty member (under joint sponsorship of the SIO Sea Grant Program and the UCSD Medical School) highly competent in the physiology of diving in mammals. Research in this field, initiated at the Scripps Institution of Oceanography in 1952 (Livingston and Bradner, 1958) is of high importance in increasing man's competence to work in the ocean, yet few men are being trained in the physiology of diving in a location where they have access to the facilities and knowledge in both a medical school and an oceanographic institution. The early work by Livingston and Bradner has served as the basis for the diving safety regulations and practices taught in the SIO Diver Certification program, which has itself taught many of the persons now running SCUBA diving courses throughout the country, including ones at other Sea Grant Institutions. We proposed to start a program of education in diving physiology within our Marine Biology curriculum and in cooperation with the UCSD Medical School, and to improve the ability of the SIO Diver Certification program to take on the task of training key personnel who will be responsible for Diver Training programs at their own institutions. This program of education in the physiology of diving will start in a small way in the coming year; it is expected to be considerably expanded during the coming five years.

The SIO Diver Certification program has for years trained all SIO divers; in addition, a few persons from outside organizations have been trained without cost. The number of outside participants has been severely limited by lack of appropriate funds. We requested a small amount of supply money to cover the extra costs incurred in rendering this service, and will publicize the opportunity to other Sea Grant organizations.

Report of Work Accomplished

Part 1: Diving Physiology (Elsner).

Formal training in the physiology of diving was initiated during the winter quarter, 1971. In a course on physiology of marine mammals several aspects of the physiology of diving were examined, including those special adaptations of the respiratory and cardiovascular systems with which marine animals are endowed. When appropriate, comparative knowledge of terrestrial species, including man, was examined. Some consideration, reflecting student interest, was devoted to applications to medical physiology, especially concerning the phenomenon of asphyxia.

Elsner supervised a course in comparative marine physiology, in which the topic of diving was treated in several lectures on comparative and hyperbaric physiology.

One SIO graduate student will complete his thesis work for the Ph.D. degree during 1971 under Elsner's supervision. The thesis, dealing with the topic of diving physiology, is entitled, "Cerebral Tolerance to Asphyxial Hypoxia: A Comparative Study of the Dog and the Seal".

Part 2: Diver Trainer Training (Stewart).

During the past year we have conducted six 14-day SCUBA

classes with an average enrollment of 12 persons per class. Among the students were individuals from the National Park Service, the U.S. Coast Guard, the University of Hawaii, Universidad Autonoma de Baja California, San Diego State College, Grossmont College, the Office of Polar Programs (NSF), Humboldt State College, and Scripps Institution of Oceanography.

The Diving Safety Manual is now completed and being printed. This publication has been discussed with Diving Officers from Texas A. & M. and the University of Michigan in an effort to seek standards common to the scientific diving groups in general.

The Hand-Held Sonar has been put into use on instrument recoveries and a number of persons have been instructed in its use.

In August, SIO co-sponsored an Industrial Orientation class with the National Association of Underwater Instructors. This is the fourth year such a class has been offered and it is open to diving instructors who have a desire to learn various underwater techniques and who use the latest in underwater equipment. Lectures in the use of the equipment are presented by the manufacturers' representatives and then students use the equipment, under supervision, in the ocean. These classes enable the individuals to return to their own areas of instruction with a more thorough knowledge of off-the-shelf equipment, its availability, and its function.

Project UCSD-5

SIO, San Diego State College

UNDERGRADUATE TRAINING IN MARINE TECHNOLOGY ON-THE-JOB

Norman E. Anderson and George T. Hemingway

Summary of Proposed Work

Undergraduate education leading to a B.S. degree in Oceanography is not offered at Scripps since we feel that a student should receive a good grounding in basic sciences first. On the other hand, the addition of marine-oriented courses within traditional undergraduate options serves to increase the relevance of the undergraduate training, and prepare a student better for graduate study or employment in marine industries. The addition of practical experience and "on-the-job training" in the technology of marine science can also be of considerable benefit to an undergraduate student, whether he plans to go on to graduate work or directly to employment in marine industries. Such opportunities for work in marine technology already exist on an informal basis for UCSD students, many of whom are employed part-time at the Scripps Institution of Oceanography.

Undergraduate education in the marine sciences of the type that should be encouraged already exists in the various departments and schools of San Diego State College, where marine-oriented courses are being taught in the departments of Geology, Biology, General Education, Physics, and Chemistry; a critical lack in their program is the opportunity to learn at first hand the technology involved in working in the ocean. Such opportunities have existed up to now only for a limited number of SDSC students who work part-time within the Naval Undersea Research and Development Center at Point Loma, and in local industrial laboratories such as Westinghouse. We arranged with the Bureau of Marine Sciences at SDSC to institute a program whereby a limited number of undergraduate students at San Diego State College will be released from their normal classes for a semester of independent study, go through training that is given to newly-hired marine technicians at the Scripps Institution of Oceanography Data Collection and Processing Group, and then work for the remainder of the semester within research groups at SIO and the National Marine Fisheries Service to learn

the skills and technology that can only be learned "on-the-job". All students so employed will participate in work at sea, aboard SIO or NMFS ships. It is expected that some will go on to graduate school, in which case the acquaintance with marine technology will provide them with the ability to perform their own research better; others will come out of the program equipped to become marine specialists of high calibre.

Report of Work Accomplished

The program was tried on an experimental basis in 1970-71; it will be continued this year and arrangements made with local commercial and governmental marine research, development, and operational groups for additional opportunities in on-the-job training.

On 1 February, 1971, five selected students from San Diego State College reported to the Data Collection and Processing Group, SIO, for on-the-job training in current marine technology.

The four-month program began with brief orientation and a cruise on the R/V AGASSIZ to San Francisco. Each student participated on other cruises later in the program and thus gained practical experience in all manner of shipboard work (e.g., bongo casts, the AutoAnalyser, oxygen apparatus, hydrography, instrument reading and calibration, and techniques of sample analyses).

Seminars, lectures, and demonstrations were held both during the cruises and at SIO and NMFS. Some of the early seminars covered work being done during the first cruise (e.g., relationships between plant nutrient chemistry, chlorophyll a, phaeophytin, and zooplankton density; vertical and horizontal distribution of oxygen in the upper waters; distribution of density in the oceans). There were lectures on the Deep Sea Drilling Project, drilling technology, instrumentation, phytoplankton ecology, zooplankton collecting, taxonomy, and distribution; plus general exposure to all aspects of oceanography.

The students learned to perform normal shore-side marine technology duties, including: thermometer calibrations and graphings, oxygen flask calibrations, analysis of expedition and shore station salinities, reading AutoAnalyser traces, making biological equipment repairs, and hand-processing of various forms of data. Working time was spent in the Marine Life Research Group's Biomass Laboratory learning to identify zooplankton and nekton species from the California Current area, and each student compiled a reference set of specimens.

In addition, the students were assigned to work with SIO research personnel outside of the Data Collection and Processing Group in order to understand what becomes of raw data collected by marine technicians but not processed by

DCPG. These individual two-week assignments covered the following: sea urchins, collecting and examining copepods, examining core samples for radiolarians, working with bathymetric data, and counting euphausiids and compiling data.

It was felt that the program exposed each student to a wide spectrum of marine technology and theoretical areas.

This program is in conjunction with Project SDSC-2 at San Diego State College, under the direction of Glenn Flittner.

Project UCSD-6

UCSD Extension

EXTENSION EDUCATION IN OCEANOGRAPHY FOR ENGINEERS;
SURVEY OF NEED, PLANNING, AND DEVELOPMENT OF COURSE SEQUENCE

Martin N. Chamberlain

Summary of Proposed Work

University extension has represented an important but under-recognized medium for the training of ocean engineers. Competent men, trained in other branches of engineering, have fitted themselves to jobs in ocean industry with varying success by taking oceanographic courses from university extension programs. A large number of such courses have been given in the past, both through the University of California extension programs here and at Los Angeles, and through the various junior colleges, San Diego State College, and the San Diego City Schools Adult Education program. What most of these courses have lacked is coherence and logical sequence; in few cases has a course sequence been established to meet the needs of potential students (especially engineers) and carried out in logical order. We proposed to work with the officials of the University of California Extension, survey the needs of students presently enrolled in extension courses in oceanography and ocean engineering, and the personnel needs of local industry, and then to develop course sequence to fit.

Report of Work Accomplished

During the past year we arranged for a survey of the training needs of ocean-oriented industries and of students currently enrolled in ocean related courses in the San Diego area. A formal report is being reproduced for general

distribution.

Two separate surveys were conducted, both through the mails. In the first, we polled students, present and past, of Extension courses in Oceanography and Ocean Engineering; in the second, questionnaires were sent to representatives of local ocean-oriented industries. Follow-up interviews were conducted with four of the largest of the industries surveyed.

The student survey forms were mailed to approximately 250 students who had taken at least one course in oceanography within the last two years, and 120 completed forms were returned. As anticipated, students indicated that their primary reason for taking Extension Oceanography courses is their general interest in the field. A desire to take additional ocean-related courses was indicated by 103 (86%) of those responding, and a general preference for courses of a biological nature was expressed. This information, together with specific course suggestions, has been forwarded to programmers at Extension. In addition, programmers have been urged, on the basis of the strength of continuing interest among our students, to develop broad, survey-type sequences in the requested areas. Because of the somewhat biased nature of the reporting group, however, the question of the need and feasibility of a Certificate Program still cannot be answered conclusively.

The industrial survey was sent to 96 ocean-oriented industries, selected from a San Diego Chamber of Commerce publication entitled "Ocean-Oriented Industries," and from the mailing list of the Oceanographic Development Committee of the Chamber of Commerce. Of these, 56 returned our survey. An additional eight companies indicated cessation of oceanographic activity.

Among the important findings of the survey were the following:

1. Most businesses are not increasing their oceanographic involvement.
2. There is a current need for BS and MS level electrical-mechanical engineers with oceanographic background.
3. Retraining programs to meet projected personnel needs apparently cannot be justified at this time.
4. Upgrading present employees was considered at least as important as primary education in the field of oceanography.

The last consideration seemed to warrant action by University Extension and interviews were set up with representatives of Bissett-Berman Corporation, General Dynamics, Lockheed, and the Naval Underseas Research and Development Center. They unanimously agreed on the importance of upgrading present employees to the extent that they were

willing to consider helping support such a program. The support, however, would be an overhead expense that could only be justified by a very worthwhile program.

Each of the representatives seemed eager to participate in an exploratory session with University Extension officials to examine upgrading needs in detail, and, in fact, the University Extension has undertaken the planning of such a meeting. The need for upgrading programs in ocean engineering has been established. The economic feasibility of such a program requires thorough scrutiny.

PRIMARY AND SECONDARY SCHOOL
INSTRUCTIONAL PROGRAMS IN OCEANOGRAPHY

Donald W. Wilkie

Summary of Proposed Work

For many years the T. Wayland Vaughan Aquarium Museum has served the primary and secondary schools of the San Diego area as a major resource for studies in marine biology and oceanography. During the 1968-69 fiscal year, in addition to about 250,000 persons who visited the aquarium-museum as individuals, about 800 school groups (32,000 persons) visited from southern California areas. Some gift funds were obtained last year from individuals and industrial firms to modernize exhibits; more funds would make it possible not only to increase the exhibits of the museum, but also to make up-to-date movable exhibits that can be lent to schools as well as displayed to visiting school groups. Industrial support for such exhibits is being sought, as well as assistance from commercial oceanographic exhibitors. Long-range plans exist for expansion of the aquarium-museum to accommodate more visitors, but building funds are not available within the foreseeable future.

Report of Work Accomplished

Sea Grant support was given to continue and expand the existing education program at the Aquarium-Museum, and to innovate new programs.

During the 1970-71 school year, over 36,000 students visited in organized groups. After the teachers telephoned

for their appointments, education programs were mailed to them. These programs were prepared for five grade levels: K-1, 2-3, 4-5-6, junior high, and high school. The packet includes instructions, confirmation of date and time of appointment, pre-visit classroom questions and answers on oceanography, guidesheet, and post-visit classroom questions and answers. The K-1 and 2-3 grade programs and guidesheets were translated into Spanish. English-as-a-Second Language is a federally-sponsored program which requests these regularly.

The docent training program for 1970-71 began in October with 33 volunteer guides receiving instruction four hours a week for four weeks. Monthly meetings thereafter were held for question and answer sessions and current lectures. Six docents were assigned to each day of the school week and they lectured weekly during the school year. Upon arriving at Scripps the students are given an introductory lecture and then escorted on a guided tour of the aquarium and museum.

A symposium was held for teachers to present current information on the major environmental problems and to determine the major concepts that would be desirable to develop in the classroom. Leading scientists from the University of California in the field of ecology presented the latest information and viewpoints in the various fields of pollution science. Announcements were distributed through the San Diego city and county schools by the Community Education

Resources office of the Department of Education. The day-long seminar was attended by 264 educators and the reactions were so favorable, it is planned to make this an annual symposium.

In response to a constant demand, three summer courses were held in which a total of 80 students enrolled: elementary - "Oscar Oceanography", junior high - "Ecology and Environmental Awareness", parent & child - "Sea Life Study for the Family".

Project UCSD-8a

SIO, NMFS

HISTORICAL LEVELS, AREAS, AND ROUTES OF PESTICIDES
IN THE PLANKTON AND FISH OF THE CALIFORNIA CURRENT

Alan R. Longhurst

Summary of Proposed Work

The present high levels of halogenated hydrocarbons in the tissues of commercial fish in California waters may be the result of a slow buildup through the food chain.

It was proposed that the biological samples in the Scripps Collections be employed to elucidate the rates, areas, and steps in this buildup, covering the early 1950's to the present. Concurrently the pathways of DDT accumulation and concentration factors in the marine food chain will be investigated, based on the first findings from the collections. Continuing sources of such pollution will thus be indicated, and steps directed toward abatement can be more intelligently approached.

Report of Work Accomplished

There is clear evidence that the pelagic ecosystem has been seriously contaminated by pesticides as shown by the disastrous die-off of fish-eating sea birds in California and the recent difficulties in marketing DDT-contaminated commercial species of fish in the California region. Investigators in this project thus initially directed their attention to a single series of questions: namely, what are the routes and

rates of transfer of DDT and other pesticides into the offshore ocean pelagic ecosystem, and what is the effect of the observed contamination upon the pelagic fish resources off California?

Since the early 1950's, plankton samples have been routinely and systematically collected at stations in the California Current by the California Cooperative Oceanic Fisheries Investigations (CalCOFI). The first problem considered was whether it was possible to use this unique plankton bank to trace the historical origin of DDT contamination of the ecosystem; results have now demonstrated that this approach is completely feasible. Two target species, both small myctophid fishes, were chosen and sorted from selected samples taken from all the major sections of the California Current and extending back 20 years in time. These samples, together with special ones taken currently with plankton nets over the same grid of CalCOFI stations, are being analyzed to trace the routes of transfer of hydrocarbon pesticides through the planktonic food chain leading to commercial fish species.

One species of myctophid fish, Stenobrachius leucopsaurus, is abundant off southern California. Although only a few of these, all from the Los Angeles area, have been tested thus far, the results indicate an interesting historical sequence. No pesticides were found in a specimen taken in

1940 nor in another taken in 1951 although traces could have been masked by a low polychlorinated byphenyl (PCB) background present in the latter. By 1953 DDT and its derivatives (DDD, DDE) amounted to 0.35 ppm in one fish; in 1954, DDT averaged 0.83 ppm (three fish); 1955, 1.40 ppm (two fish); in 1957, 2.21 ppm (two fish).

The major Los Angeles DDT-producing company received its first permit to dump wastes into the Los Angeles County sewer system in 1953. Although no firm conclusions can yet be made it seems that contamination from this source was very great in a restricted area (the Los Angeles Bight) while contamination from other sources has generally been lighter although very widespread.

Mixed plankton samples from 1969 to the present show a predominance of PCB contamination (0.1 to 1.0 ppm) which generally masks any DDT or its derivatives on chromatograms.

Because of this, it has been necessary to develop new techniques for the analysis of chlorinated hydrocarbons. A micro-method has been perfected which separates chlorinated hydrocarbons from biological materials, is extremely rapid and can also be used on milligram range samples, rather than requiring samples comprising several grams of material. A manuscript describing this technique has been completed.

The progress reported here is the result of a newly-organized group of scientists at the National Marine Fisheries

Service, Fisheries-Oceanography Center, La Jolla, combining a variety of disciplines to develop the capability to carry out pesticide analyses. As further progress is made, it is anticipated that this group will also train other scientists from university and government laboratories in the rapidly-expanding technology of this field.

The work has been under the direction of Alan Longhurst, Director of FOC and Adjunct Professor at UCSD. Vance McClure, UC Sea Grant staff, has worked on this project under Longhurst's direction.

Publications

McClure, V. Precisely deactivated adsorbents for column chromatography. (To be submitted to J. of Chromatography.)

Project UCSD-8b

SIO, NMFS

NUTRITION AND FEEDING OF LARVAL FISH
AND THE EFFECTS OF HIGH SALINITY, HEAT, AND OTHER POLLUTANTS

Reuben Lasker

Summary of Proposed Work

The success of fish populations is closely determined by the survival of the larval and juvenile stages. These are also the stages that are most susceptible to damage by extremes of conditions and by toxic substances.

It was proposed to investigate the effects of salinity, heat and of such other pollutants as DDT, on the feeding and survival of larval fish.

The work is relevant to understanding the effects of man's acts; to understanding permissible ranges of pollutants; and, in a more positive direction, the opportunities of culture in natural and artificial ponds and estuaries. In this regard, the introduction of suitable marine species of plankton and fish into saline lakes of continental interiors has great recreational potential, and the limitations and needs for such introduction will be elucidated. The findings will be of direct guidance for future programs of experimental introductions.

Report of Work Accomplished

A significant technical advance at the Fishery-Oceanography Center this past Sea Grant year has made it possible to spawn routinely the adult anchovy Engraulis mordax and the croaker, Bairdiella icistia, in the laboratory, to obtain

supplies of viable eggs and young larvae for experiments. This accomplishment has permitted the development of experimental techniques and standard diets for rearing these young larvae through their first few weeks of life.

Work performed under this project contributed to efforts to find culturable food organisms acceptable to anchovy larvae which could replace nutritionally inadequate foods, e.g., the brine shrimp, Artemia salina.

A manuscript (abstract following this report) describing the mass culture in the laboratory of a rotifer, Brachionus plicatilis, as food for larval anchovy has been published (Theilacker and McMaster, 1971). As a result of the success with Brachionus, several mariculture organizations, government laboratories, and universities have requested and been supplied with Brachionus cultures from this laboratory.

The size, suitability, and nutritional adequacy of copepods and other marine invertebrates were studied as food for fish larvae. Of these, the euryhaline calanoid, Eurytemora affinis, was found to be readily acceptable as food for larval anchovy and experiments were conducted to find simple but efficient means of producing nauplii on a large scale in the laboratory. Its short generation time, coupled with a tolerance to extreme salinities indicated that Eurytemora might be suitable for mass culture over a wide range

of conditions. Further advantages of this organism are its ability to feed and reproduce on a wide variety of phytoplankton food and its size range at various stages of development.

In a study on the effect of salinity and temperature on fish larvae, it has been found that Bairdiella eggs and larvae are more sensitive to high salinities of Salton Sea water than of normal sea water. Histological sections of Bairdiella embryos subjected to different salinities have been completed and abnormalities found to be common during development. In related experiments, adult Bairdiella are being maintained at different salinities in order to evaluate the effects of parental acclimation on the resistance of their young to altered salinities.

A second line of investigation with Bairdiella is a study of the effect of DDT contamination levels upon the survival of their pelagic eggs and larvae since it appears that a considerable quantity of the body load of pesticides is transferred during the reproductive cycle.

Only technical aspects of this study have thus far been completed; these include administration of DDT orally to adult fish; the determination of DDT toxicity levels on larvae; and the perfection of the system for spawning Bairdiella under controlled conditions.

The work has been carried out by Reuben Lasker (FOC staff member and Adjunct Professor at UCSD) assisted by David Leighton, UCSD Sea Grant staff member. In the coming year the work will be continued by Douglas Conklin.

Publications

Theilacker, G. H. and M. F. McMaster. 1971. Mass culture of the rotifer Brachionus plicatilis as food for the larval anchovy. *Marine Biology*, July 1971, 10 (2): 183-188.

Abstract

Growth rates of anchovy larvae, Engraulis mordax, reared for 19 days under constant environmental conditions on a diet of laboratory cultured organisms exceeded the growth rates of anchovies fed on a diet of wild plankton. The rotifer, Brachionus plicatilis, was found to be a nutritious food source when fed to the larvae in concentrations of 10-20/ml and in combination with the dinoflagellate Gymnodinium splendens (100/ml). Optimum conditions were determined for mass culturing the rotifer. A high food concentration was the most important parameter needed to assure a high yield of rotifers. Large volumes (464 liters) of the unicellular flagellate Dunaliella sp. were cultured for feeding the rotifers. The rotifer culture technique described produces approximately 2.5×10^6 organisms/day, providing a reliable food source for rearing studies.

The lengths of Brachionus (without eggs) ranged between 99 and 281 μ , most being larger than 164 and less than 231 μ . Individuals weighed 0.16 μ g and contained 8×10^{-4} calorie.

STUDIES OF VERTICAL MIGRATION OF ZOOPLANKTON

James T. Enright, John D. Isaacs, and Sargun A. Tont

Summary of Proposed Work

The majority of the larger zooplankton undertake a rather mysterious vertical migration from the surface at night to some hundreds of meters deep during the day. The causes of this behavior have never been satisfactorily explained, yet the compulsion is clearly of very fundamental import.

Two theses will be investigated:

- (1) that this is primarily a tactic to maximize net yield of primary production to the zooplankton and,
- (2) that this is primarily a tactic that leads the participating zooplankton to high levels of available food.

Not only does this migration result in characteristics of transport unlike any other component of the oceans, but these zooplankton are probably one of the few manipulable creatures of the open sea. Knowledge of the nature and proximate cause of this tactic is thus of broad significance, ranging from an understanding of concentration of fish to possible methods of manipulation of zooplankton into commercially harvestable concentrations.

Report of Work Accomplished

Thesis 1: Vertical migration, a tactic to maximize net yield of primary production to the zooplankton (Enright).

The field work for studies of the vertical migration of zooplankton has been completed. Three cruises were undertaken, with an aggregate duration of 12 days; and a total of 684 vertically stratified samples were taken. These cruises demonstrated, first of all, that the sampling gear designed for this project functioned beyond all expectations. A full description of the net design is being prepared for publication by H. W. Honegger.

A preliminary examination of the samples indicates that they provide clear evidence for the existence of vertical migration in the area sampled, at the time of sampling. Because of the frequent reports in the literature of an absence of conspicuous vertical migration at some given place and time, this conclusion is not a restatement of the obvious, but an indication that the samples, as taken, should be an adequate basis for a test of the metabolic-efficiency hypothesis.

A number of preliminary steps have been taken toward full analysis of the samples taken. Honegger has spent considerable time familiarizing himself with the more abundant species present in the samples, and selecting the appropriate organisms for detailed analysis: animals that are

known to be herbivorous, and which performed clear vertical migrations.

No detailed information is yet available on the precise timing of the vertical migrations of these species. A gross examination of the samples indicates that many euphausiids entered the surface waters at or immediately after sunset, but these animals are not an appropriate test of the hypothesis because they are not exclusively herbivores; beyond this, because their depth range exceeds the deepest of the sampled strata, the sampling program cannot exclude the possibility of local patchiness as the cause of their changes in abundance.

During the second year of the project the samples will be analyzed and the results, positive or negative, prepared for publication.

Publications

Enright, J. T. 1971. Heavy water slows biological timing processes. *Z. vergl. Physiologie*, 72: 1-16 [© by Springer-Verlag 1971].

Abstract

Deuterium oxide lengthens the period of the endogenous tidal activity rhythm of the sand-beach isopod, Excirolana chiltoni. Heavy water has also been shown to retard the circadian rhythm of deer mice, when added to the animals' drinking water. The average dosage dependence of the effect can be estimated with high precision for both isopod and

mouse, and the two values are indistinguishable. A similar slowing of circadian rhythms, due to D₂O, has also been reported for an alga, a higher plant, two species of birds, and three other rodents. Although data permitting reliable estimates of dosage dependence have not been published for these latter cases, the effect is apparently also of about the same magnitude. This evidence suggests fundamental similarities in the rhythmic mechanisms. Heavy water also produces a reversible slowing of several biological rhythms with periods in the millisecond range: the electric-organ discharge of a gymnotid fish (Stenarchus albifrons); the respiratory cycle of goldfish, as well as of an amphipod (Paraphoxus) and an isopod (Excirolana); and the cardiac cycle of a clam (Donax) and a crab (Emerita). Since these high-frequency rhythms originate in pacemakers dependent on diffusion processes, the experimental results suggest the possibility that long-period biological clocks are also based on diffusion-dependent pacemakers.

Report of Work Accomplished

Thesis 2: Vertical migration, a tactic that leads the participating zooplankton to high levels of available food (Isaacs, Tont).

The relationship between the deep scattering layers (DSL), transparency, and the displacement of organisms due to current shear has been examined.

It has been determined that DSL organisms go deeper in highly transparent water than in lower transparency. Furthermore, we found that organisms spend less time in low productivity areas (high transparency) and more time in high productivity areas (low transparency) due to the combined effect of transparency, migration depth, and current shear. Other contributing

factors, such as cloud cover over newly upwelled water may lead DSL organisms to these waters prior to the development of phytoplankton blooms!

Our present studies include an examination of the high productive areas of the world ocean as related to DSL.

Project UCSD-9

SIO, NMFS

SUPPORT OF ALBACORE ADVISORY SERVICE RADIO BROADCASTS

George G. Shor, Jr.

Summary of Proposed Work

To help improve communications with Albacore and Yellowfin tuna fishing boats, we proposed during the coming year to add new equipment to radio station WWD, using university matching funds.

Report of Work Accomplished

Improvement of coverage in voice mode has been achieved by addition of new receivers at the station, since the weakest link in the system at present has been the receipt of reports from the fishing boats to the central facility, rather than the broadcasting of the advisory reports. The addition of three new modern receivers has been accomplished during July, 1971, and has greatly improved receipt of fishing and environmental reports. In addition, the NMFS has arranged for rebroadcast of the advisory bulletins by additional stations along the northern California coast to cover the gap between our working area and that of the Oregon State University advisory broadcasts.

Project UCSD-10

SIO, AMES

IMPROVEMENT OF METHODS OF PREDICTING SEA-SURFACE TEMPERATURES

Carl H. Gibson

Summary of Proposed Work

Present predictions of isotherm location, used to predict the location of albacore, are primarily based on averages of temperature distributions in past years, along with some ingenious but subjective forecasting based on fragmentary data, primitive transport models and weather reports. Clearly any contribution that could be made toward improving these forecasts would be of considerable value to California's fishermen, whose annual catch is already increased by an estimated one to two million dollars per year by present forecasting techniques.

It was proposed that a study be made to improve the modeling and data base for sea surface temperature forecasts in the eastern Pacific. Coordination would be necessary between the various data sources such as buoys, ships of opportunity, FLIP and future airborne heat flux and sea surface temperature measurement systems, as well as with the National Marine Fisheries Service.

Precise methods of measuring heat and momentum flux from the open ocean have been developed during a series of expeditions using FLIP. A series of experiments were planned with R. Davis, T. Foster, and G. Stegen to provide ground truth flux measurements from FLIP to compare with the airborne infrared radiometric total heat flux detector developed by E. D. McAlister of Scripps. If the tests are successful the airborne system could provide heat flux data over large areas at rates compatible with the requirements of a substantially improved sea surface temperature forecasting scheme.

Report of Work Accomplished

During the past year work related to the prediction of sea surface temperature has included two cruises on FLIP to develop heat flux measurement techniques, as well as laboratory computer data analysis of analog tape recordings from previous expeditions.

Reasonably good agreement between direct Reynolds flux measurements of latent and sensible heat flux are obtained when universal constants used in the analysis are revised according to recent measurements in this laboratory from Project BOMEX. Intercomparison with an airborne two-frequency infrared radiometer technique was possible for one night run and the various methods agreed within experimental uncertainty. This was reported at the IUGG 15th General Assembly in Moscow.

Work on fundamental turbulence question related to the departure from simple universal similarity due to the variability of local dissipation rates has been reported in a recent conference at UCSD on Statistical Models in Turbulence. This effect would change heat flux estimates by the dissipation technique by over 100%, so it is of practical significance.

Publications

Gibson, C. H. 1970. Turbulent velocity and temperature measurements in the marine boundary layer (BOMEX/FLIP). Transactions of the AGU, 51 (4): 303.

Abstract

Vertical and horizontal components of velocities were measured from FLIP at positions from 2 to 30 meters above mean sea level using hot wire anemometers. Preliminary spectral measurements appear to confirm the rather slow approach to local isotropy discovered by previous investigations at lower Reynolds numbers. Various statistical parameters of the turbulent velocities and velocity derivatives as well as temperature and temperature derivatives have been calculated. Dissipation rates are compared with log normality predicted by Kolmogoroff's third hypothesis and the influence of such "intermittency" on the turbulent parameters is examined.

Gibson, C. H., G. R. Stegen, and R. B. Williams. 1970. Statistics of the fine structure of turbulent velocity and temperature fields measured at high Reynolds number. J. Fluid Mech., 41 (1): 153-167.

Abstract

Derivatives of velocity and temperature in the wind over the ocean were found to be quite variable. Probability distribution functions of squared derivatives were consistent with lognormality predictions by Kolmogoroff, Obukhoff and Yaglom. Kurtosis values for velocity derivatives ranged from 13 to 26 and from 26 to 43 for temperature derivatives. Universal inertial subrange constants were evaluated from dissipation spectra and were found to be 40 to 300% larger than most values reported previously. Evidence for local anisotropy of the temperature field is provided by non-zero values of the measured derivative skewness.

Gibson, C. H. and P. J. Masiello. 1971. Observations of the variability of dissipation rates of turbulent velocity and temperature fields. (To be published in the series Lecture Notes in Physics, by Springer-Verlag, New York.)

Abstract

Velocity and temperature derivatives are squared and averaged for comparison with lognormality theories of Kolmogoroff, Obukhoff, Yaglom, and Gurvich for the variability of local dissipation rates. Averaged squared derivatives were found to depart from lognormality for small values, especially velocity at lower Reynolds numbers, contrary to the proposal of Gurvich and Yaglom (1967). The universal constant μ of Kolmogoroff's third hypothesis was estimated to be 0.47 ± 0.03 from the variation of

$$\sigma^2_{\ln \dot{u}_r^2} \quad \text{with} \quad \ln(L_o/r),$$

and 0.49 ± 0.2 from the variance of the ratio

$$(\dot{u}_r^2 / \dot{u}_{2r}^2)$$

for various scales r . The departure from lognormality for small values may be due to the fact that squared derivatives are not always proportional to the local dissipation rates.

Gibson, C. H. 1971. Measurements of turbulence, humidity and temperature over the open ocean from a stable platform. Presented at 15th Assembly IUGG Moscow, August 1971.

Abstract

Crossed hot wire anemometers, Lyman- α humidiometer, and 0.6 micron resistance wires were positioned from zero to 30 meters above the sea from the Scripps Floating Instrument Platform FLIP. Results from a series of expeditions are discussed. Statistical analysis of the data was accomplished using on-board and land-based computers. Averaged viscous and diffusive dissipation statistics were studied for both velocity and temperature fields and compared to lognormal predictions of Kolmogoroff, Obukhoff, Yaglom, Gurvich and others. The universal constant appearing in Kolmogoroff's third hypothesis was found to be about 1/2, in agreement with values inferred from spectra of dissipation. Temperature and humidity fields were remarkably similar. Both displayed a ramplike anisotropy, with sharp increases in the downwind direction. Spectra of variables, derivatives, squared derivatives, etc. were calculated, normalized with mean dissipation rates and some six universal constants evaluated (most were about 1/2) characterizing the inertial subranges observed. Flux values were measured, inferred and compared to simultaneous measurements from an airborne two-frequency infrared radiometer system.

INVESTIGATIONS OF USEFUL PHARMACEUTICALS
IN STARFISH, GORGONIANS, AND OTHER MARINE SOURCES

D. John Faulkner

Summary of Proposed Work

With the advent of sophisticated undersea technology, it appears that many natural products of great benefit to man will, in the future, be obtained from the marine environment. As an alternative to random pharmacological screening of all sources, the observations of marine biologists may be used as a guide to probable sources of physiologically active compounds. Marine biologists have long been fascinated by the complex interactions between marine organisms, ranging from competition to symbiosis. The occurrence of these interactions between organisms of vastly different distributions so that the cause cannot be ascribed to familiarity, has led to the conclusion that these phenomena must be attributed to minute concentrations of highly active chemicals. Despite the small quantities available, these chemical messengers are gradually being isolated and their pharmacological potential evaluated.

The highly toxic substances tetrodotoxin and saxitoxin, both obtained from marine sources, have proved invaluable research tools in neuropharmacological studies. Holothurin, a preparation of interest in the field of cancer chemotherapy, was isolated from the sea cucumber. A member of the prostoglandin family of drugs has recently been discovered in a gorgonian coral. These examples, the results of rather sparse research efforts, herald the discovery of new and powerful drugs from the marine environment.

Our approaches to the discovery and exploitation of new physiologically active compounds from the marine environment have been limited thus far by the lack of the specialized equipment to handle small quantities of materials, and by the absence of facilities for pharmacological screening. The latter problem has recently been greatly alleviated by the establishment of a marine pharmacology planning group, which will coordinate marine-medicine-biology activities of the

medical school, the chemistry and biology department of UCSD, and the marine biology and marine chemistry groups within SIO and IMR. Faulkner of SIO has initiated several projects in this field.

It should be stressed that we do not propose random pharmaceutical screening. We propose to investigate only those organisms which have been shown to exact a specific effect on their neighbors, particularly those organisms (e.g., starfish) whose interaction with other species has resulted in the reliable documentation of behavioral observations.

Report of Work Accomplished

A cardioactive substance named "eptatretin" was isolated by Jensen from the aneural branchial heart of the hagfish, Eptatretus stoutii. After considerable effort, we have been unable to isolate any compound having chemical properties identical to those described for eptatretin. Although our results tend to confirm Jensen's postulate that the hagfish heart contains interesting and perhaps novel compounds, the logistics of obtaining large numbers of hagfish hearts (Jensen used 16,000) renders this project totally unsuitable for study by a graduate student.

We have had little success in separating the saponin mixtures from various starfish. The saponin mixture from Heliaster kubinjii was separated into two fairly pure components by chromatography on kieselguhr, but this method could

not be applied to the more complex mixtures from other starfish.

The saponin mixtures are being assayed for toxicity towards Fundulus heteroclitus. There appears to be two fairly separate classes of starfish, one with highly toxic saponins and the other with mildly toxic saponins. This interesting result will be studied further.

The crown-of-thorns starfish, Acanthaster planci, is known to contain toxic substances. A related species, Acanthaster ellisii, was found to be almost as toxic as Acanthaster planci when crude saponin extracts were assayed using Fundulus heteroclitus. We have determined, however, that A. ellisii should not be added to the list of starfish capable of causing serious injury to man.

We have started to screen local sponges for antibiotic activity. We have obtained both gram positive and gram negative bacteria from local hospitals. We feel that although these bacterial strains are probably highly resistant to many antibiotic substances, any positive results will be of greater significance than similar results on wild types.

GEOPHYSICAL AND GEOLOGICAL DATA CENTER
FOR INFORMATION ON PETROLEUM RESOURCES

Thomas E. Chase

Summary of Proposed Work

The resource of greatest current economic importance is the petroleum beneath the continental shelf and possibly beneath the ocean floor at greater depths. Although the oil industry may not seek our help in developing new methods of exploration, drilling, or production at this time (the NSF-funded deep-sea drilling project on the GLOMAR CHALLENGER has resulted, however, in a number of improvements in drilling technology being employed by oil drilling organizations), we do have a public advisory service to render. Scripps ships conduct geological and geophysical exploration of the deep oceans using pneumatic reflection profiling systems, magnetometers, and echo-sounders that produce information of considerable interest to oil companies throughout the world. Such information makes it possible for companies to get a rapid assessment of the potentialities of areas not explored by commercial contract geophysical firms, and makes possible better planning of exploration programs. More than twenty major oil companies have requested copies of data in our files in the past; several have made gifts to assist in the acquisition and archiving of the data.

In the past the acquisition of such data has been funded almost entirely by federal funds for specific research projects; no money has been available (other than state funds and the gifts noted above) to pay for operating a data library for ourselves and for potential commercial users. With a reduction in Navy funding that previously supported a considerable part of the data-processing and acquisition function, this service to industry will have to be reduced rather than expanded unless new support is received. We are therefore currently contacting the oil companies that have in the past shown interest in such data, asking that they provide partial support of both the reflection profiling and the data archiving work. We hope that in time this will

represent the major support of the data-handling work; this year, however, we requested matching support from Sea Grant to permit us to maintain and expand the data archives.

Report of Work Accomplished

The work has been divided into several parts. Each has been carried out simultaneously with the others towards the end objectives of a working data center.

The first objective is the indexing of data and the location of original records. The indexing is divided into three main types of data within the center: bathymetry, magnetics, seismic reflection, refraction. Navigation also is correlated to the data for a geographical "tag" in addition to quantity of data within a given area.

All three of the index charts (Bathymetry, Magnetics, Seismic Reflection, and Refraction) act as overlays to given areas of the Pacific. Upon completion of the indexes, each will be issued as a Sea Grant Report.

Charts of the bathymetry of the sea floor have been prepared and published during the year. Ten four-color charts were issued in December, 1970, with contours and diagrammatic abyssal topography. A single three-color chart of contours only on the North Pacific was issued in June, 1971 (IMR Technical Report Series TR-17).

Processing of digital data from shipboard collection by computer has been carried on during the year at sea and ashore.

We have answered many requests for data, both for copies of original records and for processed data. Users of the data include oil companies, graduate students, professors, other institutions and agencies.

Contacts with various oil companies have been made throughout the year. This has resulted in donations to the University for support of the Geological Data Center; thus, as had been hoped, it will not need Sea Grant support next year.

With the aim of making the Center a more complete working center, we have requested data from many individuals and agencies. These requests are made selectively for it is not intended that we become a handler of all the world's data.

IN SITU TRAFFICABILITY OF THE CONTINENTAL SHELF

Victor C. Anderson

Summary of Proposed Work

This project concerns research in the correlation of in situ trafficability of the Southern California continental shelf sediments with laboratory measurement on documented cores. It is related to and coordinated with the sampling study (Project SDSC-5 of this report) at San Diego State College under which the laboratory analysis of the sea floor samples will be carried out. It is complementary to research underway at the U.S. Navy Civil Engineering Laboratory.

Both the U.S. Navy and private industry have, in the past several years, placed a great deal of emphasis on the development of manned deep submergence vehicles equipped with manipulators to meet this sea floor work requirement. Far less effort has been expended in the development of remotely controlled unmanned vehicles, and, of this effort, only a small fraction has been concerned with true sea floor work vehicles.

Sea floor work systems must come to grips with the engineering problems of operating in contact with and being supported by the bottom of the ocean. Load-bearing strength and trafficability of submerged sediments in both the disturbed and undisturbed state must be known and understood before engineering designs of fixed and/or mobile sea floor systems can be seriously undertaken.

The existence at Scripps of the tracked, remotely controlled, unmanned sea floor work vehicle RUM and its surface support platform ORB, provides a facility which can efficiently obtain in situ measurements of the trafficability parameters of the bottom down to the greatest depths occurring in the California continental shelf zone. With this vehicle, documented core samples can be obtained for accurate correlation of the in situ measurements of slip, horizontal shear (drawbar pull), and penetration with laboratory analysis of cores from precisely the same location.

Report of Work Accomplished

The RUM/ORB sea floor work system was taken to sea on four operations totaling 43 days between July 29, 1970, and July 9, 1971. RUM was operational on the sea floor approximately one third of the total time on station.

Operations were conducted on the floor of the La Jolla Canyon at depths ranging from 370 to 420 meters and in the San Diego Trough at 1,230 to 1,260 meters. A great deal of experience has been gained in manipulation, maneuvering in, and traverse over, the soft sea floor sediments.

RUM has been instrumented for remote operation of a two-foot long, three-inch diameter corer, a vane shear meter, a cone penetrometer, an anchor winch-tensiometer combination for the measurement of drawbar pull, and a short-range high resolution echo-sounding profiler for examination of track depression. This completes the first phase of the project. The corer, vane shear meter and cone penetrometer are adapted for use by the manipulator arm on RUM. These instruments, which telemeter their data to ORB, on the surface, via the coaxial strain cable, will be used to make in situ soil mechanics measurements and conduct trafficability studies in several areas of interest on the sea floor off the Southern California Coast during the coming year.

Although modification and improvement of the various

instruments will continue for some time, as experience suggests, they are now operational and have been used to collect a limited amount of data. This essentially completes phase two, the check of the instrumentation.

The documented core samples which are taken simultaneously with the in situ measurements are turned over to I. Noorany at San Diego State College where the laboratory analysis of the samples is performed under project SDSC-5. Even though measurements made to date are extremely limited, a good correlation can be made between the various in situ measurements and the results of the laboratory analyses. The actual drawbar pull developed by the vehicle moving on highly plastic silt is found to be consistent with the measured soil strength and is generally independent of track pressure. These measurements have been effectively accomplished because of the unique handling and data telemetry capabilities of the RUM/ORB work system.

This instrumentation suite and the data obtained, from their initial use, in January, on the floor of the La Jolla Canyon, are described in a paper by Anderson, Clinton, Gibson, and Kirsten (abstract follows this report).

The operations themselves are described in the Marine Physical Laboratory "Sea Floor Technology Report No. 3 RUM/ORB Operations Dec. 70 through July 71," by Anderson, Gibson, and Kirsten which is now in preparation.

Publications

Anderson, V. C., J. R. Clinton, D. K. Gibson, and O. Kirsten.
1971. Instrumenting RUM for in situ sub sea soil
surveys. Amer. Soc. Testing Materials, Spec. Tech. Pub. 501,
(MPL-U-94/70) (in press).

Abstract

RUM (Remote Underwater Manipulator) is one of the laboratory research vehicles of the Marine Physical Laboratory. It is a tracked vehicle capable of operating on the sea floor to depths of more than 6,000 feet. An umbilical coaxial strain cable physically connects it with a surface support platform ORB (Oceanographic Research Buoy) and provides the power and data transmission required for unmanned remote sea floor operations. A brief description of this sea floor work system will be presented. However, inasmuch as the RUM/ORB system was described at the 1970 Marine Technology Society meeting the main emphasis will be on the instrumentation suite developed for in situ soil trafficability studies with RUM. RUM has been instrumented for remote operation of a two-foot corer, a vane shear meter, a cone penetrometer, an anchor-winch-tensiometer combination for the measurement of drawbar pull, and a short range, high resolution echo-sounding profiler for examination of track depression. All of these instruments are adapted for use by the manipulator arm mounted on RUM, and all telemeter their data back to ORB via the coaxial strain cable. The results of the initial measurements with the system will illustrate the type of in situ data which can be obtained.

PYHICAL FACTORS CONTROLLING COASTAL PLANNING

Douglas L. Inman, Charles W. Van Atta, and Russ E. Davis

Summary of Proposed Work

California beaches lose fifty million cubic yards of sand each year; either permanently by deposition in deep water, or in harbor entrances where annual dredging is required. The procedure appears to have been one of working against rather than with natural forces.

The central problem to the application of engineering technology to the nearshore zone is that concerned with the coupling between the energy transport mechanisms such as waves and currents and the sediment load. Therefore, it is important that a program for studying these mechanisms be initiated. The objectives of such a study would be the understanding of the budget of mass, momentum, and energy in and near the surf zone. This would require measurements of fluxes into the zone as well as an understanding of the various transport and dissipative mechanisms.

The study would include both field and laboratory investigations, and would begin with controlled experiments of factors such as the momentum flux into the surf zone, the boundary roughness and stress under wave motion, the relation between bed and suspended load transport, and the rate of dissipation of momentum associated with sand transport.

Isolated portions of some aspects of these problems have received cursory consideration in the past. Although they appear to be solvable in terms of today's technology, none have received the integrated, synoptic study necessary for their solution, and none has been solved.

The findings from such a study would have direct application to problems of beach erosion and would lead to the rational design of coastal engineering structures and harbors, extension of existing beaches, and formation

of new shorelines. Related studies are needed over more extensive areas of deeper coastal waters, including the effect of atmospheric winds and the coupling of local wind and wave conditions and their correlation with gross properties of regional weather.

Despite considerable theoretical effort toward improved wave prediction there appears to be very little good wave data with which to test these predictions.

Waves and wave-generated currents are known to be effective agents for mixing and transporting fluids and sediments. Consequently, there are increasing demands to use the shoreline for dispersing effluents of various kinds. Having identified the mechanisms that are operative in the surf zone, it is essential that studies be extended to include: (1) a more comprehensive study of the surf zone mechanisms so that criteria for forecasting the mixing coefficients and dispersion rates can be developed for the surf zone; (2) extend the study to include the circulation and mixing of surf zone waters with those farther offshore, and (3) extend the study to include the dispersion of thermal and other non-conservative pollutants.

Report of Work Accomplished

Part 1: Developing Physical Criteria for Long-Range Planning of the Coastal Zone (Inman).

Progress has been made in bringing the physical factors controlling coastal planning more sharply into focus. A paper describing our present understanding of shore processes was presented at the American Geophysical Union meeting in San Francisco, December, 1970. This presentation resulted in an invitation from Phillip Abelson, Editor of the AAAS Journal Science, to provide that journal with a lead article dealing

with similar problems. A manuscript entitled "The Coastal Challenge" is nearing completion. A theory for the formation of submarine sand bars by edge and incident waves was developed and then verified by experiment in the laboratory (Figure 1). This study has resulted in two manuscripts (Bowen and Inman, in press; and, in preparation).

Inman, together with Birch Brush, Oceanographic Engineer, attended the Sea Grant meetings at the University of Southern California dealing with coastal planning problems. Inman was a participant several times in the U.S.C. Environmental Conference in Los Angeles; he delivered lectures before the San Diego City Science Teachers of the San Diego Unified School District (on "The Coastal Environment") and the L.A. Basin Geological Society (on "Littoral Sand Transport and Submarine Canyons").

Inman also agreed to serve on the advisory panel of the State Water Resources Control Board dealing with water quality standards for the San Onofre Power Plant; conferred with and advised the State Department of Navigation and Ocean Development on conservationist measures; acted as advisor for the San Diego County Planning Division, dealing with long-range study of county beaches; agreed to serve as a member of the UCSD Natural Land and Water Reserves Committee; and served as advisor, on location, to the U.S. Army Corps of Engineers, Honolulu District, on the environmental impact on various Hawaiian beaches.

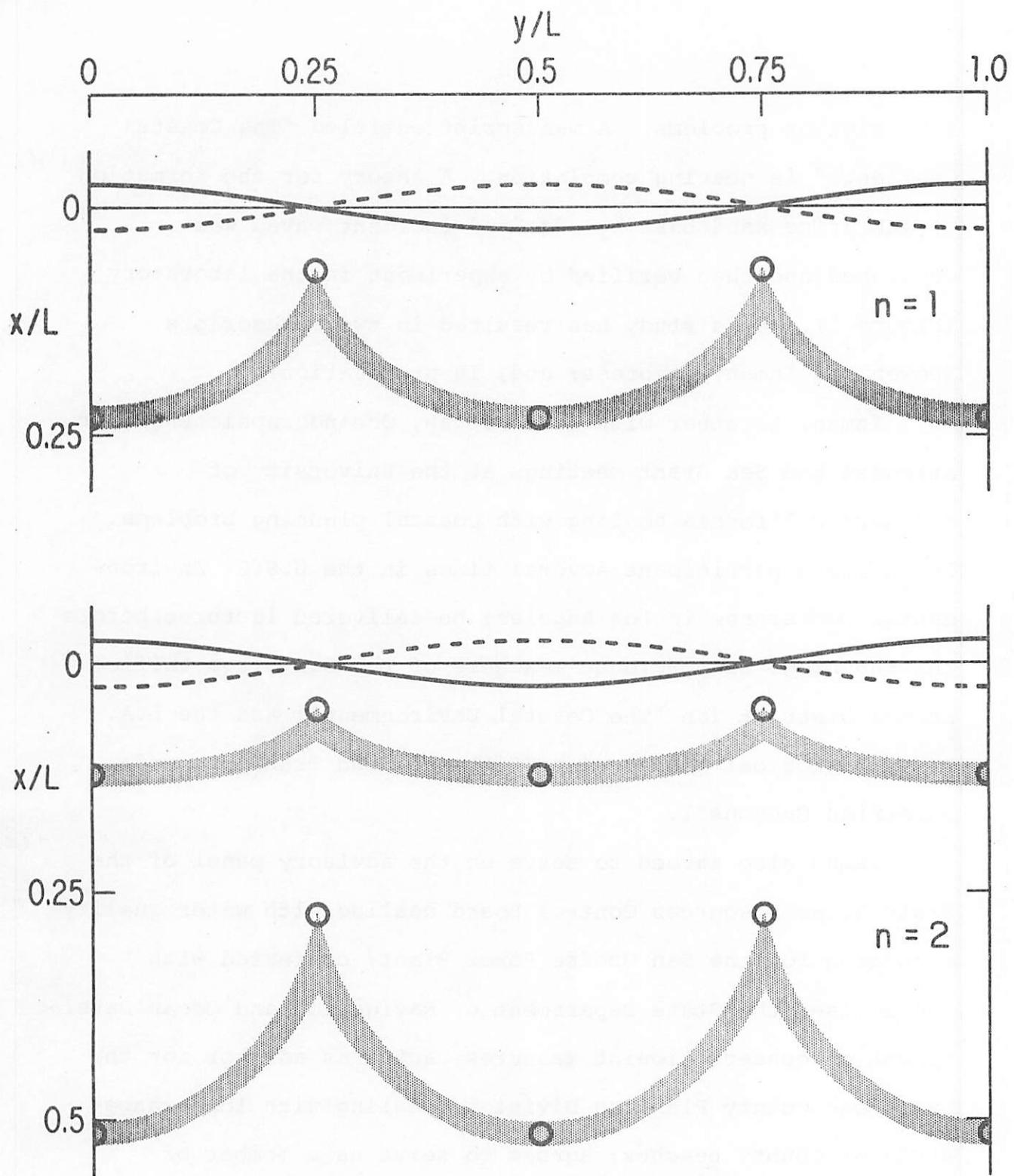


Figure 1. Schematic diagram of the crescentic bars formed by edge waves of modes $n = 1$ and 2 . The horizontal motion of the edge wave at the shoreline is illustrated suggesting a possible mechanism for forming cuspatate features. Sand bars with these configurations were formed in laboratory experiments (from Bowen and Inman, in press, Figure 4).

Liaison and information dissemination with technical societies and other universities has been established and maintained, and the shore processes group has generally become involved in a greater scope of information dissemination activities as a result of Sea Grant sponsorship.

The need for dependable data acquisition from the deeper shelf waters has led to the design of a group of modular units called SASS, Shelf and Shore Simultaneous System (Figure 2).

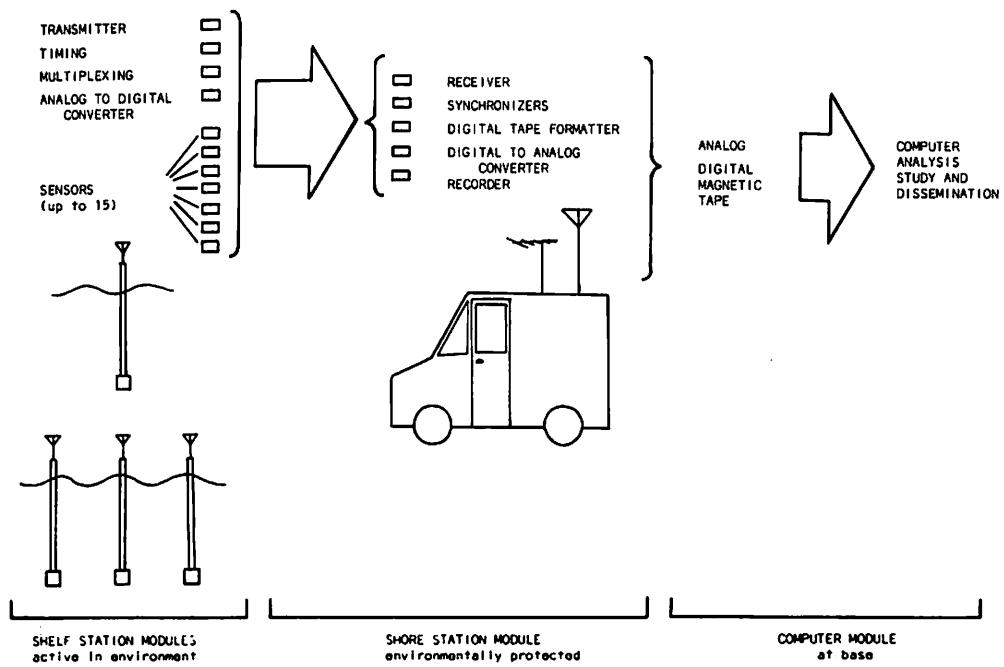


Figure 2. Schematic diagram of the Shelf and Shore Simultaneous System (SASS System). The system accepts data from six spar buoy shelf stations, and each station will accommodate up to 15 sensors. Data is telemetered to a shore van recording station.

This system consists of: (1) an array of shelf stations that contain various sensors and telemetering RF transmitters (Figure 3); and, (2) a van mounted shore station that receives the RF signals and interfaces them to data recorders.

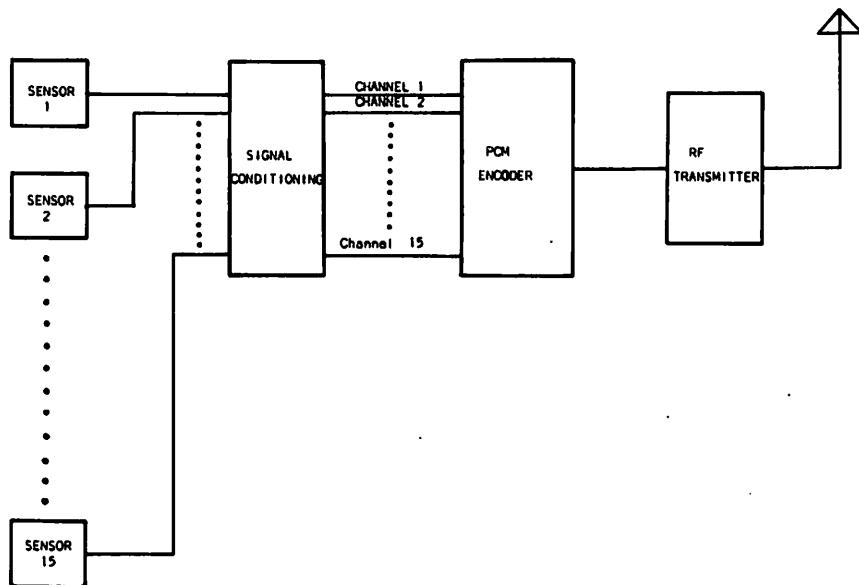


Figure 3. Block diagram for the shelf station of the SASS system.

The shelf station part of the system is a bottom-referencing spar buoy that is deployable from a small boat with only limited diver participation in its installation. Each shelf station buoy is designed to accept up to fifteen sensor inputs and acquire the data from these sensors with simultaneity. The various outputs from the sensors are conditioned into one of two formats. All analog signals

are scaled to a voltage range of ± 5 volts and all digital data are formatted into serial 10 bit words. This signal conditioning allows data accuracy to be maintained at 0.1%. The sampling of the sensor is a sequential process, but is accomplished at a very high rate (approximately 8,000 samples per second). This high sampling rate ensures less than one degree of phase error (for a 3Hz signal) between any two data channels.

Data acquisition by the shore station is a multiple radio link using a pulse code modulated telemetry system. The van mounted shore station (Figure 4) is extremely mobile

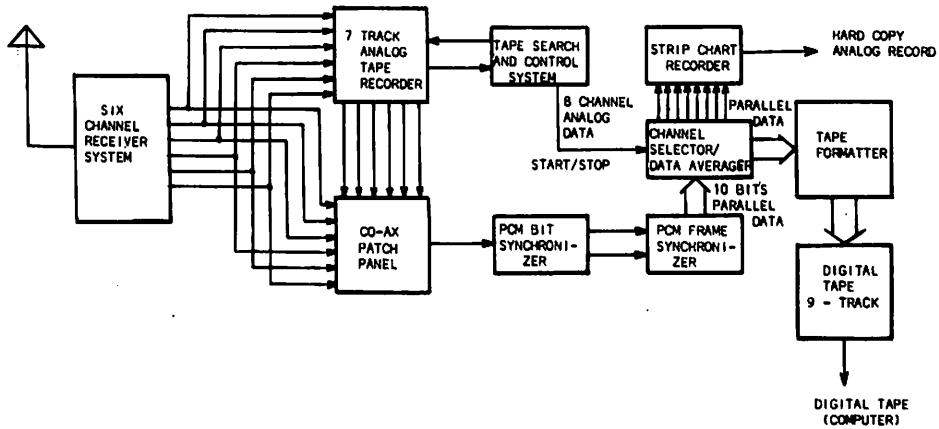


Figure 4. Block diagram for the shore station of the SASS system.

and can receive data from as many as six shelf stations deployed along a coast at any one time. Data acquisition by the shore station consists of receiving the telemetered RF signals and recording them on a wide band analog magnetic tape recorder together with a serial time code. The time code information on the tape is used to start and stop the analog recorder at the desired time to permit data reduction and display from any one of the six shelf stations. It is through the use of the time code that virtually simultaneous data samples are obtained from all the shelf stations. The selected shelf station signal is synchronized and detected so that each data channel is identified and sampled. Because the actual data sampling rate is much greater than the computing equipment can handle, each channel can be gated to reduce the total number of data points. The selected channels are gated to provide an output data rate matched to the digital tape format of 16, 8, 4, 2 or 1 sample per second. If still lower sampling rates are desired, they may be provided by lowering the sampling rate of the shelf station itself. The shore station provides two data outputs from the SASS system; an 8-channel strip chart recording, and a 9-track digital tape. The digital tape is used to input the data into an IBM 1130 computer system.

The sensors most frequently used on the shelf station will be digital wave staffs, absolute pressure sensors and electromagnetic current meters. In addition, depending upon the parameters of interest, a suspended sediment meter, thermal measuring devices, and bottom boundary observation devices can be added to the other available data channels of the SASS system. Along with the development of the SASS, progress has been made in the acquisition and design of the more specialized sensors for making environmental measurements.

A modified two-component electromagnetic flow meter, developed by the British National Institute of Oceanography*, has been acquired for use with SASS. This sensor shows promise as an accurate orbital current meter because of the small size of the sensing head which offers minimal resistance to flow. It is a two-component displaying device and a choice of mounting offers current velocity of any two of three orthogonal axes. Each of the two pairs of sensing electrodes are 7.7 cm apart, so it is anticipated that orbital motion or turbulence may be seen down to that scale. Calibration of this meter is now complete and it appears that the meter is reasonably linear at velocities from 0 - 1.0 m/sec. The meter is going to be field tested in

*Tucker, M.J., N.D. Smith, F.E. Pierce, and E.P. Collins. 1970. A two-component electromagnetic ship's log. J. Inst. Navig., 23 (3): 302-316.

the natural environment on Scripps Beach.

A sensor for measuring the concentration of suspended sediment in the nearshore zone of the ocean and in rivers has been designed based on the integrating scatterance meter introduced by Beutell and Brewer (1949). This sensor consists of: (1) a small incandescent bulb placed behind a diffusing glass; and, (2) two silicon photodiode detectors, each using a small lens for focusing the light on the active area of the detector with a filter behind the lens to blockout wavelengths below approximately 7000 Å. The light source emits light with a cosine distribution of intensity as a perfect diffuser. The two detectors with small angles of acceptance receive light from the source; with the first positioned normal to the surface of the source, and the second parallel to the surface of the source. The first detector senses radiation arriving directly from the source, the second detector receives light which has been scattered. The ratio of the two detector signals can then be related mathematically to the scattering coefficient of the medium around the instrument. The scattering coefficient is proportional to the concentration of suspended sediment.

The design and development stage of the SASS system and sensors is now essentially complete and field testing of a prototype shelf station will be undertaken in the near

future. Once a field testing program has been successfully completed, arrays of shelf stations will be constructed and deployed for data acquisition from any shelf and nearshore area of interest.

Publications

Bowen, A. J. and D. L. Inman. Edge waves and crescentic bars. *J. Geophys. Res.* (in press).

Abstract

The velocity fields associated with edge waves on a sloping beach are examined as possible causes of sedimentary features which have regular, rhythmic pattern in the longshore direction. It is shown that standing edge waves provide a satisfactory explanation for the formation of crescentic bars in regions of small tidal range, the bars having a longshore wavelength of one-half that of the edge waves. In the absence of large, incoming surface waves, the edge waves may also form cuspatate features on the beach face, with the points of the cusps directly opposite the horns of the crescentic bars (Figure 1). This situation is commonly observed in nature.

The results suggest that standing edge waves with periods of 30-60 sec and with significant amplitudes must occur extensively on real beaches.

Bowen, A. J. and D. L. Inman. Selective trapping of edge wave modes. (in preparation).

Inman, D. L. and B. Brush. The coastal challenge. *Science*, (in preparation).

Klein, S. 1971 Optical measurement of suspended sediment concentration. (Presently an unpublished technical report treating the theory and design of the sensor, to be completed and submitted for publication when the sensor has been built and calibrated.)

Report of Work Accomplished

Part 2: Mechanical Effects of Rotation, Stratification, and Boundaries on Laminar and Turbulent Flows (Van Atta).

Design of a closed circuit stratified continuous flow channel has been completed and construction is expected to be completed soon. The design is a novel one, using two pumps each consisting of two sets of horizontal interleaved vanes mounted on a rotor and a stator, respectively, which drive the fluid by viscous forces and do not mix it vertically as in conventional pumps. Results with a small-scale model were encouraging.

Work has continued on the Ekman layer upwelling experiment. Theoretical solutions have been computed for comparison with the data for radial variation of the vertical upwelling velocity, and are in qualitative agreement with the observed flow patterns.

Further computations of the structure of turbulence near the air-sea boundary were completed during the past year. Part of this has been published (see abstracts). Work is continuing on extending the structure function measurements to higher-order in order to compare with widely conflicting theoretical predictions.

Publications

Van Atta, C. W. and W. Y. Chen. 1970. Structure functions of turbulence in the atmospheric boundary layer over the ocean. *J. Fluid Mech.* 44 (1): 145-159.

Abstract

Structure functions of turbulent velocity fluctuations up to fourth order have been measured at several heights in the atmospheric boundary layer over the open ocean, and the results are compared with theoretical predictions for separations in the inertial subrange. The behavior of second-and-third-order quantities shows substantial agreement with the predictions of Kolmogorov's original theory over a wide range of separations, but the results of a recent modification of the theory, attempting to account for intermittency in the local dissipation rate, are also consistent with the data over somewhat shorter separation intervals. The behavior of the measured fourth-order structure function disagrees with that predicted from Kolmogorov's original work, but good agreement is found with the results of the modified theory.

Van Atta, C. W. and J. Park. Statistical self-similarity and inertial subrange turbulence. *Proceedings of the Symposium on Statistical Models and Turbulence, La Jolla, July 1971.* (in press).

Abstract

The probability density of the increments of the turbulent velocity in the inertial subrange is not strictly self-similar but a remarkably close approximation to self-similarity does exist over a restricted range of velocity differences and separations. Under the assumptions of the original Kolmogorov theory, statistical self-similarity is consistent with the predicted behavior of the moments of the increments of the fluctuating velocity in the inertial subrange. Statistical self-similarity is, however, not consistent with the predictions of the modified theory. The measured behavior of the structure functions and the non-self similar behavior of the increments which generated them furnish suggestive evidence for the validity of the modified theory, but more extensive data are needed for $p(\Delta u; r)$, especially for large values of Δu and small values of r in

order to accurately compute the higher-order structure functions over the entire range in r to produce a more conclusive test.

Van Atta, C. W. and J. Park. 1971. Statistical self-similarity and atmospheric turbulence. Proceedings of Internat. Symposium on Probability and Statistics in the Atmospheric Sciences, June 1971.

Abstract

The increments of time series of the fluctuating velocity obtained in the atmospheric boundary layer over the open ocean are found not to be self-similar in the inertial subrange, contrary to a previous conjecture by Dutton and Deaven. The measured probability density function of the velocity difference continuously evolves from a strongly non-Gaussian form for small values of r , characteristic of the probability density of the velocity derivative, to a nearly Gaussian form at the largest separations, although the structure functions up to fourth-order and spectra have nearly the form expected for self-similarity.

Van Atta, C. W. 1971. Higher order structure functions and statistical self-similarity of turbulence near the air-sea interface. Presented in the Air-Sea Interaction Symposium at the 15th General Assembly of the IUGG, Moscow, August 1971.

Abstract

Structure functions of longitudinal velocity fluctuations up to fourteenth order have been measured close to the water surface in the atmospheric boundary layer over the open ocean, and the results are compared with conflicting theoretical predictions for separations in the inertial subrange. The behavior of the measured structure functions of fourth and higher order are in clear disagreement with that predicted by Kolmogorov's original theory. Good agreement is found up to eighth order with the predictions of a later modification of the theory by Kolmogorov, Obukhov, and Yaglom, which accounts for the intermittency in the local dissipation rate. For higher orders the behavior of the data and the modified theory are also not in agreement. Computations of the probability distribution of the increments of the fluctuating velocity at one point show that in

the inertial subrange the increments are not self-similar in the sense defined by Mandelbrot and Van Ness, contrary to a previous conjecture of Dutton and Deaven. The measured probability density function of the velocity difference increments continuously evolves from a strongly non-Gaussian form at small separations to a nearly Gaussian form at the largest separations, and the higher-order skewness and flatness factors approach values appropriate to a Gaussian joint probability distribution only for the largest values of the separation. Cross spectra of velocity fluctuations and the local wave height are examined in an attempt to assess the influence of air-sea interaction on the measurements.

Report of Work Accomplished

Part 3: Growth Rate of Ocean Waves Generated by Wind (Davis).

The objective of this program is the determination of the growth rate of ocean waves generated by wind. This information is essential to the development of a reliable scheme for predicting sea state from meteorological data. Because funding of this project ceases in 1971, the original plan of obtaining this information from long-term measurements of waves at coastal locations had to be abandoned. Instead, effort has been directed toward developing an instrument system capable of determining wave growth directly by following a packet of waves at their group velocity and measuring simultaneously variations of the energy of the wave group and the wind conditions producing the variation. This technique, in contrast to other possible approaches,

allows all the data necessary for prediction of wave growth to be collected by a single observation system.

Theoretical investigation of the response of various possible instrument arrays has shown that the simplest practical system consists of two towed instruments which measure wave elevation at positions separated by approximately one-half the wave length of the waves of interest. Methods of analyzing such data in order to estimate the directional wave spectrum and the energy of those waves whose energy is traveling with the instrument system have been developed.

A prototype instrument consisting of a floating tube, 3 meters in length, housing a servo feed-back accelerometer and associated electronics has been developed and tested. The instrument responds adequately to waves of length exceeding 10 meters and is capable of being towed along a straight course at speed in excess of 12 knots. A novel method of mounting the accelerometer so as to maintain the sensing axis near vertical in the presence of pitch and roll has been developed and tested.

The instruments are now being used to measure growth rates of waves in the North Pacific. The project will be continued through 1972 (under other funding) during which time wave growth off the Argentina coast, in the "roaring forties" winds, will be studied.

BIOLOGICAL AND ECOLOGICAL STUDIES OF NORMAL POPULATIONS,
NATURAL VARIABILITY AND EFFECTS OF ENVIRONMENTAL CHANGES
IN THE NEARSHORE ZONE

William A. Newman and Paul K. Dayton

Summary of Proposed Work

In order to conserve and utilize our marine biological resources effectively we need to know how each fits into the ecosystem in which it occurs. This can be determined by intensive studies of single species or by attempts to look at large segments of the marine communities. Some of the information can be gained from relatively short term studies but, because the processes involved have a wide spectrum of time scales, very long term studies will also be necessary.

One such study has shown that the benthic community on sand in shallow water is remarkably stable in the face of large fluctuations in the physical aspects of the environment. There is some indication that this may also be true of the rocky bottom and intertidal communities, but neither of these have been studied for a long enough time. The changes in these communities that result when man perturbs the environment are almost unknown and cannot be determined unless more effort is applied to defining the baseline conditions. Such research will have to look at the total community, determine the interactions within it and the natural variation in abundance and intensity of interaction. One method of discovering the dynamics of such communities is to provide new substrate and follow in detail the steps leading up to the final community structure. The first steps toward this have been taken by putting a standard solid substrate in the midst of a broad area of sand bottom. The increasing association of fish and invertebrates with the "rocks" and the growth of algae on them have given a greater insight into both the theory of community formation and the practical results of the establishment of artificial reefs.

The recent concern about the depredations of a starfish, Acanthaster planci, on coral reefs emphasizes a behavior that seems characteristic of many echinoderm populations.

The effects of sea urchins, Strongylocentrotus spp., on kelp beds are another example. In both cases, large numbers of individuals are concentrated in small areas and effectively eat their food out of existence. They often attack species that are of interest to man and can have considerable economic effect. Little is known about the population dynamics of such species, the communities in which they live, or the factors that normally keep them at moderate densities and those that allow or cause them to become epidemic. There are closely related species that have not yet shown this phenomenon. The comparative study of these, along with detailed study of the "pest" species, should give us insight into the operations of the nearshore communities and populations that man will affect and try to manage.

Report of Work Accomplished

Part 1: To Establish an Ecological Base Line for Coral Reef Areas in the Tropical Eastern Pacific (Newman).

The proposed research was designed to establish an ecological base line for coral reef areas in the Tropical Eastern Pacific. Determining the organization of reef coral assemblages and the interactions between members of these assemblages and certain other components of coral reef communities, numerical abundances, as well as general oceanographic information would allow detailed comparisons to be made between well developed reefs in the Central Pacific and the Caribbean. The results will aid in assessing fluctuations in reef community populations--especially should these areas be disturbed through the future activities of man.

Knowledge of coral reefs is exceedingly elementary. We presently have no sound basis for suggesting methods or procedures of managing the environment should it be desirable say to increase the yield of certain fishes or shell fish. For example, when it was recently discovered that a particular starfish was killing large numbers of corals, the immediate response was to recommend extensive control measures. This is much like our response had been to fire, where we now realize there has been over-control and schemes for periodic systematic burning are being considered. No one has yet suggested that reefs might respond favorably to systematic "burning" even though we know that areas are periodically destroyed by storm waves and freshwater runoff. Yet, ultimately man should be able to improve the quality of the reef environment rather than relying on the vicissitudes of nature.

Our work was carried out on R/V ALPHA HELIX, Cruise Leg II, from 11 September to 9 October, 1970.

The tropical eastern Pacific and the western Caribbean Sea, separated spatially by the narrow isthmus of Panama and temporally by a few million years, differ radically in their relative development of coral reefs--poorly in the eastern Pacific; flourishingly in the Caribbean. Suboptimal temperatures may, in part, account for the lack of local reef development. However, no upwelling is reported from

the southern coast of Panama. The expedition's studies were therefore designed to compare the physical environment and reef communities between the tropical eastern Pacific and the western Caribbean and thereby uncover answers to the general problem of the lack of coral reef development in the eastern Pacific.

Environmental factors measured included temperature, salinity, relative turbidity, light, tides, currents, dissolved oxygen, and sedimentation rates. Principal reef study areas were Isla Cavada, Islas Secas (Pacific) and Agualargana or Holandes Cay, San Blas Islands (Caribbean).

Temperature and salinity profiling using XBT's and an STD off the Pacific coast revealed the presence of a warm, dilute surface layer extending some 55 km offshore. A rather sharp thermocline extended from a depth of approximately 15 m to around 65 m. Surface salinities were never below 34 ppt. Using the STD as a "Sechi disk" during STD profiling in the Pacific, water clarity varied from 3.5 m with a dark green color on the inshore ends of the transects to 14 m and a nearly oceanic blue color some 55 km offshore. Irradiothermographs developed by ourselves and the Visibility Lab of Scripps were employed to record continuously light levels and temperature in reef study areas. In the Caribbean study area nearly 10 days of records were obtained from depths of 3, 7, and 20 m. Temperature traces are very nearly straight

lines with virtually no differences in depth. Isaacs current meters were used for a 24-hour period just off Isla Cavada at depths of 10 and 20 m. Ten days of records were obtained from depths of 7 to 20 m at Agualargana. Off the reef at Agualargana water samples were collected hourly for 26 hours with Nansen bottles at depths of 25, 15, 5.2 m, and at the surface. Dissolved O₂ (as mm of Hg) was measured with an oxygen electrode. At no time was O₂ below 75% saturation.

Reduced surface salinities, the shallowness of temperatures suboptimal for vigorous coral growth, and relatively high turbidity—conditions not prevalent on the flourishing Caribbean reef studies—quite likely are the principal physical factors inhibiting present day coral reef formation along the Pacific coast of western Panama. The results will for the most part constitute a portion of the thesis of Thomas Dana.

Part 2: Research on the Organization of Certain Kelp Communities (Dayton).

Research on the organization of certain kelp communities has involved a consideration of the extent of natural variation in community composition in space and time; experiments to evaluate the effects of competition for light between canopy levels; and efforts toward elucidating the ecological implications of quick-lime sea-urchin eradication.

To suggest answers as to the extent of natural variation in community composition in space and time, "baseline" sampling was designed and begun in the summer of 1971, and permanent transects and quadrats are now in place. The controls used for the other two experiments mentioned above are serving also as additional sources of "baseline" data.

Experiments evaluating the effects of light competition between canopy levels have been started at Pt. Loma and Catalina Island. These involve reciprocal canopy removal and adjacent controls. The experiments have not yet yielded conclusive data, but the controls are offering information on the effects of kelp harvest.

Research directed toward greater understanding of the ecological implications of the quick-lime sea-urchin eradication projects has included the surveying of areas limed at different times in the past, and a comparison of these areas with adjacent unlimed ones. Sufficient variation between the "control" unlimed areas has been found so that, to date, no general statements can be made as to the effects of lime on the community.

The investigators took part in a series of Sea Grant-sponsored conferences at the University of Southern California Center of Urban Affairs on the development and management of the coastal zone of California, and lectured at the Pollution Symposium for Teachers at the T. Wayland Vaughan Aquarium-Museum

at UCSD (see Project 7). Public lectures were also given to the American Cetacean Society, a conservation group, and to the NSF summer high school program at the Bishop's School in La Jolla.

In the area of marine resource utilization, discussions were held with the San Diego County Lobster Fishermen Association concerning means of improving the lobster fishing. In meeting with Kelco personnel, the implications of kelp harvest technique were discussed. Two days were spent in Bellingham, Washington consulting with the Lummi Indian Aquaculture Project leaders to consider the potential community impact of their algal harvest and the means of obtaining a sustained yield of the harvest. Two weeks were spent at Amchitka, Alaska surveying the kelp community there prior to the AEC nuclear test.

Publications

Dayton, P. K. and G. A. Robilliard. 1971. Implications of pollution to the McMurdo Sound benthos. Antarctic J. of U. S., 6 (3): 53-56.

Abstract

There are three possible sources of marine pollution in McMurdo Sound near McMurdo Station: heated seawater released from the nuclear-powered distilling plant, inorganic trash dumped on sea ice, and organic food wastes and sewage dumped on sea ice that is eventually broken in situ by icebreakers. Eutrophication is considered potentially the

most damaging because it selectively affects particularly important species.

Dayton, P. K. and R. R. Hessler. 1971. Role of biological disturbance in maintaining diversity in the deep sea. Deep-Sea Research, (in press).

Abstract

This paper presents the hypothesis that the maintenance of high species diversity in the deep sea is more a result of continued biological disturbance than of highly specialized competitive niche diversification. Detrital food is the primary resource for most of the deep-sea species, but we suggest that in deposit feeding, most animals would consume available living particles as well as dead. We call this dominant life-style "Cropping." Predictable cropping pressure on smaller animals reduces the probability of their competitive exclusion and allows a high overlap in the utilization of food resources. Since cropping pressure is in part proportional to the abundance of the prey, proliferations of individual species are unlikely.

Through time many species have accumulated in the deep sea because of speciation and immigration. Extinction rate is low because the biological and physical predictability of the environment has suppressed the possibility of population oscillations. Predictability in food supply for smaller deposit feeders is enhanced by the larger, mobile scavengers which consume and disperse large particles of food which fall to the ocean floor.

Dayton, P. K. 1971. Competition, disturbance, and community organization: the provision and subsequent utilization of space in a rocky intertidal community. Ecological Monographs, 41 (4) (in press).

THE JUVENILIZING FACTOR IN CRUSTACEAN EYESTALKS

D. John Faulkner and John D. O'Connor

Summary of Proposed Work

A study of the effects of currently used and proposed pesticides on the population of the nearshore region is an appropriate long-term study to ensure that the load of pesticides in agricultural run-off and municipal wastes will not do irreparable harm to the coastal biota; a similar project has been proposed for the offshore fishery program where the problem is already severe. We intend in the future to increase our efforts in this field.

One pesticide problem, if studied immediately, can prevent damage before it occurs. A suggestion has been made that insect juvenile hormone or one of its many mimics might be used in insect control now that DDT replacements are urgently needed. The molting cycles of insects and crustaceans are strikingly similar, and the probability that agricultural use of juvenilizing compounds would lead to their presence in streams and coastal waters points to the need for further research on juvenilizing compounds in crustaceans. At worst, one might reasonably speculate that unchecked use of juvenilizing compounds might lead to the destruction of fresh-water crayfish, the economically important crab and lobster, and smaller crustacea, which play a vital role in the marine food chain. We proposed to isolate and identify the juvenilizing factor of crustacean eyestalks and investigate its physiological action.

Report of Work Accomplished

Juvenile hormone controls the qualitative nature of insect molting. It is suspected that the mechanisms of crustacean molting are similar to those of insect molting. We therefore set out to screen extracts from various crustaceans for juvenile hormone activity using an assay procedure employing Galleria mellonella as the test organism.

We obtained 1.5 kg of eyestalks from Panulirus interruptus from the lobster processing plant at Ensenada, Baja California. We obtained 20 g of eyestalks from Homarus americanus from Bar Harbor, Maine, and approximately 1 g of ether extracts from Calanus sp. from Butte Inlet, Canada.

The extracts from Homarus americanus give disappointing assay results, with only one ethanol extract showing a slight positive result.

The ether extracts from Panulirus interruptus were partitioned between hexane and 95% methanol. The methanol extract was subjected to chromatography on silica gel plates, from which two adjacent active fractions were obtained. At each stage of the purification, all fractions must be assayed for juvenile hormone activity. The activity of one of the fractions from the silica gel plates revealed a 40,000 fold purification of the material. Both of the two active fractions were subjected to preparative vapor phase chromatography

but no particularly active fractions were obtained. This may be due to either insufficient material for bioassay or destruction of the active fraction on v.p.c. There can be no doubt, however, that the active material is not identical to the C-17 or C-18 Cecropia juvenile hormones, which have been synthesized as control compounds.

The extracts from Calanus sp. are currently under investigation while we await the beginning of the lobster season in Mexico.

This project is coordinated with the present lobster studies in progress with Sea Grant support at San Diego State College.

SIO

CUIMR-Z-71-018

ENHANCEMENT OF NATURAL MARINE PRODUCTIVITY
BY ARTIFICIAL UPWELLING

John D. Isaacs and Walter R. Schmitt

Summary of Proposed Work

We proposed to investigate the possibility of harnessing the waste heat of large power plants (atomic or fossil fuel) to create artificial upwelling (and heating) of the deep nutrient-rich water, and using the water to increase, ultimately, the sustained yield of animal protein. Such a disposal of heat will avoid thermal pollution, as the water would be discharged at virtually the same temperature as the natural surface waters.

One can postulate substantially enhanced productivities from artificial upwelling in the open sea, but the effects of the application of even very large amounts of waste heat would be masked by natural fluctuations in productivity. Long-term statistical studies would be required to determine this benefit. The engineering problems of conveying heat from a plant well out into the sea, and the problems of appraising the "crop" in unconfined areas also argue against a high-seas location for a meaningful first experiment. A more practical test would be the establishment of an artificial lagoon with an adjacent large thermal power plant at a location close to both populated areas needing power and a source of deep water. Such sites exist in southern California as well as elsewhere in the world.

By using a coral atoll, one can avoid the problem of building an artificial island. There, the task of obtaining deep nutrient-rich seawater can be accomplished more easily than on a continental margin. It will probably be possible to drill into the atoll and pump water that has the same chemical composition (and temperature) as the sea surrounding the island.

The following four phases of the investigations are envisioned:

- I. Study of a lagoon's broad ecological factors, including nutrient supply; investigation of the permeability of coral atoll material and

through-atoll water flow; selection of a site for the experiment; detailing of Phase II and advanced planning of Phase III.

II. Thorough ecological study of the selected atoll. Sampling of food-chain populations, measurement of circulation, chemistry, and nutrients in and around the atoll, several times a year. A test of nutrient enrichment on plant growth will come early in this phase. The permeability investigation will be continued involving light drilling of the reef.

III. Construction of impoundment enclosure and pumping system, including pipeline; periodic biological monitoring of experimental and control areas after pumping has begun.

IV. Complete restudy of experimental and control areas. Determination of potential harvest and perhaps actual harvest of some population. Estimates of probable benefit if nutrient enrichment were extended to unconfined coastal areas employing waste heat for upwelling.

Report of Work Accomplished

Work on this project encompasses permeability studies on coral reef material in situ, selection of an experimental site in the Pacific, and administrative and laboratory preparation and staging of a field work trip by eleven people in September, 1971.

The permeability studies were undertaken by Ronald Lam on Swains Island. Subsurface permeability for this atoll was derived from measurements of groundwater tides along a radial

transect, employing pressure transducers and mechanical-float tide recorders in open water and wells. Supplementary barographic and thermographic records were also obtained during this period and 12-hourly rainfall averages were available on the island. Water and sediment samples were taken from the wells and select lagoon locations and six hydrocasts performed in the lagoon's deepest portions. The data and results have been incorporated into Lam's Ph.D. thesis, SIO.

The search for an experimental site led to the selection of two proximate nuclear craters on Runit Island, Eniwetok Atoll, in the Marshall Islands. These craters are about one acre in size and 40 feet deep each and have become populated by marine organisms.

We are presently preparing for a party of ten (plus one radiation safety officer) to conduct our first field work on Runit Island between September 1 and 22, 1971. The aims of this field trip are: sampling and surveying the two craters for biological, biochemical, ecological, and productivity parameters; and detailing of a sampling and surveying procedure for the determination of baseline data on these parameters which we intend to gather every four months for a year. The samples, whenever practicable, will be examined and evaluated on campus. For non-storageable data the necessary instruments

and gear are being flown to the experimental site for examination in the field.

The sampling and surveying of the entire natural food chains present in two man-made reef ponds have been organized into four complementary parts: planktonic, chemical, ichthyofaunal, and benthic surveys. Each part is assigned to two investigators who have worked out a schedule of field work.

During the September, 1971, field trip we will also firm up our plans for the acquisition of deep nutrient rich seawater and for the construction of a seawall to fully enclose the experimental pond.

At the moment we are confident that acquisition of deep seawater can be accomplished by means of a hole drilled into the reef. Coral reefs are commonly very pervious sediments, and temperature and tidal measurements on Swains Island and in two deep drill holes on Eniwetok Atoll confirm this. These two holes were drilled in 1952 down to the volcanic basement of Eniwetok Atoll, some 4200 and 4600 feet. One was subsequently blown up in an atomic test. The other, named E-1 and located on Parry Island, still exists and is cased for 4100 feet. We would like to run a nutrient profile in this hole, but we do not now know the hole's location or the integrity of its casing. Hydrocasts 600 miles east and 900 miles west of Eniwetok indicate a strong nutrient build-up at a depth of about 1500 feet. A flow test of E-1 is also planned.

E-1 is not likely to serve as a deep well for the artificial upwelling experiment since it is 12 miles distant from the two craters and a pipeline would have to span a rough channel in the reef. The casing might also have to be perforated. Yet there arises the intriguing speculation as to the comparative merits and costs of drilling a hole on Runit versus enclosing a reef area on Parry. We will invite contractor estimates on these possibilities.

NEW APPLIED DEVELOPMENTS

John D. Isaacs

Summary of Proposed Work

This program will involve short explorations into the feasibility and practicability of a number of ideas that have applied potential. A few examples of such projects, now successfully being pursued, delineate the general nature of the proposed work.

Power Generation from Waves: The development of a new single entree that effectively converts motion into power from a broad range of frequencies of surface waves.

Submerged Breakwaters: Model studies utilizing the peculiar properties of "non-Archimedean" bodies to degrade wave energy for structure, beach, or harbor protection, or for the creation of open sea refuges.

Environment, Genetics, and Crossbreeding of Halophytes: Studies and experiments with the highly salt-tolerant salt marsh plants to ascertain the physical and genetic conditions of salt tolerance, for creating a viable seawater agriculture.

Report of Work Accomplished

Wave Power.

The research has involved both the utilization and dissipation of wave energy.

The work on utilization has involved the broad-band wave power generator. The work on dissipation has involved two aspects: the effect of air (the atmosphere) and the dissipation resulting from "non-Archimedean" bodies and artificial reefs.

Vacuum Experiments.

The effect of air has been appraised by the construction of a 30' x 3' vacuum wave channel. Experiments were run mainly at atmospheric pressure and at the vapor pressure of refrigerated water. Considerable alteration of the common phenomenon of breaking was observed in a vacuum. Principally this involved a preservation of the rotary motion after breaking, a great diminution of the disturbance (and secondary waves) produced by the eruption of the air enveloped by the breaker, and several interesting alterations in the wave and breaker profiles. A comprehensive report (including a side-by-side motion picture comparison) is completed and will be distributed as an SIO technical report.

"Non-Archimedean" Bodies.

Work on the "non-Archimedean" bodies has continued with a graduate student, Richard Seymour.

We have employed the term "non-Archimedean" bodies to refer to any of a group of objects submerged or floating on the sea, for which the ordinary Archimedean laws do not apply. Such bodies include taut-moored instrument stations or buoys, totally submerged taut-moored objects, salvage ships when lifting, hydrofoils, rising bubbles, etc.

Characteristic of such bodies is a marked departure of their behavior, in the presence of waves, from that of the water or of "Archimedean" bodies. This is for the reason

that the varying wave forces are acting on much different (greater or lesser) masses than the mass of the water that the body displaces.

In the case of light objects, taut-moored just below the sea surface, the effect of waves is to force the bodies into highly amplified reciprocal motion. Since the power dissipated by an object moving in respect to the orbital water motion is a function of the cube of the differential velocity, these objects are much more effective in dissipating wave energy than an equivalent volume of rigid structure. We can thus visualize a new kind of breakwater, wave barrier, or offshore refuge, constructed of the lightest possible materials, rather than the heaviest.

Channel and basin experiments have shown quite spectacular results, with some simple configurations reducing the wave energy to 25% of the incident energy.

The complex problem of parameterizing the system is progressing well and is now in a state that will allow extrapolation to large-scale installations.

Phase-Shifting Reefs.

During the channel and basin tests on "non-Archimedean" bodies, we have also tested a new idea. This is the possibility that simple long strip reefs, placed parallel

to the direction of travel of a wave train, can be effective in dissipating wave energy. The requirements are that the reefs be narrow in comparison to the wave length, that they be interspaced with similar widths of deeper water, and that the length and difference in depth be such that the crests of the waves over the reefs are substantially displaced (e.g., phase shifted), during their travel over the reef in relationship to the crests traveling over the channels.

A model has been placed in the large wave basin that simulates Pacific swell passing along 30 foot deep reefs with 60 foot deep interspaced channels.

The results of this model in the wave basin are quite surprising. The incident waves (and the surf on the beach) are virtually destroyed. Some of the wave energy is apparently dissipated by eddies. The principal effects appear to be destructive interference and multiple high frequency wave generation. However, much needs to be elucidated before construction of a prototype is attempted. The potential sanding problem of the channels is probably correctable by use of an effective scheme now under development by D.L. Inman.

The results of both this and the "non-Archimedean" bodies are most encouraging and are to be reported in a paper that is now being prepared.

Inland Surfing.

A small model experiment involving a circular toroidal tank with the bottom configured so that waves were propagated in appropriate circular paths demonstrated that such continuous waves can be maintained. This makes possible inland surf sports without great expenditures of mechanical power, as is now employed.

Wave Powered Electrical Generator.

The wave powered pump, tested in archetype early this year, is now in final design as a power generator. Advanced computational models lead to a 10% to 20% conversion of wave power into electric power!

Final structural design is now underway on a prototype for 5 and 7.5 kw continuous generation in the trade-wind sea. Although the buoy assembly will be the same, two different pipes will be designed and used. One will be a half-wave rectifying pipe, circulating seawater, and one will be a full-wave rectifying pair of pipes in a closed system.

The system depends upon the differential response of two coupled systems: a) the buoy and water-filled pipe and b) the water within the pipe. The differential response permits the water to be delivered at a pressure much above that represented by the wave height. The essential features

of the system are that system a, above, must have a frequency of vertical heave that is high in comparison to the waves, and system b must have a much lower frequency than the waves. The result is that the system will produce power over a wide mixture of wave frequencies — a band-pass system, unlike many other proposed systems which would be useful only through a very narrow spectral band.

One of the disadvantages of the prototype model for installation in the real ocean is that the length of the system cannot be sealed and hence must have the same length as an eventual large-scale plant.

The calculated conversion efficiency of this system leads to the conclusion that a wave-powered system of a mass equivalent to that of a nuclear power plant, in toto, and installed in the trade-wind sea would generate similar power levels!

Halophyte Culture.

The experimentation on seawater culture of higher plants has been able to proceed without Sea Grant expenditure under the sponsorship of the Foundation for Ocean Research.

Some results (e.g., the cultivation of healthy table beets in 100% seawater) are so encouraging and exciting that we may propose a major expansion of this program in the near future.

Underwater Electrical Potential (UEP) Diver Communication.

Although principally supported by the Foundation for Ocean Research, some Sea Grant support was employed in the preliminary development of UEP divers' communication. The work has involved the building of simple preamplifier circuits and tests. First results at low power and amplification gave very clear voice communication over a range of about 300 feet. As, unlike acoustics, there are ordinarily no reflections or multipaths in this mode of communication and there is a very low background, it appears that a superior communication can be conducted between divers for several hundred feet or so, and between boat or shore and diver for even greater ranges. Development and testing continue.

Publications

Isaacs, J.D. and R.J. Seymour. 1971. The ocean as a power resource. Presented to the 68th National Meeting of American Institute of Chemical Engineers, March 1971, (in manuscript).

BUREAU OF MARINE SCIENCES
PROGRAM EXPANSION

Glenn A. Flittner

Summary of Proposed Work

The Director of the Bureau of Marine Sciences at San Diego State College will function as full-time Project Manager for Sea Grant affairs, and will administer and coordinate projects and activities under Sea Grant sponsorship through the San Diego State College Foundation. Full-time Bureau staff will support and coordinate activities of various principal investigators. Administrative, publications, and advisory services will be handled by the Bureau, and joint programs involving Scripps Institution of Oceanography and San Diego State College will be served through this medium.

A major function of the Bureau will be to direct qualified graduate students to Marine Sciences Faculty in appropriate departments, and to provide fiscal support during their training. Opportunities will be offered to graduate and undergraduate students to participate actively in the conduct of research funded by the Office of Sea Grant Programs, as well as other agencies.

As more San Diego State faculty members prepare and submit project proposals to the Office of Sea Grant Programs, the Director of the Bureau can expect an increasingly heavy workload. Also a growing volume of requests for summer institute programs in oceanography continues to be directed to San Diego State and plans are being drawn up for a multi-disciplinary course offering in oceanography.

Report of Work Accomplished

Principal efforts of the office of the Director have been devoted to the administration and coordination of the Sea Grant projects (SDSC-1 through SDSC-5). Full-time staff assistance was offered to the principal investigators during the year and a number of negotiations were carried out with the San Diego Gas and Electric Company for access to tide-lands space at both the South Bay and Encina power plant sites.

During the year, nearly 200 students declaring an interest in oceanography were interviewed and counseled. Those students having specific interests were directed to members of the Marine Sciences Faculty in several departments.

The office of the Director provided administrative support to instructors of several classes who requested ship time for field trips at sea. Through the cooperation of the Scripps Institution of Oceanography, two upper division classes were taken to sea for a day aboard R/V ALEXANDER AGASSIZ. One special day trip each semester was arranged for undergraduate students in our Oceans-100 course, and, although these trips were arranged on idle sportfishing vessels, the students were willing to pay approximately \$5.00 each to defray the cost of the charter.

The Director represented San Diego State College at a number of national meetings during the year. Among these were

the Eastern Pacific Oceanic Conference, the Association of Sea Grant Institutions, the Inter-American Institute of Ecology, and the Marine Technology Society. He also attended the 15th Annual General Assembly of the International Association for the Physical Sciences of the Ocean, Tokyo, Japan, where he presented an invited paper (see abstract following this report).

On-campus activities other than those noted previously centered about developing faculty interest and supporting involvement in the marine sciences. Two new project proposals were submitted for review in our 1971-72 program document; these were the first proposals to originate from our Economics and Geography Departments within the College of Arts and Letters.

An interim report on Sea Grant Project GH-36 was issued on June 18, 1970, by David A. Farris, Project Manager. This report summarized the work of four principal investigators and eleven undergraduate and graduate students who participated to various degrees in the project.

One manuscript entitled "Molting and growth in laboratory-reared phyllosomes of the California spiny lobster, Panulirus interruptus" by Deborah M. Dexter has been accepted for publication in the California Fish and Game Quarterly journal. One Master's thesis entitled "Food Preferences and Feeding Behavior of Panulirus interruptus Phyllosoma Larvae" has been completed by Joan Mitchell. Two other Master's theses,

one on "Recruitment, Habitat, Preference, Growth, and Laboratory Rearing Studies of the Puerulus through Mid-Juvenile Stages of Panulirus interruptus" by Steven Serfling, are nearing completion. A manuscript entitled "Catch Analysis and Mark-Recapture Studies of Panulirus interruptus" by David A. Farris is now being revised.

Publications

Flittner, G. A. 1970. Applications of synoptic environmental data in forecasting availability and distribution of albacore tuna on the U.S. west coast. Presented at the Fifteenth General Assembly of the International Association for the Physical Sciences of the Ocean, Tokyo, Japan, 24 September, 1970.

Abstract

The availability and distribution of albacore tuna off the U.S. West Coast appears to be influenced by the temperature of the upper mixed layer of the sea. A five-year record of catch vs. temperature data from the California fishery shows a modal temperature of about 17°C with upper and lower two-thirds limits at 20.0°C and 15.5°C. Albacore are found normally at the surface, but the late-season live-bait fishery often takes fish from the preferred thermal layer at depth off Southern California. The influence of weather and oceanic climate on the annual thermal cycle in the upper layer of the sea is discussed. Short-term, large-scale displacements of the centers of fishing activity due to pulses in the upwelling regime are shown, and the effects of weather and sea conditions on vessel and gear operation are treated. Forecasts of environmental parameters for albacore fishing operations fall into two general categories: (1) long-term and (2) short-term. The masking effects of summer (short-term) heating on long-term trends are treated. Failure of standard meteorological-climatological forecasts is discussed, and the value of day-to-day monitoring of environmental conditions and trends is shown. New techniques in environmental forecasting being developed by the U.S. Navy's Fleet Numerical Weather Central at Monterey, California are described and their potential application to fishery forecasting is discussed.

UNDERGRADUATE TRAINING IN MARINE TECHNOLOGY
(with Scripps Institution of Oceanography)

Glenn A. Flittner

Summary of Proposed Work

This project proposed to add a practical "on-the-job" course in the technology of marine science to the curriculum at San Diego State College, employing the unique capabilities of the SIO staff and their sea and shore facilities.

San Diego State College does not offer an undergraduate program leading to a degree in Oceanography. The faculty supports a strong undergraduate program in the basic sciences with secondary emphasis on marine-related subjects. San Diego State recognizes the need to add marine-oriented courses within traditional undergraduate options. The addition of a practical "on-the-job" course in the technology of marine science should be of considerable benefit to an undergraduate student whether he chooses to go on to graduate work or enters into employment in marine industries. The experience in itself would provide first-hand contact with the rigors and technical difficulties of work at sea under the guidance of the SIO Data Collection and Processing Group staff. A one-semester course of activity will include (1) independent study, (2) marine technician training, (3) work at sea on scheduled cruises, and (4) work experience within research groups working on projects of timely interest. If a student should decide that this is not what he wishes to do, he may then alter his undergraduate program subsequently on completion of his semester of practical training.

Report of Work Accomplished

Five students, representing the mechanical engineering, microbiology, chemistry, and marine biology disciplines, were selected from a group of approximately 50 eligibles to participate in the Spring Semester course at Scripps Institution of Oceanography.

At the time the first group of students put to sea in early February, campus-wide announcements were made requesting interested persons to file applications for the Fall Semester. Approximately 34 applications were received, and of these, five were selected. Student interest continues to run high, despite a fairly rigorous set of educational prerequisites and preliminary interviews.

For a more detailed summary of the course, see Project UCSD-5 of this report.

MARINE ADVISORY SERVICES EXPANSION

Glenn A. Flittner

Summary of Proposed Work

To meet the specific intent of the Sea Grant legislation, advisory services of a wide variety, including innovative methods for using HF and TV-FM radio communications media, will be developed for the marine user community.

The San Diego State College Center for Regional Environmental Studies (CREST), established on the campus to support departmental programs in ecology, biology, zoology, geography, engineering, and others, will have as an adjunct on campus a Marine Environmental Data Center. The Center will acquire and maintain synoptic environmental computerized data, both atmospheric and oceanographic, which have direct application to education and research in the marine sciences. The data base will be derived from both civilian and military agencies and accumulated in digital as well as chart-type formats.

Report of Work Accomplished

Formal approval for establishment of a Naval Environmental Data Network tieline terminal has been received from the Director of the Naval Weather Service. Receipt of formal approval culminated approximately 15 months of negotiation with Naval authorities. Arrangements are now proceeding for installation of the tieline terminal in the Meteorology

Map Room administered by D. I. Eidemiller of the Geography Department on campus. Products to be received will be used to augment the National Weather Service analyses now being received by landline facsimile equipment.

Standard surface meteorological data have been collected at the weather station maintained by Eidemiller on the San Diego State campus since April, 1961. Many of the parameters have been logged as analog traces on remote kymograph recorders operating in the Meteorology Map Room. Data for the period July 1971 - October 1967 have been prepared for future evaluation in a study of coastal zone climatology. Raw data have been selected on an hourly interval basis for temperature, relative humidity, dew point, barometric pressure, wind direction and velocity, and solar radiation; and tabulated for evaporation, sky cover, cloud types, and visibility.

All data on record will be converted to IBM card format for automatic data processing. Present plans are to continue to work back to the starting date as time and available labor permit.

A series of discussions have been held during the year on the role that San Diego State's Public Broadcasting Stations KPBS-FM and KPBS-TV might play in the marine sciences area. Greatest need is for quality programming materials of both documentary and public service types to fill out an 18-hour broadcasting day initiated at the FM station 1 June 1971.

Two grants were received by KPBS-TV/FM from the Department of Health Education and Welfare for the purchase of new studio and transmission equipment, thus enabling the TV and FM stations to provide quality broadcasting services to the educational community and the public.

Preliminary estimates of production costs for various documentary programs have been made, and discussions are continuing with respect to the kinds of marine-related program materials that can be offered to the public on both regular and irregular intervals.

LOBSTER RESEARCH PROGRAM

Summary of Total Project

Summary reports for each of the projects enumerated below follow separately as projects SDSC-4a, 4b, 4c, and 4d. Six principal investigators and nine graduate students in marine ecology, fisheries biology, and biochemistry will participate in these projects. In addition, two laboratory technicians will be involved.

- SDSC-4a. Changing trends in the character of the commercial fishery for California spiny lobster (Panulirus interruptus) will be studied subsequent to a major change in state regulatory measures. Laboratory investigations of natural growth and molting processes will be extended.
- SDSC-4b. Rearing studies and laboratory investigations of P. interruptus behavior will be extended in light of information gained in the 1970-71 project. Puerulus and juvenile recruitment, relation of growth rates to ambient sea temperature, and evaluation of rearing of puerulus to late juveniles in hatchery situations will be investigated.
- SDSC-4c. This project will direct its effort toward a practical evaluation of introducing the American lobster (Homarus americanus) into California. It will involve: developing experimental culturing facilities and refinement of techniques to produce juveniles for stocking; evaluating potential interactions of H. americanus with native species; evaluating and selecting specific stocking sites for introduction of H. americanus; small-scale culture and stocking of the juveniles in a suitable semi-enclosed pilot site; investigating the population dynamics and ecological effects of introduced stocks.
- SDSC-4d. This project will study two potentially controllable factors detrimental to both wild and captive lobster populations of both species, pathogenic microbes and chlorinated hydrocarbons.

EVALUATION OF THE CALIFORNIA SPINY LOBSTER FISHERY
AND RELATED POPULATION CHARACTERISTICS
DURING A PERIOD OF REDUCED FISHING EFFORT

David A. Farris

Summary of Proposed Work

It was proposed to study changing trends in the character of the commercial fishery for California spiny lobster (Panulirus interruptus) subsequent to a major change in state regulatory measures. Fluctuations of catch in relation to effort were to be compared both before and after the change in the licensing fee structure. Additional data on tag returns would be collected, as well as length-frequency distributions, landings, effort, and price data.

This study will be essentially completed upon the close of the 1971-72 lobster fishing season. A summary report of analyses and findings will be prepared by mid-1972.

Report of Work Accomplished

During the Sea Grant studies of 1970 and 1971 catch, effort, and price records for the Southern California Panulirus interruptus fishery have been analyzed for the years 1947 and 1970 by point of origin and point of landing. Data partitioned by port of landing (Santa Barbara, Los Angeles, and San Diego) indicate that catches by the San Diego fishery are the most stable, while those at Santa Barbara

show considerable variability. Total annual landings in Southern California during this period were small, showing major variations from 300,000 to well over 900,000 pounds.

Final official California Department of Fish and Game tabulations of calendar year 1970 for spiny lobster landings were not available at the time this report was prepared. Preliminary estimates suggest that 1970 landings will probably fall below 1969, when 309,000 pounds were tallied, representing the poorest catch in over twenty years. The 1970-71 lobster fishing season opened on October 7, 1970, and closed March 17, 1971, but fishing was so poor that many San Diego fishermen had quit for the season by the latter part of November, 1970.

Despite the imposition of a \$100 lobster license fee, about 170 licenses were sold, whereas 152 boats were in the fishery the preceding year.

Catches were summarized for 1970 by the standard California Department of Fish and Game statistical blocks and grouped into four classes: coastal, island, mid-ocean, and unknown. As shown in previous years, the bulk of the 1970 catch originated in coastal blocks with appreciable quantities coming from the islands. Catches from mid-ocean (probably shoal areas) are generally small, but have on occasion been sizable. On the other hand, catches adjusted for effort indicate a very high catch per unit effort (CPUE) for the mid-ocean regions with a lower CPUE for the islands and shore in that order.

The 1970 catch-area data appear to follow the previous year's trends.

During August, 1970, there were 1,430 lobsters tagged and released in the experimental area between Point Loma and La Jolla, California. Of these, 239 were of legal size. The rate of exploitation for the first week of fishing was about 11%, while that for the entire season was 29%. Annual mortality rates, estimated from catch curves, were in the neighborhood of 50%. The estimate of the rate of exploitation is probably low since it is unlikely that all recaptures were reported. In any case, the major cause of mortality rates appears to be fishing.

In mid-June, 1971, a program was initiated to determine the spawning period of the California spiny lobster in the San Diego study area and to relate these data to current catch records, as well as previous studies. Five commercial lobster traps were kept under observation and records were kept on lobster size, sex, and reproductive condition. One dozen berried females were brought to the laboratory to estimate fecundity rates. Estimates so derived indicate that female lobsters in the 80 mm carapace (legal) size range carry between three and four hundred thousand eggs.

STUDIES OF RECRUITMENT AND GROWTH OF PUERULUS
AND JUVENILES OF THE CALIFORNIA SPINY LOBSTER

Deborah M. Dexter

Summary of Proposed Work

The original purpose of this study was to determine means of enhancing the fishery of the California spiny lobster (Panulirus interruptus) through augmentation of the puerulus and/or juvenile stages and through increased growth rates of juveniles and sub-legals with the use of thermal effluents from a coastal power plant. A concurrent energetics study would determine the energy budget of small lobsters at elevated temperatures and consider the economic feasibility of this approach.

Report of Work Accomplished

Since access to thermal effluents from a coastal power plant was not available, effects of increased temperatures on growth rates of P. interruptus have been studied in the laboratory.

Seasonal changes in abundance of puerulus larvae off San Diego have been monitored using seaweed habitat traps located at Scripps Institution of Oceanography. Recruitment of pueruli during 1970 and 1971 was of the same order of magnitude and significantly lower than puerulus recruitment in 1969.

An experimental laboratory design, with a choice of habitats, was developed to examine the preference of individual pueruli with respect to substrates and flora. Results from these preference experiments can be applied in describing lobster nursery grounds.

The gradual changes in morphology, pigmentation, and behavioral responses of pueruli, as well as behavioral and morphological changes for early, mid, and late pueruli, and for the post-puerulus and early juvenile lobster, have been described. Time relationships of these changes, and intermolt periods between puerulus, post-puerulus, and juveniles have been followed.

The distribution and relative abundance of recently settled post-puerulus and early juveniles (1st and 2nd year classes) of P. interruptus have been determined through a survey of various subtidal habitats in Southern California.

Laboratory choice tests were designed to examine the habitat preference of early juveniles. Equipment and experimental design have been developed for the energetics studies on the juveniles, which included determination of caloric values of the three main laboratory food items, and preliminary studies on ingestion rates.

Laboratory studies on effects of increased temperatures on growth were conducted. It was shown that juvenile and sub-legal lobsters of P. interruptus grew significantly faster

at elevated temperatures than under natural conditions. Growth data are available on 67 animals and show a greater percent of growth per molt in small lobsters than in larger ones. There were no instances of molting without growth or negative growth in the laboratory studies, indicating that a suitable environment for growth was provided.

Our studies suggest that enclosure of lobsters in an area free of predation, tidal surge, abundant in food, and elevated in temperature could at least double natural growth rate. It is clear that lobsters can be successfully maintained in a clean, thermally enriched environment.

It is evident from concurrent studies on puerulus and juvenile recruitment that these stages are present in limited quantity in accessible habitats along the San Diego coastline. It is not feasible to suggest that collection of large numbers of pueruli and/or juveniles is possible. Sub-legal lobsters (greater than 40 mm carapace length) are abundant in subtidal San Diego habitats. If sub-legal lobsters were collected and added to a thermally enriched, protected area, it is likely that they would reach legal size within one to two years. Concurrent energetics studies will determine energetic requirements of lobsters at elevated temperatures. The economic feasibility of such an approach can then be defined.

Two graduate research associates are participating on this project: James B. Blecha and Kenneth P. Parker.

Publications

Dexter, D. M. 1971. Molting and growth in laboratory-reared phyllosomes of the California spiny lobster, Panulirus interruptus. California Fish and Game, (in press).

Abstract

Phyllosome larvae of the California spiny lobster Panulirus interruptus were reared in individual, multiple, and mass cultures in laboratory closed circuit sea water systems. Laboratory-reared larvae progressed through six phyllosomal stages in a series of eight molts. Maximum length of larval life in the laboratory was 114 days; gradual mortality indicated that nutritional factors were the likely cause of death.

INVESTIGATION AND DEVELOPMENT OF AN AMERICAN
LOBSTER (Homarus americanus) FISHERY IN CALIFORNIA

Richard F. Ford and George O. Schumann

Summary of Proposed Work

The initial phase of this three-year project was to consist of two major projects: (1) laboratory culture and evaluation of environmental relationships of Homarus americanus in California (Schumann); and (2) behavioral and ecological studies concerning the introduction and establishment of H. americanus in California waters (Ford).

Both subprojects would be directed to developing experimental lobster culturing facilities and refinement of techniques; evaluating potential interactions of larval and demersal H. americanus with native species, including Panulirus interruptus and Cancer spp.; evaluating and selecting specific stocking sites having suitable habitat and food conditions; small-scale culturing and stocking of juvenile H. americanus in a limited coastal area; and investigation of the population dynamics and possible ecological effects of the stocks introduced.

The primary purpose of these investigations is to obtain information on which to base an assessment of the potential for large-scale stocking and the establishment of an H. americanus fishery in California.

Report of Work Accomplished

Investigations concerning laboratory culture, behavioral interactions, and environmental requirements were conducted during the past year. Two full-time research technicians and two graduate student research assistants have been employed. In addition to assisting with project work, each of these individuals has initiated a major aspect of the study as his own research.

Larval Culture Studies.

The larval culturing phase of the project has been concerned with the establishment of laboratory facilities and the development of techniques for large- and small-scale experimental culture of larvae. Concurrently, several preliminary small-scale experiments on larval behavior and environmental relationships have been carried out, and final preparations are nearing completion for an extensive larval research program.

During the first year, major emphasis has been placed on developing and evaluating facilities at three separate locations (South San Diego Bay, San Diego State College, and Scripps Institution of Oceanography) to allow experiments in a variety of environmental conditions.

The Limnos Corporation laboratory in south San Diego Bay

was used to evaluate heated cooling water discharge from the San Diego Gas & Electric Company South Bay Power Plant for use in accelerated larval and juvenile growth, and year-round spawning and hatching of eggs from "brood" females. The results of initial culturing and holding trials indicate that this laboratory, as it now is designed, is unsatisfactory for culturing Homarus. This is due primarily to serious turbidity and silting problems, excessively high summer water temperatures, both within and outside of the cooling water discharge patterns, excessively high laboratory air temperatures and possible toxicity of the discharge and bay water to Homarus larvae. Concern over the suitability of power plant cooling water for larval rearing prompted a series of trials to compare survival and growth of Homarus larvae in thermal effluent versus open-coast seawater. Results indicate that growth and survival of larvae are markedly reduced in both fresh-flowing thermal effluent and south San Diego Bay intake water used in a closed system, in comparison to those of larvae maintained in water from the open coast. Consequently, Homarus research has been discontinued at the South Bay site. Arrangements have been made to establish a small laboratory at the San Diego Gas & Electric Company Encina Power Plant in Carlsbad and to expand our primary laboratory at Scripps Institution, both open-coast sites where water quality is markedly better than that of south San Diego Bay.

Environmental and physical factors affecting larval growth and survival were investigated in order to develop reliable and efficient methods for Homarus culture. Initial observations suggest that three types of systems will be suitable for mass rearing: the Hughes ten-gallon container and circulator; large 2000 to 3000-gallon circular pools; and a 100-gallon dual-chambered circular tank designed by Steven Serfling. All are suitable for either closed- or open-system circulation. The Hughes system is being used as the standard for comparison. In addition, a special 50-gallon circular, plexiglass planktonkreisel has been used successfully where a gentle, steady water circulation and unobstructed vision for behavioral observations are necessary.

Homarus larval, juvenile, and adult stages appear to do well in the temperature ranges typical of local waters (12-22°C). Only when the temperature is increased to 26-28°C or greater, does mortality appear to be significantly increased. Future temperature studies will concentrate primarily on determining optimal temperatures for survival and growth of the juvenile stages for mass rearing and accelerated spawning and hatching of eggs.

Various types of readily available natural and artificial foods were tested and compared to evaluate their effects on survival and growth of Homarus larvae. In all tests, live foods were taken more readily than frozen, and, in general,

larger organisms were preferred to smaller ones.

A number of artificial food preparations have been investigated to date. The criteria for a successful artificial food substance acceptable by Homarus larvae include qualities of coherence and non-leaching during at least one-hour exposure in seawater. Preliminary results suggest that these qualities are controlled by the type and concentration of binder used to hold finely ground food particles together.

We are concerned about potentially toxic materials and food items which could affect larval growth, viability, and behavior in the laboratory, as well as their survival in the field, if introduced. Primary concern has been for the possible exposure of larvae to chlorinated hydrocarbons (DDT and its derivatives, and Polychlorinated Biphenyls). The effects of heavy metals (primarily Cu and Hg) will also be considered in the near future. This work is being carried out in conjunction with Mathewson's project SDSC-4d.

Because Artemia are among the most suitable live-food items for mass rearing of Homarus larvae, it was necessary to examine the chlorinated hydrocarbon content of all available brands of Artemia eggs, and live and frozen adults. Initial results indicate that all brands contain a broad spectrum of chlorinated hydrocarbons. Laboratory plastic and rubber materials to which larvae were exposed were analyzed and the least contaminated ones were chosen.

Behavioral Interaction Studies.

Behavioral studies of the larval stages have been concerned primarily with interspecific interactions, the behavior of Homarus larvae in the presence of indigenous zooplankters, and predator-prey relationships.

Preliminary observations indicate that the predator-prey relationships between all stages of Homarus larvae and other plankton organisms are primarily size-dependent. Homarus larvae will readily capture and devour anything within its own size range when it has been deprived of food for short periods of time, but appear to prefer smaller forms such as copepods when they are plentiful. Homarus larvae, in turn, are preyed upon by numerous larval and juvenile fish species, and larger stages of crab larvae, i.e., Cancer megalops.

In order to assess the feasibility of a large-scale introduction of Homarus to California waters, many potential interactions with indigenous species must be examined. Behavioral observation systems (four and ten-foot diameter circular pools) which allow 4-5 replicate trials to be conducted simultaneously have been established at Scripps Institution of Oceanography.

To quantify the behavior of Homarus and its potential competitors, we have formulated and are now testing a general behavior ethogram, descriptive of the actions of Homarus and the responses of its competitors. We are attempting to keep

the behavioral units general enough so that the same coding is applicable to Homarus americanus, Panulirus interruptus, Cancer, sp., and most other decapods which may compete with Homarus. The code consists of six different generalized units of behavior: sitting, roaming, threat, contact, losing, and tolerance.

We have observed the animals under different conditions of light, habitat, food, etc., and have obtained records of the general interactions which can be expressed in terms of frequencies, duration, and sequencing of behaviors. To assess the effects of the presence of Homarus as a competitor, information on the normal behavior patterns of many indigenous decapods will have to be taken, because it is not available in the literature. A study concerned with roaming activity levels in Panulirus has been initiated. Activity levels for Homarus under similar conditions are roughly the same. However, more data are needed on innate levels of activity, aggression, and habitats of Panulirus and other potential competitors in order to interpret more accurately the influence of the presence of Homarus.

Preliminary observations indicate a high degree of variability in interspecific behavioral encounters between Homarus americanus and several local decapod crustacean species. Trials involving the simultaneous introduction of approximately equal-sized animals of H. americanus and Panulirus interruptus

resulted in interactions following a basic pattern. For example, of 48 social contacts observed, 39 resulted in Panulirus being displaced by Homarus. The retreat or displacement of Panulirus was generally caused by the agonistic displays or pushing with the chelipeds. Interactions between Cancer species and juvenile Homarus also were quite variable. Cancer generally buried itself in the sand substrates; consequently, there are few encounters between the two species. When an artificial habitat was present in the tank, the same two individuals in each case exhibited all of the following behaviors: (1) Cancer displaced Homarus from the habitat by pushing with its chelipeds, (2) Homarus displaced Cancer from the habitat, and (3) both animals occupied the same habitat simultaneously.

Although preliminary, some of our behavioral results suggest that it may be unwise to introduce Homarus within the geographic range of Panulirus interruptus. Additional detailed interaction studies will be completed and evaluated before a decision is made concerning pilot stocking of Homarus in the San Diego area.

Substrate Preference and Its Effects on Molting Frequency and Survivorship of Larval and Early Juvenile Homarus americanus.

Of practical importance in a decision to introduce Homarus americanus into California waters is an accurate appraisal of the environmental requirements of Homarus and the habitat and

food conditions of the prospective stocking sites. A study has been initiated to estimate the range of tolerance the early juveniles show for a single feature of their newly adopted habitat — their preference of substrate conditions in a variable substrate gradient.

Fourth-stage larvae reared in San Diego were introduced into a large, circular choice chamber. The observations from these trials support the conclusions of earlier investigators. After four days in the chamber, nearly all of the fifth-stage juveniles were hidden in the gravel, which suggests that the sheltering nature of the gravel substrate is of fundamental importance to successful epibenthic establishment.

Field Studies of Potential Stocking Sites.

Field observations and quantitative sampling have been conducted to evaluate and select pilot stocking sites in the San Diego area. During June and July, 1971, Ford and Serfling visited major lobster research laboratories in New England and Canada to discuss specific aspects of the aquaculture and field studies with scientists there.

Field observations and collections of sediment and animals were made in typical H. americanus habitats off Boothbay Harbor, Maine. The information obtained there and in San Diego suggests that there are extensive rock-sand areas on the open coast off California that are very similar in terms

of general ecological features and the specific habitat requirements of H. americanus. Because of the problems involved in recapture and censusing of small introduced stocks, we plan to release Homarus both free in the habitat and in large enclosures at pilot stocking sites.

PATHOGENIC MICROBES AND CHEMICAL RESIDUES
IN CALIFORNIA SPINY LOBSTER POPULATIONS

James H. Mathewson and Harvey Rabin

Summary of Proposed Work

Monitoring and controlling gaffkemia (Gaffkya homari infection) in transplanted populations of Homarus americanus will be undertaken as a service to programs studying the aquaculture of this organism. Diagnostic tests for recognition of disease states and characterization of potentially pathogenic microorganisms in Panulirus interruptus will be described. In the second and third years of the study, countermeasures against pathogen limitations on lobster populations will be evaluated.

Baseline levels of chlorinated hydrocarbon residues will be determined in natural populations of the California spiny lobster (Panulirus interruptus) and in transplanted colonies of the American lobster (Homarus americanus), and a monitoring program initiated. Correlations of chlorinated hydrocarbon residue levels with data derived from other existing studies of the organisms will be sought. Laboratory studies of the effects of various residues on reproductive success and on metamorphosis will be initiated in collaboration with existing programs.

A training program in chemical and biological monitoring techniques will be instituted, and information of value to local lobster fishermen will be promulgated on a regular basis as part of a marine advisory service.

Report of Work Accomplished

Work has continued to establish the response of P. interruptus to experimental infection with Gaffkya homari. The pilot experiments done in November and December, 1970, indicated that P. interruptus was susceptible to infection by the same microbe, G. homari, which causes a fatal bacteremia in the Atlantic lobster, Homarus americanus. The original doses were very high and all lobsters were dead by 32 days. The physiological effects of the bacterial infection appear to be similar to those observed in the Atlantic lobster: the disease is a wasting disease; increasing bacterial titers are accompanied by decline in weight, decline in hemocyte count, and an increase in clotting time of the hemolymph. It appeared that some of the infected animals died because they bled to death following loss of antennae or limbs (as a result of fighting or other injury). In an uninfected animal, the hemolymph clots so rapidly that an injury is almost immediately sealed over.

Subsequent to the pilot experiments, a series of dose-response experiments were run, using lower levels of bacteria in the inocula. The water temperature was kept at about 17°C, comparable to ambient ocean temperatures where the lobsters were captured (in the initial experiments it was 22°C — ambient was 25°C). Animals began dying as bacterial levels

rose, although the average time to death, at the lower temperature, was somewhat longer than in the previous experiments.

Following these early dose-response experiments, the lobster holding facilities were greatly expanded. The seawater is filtered through diatom filters, vigorously aerated, and cooled to about 15°C. Change in photoperiod was suspected of causing abortive molts resulting in the high mortality of animals brought into the laboratory during winter and early spring, thus timers were attached to lights in the laboratory and photoperiod controlled. Mortality of freshly caught animals declined sharply.

During the current series of dose-response experiments, temperature, salinity, photoperiod, and food are all being carefully controlled. In an effort to elucidate the effects of the bacterial infection, a variety of physiological indices are monitored during the course of the bacteremia. Hemocytes decline with the progress of the gaffkemia. Diet of captive animals is important in maintaining normal hemocyte counts; when given a varied diet of mussels, abalone, and scallops, our animals appeared to remain healthy and vigorous, although there is some decline in hemocyte counts even in control animals.

Future plans call for defining the dose-response curve more clearly and following more of the physiological changes

which occur as the disease progresses. Hemocyte counts, clotting times, hemolymph protein (some pilot work on proteins has been done using disc gel electrophoresis), and serum carbohydrates will be monitored. In addition, it is apparent that the massive physiological changes which accompany molting affect the vulnerability of the animal to a variety of external and internal challenges, including bacterial infection.

Supplementary to the laboratory investigations, the local Panulirus population is being monitored for bacterial infection. The few bacteria which have shown up on the plates are being cultured, but, so far, there is no indication of any gaffkya in the local, wild Panulirus population. We hope to be able to test imported Homarus individuals for gaffkya if the opportunity arises, as well as to test other species of native, wild crustaceans.

Studies of the impact of pesticide residues on growth and development of Panulirus were initiated. A method was developed for assaying carbonic anhydrase activity in hemolymph, and was tested on a small number of animals. This method is based on following the pH change in a buffer after the injection of a carbon dioxide-containing solution with a fast-response recording pH meter.

It is anticipated that the impact of environmental conditions on the organisms as evidenced in hemolymph enzyme

levels will be extended to Homarus as well as Panulirus during the summer of 1972. We plan to carry out these studies at the Mount Desert Island Biological Station at Salisbury Cove, Maine. This laboratory has extensive facilities for the study of physiological phenomena, and lies on the Gulf of Maine in the center of the Atlantic lobster industry. This work will be coordinated with other projects in California [University of California, Davis, Project UCD-3 (Shleser)] and collaborators at the laboratories in St. Andrews, New Brunswick, and Halifax, Nova Scotia, Canada.

EFFECT OF SAMPLING OF THE ENGINEERING
PROPERTIES OF SUBMARINE CLAY

Iraj Noorany

Summary of Proposed Work

The objective of this research program is to investigate the influence of release of ground stresses during sampling, and the great reduction of pore-water pressure during lifting of soil samples from the ocean floor on the engineering properties of submarine clays. The emphasis of the study will be on the applicability of the laboratory measured test results to the shear and settlement behavior of the soil in situ. The proposed investigation will be concerned primarily with the influence of the change of ground stresses and pore water pressure reduction and possible cavitation in pore water of the soil rather than the general disturbance of the sample, a subject which has been fairly well covered by many other researchers.

The findings of this investigation would be of immediate value for foundation engineering work related to the development of tidelands, man-made near-shore islands, marinas, recreational facilities and industrial plants.

Report of Work Accomplished

At the outset of this project, a comprehensive study of the present techniques of underwater soil sampling and testing was undertaken. The purpose of this review was to determine the current state of practice of submarine soil sampling and the primary factors which influence the

engineering properties of the recovered samples. The results of this phase of the study were presented at the symposium of the American Society for Testing and Materials (see abstract following this report)¹.

Noorany assisted V. C. Anderson of the Marine Physical Laboratory of SIO in the design of a sediment corer, a cone penetrometer, and an in situ vane shear device attached to the submarine tracked crawler RUM. These instruments were built and tested in La Jolla Canyon and in the San Diego Trough.

Extensive laboratory tests were carried out to determine the properties of samples recovered by RUM. Data obtained from the remote-controlled static cone penetrometer and the vane shear device provided an indication of the in situ strength of the sediments. Laboratory vane shear and triaxial tests provided information regarding the strength of the partially disturbed samples under the laboratory environment. The laboratory strengths were generally lower than the in situ values. Some of the laboratory data obtained at San Diego State were reported in a paper by Anderson, et al., presented at the ASTM Symposium on Underwater Sampling and Testing, June, 1971, (see abstract following report of project UCSD-14).

Samples of deep-sea sediments taken from nine different locations in water depths ranging from 1730 to 3015 fathoms in the Pacific were obtained from SIO. These samples, which were taken by space cores for Kennecott Exploration, Inc.,

provided valuable materials for laboratory studies. The engineering properties of seven brown clays in this group were reported in a paper by Noorany², and the properties of two calcareous deposits from the Pacific were reported in another paper³. There were no in situ measurements of these samples which would permit a direct comparison between the sample behavior and the in situ conditions. However, the soils were used in a testing program arranged for simulation of the process of stress removal and disturbance upon sampling of sea-floor deposits. The range of hydrostatic pressure in these tests was limited to 100 psi. The purpose of this phase of laboratory work was to separate the effects of the various factors of ground stress removal, hydrostatic pressure reduction, bubbling of dissolved gases, and disturbance. Progress in this area has been satisfactory; however, additional tests under higher pressure range (hopefully up to 10,000 psi) must be undertaken to expand the present data.

Publications

¹Noorany, I. 1971. Underwater soil sampling and in situ testing. Presented at the Symposium on Underwater Soil Sampling, Testing, and Construction Control, sponsored by the American Society for Testing and Materials, Atlantic City, New Jersey, June 1971.

Abstract

(see next page)

This paper covers the state-of-the-art of underwater sampling and in situ testing. Methods of near surface sampling, as well as deep-penetration sampling, are discussed. Underwater in situ tests and their performance record are examined. The problem of the influence of sampling on the physical properties of submarine soils is briefly discussed, and attention is drawn to the areas which require concentrated research.

²Noorany, I. 1971. Engineering properties of submarine clays from the Pacific. Presented at the 1st International Conf. on Port and Ocean Engineering, Technical University of Norway, Trondheim, Norway, August 1971.

Abstract

This study was conducted in order to determine the engineering properties of some clay deposits sampled from seven locations on the floor of the Pacific Ocean at water depths ranging from 2350 to 3010 fathoms. The samples were obtained with the spade box corer during Leg 9 of the STYX cruise on R/V AGASSIZ. The laboratory tests included classification and index properties, vane shear, sensitivity, consolidation, as well as undrained and drained triaxial shear tests. Compressibility characteristics of these clays, which are chocolate brown in color and have water contents up to 290 percent, were determined under various rates of loading. Shear-strength parameters in terms of total stresses and effective stresses were measured. These results appear to be the first data on the effective stress behavior of these types of deep sea floor clays which are commonly known as "red clays" and cover most of the floor of the North Pacific and parts of the Atlantic Ocean. Particular problems associated with the evaluation of engineering properties of these clays are discussed.

³Noorany, I. 1971. Engineering properties of submarine calcareous soils from the Pacific. Presented at the International Symposium on the Engineering Properties of Sea-Floor Soils and Their Geophysical Identifications, Seattle, Washington, July 1971.

Abstract

This study was conducted in order to determine the engineering properties of some calcareous deposits sampled from the floor of the Pacific Ocean at water depths of 1730 and 2450 fathoms near Christmas Islands and south of the

Line Islands. The samples were obtained with the space box corer during Leg 9 of the STYX cruise on R/V AGASSIZ. The laboratory tests included classification and index properties, vane shear, sensitivity, consolidation, as well as undrained and drained triaxial shear tests. Compressibility characteristics of these deposits, which are primarily composed of hollow shells, under various rates of loading were determined. Shear strength parameters in terms of total stresses and effective stresses were measured. These results appear to be the first data on the effective stress behavior of these types of sea floor sediments which are commonly known as calcareous ooze and cover approximately 36 percent of the sea floor.