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UNIVERSITY OF CALIFORNIA

SEA GRANT ANNUAL REPORT

1971-1972

September 1, 1971, to August 31, 1972

UNIVERSITY OF CALIFORNIA

SEA GRANT ANNUAL REPORT

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INTRODUCTION

1971-72 Sea Grant Annual Report

The Sea Grant Program was created in 1966 by Public Law 89-688, the National Sea Grant College and Program Act. The purpose of the act is to accelerate development of marine resources, including their conservation, management, and maximum social and economic utilization. Sea Grant supports research, advisory services, and education to these ends, primarily through a group of universities that are designated as Sea Grant Institutions or Sea Grant Colleges.

The California Sea Grant institutional program had its origins in programs that were started separately at the University of California, San Diego, at San Diego State College, and at the University of California, Santa Barbara. The first two campuses joined in 1970 to establish an institutional program, covering the full spectrum of education, research, and advisory services that are expected of a Sea Grant institution. This program was further expanded in 1971 to include the existing Sea Grant research program at UC, Santa Barbara, and to establish new programs of work at other campuses throughout the state. This report summarizes the results of this second year of institutional work, the first year of statewide activity.

The program is administered by the University of California Institute of Marine Resources (IMR) at the UC, San Diego, campus. Local administrative centers are located in the IMR branch office at UC, Davis, at the Institute of Marine Science at UC, Santa Barbara, and at the Bureau of Marine Science of California State University, San Diego, (formerly San Diego State College). Sea Grant research activities are carried out on these four campuses, as well as on the UC campuses at Santa Cruz, Berkeley, Los Angeles, and Riverside. Policy guidance is provided by the Sea Grant Coordinating Council, appointed by the president of the University of California, consisting of university and public members (see page 4).

Within the broad field of applied work on marine resources in the Sea Grant act, each Sea Grant institution chooses the areas of emphasis that best suit its capabilities and the needs of its local area. Within our program of the past year, we have given principal emphasis to the problems of the California coastal zone and to the development of new aquacultural industries.

We have also initiated a marine advisory service, which we hope in coming years will employ the results of these researches to provide advice and assistance to all of those in California who earn their living from the sea or deal with the effects of the sea on man and man on the sea.

George G. Shor, Jr.
Sea Grant Program Manager

Sea Grant Coordinating Council
as of January 1, 1973

Ex Officio Members

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Cal State, San Diego

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UC, Davis

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Lockheed Missiles and Space Company

Charles Wheelock
UC, Institute of Marine Resources

Robert Wiegel
Engineering
UC, Berkeley

1971 - 1972

ACTIVITY BUDGET

	NOAA Grant Funds	Matching Funds
Administration: (program management and development)	$ 124,510	$ 96,423
Research:		
A. Coastal Zone	292,795	95,510
B. Biological Resources:		
1. Aquaculture	146,515	69,829
2. Fisheries, Seafood Technology	232,398	128,467
3. Pharmaceuticals, Marine Products	24,341	24,026
C. Engineering	203,132	114,297
Advisory Services:		
A. Extension Services	53,173	51,803
B. Data Center	0	28,896
Education:		
A. Graduate Studies	211,949	54,242
B. Technician Training	29,319	15,283
C. Public — Aquarium Museum	11,868	15,907
	$1,330,00	$694,683

SOURCES OF MATCHING FUNDS

American Bureau of Shipping

American Chemical Society

California Marine Associates

California State University, San Diego

Foundation for Ocean Research

Massachusetts State Lobster Hatchery, Martha's Vineyard

San Diego Gas and Electric Company

Scripps Industrial Associates

Southern California Coastal Water Research Project

State of California Department of Navigation and Ocean Development

State of California Marine Research Committee

Tuna Research Foundation

University of California

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Introduction

Sea Grant research programs are expected to apply research results to the solution of problems related to marine resources and to be responsive to the needs of the community in which they operate. If there is too much emphasis on local and immediate needs, however, it is possible to get trapped in the sewer outfalls, the surf, and the seacliffs, and miss the broader opportunities. To preserve a proper perspective, the University of California Sea Grant program undertakes local service research and strives to solve local problems when the answers may have a broad regional, national, or global application.

Planning for wise use of the coastal zone is a national problem of immediate concern to states that border the ocean. The people of the State of California passed the California Coastal Zone Conservation Act in 1972 to protect their coastal wealth. Recognizing the need that land-use planners have for information on the coastal zone, UC Sea Grant concentrates research on ecological studies, studies on the physical processes operating in the near-shore zone, and the development of decision-making models for better resource use.

Tapping the biological resources of the ocean is another area of UC Sea Grant research. Major emphasis this past year has been on aquaculture of such edible marine life as seaweed, lobsters, and abalone. At the same time the UC program has conducted research to help established fisheries and the seafood industry in general.

Sea Grant engineers are finding new ways of protecting coastal installations and carrying on useful work in the sea that minimizes environmental disruption.

RESEARCH/COASTAL ZONE

Introduction

One of California's most precious resources is its coastal zone. As with all valuable resources, an understanding of its potential is essential to its wise use.

To choose among the suggested and often competing uses of this resource, there must be a methodology for assessing the impact of man's concomitant intervention. We must therefore understand the natural biological, chemical, and physical processes at work and how they interact with the economic, legal, political, and other social processes necessary to civilized existence.

Ultimately we will be able to plan for long-range wise use and management of the coastal zone rather than following past procedures that allowed random development of our natural wealth.

Planning ecologically sound coastal zone development is a complicated task. A major step, assessing the environmental impact of utilizing using a coastal resource, becomes easier if planners follow an impact matrix or table, but the process still typically involves making from five to eight thousand judgments. Technical information for such decision-making is scattered among various information sources and is sometimes completely unavailable — there are serious gaps in input from the social and natural sciences. Finding a manager for the coastal zone is another problem. Authority in California is divided and possibly contradictory.

Legislation now exists to spare the coastal zone further misuse. Realizing the difficulties inherent in implementing it, four university specialists are introducing advanced planning concepts to local government.

A Framework for Identification and Control of Resource Degradation and Conflict in the Multiple Use of the Coastal Zone

Robert H. Twiss, Ira M. Heyman, T. G. Dickert, and Jens Sorensen

Major project activities are: (1) the development of procedures for assessing environmental impact on coastal zone planning, (2) creation of a data framework and base to provide information for planning decisions, (3) definition of the legislative and administrative planning context, especially in relation to land-use decisions that affect marine resources, and (4) implementation of advanced planning concepts and tools through contact with decision-making groups.

Assessing environmental impact

Research work on environmental impact assessment was directed at the creation and refinement of systematic methods for identifying and expressing interactions between resource use activities (e.g., dredging, impervious surfacing) and potential environmental effects. Present impact identification methods depend on a matrix or table to depict the relationships between a resource use and the potential environmental effects. Because of the environmental complexities of the coastal zone and the vast number of coastal resource use activities, such matrices are extremely complicated and voluminous. It is becoming clear that decision-makers have neither the time

nor the technical skills to utilize impact matrices in their basic form, as completion of typical matrices might involve making from five to eight thousand judgements.

Computer help

We developed and computer programmed a set of impact networks for typical coastal zone resource uses. The information content is coded to permit automated data storage, selection, and presentation. Computer automation has several distinct advantages. Computer automation will portray impact networks according to project type or a specific project action, making it possible to have impact display printouts for each coastal project type or for porject action as a ready reference to the local planner or decision-maker. Computer automation will also allow the addition, deletion, or correction of the display according to new information. We are presently testing the impact networks in two directions: (1) refining the actions and activities associated with two project types — housing and highways — and developing definitive impact identification checklists for these types and (2) strengthening the scientific background and referencing for the network, starting with hydrology and geology.

Technical data needs

The collection and interpretation of technical information is vital to improved planning. We are investigating how much, if any, needed data (especially those pinpointed by the impact networks above) is available and, if it is whether it is located in a form suitable for planning support. As expected, we found extremely serious gaps and deficiences in social science, natural science, and land-use topics, but we are now better able to document key data needs and to suggest partial remedies.

For use in coastal zone planning we created a data format that involves computer storage and mapping capabilities. We must report as a negative finding that, in spite of the on-line availability of this technique, no local government has indicated a willingness to invest in the system. We do expect that regional coastal land-use authorities, when and if they are created, would make use of such advanced capabilities.

Problem-solving responsibility

The legislative and administrative context of coastal zone planning is being clarified to identify key points where information and methodology will be most valuable. All California state and federal agencies with authority in coastal resource use or expertise in understanding coastal environmental factors were surveyed to determine the scope and degree of their respective responsibilities. The information collected by this survey is now being organized according to environmental factor and/or resource use topics. Such a topical organization will relate environmental effects identified by the impact networks to the agencies that have the responsibility, expertise, or information necessary to deal with them. The relating should indicate where gaps and overlaps occur in agency responsibility.

Analyzing coastal zone legislation

Existing and proposed legislation on the coastal zone, environmental quality, and land-use planning (e.g. National Environmental Policy Act, California Environmental Quality Act, the Coastal Zone Management Act, the National Land Use Policy acts, etc.) is being analyzed from legal, administrative, and technical points of view. The investigators' roles on various governmental and professional committees is invaluable to this effort.

Involvement with local government

For actual implemention of new concepts and methods in impact assessment, we are working directly with local government agencies in Santa Cruz, Monterey, San Luis Obispo, and Mendocino Counties, and in Tomales Bay. In California the institutional locus for decisions and plans for the coastal zone is as yet undecided. We are concentrating on preparing a report or manual for the improvement of planning tasks for use by whatever authority eventually is given and assumes planning responsibilities.□

The real worth of marine resources is not always appraised in immediate dollar-and-cent marketplace value. Coastal zone planners must predict future costs of man's impact on the environment and must also answer the question of equity: who pays and who benefits?

Economics of Marine Resources Decision Modeling

James J. Sullivan

Background studies

Project emphasis shifted from the specification of a decision making model to completion of the background studies. One study was of arguments for some degree of economic planning in an economy that uses the price mechanism for allocation of resources. A free-market economy that uses the price system in this way is found to suffer from some difficulties that preclude the optimal allocation of resources. Allocative inefficiency is observed in the presence of monopolies and trade restrictions, and there are always complex externalities whose evaluation and solution is beyond the power of the price system. Ignorance of market and resource information is also found to prevent optimum resource allocation in the sense that it may lead to excess capacity, resource depletion, etc.

Free-market system needs some planning

Broader outlook

Still another source of misallocation is found in the cumulative effect of small, individual decisions. In this case it is argued that society may disapprove of many small decisions if they could appraise the aggregate result. Maximizing individual personal interests does not necessarily promote society's welfare.

Decision-making process for economic planning

Another study presented some of the basic guidelines, considerations, and methods involved in the decision process known as economic planning. In general, society's aspirations and objectives are expressed through its socio-political system, and planners must use the best available techniques to realize society's desires through a decision process leading to a specific plan. The careful selection of means to achieve the objectives is a crucial question. Adequate knowledge of resources involves the gathering of relevant data in order to provide planners with useful information. This is normally a difficult and lengthy task.

Technological input

The choice of technology also implements certain projects. For example, the locational choice of industry now requires better information on such input requirements as water and residual outputs.

Qualitative considerations

As an extension of the study, the traditional concept of natural resources is broadened to include non-commodity aspects that are normally not reflected in the exchange system. Qualitative aspects of the environment are inextricably associated with commodity-producing natural resources, and to a large degree they should be incorporated as determinants of production costs.

Renewable and non-renewable resources

From a physical point of view, resources are clarified as either stock (or non-renewable) or flow (or renewable) resources. A critical zone is defined for flow resources when changes may threaten the continuation of the flow. Irreversible changes in flow may prove to have adverse effects on the environment. The creation of Indicators of the State of the Environment can help to improve policies directed toward the protection of the environmental quality. Benefit-cost analysis is an adequate method to evaluate policies and their effects on societies' welfare.

An overall view of the environment suggests that material and energy resources are limited. Man's recognition of resource finiteness must direct him toward an efficient allocation of resources for present and future generations.

Three new manuscripts

Three new manuscripts all deal with the question of equity and income distribution and their significance in public project analysis. Various propositions of several neoclassical economists on the subject of income distribution are presented in one and an attempt to analyze why this topic was traditionally avoided is made. In another, the goal of a more equal distribution of income as a socially desirable goal is discussed from a philosophical and economic standpoint. In the third, the causes of inequality are discussed.

Updated environmental economics bibliography

A 155-item environmental economics bibliography written last year for public dissemination was augmented with 172 new entries. Approximately 100 of these items now have annotations.□

Publications

SULLIVAN, J. J. Concepts and principles for environmental economics. *Environmental affairs.* (In press.)
SULLIVAN, J. J. Free market and planning. (Working paper.)
SULLIVAN, J. J. Planning techniques and the environment. (Working paper.)

The nearshore zone is a complex region of intense interaction among waves, tides, currents, river run-off, flotsam, and erosion products from the land. Before planning for future coastal zone development and applying technology to solve possible problems created by man's intervention in the coastal zone, we must identify and understand these interacting processes. We need to know more about their intensity and expenditure of energy, as well as their potential relationship to waste dispersion, beach erosion, and silting of harbors and harbor entrances.

A measuring system has been developed to collect wave, current, and other physical data within the coastal zone — the area extending from the surf zone to the edge of the continental shelf. The "Shelf and Shore" system consists of a shore station housed in a mobile van and as many as six sea stations attached to the ocean bottom that transmit environmental information back to the shore station for computer processing and analysis.

San Diego
R/CZ-3a

Physical Criteria for Coastal Planning

Douglas L. Inman

In nearshore waters the mixing, sorting, and transportation of sediments and run-off from land begins. Waves, winds, and currents mold the shorelines, and their interaction with the land and its run-off determines the configuration of coastlines and adjacent bathymetry. Our understanding of

shore processes is still in a rudimentary stage; many of the important dynamic phenomena cannot yet be described by rigorous theory. Although it is becoming increasingly clear that processes in nearshore waters are driven by basic interrelated forces that are systematic and essentially regular in form, and the mechanisms involved are currently being studied to place what we know in a planning context.

Natural forces are systematic and regular

Monitoring phenomena to be placed in planning context

At least three distinct approaches are necessary if we are to achieve the overall goal of determining the essential qualities of unifying planning criteria: (1) development of the sensors and systems for data handling that permit effective monitoring of coastal climate and sediment transport, (2) specific studies of phenomena vital to our understanding of nearshore processes, and (3) the development of new planning criteria and the dissemination of knowledge about the behavior of known processes.

Monitoring sensors and data handling systems

Because of the dynamic nature of processes in shallow water, there has been a scarcity of data, particularly simultaneous data, that is essential to the understanding of complex motions. The Shore Processes Study Group at Scripps Institution of Oceanography, UC, San Diego, has developed a non-traditional sensor system to gather simultaneous wave, current, and other physical data in the waters of the coastal zone — from the shoreline to the edge of the continental shelf. The Shelf and Shore (SAS) system consists of one to six shelf stations transmitting data simultaneously to a shore station where it is received and recorded.

Shelf station design

Original evaluation of a design concept suitable for use as the shelf station ran the gamut from a single tethered subsurface sphere (an oscillator at certain wave periods and subject to periodic torsional rotation), to a redundantly anchored subsurface sphere (again, complex because of intensive anchor

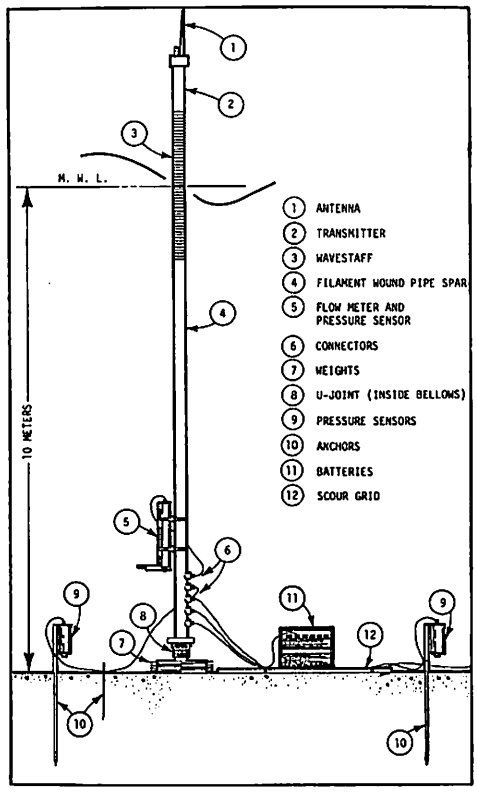


Figure 1. Shelf station

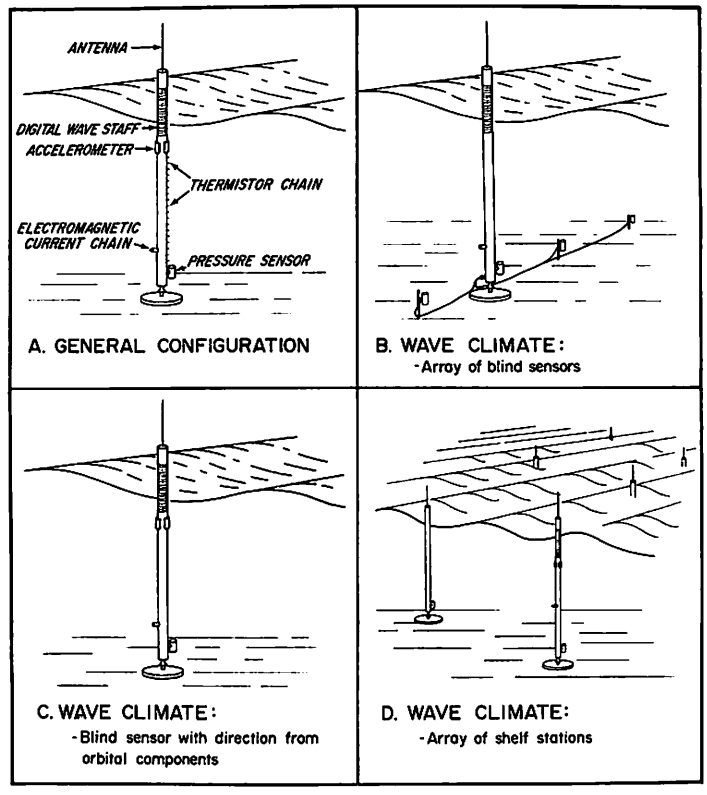


Figure 2. The shelf station is shown in four arrangements, each one of which uses common modules. Survival of prototype units encourages speculation that storm data may be taken continuously.

placement and the requirements necessary for accurate anchor spotting), to surface bouyant devices (sometimes wavelength-coupled and fraught with seakeeping problems). The final choice for the shelf station is a vertical spar shape (a glass filament-wound pipe 3.5 inches in diameter) that is securely anchored to the ocean bottom through a universal joint (Figure 1). This design prevents vertical motion so wave height and direction can be measured, but allows motion in the horizontal plane. The shelf station can be placed in various water depths by adding or removing sections of filament-wound pipe and adjusting their bouyancy. The design allows the station to operate in a variety of modes (Figure 2).

Sensor data is digitized within the shelf station and transmitted by telemetry to the shore station. Power for the sensors and transmitter is supplied by a bottom-mounted lead-acid battery pack.

Shore station design

The shore station receives transmitted information simultaneously from one or more shelf stations. The shore station consists of six UHF receivers (one for each shelf station), a wide band instrumentation recorder, a pulse code modulation (PCM) synchronizer, and a digital tape recorder. To allow access to primitive coastal areas, this reception and recording equipment is rack-mounted in a specially modified mobile van.

Data acquisition

The van-mounted shore station receives the transmitted information from the shelf stations simultaneously and processes the data to provide outputs in the form of hard copy, eight-channel strip chart records, and IBM-compatible digital magnetic tapes. Digital tape provides the means for inputting the data into a computer system for spectral and cross-spectral analysis.

Nontraditional approach

The SAS System provides a nontraditional approach to simultaneity of measurement from large arrays placed in a variety of configurations. Each record provides background for other measurements and for cross-spectral analysis between various measurements. Synoptic collection of data is essential to a comprehensive and unifying study of the dynamic environment of the nearshore zone.

Prototype experience shows storms can be monitored

A second-generation prototype shelf station has been installed in 10 meters of water offshore at Scripps. It has successfully measured waves and their frequency and directional spectra during all local wave regimes, including storms for the past six months. Good performance of the shelf station in inclement weather shows that storms may now be instrumented in the nearshore zone — these are occasions of compelling interest in the study of nearshore processes.

Shelf station arrangement varies with applications

The SAS System has many possible modes of operation, some of which are depicted in Figure 2. The general configuration, shown in Figure 2A, could be used to study surface waves in the presence of a thermocline or to study the interaction of internal and surface waves. This configuration distributes sensors along the water column. Configurations B and C permit "wave climate" to be obtained using a single shelf station. Configuration B uses an array of pressure sensors placed along the bottom from which wave energy and directional spectra can be determined. Configuration C uses a passive, electronic current meter to resolve direction and a pressure sensor for measuring wave height. Finally, an array of shelf stations can be used to study larger scale phenomena, such as edge waves and circulation and mixing over the shelf.

An optical sensor for measuring the concentration of suspended sediment in nearshore waters was developed and is now undergoing calibration and field testing. Taking into account the known restrictions on the sensor, it is expected that meaningful field data on suspended sediment concentrations

New optical sensor for suspended sediment measurements

can be obtained from the following locations: (1) tidal currents in lagoon channels, (2) deep run-up zones on the beach face, (3) inside the surf zone away from breaking and rebreaking points, and (4) outside the surf zone above large ripples on sand bottoms. A newly developed grab-bag sediment sampler is being used to collect simultaneous, undisturbed samples to correlate and calibrate the optical meter.

Water particle velocities

A modified two-axis, electromagnetic flow meter is being used to obtain water particle velocities within the surf zone. The data will help verify some of the existing wave theories as there is a paucity of data.

High resolution sonar

The Shore Processes Study Group also developed and is field testing a high-resolution sonar to obtain detailed profiles of sand ripples and their formation under dynamic conditions. Correlation of ripple profiles with simultaneous wave data expected to result in a correlation between spectral wave parameters, such as root-mean-square wave height and wave period when compared with ripple length and height.

Instruments, techniques, and results of research were widely disseminated at scientific meetings, including the Thirteenth International Conference on Coastal Engineering; the Eighth Annual Marine Technology Society Meeting; the Geological Society of America Meeting, Minneapolis, Minnesota; and the Second Annual Ocean Technologists Meeting.

The key to describing dynamic energy transport phenomena in the coastal area is simultaneous data acquisition of the principal energy parameters. For example, if the wave climate were known, reasonable estimates could be made of longshore sediment transport. Before rigorous theory can provide reasonable estimates of nearshore circulation and mixing, accurate simultaneous data of shore processes are needed to provide a foundation for understanding the energy transfer mechanisms. If circulation and mixing were known, the effects of pollution — solid, heat, chemical, radioactive — could be evaluated as an input to total coastal planning criteria.□

Publications

BRUSH, B. M. and Douglas L. INMAN. Coastal processes and long range planning. *Marine Technology Society*. 1972. (In press.)

The topics of coastal management and coastal planning are more frequently in the public conciousness than heretofore. The recent decade has produced new insights into the physical processes of the coastal zone which are of value to policy making as well as to science. These developments now enable remedial methods to be undertaken. This includes existing technology, adaptable methods, and practical future design for retarding the potentially irreversible loss of priceless coastal features. A review of the scope of the interference of manmade works shows that it is difficult to deal with the coastal problem without considering all of the factors concerned.

> Oceanic engineering must worry about social needs, must be imaginative, must look forward to the proper use of new materials, of almost unlimited power, and by putting things together that haven't been joined before in a systems concept, make more of the addition than just the sum.
> — Athelstan Spilhaus, 'Technology, the Engineer and the Ocean,' 1964.

INMAN, Douglas L. and Birchard M. BRUSH. The coastal challenge. *Science*. 1972. (In press.)

The nearshore waters are the part of the sea that overwhelmingly dominate the everyday affairs of mankind. Conversely, the acts of man such as waste and water discharge, dredging and coastal structures, have their greatest impact in the shallow nearshore waters of the world. Thus, man's expanding use of the ocean must be concerned with processes that take place in coastal waters. It was once thought that the ocean was an infinite sink for waste of all kinds, and that pollution was a local problem. Now it is recognized that the problems are world wide and involve increases in background levels over large coastal and oceanic areas. For example, the California coastal power plant requirements of 38,000 megawatts for 1980 will use seawater as a coolant, at a flow rate, if raised 1° Celsius, equal to 1/1,000 of the total flow of the California Current. From the standpoint of beach preservation, a serious artificial loss of beach sand is caused by dams constructed for flood control, water supply, and hydroelectric power. Replacement of sand on southern California beaches amounted to over 45 million m^3 at a cost of $30 million during the past ten years.

These trends in waste disposal and beach erosion must be reversed through long range planning and application of new concepts to the management of coastal waters.

INMAN, D. L. and E. B. TUNSTALL. Phase dependent roughness control of sand movement. *Thirteenth International Conference on Coastal Engineering, Vancouver, American Society of Civil Engineers.* 1972. (In press.).

Experiments with wave motion over asymmetrical "ripple-like" forms show that the difference between a net sand transport in a down-wave versus an up-wave direction is related to a subtle phase-dependent mechanism associated with the intensity of vortex formation in the lee of the form. Artificial roughness modules have been developed, consisting of arrays of asymmetrical forms resembling natural ripples. The asymmetry of the forms causes an intense vortex to form in the lee of the steep face. This vortex traps and suspends sediment, which when the orbital motion reverses its phase, is lifted about the roughness element and carried in the new direction. Thus, the direction of the net sand transport is dependent upon the relation between the steep face of the roughness element and the phase of the orbital velocity; the net transport being in the direction of the orbital velocity that is out-of-phase with the maximum vortex formation.

Engineers built a new closed-circuit flow channel to study properties of stratified water — water layered into different densities. Already they know that stratified water damps out turbulence faster than unstratified water and that it affects effluent dispersal because substances dumped into stratified liquids settle in layers similar in density to their own. The new flow channel has recirculating water, an innovation designed to overcome many operational problems associated with conducting turbulence experiments by towing objects through tanks of stationary water.

San Diego
R/CZ-3b

Investigations Using a Closed-circuit Stratified Flow Channel

Charles W. VanAtta and Ronald Oda

We are interested in making investigations of wakes in stratified flows caused by heated or unheated objects; of flow over obstacles, such as ridges or multiple sand ripples; or of sewage outfall plumes in a stratified current.

Tow tank disadvantages

Experiments on stratified water flows are usually carried out in a towing tank. There are disadvantages to this method however. Towing objects through a stationary stratified medium, whose density is controlled by salinity, often destroys the original density profile. Problems also arise due to the necessity of having the instrumentation mounted with the object being towed.

Practical solution

Presently there are very few practical versions of continuous stratified flow channels, although work continues on what appears to be a practical version.

New channel has triangular flow path

The new apparatus is a closed-circuit stratified flow channel. The flow path is triangular involving a disc pump in each of two corners and a settling chamber in the third corner. Each corner has a functional purpose: one corner has a disc pump that pulls the fluid out of the observation channel, the next corner has a disc pump that pushes the fluid into the settling chamber, and the third corner is the settling chamber. The settling chamber serves as a point where the water becomes saturated from salt crystals located on its bottom.

The disc pumps originated from an idea by Leslie S. G. Kovasznay, John Hopkins University, Baltimore, Maryland. They consist of discs of two sizes alternately stacked, so that upon rotation about the discs the fluid is viscously dragged between the larger discs. Trapping of the fluid is prevented by stationary fins that are situated between the large discs. The large discs also help to minimize vertical mixing that might destroy the stratification. The performance of a small-scale model of the disc pump with interlacing stationary fins has been encouraging.

Longer experiments now possible

There is also a freshwater input and an overflow duct. With a freshwater input at the surface and a salt input at the bottom, we hope to achieve a linear density gradient that can be maintained for long periods of time. This steady state would permit enough time to take sufficient amounts of data so that statistical analyses would be reliable.

The measurements will be taken from a trolley setup with three degrees of freedom, located above the observation channel. On the trolley will be both conductivity probes to measure salinity that is directly related to density and hot film probes to measure velocity. Velocity measurements could also be made visually using a hydrogen bubble pulsator or dye injection. Also, if time and money permit, a Doppler velocimeter might be utilized.

Slight modifications would enable studies in stratified flow over a heated bottom or shear flow using a double axle disc pump with the upper and lower sets of discs rotating at different angular speeds.□

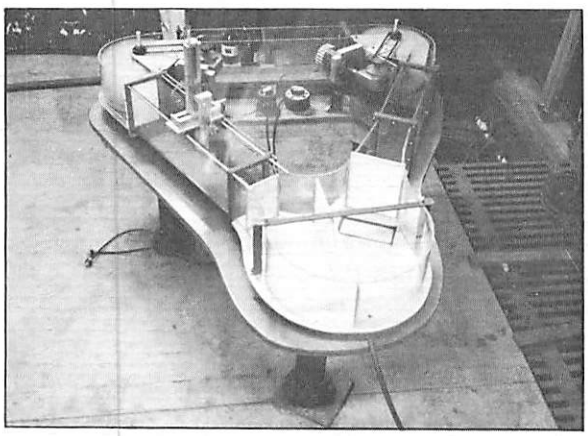
Publications

VANATTA, C. W. and J. PARK. Statistical self-similarity and inertial subrange turbulence. Statistical models and turbulence. *Lecture Notes in physics,* #12. Springer-Verlag. 1972. pp. 402-426.

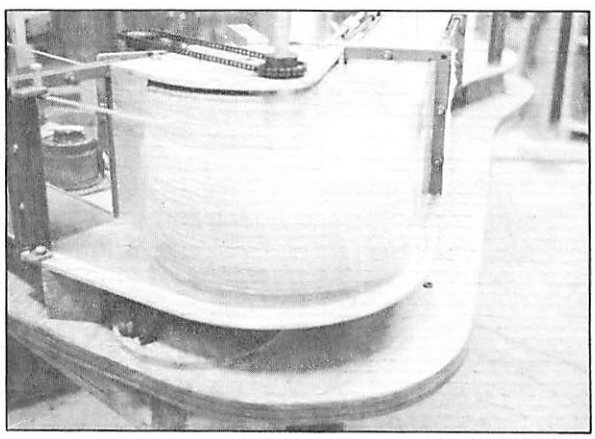
Measurements in the atmospheric boundary layer over the ocean show that the probability density of the increments of the turbulent velocity in the inertial subrange is not strictly self-similar, but a remarkably close approximation to self-similarity does exist over a restricted range of velocity differences and separations. Under the assumptions of the original Kolmogorov theory, statistical self-similarity theory is found to be 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 the 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.

Cooperating Organizations

University of Southern California, Los Angeles, California



Closed-circuit stratified flow channel has a disc pump in each of two corners and a settling chamber in the third corner.



Disc pumps rotate water through two sizes of alternately stacked discs.

Whether or not an increased population of the Crown-of-Thorns starfish, *Acanthaster planci*, threatens to destroy coral reefs in the tropical Pacific is an ecological debate. Whether or not the observed large aggregations are an abnormal increase is also questionable — do the great numbers result from man-induced environmental disturbances or are they simply a redistribution of members of a normal-sized population? There is some evidence that the latter is the case.

San Diego
R/CZ-4

Natural Variability and Effects of Environmental Changes in Coral Reefs

William A. Newman

Trade wind direction and *Acanthaster* abundance

Information from the 1969 Westinghouse Corporation *Acanthaster* survey provided a basis for examining the problem of large aggregations of *A. planci* on coral reefs in the Pacific. The data were categorized by habitat type and summarized to indicate the relation of abundances to habitat. While abundances were highly variable, large numbers of *A. planci* were most frequently associated with leeward seaward reefs, areas of moderate to luxuriant coral growth, and water less than 18.3 m deep. An analysis of variance procedure indicates that position relative to trade wind direction on any given island or atoll is the most significant environmental factor associated with *Acanthaster* abundance.

Definitions in the literature of what constitutes normal and infestive population sizes are judged inadequate. There are no sharp breaks in the distribution of numbers of samples versus population density. Few of the reported infestations meet the published criteria.

Normal growth

Field evidence is lacking to support the idea of increased larval settlement or increased survivorship at any life stage. Size-frequency distributions from normal and infestive populations can all be interpreted as unimodal with peaks at intermediate sizes. This shape does not require abrupt changes in population dynamics, indicating that populations comprising large aggregations of *Acanthaster* have grown in a manner little, if any, different from those considered normal.

Typhoons linked with large aggregations

The hypothesis is presented that large aggregations of *A. planci* are active behavioral phenomena; that is, they are redistributions of existing populations that at some point in their recent history have been brought under conditions of food limitation. Typhoons are the proposed principal causative agents. Average *A. planci* density estimates and recorded recent typhoon frequencies are cited in support of the hypothesis.□

Publications
DANA, T. F., W. A. NEWMAN, and E. W. FAGER. *Acanthaster* aggregations: interpreted as primarily responses to natural phenomena. *Pacific Science*. October, 1972. (In press.)

Cooperating Organizations
U.S. Department of Interior, Washington, D.C.
Westinghouse Ocean Research Laboratory, San Diego, California

When ecologists place an artificial substrate, a one-meter cube made of iron and asbestos board, in intertidal waters and allow it to remain there for weeks or years, a marine-life community forms. As the substrate ages, a covering of encrusting organisms develops, algae establish themselves, and motile animals swim and feed around the new growth.

The structure of the community in terms of species and relative abundances constantly changes. An example of this in the recent past may have been the disappearance of kelp communities from certain California coastal areas. Kelp comes and goes in the artificial substrate communities as well.

Community activity is sometimes as varied in natural, undisturbed areas as in relatively polluted regions. Therefore, information on how much damage man-caused disturbances really create is available only after first carefully conducting baseline studies to identify existing communities and then watching the variability of those communities over time.

Ecological Studies of the Nearshore Zone

Edward W. Fager and
Paul K. Dayton

Fish are first-comers to substrates

The effects of placing solid substrates in open sandy areas in intertidal waters have been a continuing subject of study for over four years. The most immediate result is the concentration of fish, such as sandbass, *Paralabrax* spp., that are normally scattered widely over the sand. These fish do not depend on the solid substrate for food, but do seem to use it for orientation and perhaps for shelter. As the substrate ages in place, a covering of encrusting organisms develops, mostly bryozoa, colonial anemones, barnacles, and rock oysters. The difference in species composition of the cover on different sides of the same piece of substrate is usually greater than the difference between sides with the same orientation on separated pieces. Interspersed among the encrusters, and feeding on some of them, are such motile animals as starfish, large crabs, octopuses, and spiny lobsters. Though these do use the community on the substrate as food, they also utilize material brought in by water movement — especially drifting algae. The starfish themselves probably arrive mostly by being carried on detritus that is slowly moved across the bottom by a complex of currents.

Same conditions, different flora

In addition to the animals, various algae become established — especially a few species of small red algae and occasionally some of the larger brown algae that are important in the kelp beds. There have been *Macrocystis* plants over 30 feet long and full-sized *Laminaria, Pterygophora,* and *Egregia.* The latter seem to be the most often successful (both in establishment and persistence), but individuals of all species decline within a year or so for various reasons that do not include predation by urchins. Identical substrates placed at the same depth and within a few hundred feet of each other on the sand show marked differences in the flora that establishes.

What has emerged from this study is a beginning of an understanding of the complex of interactions between the organisms and the environment, with time scales ranging from weeks to several years. The differences among replicate examples are often so great that, although general trends

Recognition of natural variability essential in environmental surveys

can be noted, specific results can only be predicted on a probabilistic basis. Recognition of this variability and quantification of it is a necessary part of the assessment of the impact of man's intervention in the nearshore region, and it is becoming more and more important as environmental surveys become more adequate. Some of the differences we already have seen in this relatively unpolluted region are as great as those which have sometimes been ascribed to pollution.

Community diversity independent of predation

We continued long-term manipulation of the environments that we placed on the sand. Removing predators did not have the striking results expected on the basis of similar studies done in the intertidal. The composition of our subtidal community seems far less dependent on predation as a mechanism for maintaining diversity.

Community studies near sewer outfall

Gary Smith has now looked at more than ten percent of the 350 samples he took around two Orange County sewer outfalls. Major faunal changes were seen at the shallower one (60 feet) within two months of its being turned off. Overall, there was a trend toward more even distribution of individuals among species. Concurrently, the chemical characteristics of the sediment changed markedly from one with a high content of hydrogen sulfide and metallic sulfides to one similar to that found at these depths in unstressed conditions. At the deeper outfall (190 feet) changes were a little slower. After four months, there was still no major change in the chemistry, but the number of individuals of both crustacea and polychaetes had increased by three to fourfold. There was a trend toward less even distribution of individuals among species. In both cases, the species lists were not changed appreciably, but the relative abundances of specific species were altered, often drastically. The same sort of change was seen in the larger predators at the deeper site. Given more time for organic buildup, it appears likely that the sediment chemistry at the deeper site will change toward that seen at the shallower location before flow was diverted from it.

Popular diversity indexes critiqued

During the past year a sampling study of diversity indexes was published. This showed clearly the virtues and the limitations of these indexes that are so widely used to judge the state of a community. The response to this paper indicates that a large number of people want guidance on what index to use and how to interpret it.

Studies on natural variation in kelp community

Many projects concerned with the ecology of the kelp community are also being carried out. This community, a complex association of species, has disappeared from certain areas of the California coastline in the past ten to fifteen years and has been drastically reduced in other areas. The kelp harvest, large abalone and lobster fisheries, and such extensive recreational activities as sport fishing and skin diving are dependent upon the maintenance of the kelp community. Proposed research is directed toward an evaluation of natural variation in time and space of selected populations in the kelp community and toward an evaluation of effects of man-caused disturbance on the kelp community.

Del Mar survey site

In evaluating the natural variation of selected populations in the kelp community, we will continue to monitor (begun in July, 1967) permanent quadrats in the kelp bed off Del Mar. The adult *Macrocystis pyrifera* population in these quadrats slowly declined until June, 1970, when some slight recruitment occurred. None of these young plants survived, however, and the first adult plants recorded reaching the surface were seen in June, 1971. Since that time the population has again declined. Observations in February, 1972, showed another major *Macrocystis* recruitment. Although this recruitment appears to be successful, it is too early to evaluate the survival of these juvenile plants. We can certainly conclude that five years is not sufficient time to evaluate natural fluxes in the *Macrocystis* population.

Pollution indicator species disclaimed

Another interesting observation in the Del Mar kelp bed is that there was a very large "explosion" of *Diopatra ornata* in 1971. *Diopatra* is sometimes considered a "pollution indicator" species; the outbreak at Del Mar in the complete absence of known pollution, throws doubt on the use of *Diopatra* as such an indicator species.

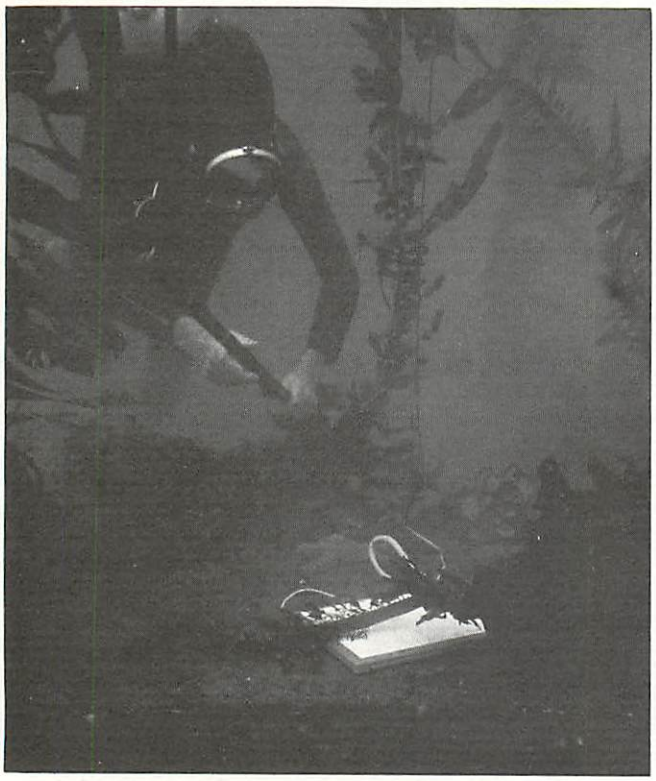
Diver places iron and asbestos board substrate in intertidal waters off La Jolla.

Pt. Loma survey site

In addition to the Del Mar study, permanent baseline quadrats were begun in June, 1971, at Pt. Loma and in March, 1972, at Catalina Island. It is too early for meaningful analysis, but the following comparative statements can be made regarding survivorship of adult (plants with fronds on the sea surface) *Macrocystis.* The Del Mar bed, which is considered unstable in the literature, had a 78 percent survival for one year (July, 1971, to June, 1972), while the reputed stable Pt. Loma bed has only 53 percent survival of such plants over the same time period. The *Macrocystis* population at Fisherman's Cove, Catalina Island, would seem to be in an ideal habitat because it is protected from the storms that caused most of the mainland *Macrocystis* mortality and because it has extremely clear water; nevertheless, this population had by far the highest mortality — we observed a survivorship of only 50 percent in five months. For comparative purposes, this would extrapolate to 100 percent mortality within one year. These results are unexpected and emphasize the need for careful long-term monitoring programs of permanent quadrats. Similar one-year baseline data, grouped with observations from the unaltered controls of various experiments, are available for Pt. Loma populations of brown algae.

Starfish, urchin predator, more abundant near sewer outfall

We plan to continue studying the patterns of distribution and abundance of the starfish *Patiria miniata.* It has been hypothesized that eutrophication is a major factor in increasing the successful recruitment and survival of urchins; in the same sense it is possible that moderate levels or organic enrichment also selectively increase the population of *Patiria,* a predator with a very generalized diet that includes urchins, larval invertebrates, and detritus. Preliminary sampling has shown that the *Patiria* population may be enhanced by organic effluents from the San Diego sewer outfall, as there appears to be a higher density (0.65/m²) in the vicinity of the sewer outfall than one-half mile north (0.005/m²) and two-thirds of a mile north (0.0025/m²) of the sewer outfall.□



Diver surveys plant and animal growth on substrate after it has been in place for approximately a year.

Publications

DAYTON, P. K. Competition, disturbance, and community organization: the provision and subsequent utilization of space in a rocky intertidal community. *Ecological Monographs.* v. 41, Fall 1971. pp. 351-389.

DAYTON, P. K. Toward an understanding of community resilience and the potential effects of enrichment to the benthos at McMurdo Sound, Antarctica. In *Conservation Problem in Antarctica.* Edited by Bruce C. Parker. Allen Press. 1972. pp. 81-95.

DAYTON, P. K. and R. R. HESSLER. Role of biological disturbance in maintaining diversity in the deep sea. *Deep-Sea Research.* v. 19, no. 3, March 1972. pp. 199-208.

DAYTON, P. K. and G. A. ROBILLIARD. A new species of platyctenean ctenophore, *Lyrocteis flavopallidus* sp. nov., from McMurdo Sound, Antarctica. *Canadian Journal of Zoology.* v. 50, 1972. pp. 47-52.

FAGER, E. W. Diversity: a sampling study. *The American Naturalist.* v. 106. no. 949, May-June 1972. pp. 293-310.

Working at nine sites in the intertidal zone along the shores of Santa Cruz and San Mateo Counties, biologists are checking the diversity, distribution, and abundance of algae. At each site permanent reference quadrats are established and marked off with stainless steel rods cemented into the ocean bottom. This allows for survey comparison between different study sites. It also simplifies quarterly monitoring of changes in the same site.

Baseline findings will be used in the future to help assess the effects of man's coastal zone activities on the algal populations and to advise local government on use of the underwater regions for education and research.

Marine Algal Resources of Santa Cruz and San Mateo County Coasts

William T. Doyle

Study site selection

The first year of a two-year study of the intertidal resources along the Santa Cruz and San Mateo County coasts saw the selection of study sites, the establishment of permanent quadrats at each site, the quantitative and qualitative enumeration of algal resources for four seasons, and the determination of biomass for three seasons. Sea Grant supported the establishment of seven study sites along the open coast from the Santa Cruz city limits north to Pigeon Point (San Mateo County). Financial support from the Association of Monterey Bay Area Governments helped simultaneously establish two additional sites — one within Monterey Bay and one out of the Bay, immediately north of Santa Cruz Point. All sites were studied quarterly. Voucher specimens and identifications verified by Dr. Isabella Abbott of Hopkins Marine Station, are being maintained at UC, Santa Cruz.

Quantitative studies

Replicate permanent quadrats, each marked by a stainless steel rod cemented in the substrate, were established on flat surfaces in the upper, middle, and lower intertidal at each site. In the quadrats, larger plants that grow as individuals were counted as individuals and the other plants were scored by counting the number of ten centimeter squares in which they occur. This procedure allows a comparison of species numbers and approximate percent cover in the same intertidal zones at different study sites.

Stainless steel rods, cemented into holes drilled in the substrate by a rock coring device, are being surveyed and in future years will aid in determining the rate of intertidal shelf erosion in this coastal section of California.

Qualitative studies

Site by site the entire intertidal shelf is quarterly surveyed floristically, and voucher specimens of each species at each site are collected for future reference. This study results in a more complete picture of algal diversity at each site and allows determination of the percentage of total intertidal species present that are also present in the quadrats (quantitative study).

Sessile organisms allow biomass measurements

Benthic algae are sessile and their growth and distribution are influenced by the physical and chemical conditions of the water in which they live. Thus the determination of the amount of organic matter present at each site might provide useful information for comparative studes. Seasonal biomass studies were initiated during the winter of 1972. Replicate quarter meter quadrats of flat rock surfaces in the lower intertidal were denuded and the algal samples brought back to the laboratory for sorting, identification, drying, and weighing. Marking of the denuded areas is permitting rescraping of

these same areas at known time intervals, which will provide figures on the rate of regrowth or productivity at each site in this central California coastal section.□

Cooperating Organizations
Association of Monterey Bay Area Governments, Monterey, California
Hopkins Marine Station, Stanford University Pacific Grove, California

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Underground oil seeps steadily into the Santa Barbara Channel from sea floor leaks at Coal Oil Point. Having explored and mapped these natural seeps, chemical engineers are now studying chemical changes that take place in floating samples of the escaped oil. Information will be useful in identifying the source of future oil spills and in assisting the development of oil spill clean-up equipment.

Studies require following a small oil globule from the time it enters the ocean until it washes ashore as sticky black tar. The exercise may have further application in monitoring and containing large oil slicks.

Santa Barbara
R/CZ-9

Pollution of the Sea by Oil: an In-depth Study of Natural Oil Seepage at Coal Oil Point, Santa Barbara, California

Paul G. Mikolaj

Chemical analysis of tar blobs identifies pollutant source

To identify the exact source of pollutant beach tars, monthly surveys were conducted in which individual pieces of tar were picked up from beaches along the Santa Barbara Channel and brought back to the laboratory for chemical analysis. During the period of July, 1969 to June, 1970, the surveys were performed at nine beaches covering 75 miles of coastline. For this same period, samples were also obtained from the two most conspicuous sources of submarine oil seepage in the Channel — the natural seeps at Coal Oil Point and the residual leakage from the blowout at Union Oil Company's Platform A.

The method of identification used was trace metal analysis — specifically measurement of concentrations of nickel and vanadium. Before analyses of the beach tars and suspected oil sources could be compared, however, it was first necessary to establish how these metal concentrations might be affected by exposure of the oil to the marine environment. Furthermore, it was necessary to account statistically for uncertainties in metal analyses and for the unknown history of each tar deposit. These tasks required a year and a half to perform. The results showed that approximately 70 percent of the tar deposits found on beaches of the Santa Barbara Channel could be identified as originating from natural seeps at Coal Oil Point, while only about two percent originated from Platform A.

Most beach deposits from natural seeps

New method for interpreting data

In the process of statistically analyzing the beach pollutant data described above we learned of a correlating model that proved useful in the reduction and interpretation of environmental pollution data. This model is the Weibull distribution function, an empirical three-parameter function which has already been applied to a wide variety of topics, including fatigue (life) testing, quality control, particle size analysis, and odor threshold.

Of the three parameters in the Weibull distribution function, the one of greatest interest is the threshold parameter. In its broadest sense, the threshold parameter may be interpreted as the minimum value that the random variable being tested is likely to attain. (In other words, the probability of observing a value of the random variable that is less than the threshold parameter is essentially zero.) Thus, in addition to the usually computed mean and variance, another term is available to help interpret the data.

In situ gas chromatography measures oil slick evaporation

The Weibull function was then applied to a number of oil pollution topics to see if the threshold parameter could indeed aid in data interpretation. These topics included the quantity of beach tar deposits along southern California; the size of minor, moderate, and major oil spills; the extent of coastline contamination resulting from major oil spills; and the duration of major oil spills. In each case, the computed threshold parameter offered new insight for explaining the data. Application of the Weibull method to other types of environmental problems and pollutant monitoring data appears quite promising.

An oil slick on the open sea, whether of natural or manmade origin, undergoes many processes that affect its ultimate fate. The first and most rapid of these processes is evaporation. To study this process, a gas chromatographic method was developed to measure, *in situ,* the rate and extent of evaporation from oil slicks. The method consists of quantitatively comparing chromatograms of the fresh, unweathered oil with those of oil exposed to the marine environment. (Evaporation of all types of petroleum products, ranging from kerosene and light fuel oils to crude oils and heavy residual oils, can also be studied by this new method.)

Volatile components evaporate within one to two hours

The analytical method was first tested in open waters of the Santa Barbara Channel on oil from one of the natural seeps near Coal Oil Point. Results of these experiments showed that most of the oil's volatile components evaporated within one to two hours under Sea State #3 conditions. Based on laboratory analysis of the natural seep oil, the measured extent of evaporation would produce an oil slick residue of near neutral buoyancy. Thus, there is considerable likelihood that much of the oil released from natural seeps at Coal Oil Point enters the water column and either sinks or is transported by subsurface currents throughout the Santa Barbara Channel.

During the past four years, we have noticed that the activity (oil flow rate) of the natural seeps at Coal Oil Point often varies considerably from one observation time to the next. At times there is significantly less oil on the water than at other times. With the hope of identifying a cause-effect relationship, we therefore initiated a program to obtain quantitative data on this variation in seepage activity.

Plastic bags trap escaping oil

Because the total area of oil seepage is so large (many thousand square meters), we selected six sampling stations scattered throughout the general seepage area. At each station, a collection ring (17 cm in diameter) was permanently attached to the ocean bottom. Scuba divers then installed plastic bags over these rings to trap the rising oil globules as they escaped from the sea floor. After a specified time (nominally four hours) the bags were retrieved and brought to the laboratory where the quantity of oil collected was measured.

Natural oil flow rate decreases as tide rises

Examination of these data indicates that the principle causal phenomenon associated with variations in oil flow rate is tide height. Statistical analysis shows that there is a significant measure of linear correlation between these variables for five of the six sampling stations. Based on data collected over a seven-month period, the statistical analysis indicates that for each one-foot increase in tide height, the oil flow rate decreases by up to 40 percent. These measurements will be continued during the new grant period to establish

long-term effects, and efforts will also be directed toward relating these findings to the mechanism of submarine oil seepage.□

Publications

CHAPIN, D. W. Source identification of tar deposits from the Santa Barbara Channel Coastline by trace metal analysis. University of California, Santa Barbara. M.S. 1972. (Thesis completed.)

DELANEY, R. C. Trace metal weathering effects and characterization of oil from natural seepage in the Santa Barbara Channel. University of California, Santa Barbara. M.S. 1972. (Thesis completed.)

MIKOLAJ, P. G. Environmental applications of the Weibull distribution function: oil pollution. *Science.* v. 176, no. 1019, June 2, 1972. pp. 1010-1021.

The Weibull distribution function is an empirical three-parameter function that has been applied to a wide variety of topics, including fatigue (life) testing, quality control, particle size analysis, and odor threshold. The Weibull function has recently been used as a correlating model in the reduction and interpretation of environmental pollution data.

MIKOLAJ, P. G., A. A. ALLEN, and R. S. SCHLUETER. Investigation of the nature, extent, and fate of natural oil seepage off southern California. *4th Annual Offshore Technology Conference, Houston, Texas. Proceedings.* Paper OTC-1549, May 1-3, 1972.

Natural oil and gas seeps in the Santa Barbara Channel and in Santa Monica Bay have been investigated using aerial, surface, and underwater survey techniques. Ten separate zones of offshore seepage have been studied. Oil is released from these seeps at a total rate approaching 100 barrels per day, and the resulting oil slicks contaminate several square miles of surface water. Standardized methods have been developed for sampling, classifying, and characterizing oil-tar beach pollutants; these techniques have been field-tested and have provided baseline pollution levels along several miles of coastline.

SIVADIER, H. O. Experimental measurement of evaporation from an oil slick on the open sea. University of California, Santa Barbara. M. S. 1972. (Thesis completed.)

Cooperating Organizations

Santa Barbara City College, Santa Barbara, California

Union Oil Company of California, Los Angeles, California

Although much of the California coast is seismically active, community development has not been restricted by fear of earthquakes. Developers ignore geologists who say it is inadvisable to build on a known fault.

To more strongly argue their point and influence future development in the coastal zone (including installation of offshore oil wells), several geologists are now reporting results of a seismic survey conducted in a heavily populated urban area near the Santa Barbara Channel.

Designed to determine where and how frequently destructive earthquakes are likely to occur, the investigation showed vertical movement along a segment of the supposedly inactive Mesa fault. One downtown boulevard was surveyed four times with movement detected each time.

Santa Barbara
R/CZ-10

An Investigation of the Seismicity and Earthquake Hazards of the Santa Barbara Channel Area

Arthur G. Sylvester

Three level lines and one triangulation network were established across the Mesa fault at various locations. Each of the lines was surveyed at least

Level lines established across Mesa fault

two times and one line within the net was resurveyed four times. At least first order leveling (closures of 4 mm $\sqrt{K}$ where K is distance in km) was accomplished on all lines, with most of the lines being Hollister first order (2 mm $\sqrt{K}$).

Located astride the Mesa fault was a comparatively dense net consisting of some 52 stations along interconnected lines and including four of the U. S. Coast and Geodetic Survey (USCGS) level bench marks. It is this net that provides the most conclusive evidence of fault movement. One of the lines in this net, Cabrillo Boulevard, was surveyed four times with detectable changes on each of the resurveys. The ends of the lines, each of which is a USCGS bench mark, have moved 1.5 cm relative to each other in the two-year survey period with observed short-term rates of from 5 to 12 mm per year. The entire net exhibits a similar pattern. The data suggest the movements are aperiodic but continuous along the segment. One of the more unusual features of the movement is that it is opposite in sense to that inferred from the geology and well data for the Mesa fault.

Aperiodic but continuous movement

It is obvious from these data, from the existence of a relatively high-density urban population, and from an active earthquake history for the region that additional studies should be conducted in the Santa Barbara Channel area.

Channel Islands surveyed

Numerous other first-order, small-scale geodetic arrays and level lines were established across individual faults in the Channel Islands and on the mainland to determine whether or not perceptible movements are occurring across the faults or if strain is accumulating close to the faults. Resurvey of these arrays and lines show no changes to date with the possible exception of a level line across the More Ranch fault.

Repeated surveys of a level array across the Sylmar fault segment revealed a measurable amount of vertical afterslip. While negligible (1 percent) when compared to the total vertical movement on the fault, the afterslip exhibits a logarithmic decrease with time.

An analysis was made at the first order level lines (four) extending from San Jose to San Pedro for the period 1920-1971 (Willott, 1972). The data indicate vertical movement occurs not only near faults but also along entire segments between faults.

North of the western Transverse Ranges, the patterns and rates of modern vertical movements are random in nature except at the San Andreas fault north of Salinas. The transverse segments of the San Andreas fault are tilted away from it. North of the San Andreas fault the transverse segments are consistently tilted toward the north.

History compiled on seismic activity around Santa Barbara

A compilation of the history and effects of felt earthquakes of the Santa Barbara area from 1800-1970 was completed. The study generally suggests that: (1) earthquake swarms are common on Channel faults and occur on the average of every 20 to 30 years, (2) most earthquakes occur in the eastern part of the channel, (3) the frequency of moderate to large earthquakes is low, perhaps lower than other seismically active areas in California, and (4) felt reports and damage are most frequent in parts of Santa Barbara and other coastal cities underlain by unconsolidated or poorly consolidated sediments and landfill.

New surface geologic maps

Surface geologic mapping of selected critical areas along several faults and suspected faults clarified the details of fault locations and geometry. Of particular interest are two previously unmapped faults in the Santa Ynez Valley and a detailed mapping of the More Ranch fault. Detailed maps of these two areas as well as a fairly detailed structural geological map (1:250,000 scale) of the Santa Barbara Channel area were completed.

Design and fabrication of a "new" type of tide gage was completed. The gage is relatively low-cost, portable, and provides a computer-compatible digital recording (punched paper tape).

New tiltmeters for registering creep

To date three inexpensive nonrecording-type tiltmeters have been built. Two are installed in the San Fernando area and one is contemplated for the Mesa fault region. It is hoped the tiltmeters will help in the identification of creep events suggested by the level data. Three additional tiltmeters are under construction and will be installed in the Transverse Range region.□

Publications

SYLVESTER, A. G. and D. D. POLLARD. Afterslip on the Sylmar fault segment. *California Department of Conservation, Division of Mines and Geology Special Report.* (In press.)

A series of first-order precision levelings of two 200-m-long lines show that more than 6 mm of vertical afterslip occurred in the period from 4 to 330 days following the main shock of the 1971 San Fernando earthquake. This is only about one percent of the total vertical component of slip measured at the site shortly after the earthquake, and it is negligible compared with afterslip documented for other recent California earthquakes at Parkfield in 1966 and at Borrego Mountain in 1968.

SYLVESTER, A. G. and D. D. POLLARD. AFTERSLIP ON THE Sylmar fault segment following the San Fernando, California earthquake of February 9, 1971. *Cordilleran Section Annual Meeting, Geological Society of America, Hawaii, March 1972. Abstracts with Programs.* p. 261.

SYLVESTER, A. G. and D. D. POLLARD. Observation of crustal tilt preceding an aftershock at San Fernando, California. *Bulletin Seismological Society of America.* v. 62, no. 4, March 1972. pp. 927-932.

Anomalous drift of a theodolite plate-level bubble was observed about five hours before two of the stronger aftershocks of the San Fernando earthquake of February 9, 1971. The phenomenon may be related to crustal tilting during the accumulation of strain prior to the aftershocks.

WILLOTT, J. A. and A. G. SYLVESTER. Geodimeter study on Santa Barbara Channel, California, (Paper presented at Second Coastal and Shallow Water Conference, University of Southern California, October 1971.) p. 5.

WILLOTT, J. A., A. G. SYLVESTER, C. O. GREENWOOD, and J. A. GREENWOOD. Geodimeter measurements for regional horizontal strain, Santa Barbara Channel, California. *Cordilleran Section Annual Meeting, Geological Society of America, Hawaii, March 1972. Abstracts with Programs.* p. 261.

After it is finally agreed that the finite area of the coastal zone should be managed to insure optimum economic development with minimum environmental damage, a greater problem arises in developing a plan to realize the goal. A pilot project to assist the Santa Barbara County Planning Department in directing seacoast development reveals the intricacies of coastal zone management and shows how university research can assist in the formulation of coastal plans.

Five interrelated studies were conducted in this one pilot project, "Sea Coast Planning Project."

Santa Barbara
R/CZ-11

Sea Coast Planning Project: Santa Barbara Channel Islands

James J. Sullivan

Environmental-economic costs of three plans

There were three alternative uses proposed for Santa Cruz Island: (1) national park status, (2) the commercial-residential status represented by the master plan for the Gherini property on the eastern end of the island, and (3) the status quo, the retention of agricultural and scientific research activities on the island under private ownership. Students organized a study on the comparative environmental-economic costs of each plan.

The project staff met with Dr. David Podoff, fiscal economist from the University of Massachusetts, Amherst, who is providing consulting services. A comparative cost-benefit analysis focused on the national park and commercial-residential plans, where development costs and benefits could be measured more easily than they could under the status quo alternative.

National park status

It was felt that for evaluation of the national park plan, recreational benefits could be determined by deriving a demand curve imputed from travel costs incurred by visitors to the park; concentric travel distance zones, as developed by Hotelling and other economists, were used in the computations. Dr. Podoff is now working on the specific formulation of such a model.

Commercial-residential development

From an earlier careful review of the commercial-residential plan as described in the Gherini Ranch Master Plan of 1965, it became apparent that there was little information on the level and cost of public services to be provided. Here again Dr. Podoff is helping to incorporate comparable public services data obtained from the project staff's field study of the City of Avalon on Santa Catalina Island. While information from Avalon should provide reasonable unit cost measures for such services, Dr. Podoff also felt this information to be of importance in viewing the intergovernmental fiscal relations between an isolated island city and respective county and state governments.

In preparation for performing a comparative benefit-cost analysis of the National Park and Gherini plans, pertinent cost data were extracted from the following two major sources: (1) *The Channel Islands,* a preliminary five-island park feasibility report prepared by the Bureau of Outdoor Recreation in 1968 and (2) the *Gherini Ranch Development Master Plan,* prepared in 1965.

Islands in Massachusetts, North Carolina, and other parts of California have similar concerns

Along with a careful examination of these two reports, comparative information was gathered from a wide range of sources. This includes information on housing, transportation, land use, etc. from the islands of Martha's Vineyard and Nantucket in Massachusetts, Smith Island in North Carolina, and Santa Catalina in California. Research assistants spent a day on Catalina interviewing members of the Catalina Company as well as officials of Avalon.

Primary sources of information pertaining to the status quo alternative are from the University Marine Biology Field Station on Santa Cruz and from the Santa Catalina Island Company, in regard to their range and wildlife management program on Catalina.□

Sea Coast Planning Project: Public Policy and the California South Coast's Tourist and Retirement Industries: Political Economy of Coastal Zone Resource Use

W. Elliot Brownlee, Lloyd Mercer, and W. Douglas Morgan

Capital use influenced by property taxes

One way of determining the impact of public policy on coastal zone resource development is by looking at the use of capital — land, structures, and equipment — as influenced by property taxes. Citizens can choose which goods and services they want in their community by voting certain businesses preferential treatment in the form of low taxes. Until recently, Santa Barbara's public policy promoted the growth of tourism and the settling of retired citizens, so it is this "industry" that was used as a focus for this study.

Developed and applied was a model for estimating the impact of the differential rate structures of local taxing agencies — counties, cities, and special districts — on the allocation of capital among various uses and local areas. Areas within a coastal zone can be seen as competing for resources, one of the most significant of which is, of course, capital. Physical capital — structures and equipment — provides services to capital users that are essential to all the economic activities of the coastal zone, whether those users provide residential housing, extend services to tourists, extract oil, or manufacture. Thus, competing governmental units, through policies of taxation, can shape the area location of coastal zone activities by manipulating the cost of capital. The specific procedure that was developed to examine this involves specification of the impact of inter-local differences in property taxation on the true economic cost of using capital — the user cost or rental price of capital. The model is sufficiently flexible to allow an accounting of a wide variety of local policies affecting the price of capital, for example, outright property grants and interest subsidies through development bonds, as well as property tax reductions or increases.

Focus on inter-local differences in taxes

Santa Barbara and Ventura Counties

The two major coastal zone polities within the South Coast competing for resources are Santa Barbara and Ventura counties. Hence, as a preliminary application of our tax model we compared the impact of property taxes levied by counties, cities, and school districts on capital costs in various "functional" areas of Santa Barbara and Ventura counties, based on sets of annual series of property tax rates and assessment ratios.

Santa Barbara's cost advantage declines in 1960's

While the property taxation of residential retirement property and industrial property remained more favorable in Santa Barbara, Santa Barbara's relative cost advantage declined during the 1960's. Prior to the early 1960's, Santa Barbara's tax policy followed a consistent course of providing relative capital costs advantages to all coastal zone users. In the 1960's, however, Santa Barbara reversed that policy, which had previously compensated to some degree for the advantages enjoyed by Ventura County from its greater proximity to the Los Angeles marketplace.

Tourism-related services begin to lose importance

While the relatively heavy taxation of oil property appears readily justifiable in terms of forcing oil firms to internalize certain environmental diseconomies, this study focuses attention on the possibility that Santa Barbara is placing a powerful competitive disadvantage on tourism-related services whose expansion might well enhance the coastal zone's economic health without incurring significant diseconomies.

Finally, this study began exploring the patterns of criteria applied to planning for resource use in Santa Barbara County since the 1920's through an assessment of the outcomes of interest group competition for a series of central public policy decisions (e.g., the creation of the Architectural Board of Review and the decision to construct Cachuma Dam). Our preliminary assessment reinforces the findings from the analysis of tax policy that public policy in Santa Barbara has been designated to promote the growth opportunities of the community. Public policy in general has sought to foster the growth of activities, such as tourism-retirement, which make the most of Santa Barbara's locational advantages and which appear not to detract from those advantages, as was the case with oil development until the great spill.□

Publications

BROWNLEE, W. E., L. MERCER, and W. D. MORGAN. Optimal recreation land use assignment in a coastal zone: a model. (WORKING PAPERS)

BROWNLEE, W. E. and W. D. MORGAN. The impact of state and local taxes on capital formation: a cross-sectional view. (WORKING PAPERS)

BROWNLEE, W. E. and W. D. MORGAN. Property taxation and coastal zone resource use: California's south coast, 1921-1971. (WORKING PAPERS)

Sea Coast Planning Project: An Analysis of the Impact of Beach Pollution on the Development of the Channel Coastline with Particular Reference to Natural Oil Seeps

Carl Hetrick, Paul Mikolaj, and W. Douglas Morgan

Citizen use of coastal zone

The object of the study is an assessment of the impact of natural and man-made beach pollution in Santa Barbara County. The study focuses heavily on perceptions of oil and tar pollution of the beaches, but does so in a context that compares the importance of this form of pollution with other forms of beach pollution as well as with other forms of pollution generally. The study examines those factors underlying citizen use of the coastal zone and makes assessments as to frequency of use, reasons for use or non-use, and citizen preferences as to alternative uses of the coastal zone.

Survey of 523 community residents

Integral to the study is a survey conducted of 523 community residents with interviewing done by the Santa Barbara and Santa Maria League of Women Voters. The survey was done in such a way that all the above factors can be placed in a broader political, social, and economic context. Attitudes with regard to "the environment" and the use of the coastal zone are tied in with related political and social factors.□

Sea Coast Planning Project: Impact of Offshore Oil Production on Santa Barbara County

Walter J. Mead

A draft of a report, "Impact of Offshore Oil Production on Santa Barbara County," was completed. This report is in five parts: (1) it has an analysis of the incomes generated for Santa Barbara County resulting from offshore oil exploration and development, (2) it measures taxes accruing to Santa Barbara County, again as a result of offshore oil activity, (3) it measures the impact of offshore activity on county government expenditures, (4) it attempts to estimate the complex interrelations between oil production and other county activities, including tourism, research and development, retirement, and fishing, and (5) it surveys miscellaneous other economic sectors. The environmental impact is also reviewed in summary fashion.

This report will be reviewed in-house, then rewritten and submitted to the county for its use.□

Sea Coast Planning Project: Beach Survey

James J. Sullivan

Santa Barbara beach use

A study was conducted to determine not only who uses the beaches in the Santa Barbara area, but where users come from, how they get there, and why they choose particular beaches. Additionally, data on the cost of providing beaches were to be obtained as were socio-economics data taken on the users.

During the 1971-72 academic year raw data generated from 802 interviews obtained during the summer of 1971 were coded, processed, and preliminarily analyzed. By June, a preliminary report was written and circulated for comments.

Coded maps help interpret survey results

In response to comments and to overcome some problems in the initial survey, a partial resurvey and beach-user count were undertaken in the summer of 1972. This additional information was used for more analyses. The preliminary report then was edited, revised, and expanded. Coded maps to assist in the interpretation of the results were prepared. Time series analysis, analysis of demand of non-residents for Santa Barbara beach use, and a consumption analysis of beach services by residents expanded the scope of the report. The final draft report, "Survey of Santa Barbara Beach Use: A Pilot Study," is currently under in-house review and will be transmitted to the County of Santa Barbara shortly.□

Final report goes to Santa Barbara County officials

BIOLOGICAL RESOURCES

Introduction

Marine biological resources—the plants and animals of the ocean that man finds useful—have for centuries been the most valuable product of the sea. Research under the UC Sea Grant program has dealt with ways of keeping seafood products from turning color and spoiling, making use of seafood waste products, and improving sport and commercial catches.

In the long run, man may have to do in the ocean what he has done on land: cultivate certain species of marine plants and animals high in food value to replace or supplement catches of wild species. The UC Sea Grant aquaculture program deals with controlled rearing of lobsters, abalones, and seaweed.

Marine organisms, besides being a food source, provide useful by-products. Many marine biological extracts have potential use as pharmaceuticals, fungicides, and insecticides. They may even be used to control barnacle growth.

As the number of lobsters available in the open ocean decreases, the only way to satisfy an increasing demand for them may be to start a commercial lobster farming industry. To establish the feasibility and costs of such a venture, an aquaculture facility was set up 65 miles north of San Francisco at Bodega Bay. The laboratories are modeled after the lobster hatching facilities of the Commonwealth of Massachusetts on Martha's Vineyard, site of preliminary studies on lobster aquaculture.

Current experiments on the East Coast lobster, *Homerus americanus,* emphasize culturing laboratory-hatched lobsters to marketable size in tanks of recirculating warm seawater. This closed-system approach, an alternative to raising lobsters in a protected area of the open ocean or in tanks flushed with fresh seawater, will make it possible to single out one component or variable for test while holding the others constant.

The Culture, Selective Breeding, and Genetics of the Lobster

Robert Shleser

Studies on lobster growth rate began at Martha's Vineyard

Most of our work took place at the lobster hatching facilities of the Commonwealth of Massachusetts on Martha's Vineyard. Research was an extension of studies initiated with John T. Hughes, director of the hatchery. Primary goals were to compute studies on lobster growth that would provide a description of the increase in size/molt for lobsters living in ambient seawater. These studies were completed and allowed calculation of the growth rate of lobsters in the ambient situation. The data indicated that lobsters growing in ambient seawater required five years to molt 20 times to achieve one-pound size. Earlier studies completed by Wilder in 1953 indicated that eight years were required to reach one pound. The apparent discrepancy was explained by the higher average temperature on the Vineyard where the temperature fluctuates between 40 and 75°F. This so-called temperature effect was no surprise, since during the previous year we had completed studies of growth at 72°F that indicated that a lobster would reach one-pound size in less than two years. It was this observation that convinced us that the lobster was a suitable candidate for an aquaculture research effort.

Warm water speeds growth

Females raised at high temperatures release no eggs

An observation essential to the development of a lobster breeding program was made during our first year. It was discovered that although female lobsters reaching the twentieth molt at 70°F displayed normal sexual behavior, no eggs were extruded after copulation. On the other hand, siblings raised in ambient seawater to the same size copulated and produced eggs and offspring normally. Studies to explain this observation are currently in progress.

Crowding inhibits growth

A relationship of spaciousness of environment to increment/molt was observed. We observed that crowded lobsters did not increase in size as much as lobsters that had abundant space in which to grow. Preliminary studies indicated that a lobster must have between three and four times its area to achieve maximum increment in size/molt. Studies to precisely define this observation and an attempt to find lobsters that are not constrained by the need for larger areas are now in progress.

Selective breeding

Selective breeding studies were continued. The results indicated that it was possible to select faster-growing lobsters by picking out a faster-molting lobster. The first studies selected 15 animals mating at one to five times normal frequency that apparently showed the normal average increment/molt. Further work on this observation is now in progress and will serve as the basis of our selective breeding program.

Meatier mutants

Our mutant advertising program was initiated. In this program we contact as many lobster fishermen as possible, requesting lobsters with larger-than-normal meat parts (claws and tails). We obtained lobsters with abnormally large claws and ones with two large crusher claws. (Most lobsters have one larger crusher claw with about 20 percent more meat than the smaller pincher claw.) These lobsters were all mated and the inheritance of these economically important traits is under study. In conducting this program we also obtained lobsters of various colors. The inheritance of these traits is under study.

Habitat substrate experiments

Habitat designs for mass growth of lobsters beyond the fourth stage were examined. Different substrates, including small pieces of pipe, stone gravel, and sand, were examined for their ability to reduce cannibalism. These substrates were compared with clean bottoms. Survival from the fourth to the eighth molt ranged from 0 to 40 percent compared to lobsters raised individually. Sand substrate was least effective, and tubes aligned in a linear configuration proved best.

Evaluation of foods

This first year was also a time for preliminary evaluation of foods. The first growth rates were established using diets of clams. On this diet one year was required to reach one-pound size at 72°F. The wet-weight food conversion in these experiments was 4:1 compared with about 11:1 conversion ratios in ambient seawater. The conversion rates were based on food fed, not food eaten. Lobsters often will not feed in cold water, accounting for the high values in the latter case. We are currently studying food conversion on the basis of actual food eaten.

Natural diets

Physical systems were constructed to be used in evaluation of various diets compounded from natural products. Shrimp and fishmeal bound together with seaweed extracts produces a food that holds together for eight hours in seawater and will not crumble to produce waste for bacterial growth in the system. Two of the six diets tested produced growth equivalent to that observed for the clam diet on the Vineyard, but none approached the growth rate observed for lobsters fed on lobster or brine shrimp.

Lobster showers oxygenate holding tank water

Design and development of physical systems for dealing with large numbers of lobsters took much time. A critical problem encountered in holding many single lobsters was providing well-oxygenated water to the lobsters in the separate compartments, especially as the temperature rose above 70°F and the dissolved oxygen fell to a point that would not sustain survival. This problem was eliminated with the development of the lobster shower—a device that sprays water from above into each compartment. The effect is that the water is well-oxygenated and distributed throughout the system. Since the water comes in above, the effect is to wash wastes out the bottom as the water establishes the level in the tank. The only disadvantage is that the system is continually clogging due to organisms that grow in the lines. This problem was largely overcome with the development of the closed system.

Bodega Bay operations begin

By March, 1972, we felt that the preliminary studies conducted at Martha's Vineyard were promising enough to develop an experimental facility on the West Coast at Bodega Bay. The Bodega Laboratory of the University of California was chosen as the location for the development and testing of the component pieces for a commercial lobster farming industry. A closed

system for recirculating warm seawater is currently under test. The value of the closed system is that this will allow precise evaluation of each of the elements of a lobster farming development for both cost and effectiveness. The closed system offers the potential to single out one component or variable for test while holding the others constant. Currently under evaluation are systems for heating, pumping, and recirculating water. Devices for removing both liquid and solid wastes and systems for oxygenating the water are also being tested.

In conjunction with Dr. Sam Moyers at Louisiana State University and Dr. Myron Beigler of the Syntex Corporation, we are compounding and testing the consistency and nutritional value of foods compounded from fisheries and other by-products as a commercial lobster food. For this purpose we have designed and constructed evaluation trays for holding 3,000 single lobsters in recirculated 70°F water. Five diets were tested and one found superior to any other. Design and manufacture of an automatic food-dispensing device is now in progress.

For ease of manufacture and maintenance, we redesigned the larval rearing equipment perfected by Hughes. Using live brine shrimp as food it has been possible to achieve 60 to 80 percent survival of fry through the larval period.

Filamentous bacteria kill first hatch

Between April and June, we hatched and raised 50,000 lobsters to the fourth stage. Most of these were killed by a filamentous bacteria introduced into the system from the seawater intake. The bacteria was identified as *Leucothrix mucor* and was shown to be sensitive to streptomycin in concentrations of 1 mg/liter. This is a new bacteria disease of lobsters and seems to be endemic to the West Coast, having infected work at San Diego and Seattle. This observation only intensified our need for a full-time laboratory for diagnostic and preventative studies for aquaculture.

Second hatch

In June, a second hatch of 10,000 lobsters was completed. The animals are being used in various studies described above.

Also in June, engineering studies to characterize the kinds of wastes produced by lobsters in culture situations were started. This work, completed in September, defined the biological and chemical oxygen demand of the lobster and the system. These studies provided valuable data for the development and construction of larger systems for handling wastes in the automated lobster farming unit now under development.□

Publications

HUGHES, J. T., J. SULLIVAN, and R. SHLESER. Enhancement of lobster growth. *Science.* v. 177, no. 111, September 22, 1972. pp. 1110-1111.

HUGHES, J. T. and ROBERT SHLESER. Progress toward commercial culture of the American lobster, *Homarus americanus.* Proceedings. 1972 meeting of the World Mariculture Society, St. Petersburg, Florida.

SHLESER, R. A. Lobster culture. *FAO Aquaculture Bulletin.* v. 3, July 8, 1971. p. 8.

Cooperating Organizations

Department of Food Science and Technology, Louisiana State University, Baton Rouge, Louisiana

Massachusetts State Lobster Hatchery, Martha's Vineyard

Syntex Corporation, Palo Alto, California

In principle, humans can enter into the marine food web at a point of greater overall efficiency by obtaining animal protein from herbivores rather than from carnivores, yet most marine animals harvested are carnivorous fish. Marine biologists are studying abalones and some smaller marine herbivores with the aim of understanding what factors limit their abundance. Under consideration are breeding, growth, and mortality, availability of food, competition among species, and threats by natural enemies.

Ecology of Benthic Herbivores in the Sea

**Joseph H. Connell and
William W. Murdoch**

Abalone reproduction studies

A comparative study of reproduction in pink, green, and white abalones continued for the third year at the Isthmus of Santa Catalina Island. In March, 1972, reproductive studies were initiated at Coal Oil Point near Santa Barbara and at Gull Island on the southwest side of Santa Cruz Island. Information obtained from the pink, green, and white abalone populations in these two areas, which are near the geographic margins of these species, is being compared to information obtained at Santa Catalina Island. In addition, similar information is being gathered at Coal Oil Point and Gull Island for red abalones. A group of these red abalones was transplanted to the Isthmus of Catalina (outside their geographic distribution). Their growth, survival, and reproductive physiology are being monitored for comparison with the wild populations of this species.

Population dynamics

At the Isthmus of Catalina, data were obtained on recruitments, growth and mortality rates, age structures, and population densities for pink and green abalones. Fourteen 10m² quadrats were cleared of abalones and large brown algae in the summer of 1971. Higher than normal (X2) densities of abalones were planted in two of the quadrats, while the remainder were left to be repopulated from the wild populations. The quadrats were recensused in July, 1972.

Individual growth rates

The survivors from a group of pink and green abalones measured, marked, and released in the wild were recaptured a year later. This growth rate information is being compared to similar data obtained from animals caged and fed on the sea floor and animals kept in the laboratory.

Feeding habits

Observations on the feeding activity of pink and green abalones were made in the wild to determine: (1) the levels of feeding for day versus night, (2) whether foraging is involved, and (3) food preferences.

The standing crops of large brown algae, the amounts of drift algae, and the rates of production of new living algae, as well as the accumulation of drift algae, were measured at the Isthmus of Catalina.

Food competitors

Densities (biomass) of urchins were measured at Gull Island and the Isthmus of Catalina in order to determine if food is in short supply.

For seabed farming experiments, an improved abalone habitat was designed and 14 of these were fabricated. Final assembly and seabed installation have not been completed. A third year's growth and survival information was obtained for the pink, white, green, and red abalones planted on the previous habitat design, located at the Isthmus of Catalina.

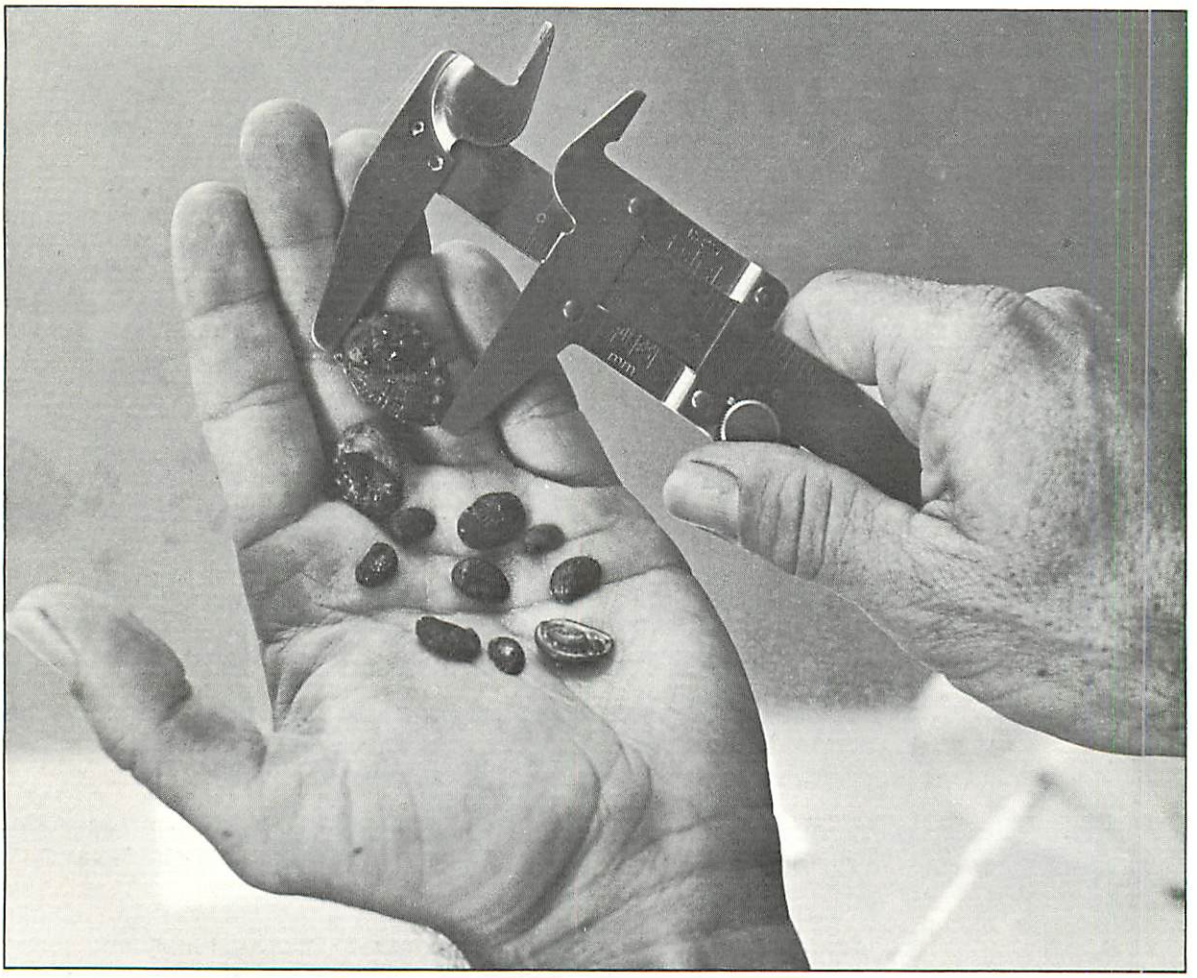
Organisms other than abalones

Research included work on organisms other than abalones. Field experiments on limpets and chitons on intertidal rocks showed that there was considerable competition between the species, which affected their growth rates and numbers.

Detritus feeders

Olivella, a snail on sand beaches, feeds on detritus—particularly small bits of algae. The algae must be partly decayed, and *Olivella,* by living in dense aggregations and reingesting its feces, obtains a high yield in the otherwise rather barren habitat of surf-beaten beaches.

Cages were set up to exclude birds from small areas of sand flat in Mugu Lagoon, a protected coastal area. Since a great number of shore birds feed here at low tide, their effect on the population dynamics of the invertebrates should be enormous.□



Inch-long juvenile pink abalone is approximately one year old.

If abalone can be reared successfully under controlled conditions, it may be possible to operate hatcheries for restocking the presently depleted wild abalone fishery and eventually to establish a commercial abalone aquaculture program that raises the animals to marketable size. Marine biologists are now growing five species of commercially important abalone to examine larvae for future *in situ* identification and to determine their physical and biological needs. At this point, the green abalone seems to be the best candidate for aquaculture, since it grows best at high temperatures and achieves a rate of growth nearly twice that of the others.

Abalone Larval Ecology and Culture Methodology

David L. Leighton

Larvae of five California abalone species successfully spawned

The abalone culture study is establishing information basic to hatchery production. Over the past year, work at the La Jolla laboratory of the Southwest Fisheries Center, National Marine Fisheries Service, has been successful in obtaining larvae from five California abalone species (the red, *Haliotis rufescens,* the pink, *H. corrugata,* the white *H. sorenseni,* the green, *H. fulgens,* and the black abalone, *H. cracherodii*). The number of spawnings obtained ranged from six red abalone to one black abalone. Larvae of only the red abalone had been observed by earlier workers. Consequently, to allow description and comparison, examination of larvae at all stages was made by light microscope and, in some cases, by scanning electron microscope. The information should aid identification of veliger larvae in plankton samples. Differences between specific larvae are subtle, with tissue pigmentation and shell microsculpture being the criteria most diagnostic.

Temperature studies

Extensive and continuing study is being made of the influence of temperature on development, survival, and growth of larvae, post-larvae, and juveniles. Observations on survival and rate of development in larvae are made at a series of ten temperatures between 8 and 31°C. Curves generated for the five species indicate that optima for the warmer-water species (the green and the pink abalones) lie between 18 and 24°C. Those for the colder-water abalones (the red and the white abalones) exist between 14 and 18°C. The black abalone, while essentially an intertidal species living over a much broader latitudinal range than the others, exhibited an optimum similar to that of the colder-water species.

Green abalone likes warmest water

Juveniles reared at six temperatures between 12 and 25°C reflected specifically different ranges for optimal growth. The green abalone survived and grew well at the highest thermal situation provided, 23-25°C. While few observations are available so far, it appears that the species is capable of growing at about twice the rate of the others. Since it does well at elevated temperatures, the green abalone might be reared profitably using heated effluent water generated from power plants.

Search was made for a naturally occurring food organism that could be cultured easily and might be used in hatchery culture of post-larval abalone. A species of *Nitzschia* (yet unidentified) appears to be particularly satisfactory.

Most sensitive at post-larval stage

Greatest attrition of mass-cultured abalone occurred during post-larval stages. During this critical period, begun at settling and lasting for two or three months, optimization of the physical and biotic microenvironment is highly important. A major emphasis is now being placed on observations and experiments that may indicate the "ideal" environment. Behavioral responses of settling larvae to substrate varied with respect to light, current, composition, texture, and quality and quantity of diatom cover are being studied. Experiments in progress are providing evidence that all these factors influence initial settling and constitute important parameters for continued survival of post-larvae.

Year-long tests continue

Juveniles of four species reared from the egg in the laboratory have been maintained under hatchery conditions (semi-controlled) for approximately one year. Size attained at one year was as follows:

	Mean (mm)	Range (mm)	No. Obs.	Record
H. rufescens	18.0	16.0-20.0	15	10 months
H. corrugata	17.6	8.2-28.4	36	11 months
H. sorenseni	13.4	8.0-21.0	19	12 months
H. fulgens	30.0	24.5-35.5	3	11 months

(Projections have been made where observations cover less than one year.)

Rather marked variability in growth rate is observed in all species. These first-year growth estimates likely reflect suboptimal feeding and growing conditions and should be considered conservative and certainly preliminary. Subsequent study will increase sample size and provide both hatchery and field comparison.□

Publications

LEIGHTON, David L. Laboratory observations on the early growth of the abalone, *Haliotis sorenseni,* and the effect of temperature on larval development and settling success. *Fishery Bulletin.* v. 70, no. 2, 1972 pp. 373-381.

Cooperating Organizations

California Marine Associates, Cayucos, California
Southwest Fisheries Center, National Marine Fisheries Service, La Jolla, California

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The California seaweed industry has encouraged university biologists to try and boost U. S. production of several varieties of algae by expanding upon ancient Japanese cultivating techniques. Research on spore formation and function and on attachment and germination may lead to new methods of propagation. The research team developed a computer-assisted harvesting model for optimal utilization of a seaweed resource and a low-cost telemetry system that transmits light and temperature data from the sea floor near planting areas to laboratory recorders.

Santa Barbara
R/A-4

Continued Studies of Seaweed Resource Management

Michael Neushul, Alex C. Charters, and Walter Mead

Visit to Japan

The Japanese have 300 years of practical experience in the cultivation of seaweed. On a visit to Japan, we were awed by many thousands of acres of

seaweed cultivation nets, new techniques of open-ocean cultivation, and techniques for holding germling stages at freezing temperatures until optimal planting times.

Supporting industry

We think the western world can expand upon traditional oriental seaweed cultivation, and the three major seaweed companies in California (Kelco Corporation, Ocean Labs, Inc., and American Agar) are very cooperative toward that end. All of them have provided us with continuing advice and financial support. Five members of the Santa Barbara Seaweed Research Group were able to go to Japan in large part because of the funds supplied by Kelco and Ocean Labs.

Marine botanists meeting

Marine biologists in California working on academic aspects of marine botany are also helpful. Sponsored by Sea Grant, a group of 27 marine biologists met at UC, Santa Barbara, in April to look at films and slides taken in Japan and to discuss problems of seaweed resource management. Participants at the meeting discussed their recent unpublished work and their ideas about some of the unique problems that face us. While we see the Japanese programs as large and well funded and our own mariculture programs as just starting, we are nonetheless optimistic about the potential in California for substantial development.

Spore studies interest Japanese

As might be expected our experience in Japan stimulated us to emulate some of the Japanese techniques. However, it must be remembered that the Japanese, by their own admission, do not have all the answers. We were pleased to find that our approaches to basic problems of spore form and function and aspects of spore attachment were of great interest to the Japanese. Nowhere in Japan did we see a multidisciplinary approach involving engineers, economists, and phycologists such as the one that is developing here. In approaching the basic question, How do you plant the crop?, we went back to the basic hydrodynamic problems of algal spore attachment and germination. Surprisingly, the Japanese have not done this. Our ultrastructural work on algal germ cells is also new and interesting to the Japanese.

Computer-assisted harvesting model

Rope-line cultivation

Over the past year we devoted effort to the completion of a computer-assisted harvesting model, a program for optimal production from a seaweed resource derived by combining economic and biological information. We tried one of the more promising types of Japanese rope-line cultivation systems and installed a full-scale unit in the sea near our laboratory. We studied the growth and survival rates for four algal species of potential economic value planted on the rope-line system. The results of this trial effort suggest to us further approaches that might be more applicable to the unique water conditions and harvesting problems that we face here in California. We have not been able to harvest in quantity or to develop packaging approaches.

Packaging problematic

Telemetry system

In order to obtain environmental data we designed and built a simple low-cost telemetry system that will transmit light and temperature data from the sea floor adjacent to our offshore planting areas directly to our laboratory recorders. The anchoring system and a trial spar buoy for the unit were installed at the outplanting site. The transmitter and receiver are in the final testing states, and the antenna-support buoy is in the final stages of assembly.

We installed outplanting structures in two areas on the sea floor near our laboratory. Using these, it is possible to follow the growth and development of algal spores on substrates that are brought into the laboratory for detailed microscopic study and then replaced in the sea. With this system we can study vegetative reproductive phenomena, competition, and sedimentation problems in detail.

Considerable effort was devoted this past year to the dissemination of information about seaweed resources. In addition to holding the seaweed research conference mentioned earlier, we hosted visits by representatives of seaweed industries and California Department of Fish and Game officials. Members of our group gave lectures to the general public and produced a TV tape that was shown twice last year.

Independent agarweed harvesting boats operate off Catalina Island

An agarweed harvesting effort involving four to five independently owned harvesting boats has developed and is operating off Catalina Island. American Agar buys the harvested plants. Our Sea Grant-funded studies of agarweed growth and reproduction will undoubtedly be of considerable use to the state officials who will be in charge of seeing that this natural resource is optimally used.□

Publications

FOSTER, Michael. Experimental studies of subtidal plant communities. University of California, Santa Barbara, Ph.D. 1972. (Thesis completed.)

FOSTER, M., M. NEUSHUL, and E. Y. CHI. Growth and reproduction of *Dictyota binghamiae* J. G. Agradh. *Botanica Marina.* v. XV, 1972. pp. 96-101.

The present study was undertaken in part to provide a more complete description of the vegetative and reproductive morphology of *Dictyota binghamiae* than has heretofore been available. In addition, vegetative growth rates were measured and the formation and release of gametes and spores was studied.

NEUSHUL, M. The effects of pollution on populations of intertidal and subtidal organisms in Southern California. In *Santa Barbara Oil Symposium.* U. S. Government Printing Office: 0-463-300, 1972. pp. 165-172.

Since 1956 the author has participated with various colleagues in three studies on this coast that can be categorized as "pollution studies." One dealt with the effects of discharged wastes on kelp. One dealt with the effects of an oil pollution incident. A third study was done recently with A. C. Charters, M. Foster, and R. Zingmark, and deals with the amounts and distribution of oil and the initial effects of the Santa Barbara Oil Spill (1970).

NEUSHUL, M. Underwater microscopy with an encased incident-light dipping-cone microscope. *Journal of Microscopy.* v. 95, prt. 3, June 1972. pp. 421-424.

Direct *in situ* microscopic observation of opaque underwater substrates is possible through the use of a modified Leitz incident-light, dipping-cone microscope.

NEUSHUL, M. and A. L. DAHL. Ultrastructural studies of brown algal nuclei. *American Journal of Botany.* v. 59, no. 4, April 1972. pp. 401-410.

The nuclei of four brown algae (*Dictyota, Padina, Zonaria,* and *Dictyopteris*) have been studied using sectioning and freeze-etching techniques. A comparison of the results obtained with those of earlier workers suggests that nuclear structure may be similar throughout the Phaeophyta.

NEUSHUL, M. and A. L. DAHL. Zonation in the apical cell of *Zonaria. American Journal of Botany.* v. 59, no. 4, April 1972. pp. 393-400.

Light and electron microscopic techniques were used to study the row of apical cells that form the meristem of the dictyotalean brown alga, *Zonaria farlowii.*

WALKER, David. Experimental studies of cytoplasmic organization in *Zonaria* apical cells. University of California, Santa Barbara. Master's. 1972 (Thesis completed.)

Cooperating Organizations

American Agar, San Diego, California
Kelco Corporation, San Diego, California
Ocean Labs, Inc., Irvine, California

An artificial brackish pond, although rich in nutrients and filled with enough phytoplankton to support secondary production of animal grazers, is nevertheless unsuitable for mariculture experiments. Only manipulation of the pond by aeration and by adding nutrients and controlling salinity could give it commercial value.

Santa Barbara
R/A-5

Ecosystem Studies and Maricultural Potentialities of a Coastal Lagoon

Robert W. Holmes

Our studies of the maricultural potential of an artificial, eutrophic salt pond ("coastal lagoon") reveal that the particular system examined is not suitable for mariculture without considerable manipulation.

Concentration of nutrients by evaporation makes pond eutrophic

Seasonal temperature and salinity fluctuations disadvantageous

Different flora alternately dominate

The pond receives water rich in nutrients in the form of campus runoff and seawater. On an annual basis, evaporation exceeds these inputs with the result that the pond effectively concentrates nutrients and is thus becoming progressively more eutrophic. While such a process should increase primary production and thence secondary production, the wide seasonal fluctuations in temperature and salinity (due to variations in rainfall and evaporation) make this a particularly harsh environment unsuitable for many organisms of commercial value. Furthermore, in its present state, two very different types of primary producers successively dominate the system. From December-January to April-May, phytoplankton are the primary producers; while from May-June to December, *Ruppia maritima,* an aquatic angiosperm, dominates and reduces nutrient levels to such low levels that phytoplankton are insignificant producers during the *Ruppia* season. Furthermore, the dense growth of *Ruppia* appears to reduce water movement sufficiently to cause the bottom water layers to become anaerobic due to the high oxygen demand of the sediments. Again, such events preclude the successful culture of organisms of commercial value that are intimately associated with the sediments. Such techniques as aeration might be employed to oxygenate the bottom water.

Productive pond not productive enough

Measurements of phytoplankton and *Ruppia* production over a year period showed that the pond was highly productive and comparable to other highly productive lakes, but it was roughly an order of magnitude less productive than many aquaculture systems.

These observations lead us to conclude that this aquatic system in its present state is unsuitable for commercial mariculture. Manipulation of the system by controlled additions of seawater or perhaps fresh water, aeration, etc. would probably make the system amenable to mariculture, but increased primary production would also be required, necessitating the addition of supplemental nutrients.□

The basis for any successful mariculture venture is the establishment of techniques to rear the target organism under controlled conditions until the early, sensitive developmental stages are passed. The northern anchovy and a species of croaker have been brought to maturation in the laboratory and are now providing viable sperm and eggs for further experiments. Marine biologists hope to repeat their success with the Pacific sardine.

The sensitivity of marine fish larvae to their environment, although a drawback in mariculture experiments, makes them excellent bioassay organisms for the presence of pollutants or alterations in the natural environment. Studies on egg and larval reaction to changes in seawater salinity, temperature, and ionic composition were completed, while new tests began on the progeny of DDT-fed mother croakers.

Rearing of Larval Marine Fishes

Reuben Lasker

Sea Grant has supported part of a joint program among Scripps Institution of Oceanography, UC, San Diego; the Southwest Fisheries Center (SWFC), National Marine Fisheries Service; and the Marine Research Committee of California, to study larval development and growth of marine fish. Several lines of research have been started: (1) the maturation and induction of spawning of marine fish in the laboratory to provide viable sperm and eggs, (2) the development of methods for the mass cultivation of larval fish food organisms, (3) the manufacture of a synthetic larval fish food pellet to replace cultured food organisms, (4) the design and production of special larval fish rearing chambers that permit timely assessment of growth and mortality, and (5) the study of environmental variables on larval fish development.

Maturation and induction of spawning marine fish

We continued to refine our techniques and capitalize on the success reported in last year's report on the induction of spawning marine fishes. The northern anchovy, *Engraulis mordax,* once entrained by a photoperiod of 4 hours day and 20 hours night, continued to spawn spontaneously throughout the year without the necessity of hormone injections. From a 700-fish school in the aquarium at the La Jolla Laboratory of SWFC, an average of 1,000 fertilized eggs per night were obtained throughout the year. The croaker *Bairdiella icistius* continues to require hormone injections, but it was discovered that an ovarian biopsy could be used to accurately predict the exact time when injections could be given to insure maximum viability of the eggs. The sardine *Sardinops caeruleus* was brought to maturity with a photoperiod of 8D-16N, but few fertilized eggs were obtained and only after gonadotrophin injection. The yellowtail *Seriola dorsalis* and the Pacific mackerel, *Scomber japonicus*, spawned spontaneously in outside tanks. This leads us to believe that they would be suitable animals for experimentation on artificial induction of their spawning.

Mass cultivation of larval fish food organisms

A culture room was set up in the SWFC aquarium to produce the dinoflagellate *Gymnodinium splendens* and the rotifer *Brachionus plicatilis* in mass culture for feeding to fish larvae. Both of these organisms have been shown to support growth of the larval anchovy. Optimum growth conditions for *G. splendens* were determined this year.

45

Synthetic larval fish food pellets

A number of microencapsulated foods of the proper size were prepared and tested with anchovy larvae. The larvae eat the particles readily and grow on them. The main obstacle to continued success in rearing these animals on microencapsulated particles is the putrefaction that occurs when the particles settle to the bottom. An alternate technique (i.e., the preparation of a time-release particle that will completely disperse and dissolve if uneaten) gives promise of success.

Rearing chambers

Special rearing containers for rearing anchovy larvae on a variety of diets were designed and built. These provide a constant but slow flow of fresh seawater and provide for the capture and removal of larvae when needed for experiments.

Environmental variables affect larval development

With Sea Grant support, Robert C. May completed his research on the effect of salinity, temperature, and altered ionic composition on the fertilization, development, hatching, and yolk utilization of *Bairdiella* eggs and larvae. He found that the production of a high percent of abnormal embryos depends on the combination of low salinity and increased temperature of the incubation seawater. The high sulfate content of water from Salton Sea, where this fish has a large introduced population, is very detrimental to development.

DDT experiments

B. icistius are receiving DDT-contaminated food and were spawned periodically to determine the effect of contaminant residues deposited in larval yolk on the survival of newly hatched larvae. Recent spawning trials suggest somewhat reduced survival of progeny from contaminated parents, although the eggs still contain less than 1 ppm (wet weight) of the contaminant. Continuing exposure of the parent stocks to dietary DDT should increase the level in the eggs and yield a threshold concentration for survival of the larvae.

The effect of DDT contamination on the ability of *Bairdiella* to acclimatize to sharp temperature change is under study. In initial trials, sexually mature fish with moderate levels of pesticide (ca. 2 ppm) residue in their tissue suffered up to 60 percent mortality, whereas non-contaminated fish suffered no mortality when temperature was decreased 6°C for 12 hours. Younger fish that have been receiving contaminated food for three months have not yet been adversely affected by such a temperature change. The severity of the temperature shock is now being increased to approach more closely the limit that can be tolerated by uncontaminated fish.□

Publications:

MAY, Robert C. Effects of temperature and salinity on the eggs and early larvae of the sciaenid fish, *Bairdiella icistius* (Jordan and Gilbert). University of California, San Diego, Scripps Institution of Oceanography. Ph.D. 1972. (Thesis completed.)

THEILACKER, G. H. and M. F. McMASTER. Mass culture of the rotifer *Brachionus plicatilis* and its evaluation as a food for larval anchovies. *Marine Biology.* v. 10, no. 2, July, 1971. pp. 183-188.

THOMAS, W. H., A. N. DODSON, and C. A. LINDEN. Optimum light and temperature requirements for a larval fish food organism, *Gymnodinium splendens. Fishery Bulletin (U. S.).* (In press.)

Cooperating Organizations

Marine Research Committee, California
Southwest Fisheries Center, National Marine Fisheries Service, La Jolla

The fatty acids of marine animals are highly unsaturated and are consequently susceptible to attack by oxygen in the air. The resulting oxidation causes decomposition and makes for rancid fish products. Isolation from air prevents oxidation, but the development and use of edible antioxidants offer a more versatile solution. N-hydroxyproline, derived from an amino acid, has been found to have promising properties.

Davis
R/F-1

Food Uses of Marine Resources (Lipids)

Harold S. Olcott

Oxidation rates studied using four methods

During the past year, rates of oxidation of unsaturated lipids were studied by several methods: (1) weight gain of water-free substrates, such as fish oil, fish oil esters, and squalene in contact with air at different temperatures, (2) development of peroxides during similar incubations, (3) loss of C22:6 fatty acid from fish oils and esters, and (4) use of oxygen analyzer to follow oxygen uptake by water emulsions of sodium linoleate with catalysis by heme compounds.

Amino acid derivatives tested as antioxidants

Amino acid derivatives tested by Method 1 were esters of proline, N-methylproline, and N-hydroxyproline. Only the last proved effective enough an antioxidant to warrant further study. N-hydroxyproline is derived from the amino acid, proline, and should be safe for a food additive.

In studies of aqueous systems (Method 4), linoleate oxidation was markedly catalyzed by solution containing heme proteins and by iron and copper inorganic salts as previously demonstrated by many others. Preparations of hemocyanin, the copper-containing blood proteins of the abalone (and other marine organisms), were found not to be catalytic, an observation that inities further investigation.

Agitation slows oxidation

Rates of unsaturated compound oxidation appeared (by Methods 1, 2, and 4) to be affected by agitation. Beakers containing squalene or menhaden oil methyl esters oxidized at a slower rate when shaken at a slow rate than their quiescent controls. Further study on this unexpected observation is in progress.□

Cooperating Organizations
Tuna Research Foundation, Terminal Island, California

Food technologists are trying to control discoloration in processed fish. They have discovered that tuna turns green when naturally present denatured myoglobins and peroxides react with each other. After being frozen, tuna turns brown and orange when nucleotides breakdown to form a sugar, ribose, which reacts under heat with amino groups in tissue protein. To keep tuna pink, newly discovered chemical stabilizers can be added.

Davis
R/F-2

Studies of Fish Muscle Proteins

William D. Brown

A number of naturally occurring muscle constituents have been found to markedly influence autoxidation of oxymyoglobins. They include various sulfhydryl-containing substances, such as cysteine and glutathione, and several organic phosphate materials, including nucleotide breakdown products (e.g., inosine monophosphate) and pyridoxal phosphate. Many of these reactions apparently involve peroxide intermediates and perhaps superoxide ions.

Peroxides will react with denatured tuna myoglobins to form a green pigment. The reaction is different from one we reported earlier (with others) that involved trimethylamine oxide and cysteine.

Breakdown of nucleotides in frozen fish muscle

We have found that continuing breakdown of nucleotides in frozen fish muscle (such as tuna) will produce, under commercial handling conditions, substantial quantities of ribose. When heated, this sugar readily reacts with amino groups in tissue proteins to form brown and orange pigments. Lower storage temperatures will inhibit the breakdown to ribose. We are exploring alternate methods of inhibition, such as using chemical additives.

Derivatives of nicotinic acid and nicotinamide produce stable pink pigments

Edible additives

We have found that a number of derivatives of nicotinic acid and nicotinamide will react with myoglobins to produce reasonably stable pink pigments. Those particularly effective are N,N-diethylnicotinamide and nicotinic acid hexyl ester. The pigments formed are subject to oxidative change, but his may be inhibited by the presence of ascorbic acid. The compounds might be used as color stabilizers in tuna used for human food. They may also have utility as substitutes for nitrite currently used in a variety of canned pet foods containing various fishery by-products.□

Cooperating Organizations
Bumble Bee Seafoods, Astoria, Oregon
Del Monte Corp., Walnut Creek Research Laboratories, Walnut Creek, California
Star-Kist Foods, Inc., Terminal Island, California
Tuna Research Foundation, Terminal Island, California

In the western world, the utilization of marine foods has been mostly limited to the consumption of fresh or canned fish products. For centuries, however, the Orient has produced acceptable, nutritious food through the microbial fermentation of all kinds of marine organisms — the less desirable included.

Investigations of the chemical changes that occur and the products produced in such fermentations reveal that the microorganisms responsible for fermentation have tremendous enzymatic capabilities. There is interest in isolating microorganisms and further characterizing their metabolic potential for producing new foods from under-utilized marine resources and for developing new economical processes for recovering fisheries waste products now creating an environmental problem.

Natural Fermentation of Marine Products

Eli V. Crisan and
Martin W. Miller

Selected Oriental fermented marine products

More than 30 samples of fermented marine products were obtained from Japan, Korea, Malaysia, and the Philippines (Table 1).

Table 1. Fermented marine products undergoing microbiological analysis listed by country of origin.

Korea
- Alaskan pollock, intestines, salted
- Alaskan pollock, roe, salted
- anchovy, salted
- clam, salted
- cuttlefish, salted
- oyster, salted
- roe, unidentified fish, salted
- sea arrow, salted
- sea urchin, salted
- shrimp, salted

Japan
- fish paste, "ounago"
- fish paste, "koami"
- gold fish with rice bran
- sardine, pickled, with rice bran

Philippines
- fish paste, "patis," solids
- fish paste, "patis," supernatant, 1 mo.

Malaysia
- shrimp paste, "belachan," 8 samples

Thailand
- fish paste, "nam pla," 33% salt, 1st grade, finished
- fish paste, "nam pla," 33% salt, 2nd grade, finished
- fish paste, "nam pla," 50% salt, 1st grade, 3 mo.
- fish paste, "nam pla," 50% salt, 1st grade, 6-7 mo.
- fish paste, "nam pla," 50% salt, 1st grade, finished
- fish paste, "nam pla," 50% salt, 2nd grade, 1 da.
- marine salt, 4 samples
- soil from "nam pla" processing area

The large variety of microorganisms present in these products were isolated, and they include such bacteria as the lactic acid bacteria and spore-forming bacilli as well as several yeasts and filamentous fungi. Studies to determine the role of each group of organisms in a specific fermentation are in progress.

Perfection of one-step method for isolating fermenting organisms

Microorganisms that ferment marine products are primarily lipolytic and/or proteolytic. Microbiological methods are being developed to permit a one-step procedure for isolating and characterizing organisms capable of digesting lipids or proteins. Methods presently available for determining such activity are inadequate for use with marine proteins or lipids.

Upgrading fish meal feed

A study was initiated to determine the efficacy of using microbiological methods to improve the quality of feed-grade fish meal. Microorganisms are being assayed to ascertain their ability to convert fish lipids, trimethylamine, and trimethylamine oxide to microbial protein. The successful removal of these undesirable substances will extend the useful life of fish meal as a feed supplement and improve its nutritive quality.

Microbial versus enzymatic fermentation

An intensive study is being conducted to characterize the microbial content and activity occurring during the fermentation of belachan, a Malaysian shrimp paste made from Acetes and Mysid shrimp. The primary effort will be made towards distinguishing between changes induced by microbial action and those resulting from the intestinal enzymes present in the raw shrimp.□

Cooperating Organizations
Food Technology Research and Development Centre, Division of Food Technology, Ministry of Agriculture and Land, Sungei Besi, Selangor, Malaysia

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Monitoring the fish communities of the Santa Barbara kelp forests points out which varieties of fish are most abundant and poses the question, Why are some abundant varieties never caught? Monitoring fish feeding habits and utilization of space also separates "generalists" from "specialists" — generalists being those fish species occupying a wider ecological niche by virtue of their ability to accept variety in the food they eat and the places they live. Biologists combine community assessment data and ecological niche data to determine whether the generalists are more catchable (percent angled/abundance) than specialists.

Santa Barbara
R/F-4

Fishes of the Santa Barbara Kelp Forests

Alfred W. Ebeling

21 resident species analyzed

Objectives of the past and present studies are: (1) community assessment — first determining kelp bed habitat groups (fish "communities") and their interactions, then comparing these groups with groups from mainland and island areas from year to year and (2) measurement of ecological niche breadths — an analysis of resource needs of the 21 most important resident species shown by the initial resolution of groups by factor analysis. Estimates of community parameters are probably sensitive enough to show the early signs of possible pollution damage. The breadth of a species' ecological niche may indicate its survival potential in a changing environment

and its "catchability" in an underexploited "pan fishery." "Catchability" will be determined as percent angled/abundance, so that the predicted concordance of catchability with ecological generalization can be tested.

Underwater filming

Community assessment involves filming, counting, and analyzing cinetransects for the among-years comparison of community structure by diversity indices and species-rank correlations. The initial analysis of samples from all seasons and habitats (1969-70) indicated that, for yearly monitoring, it would be best and easiest to film sample sets during the fall when the water is predictably clearest from canopy to rocky bottom. Therefore, a pilot monitoring collection of "cinetransects" was filmed during September and October, 1971, including sample sets from mainland and island, canopy and rocky bottom habitats. Unlike the original collection, then, the monitoring collection contains samples from relatively stable and clear rocky areas filmed during only one season. Despite the limited scope of the pilot monitoring, diversities are remarkably similar between these and the original sample sets (Table 1). This indicates either that the communities are fairly homogenous among localities and seasons or that the diversity statistic is insensitive. Forthcoming results of the second annual monitoring (1972), just completed with 160 cinetransect samples, should provide a better idea of the applicability of the diversity statistic.

Table 1. Species diversity (H) and its components of evenness of distribution of individuals among species (J) and number of species (S) for principal mainland and island communities of kelp-bed fishes.

Habitat Group	Collection	Locality sample set	Sample size	Mean "Pielou H" estimate of community diversity ± standard error	Mean sample H ± S.E.	Median sample J	Total species per sample set	Median sample S	Mean sample S ± S.E.
Bottom	1969-70	Mainland	48	2.37±.09	1.09±.06*	0.840	24	6.3	6.06±.38
		Island	46	2.41±.06	1.36±.05	0.796	23	8.9	8.89±.38
	1971	Mainland	25	2.39±.075	1.32±.05	0.866	20	7.75	7.28±.42
		Island	37	2.45±.05	1.46±.035	0.857	20	9.1	8.68±.32
Canopy	1969-70	Mainland	27	1.64**	0.83±.08	0.637	14	4.9	4.93±.50
		Island	27	1.42**	0.82±.08	0.6085	16	5.2	5.56±.48
	1971	Mainland	13	1.31**	0.51±.095	0.642	11	3.3	2.69±.29
		Island	22	1.10±.15	0.68±.05	0.504	13	5.2	4.55±.33

*Significantly lower than mean $\underline{H}$ for island sample set

**Distribution of statistic precludes calculation of standard error

Table 2. Correlation of species composition among sample sets from Mainland and Island bottom communities.

Numbers in the matrix are the Kendall coefficient of rank correlation, tau, which may be used as an index of similarity between communities (Ghent 1963, 1972). The San Diego mainland values were calculated from "sight-transect" data in Quast (1968).

		Mainland 1969-70	1971	Island 1969-70	1971	San Diego Mainland
Mainland	1969-70					
	1971	0.49*	—			
Island	1969-70	0.03	0.07	—		
	1971	0.00	0.00	0.55*	—	
San Diego mainland		0.19	0.03	0.49*	0.55*	—

*Significant at the $P<.01$ level (the others are non-significant).

Species' frequency corrolated

The general composition of the mainland and island bottom communities also remained about the same between the original and monitor sample sets. Ranks of the frequency of occurrence of the 12 most common species are significantly correlated between years within localities, but not between

island and mainland, which show substantial environmental differences. The island bottom community more closely resembles that of the San Diego mainland, which has clear water and rocky shores like the islands, than that of the Santa Barbara mainland, which has more turbid water and sandy bottom (Table 2).

Gut-content samples indicate feeding habits

Niche-breadth studies of rockfishes, seaperches, and the kelp bass are well underway. We emphasize the species' feeding habits (as determined by identification and analysis of principal dietary items) and their utilization of space (as determined by recording frequencies of occurrence by habitat from the cinetransects). Fifteen gut-content samples from each of five seaperch species were analyzed. Analyses of the others are well underway. To investigate temporal dimensionality of the niche, contents of specimens speared during the day were compared with contents of specimens speared at night.□

Publications

ALEVIZON, William S. Habitat selection and competition in congeneric surfperches (embiotocidae) off Santa Barbara, California. University of California, Santa Barbara. Master's. 1971. (Thesis completed.)

EBELING, A. W., R. LARSON, W. ALEVIZON, and F. A. DEWITT, JR. Fishes of the Santa Barbara kelp forest. *Second National Coastal and Shallow Water Research Conference, Abstract Volume.* 1971. p. 61.

This is a brief resume of how analyses of associations and habitats of kelp bed fishes will be used to detect possible temporal changes in fish communities. Underwater movie strips provide observations on fish abundances and environment used to characterize communities by various measures of species diversity. Individual studies of the ecological niches of representative species should help interpret any yearly changes in community diversity.

When evening approaches, many species of zooplankton migrate vertically to the surface of the ocean from their deep daytime habitat. They come to graze on floating unicellular algae.

Why the zooplankton do not remain on top feeding 24 hours a day is unknown. Data on the actual time of upward migration seem to suggest another explanation besides the usual one that visually orienting predators make surface waters unsafe during the day. Because zooplankton are sometimes found on the surface long before sunset, perhaps they arrive at a time when food energy is greatest in a standing phytoplankton crop luxuriant after a whole day of photosynthesizing.

San Diego
R/F-5

Studies of Vertical Migration of Zooplankton

James T. Enright

The vertical migration of zooplankton is one of the most conspicous biological phenomena in the world's oceans. The usual observation is an aggregation in the surface waters at night of many sorts of animals, ranging from small crustaceans to medium-sized fish — animals found at considerably greater depths during the daytime. Surface waters that during the daytime seem to be essentially a biological desert may at night be teeming with life.

Predation theory difficult to test directly

Why do so many animals migrate in this fashion? Since primary production takes place in the surface waters, it is obvious that herbivores must spend part of their lives near the surface to feed, so the real question becomes Why don't they feed for 24 hours a day? The most plausible answer given to date is that visually orienting predators make the surface waters unsafe during the daytime so that the selective advantage of additional food intake is overridden by the risk of mortality due to predators. This interpretation has, however, never been tested and would, in fact, be very difficult to test directly.

Computer study supplies testable prediction to support metabolic-advantage hypothesis

This research project was based upon an alternative interpretation that depends upon an interaction between herbivores and the population dynamics of the algae. Granted certain not-unreasonable assumptions about primary production and about metabolism and feeding rates of herbivores, an herbivore may be able to obtain more food energy for growth and reproduction by feeding intermittently at night than if he's fed 24 hours a day. Direct measurements of the biological parameters required to test this interpretation more rigorously are very difficult to make (e.g., herbivore metabolism at various temperatures, while the animals remain suspended in the water column, both while feeding and while "resting"). However, computer study of a mathematical model based on this hypothesis led to a surprising and readily testable prediction: if the "metabolic advantage" hypothesis is of real and major significance, the herbivores should be able to obtain maximal energy gain by beginning to feed an hour or two before sunset, rather than after sunset. The alternative "predation" hypothesis demands that the animals stay hidden in the deeper waters until darkness.

Sampling program

In order to test this prediction, a sampling program was undertaken to determine the actual time of upward migration by herbivores. This required a new sampling device for replicated, vertically stratified tows that could be repeated at half-hour intervals. The device was built. In April, May, and July, 1971, approximately 700 specimens were taken during three three-day-long samplings. And during the last year, the zooplankton in a critically major fraction of the samples (more than 400) were identified, sexed, and counted. In terms of man-hours, this last item represents the major accomplishment of the past fiscal year.

Preliminary analysis of test results shows project success

The full evaluation of the data is incomplete, but a preliminary analysis demostrated that the project was a major success. The samples are extremely consistent internally — far better than most field studies — and clearly document the time at which the most abundant crustaceans entered the mixed layer. The table below records the approximate "crossover times" (times after which more than 50 percent were in the mixed layer) for Stage V of the copepod, *Calanus helgolandicus*, the most abundant organism present on all three sampling dates. (The full original data document the trends involved much more convincingly than this abstracted table alone). During both April and May, these animals were at the surface long before sunset; in July, they rose only well after sunset. The July data are thus consistent with the "predation" hypothesis, but the April and May data are decidedly not and require some special explanation.

April 26	35 min before sunset
April 28	5 min before sunset
April 30	100 min before sunset
May 24	90 min before sunset
May 25	155 min before sunset
May 26	55 min before sunset
July 6	45 min after sunset
July 7	95 min after sunset
July 8	40 min after sunset

"Crossover times" for Stage V of *Calanus helgolandicus* during the present sampling study. (1971)

One interpretation of the data is that the "metabolic-advantage" hypothesis may account for the April and May early migrations: during the spring

Both hypotheses valid under different conditions

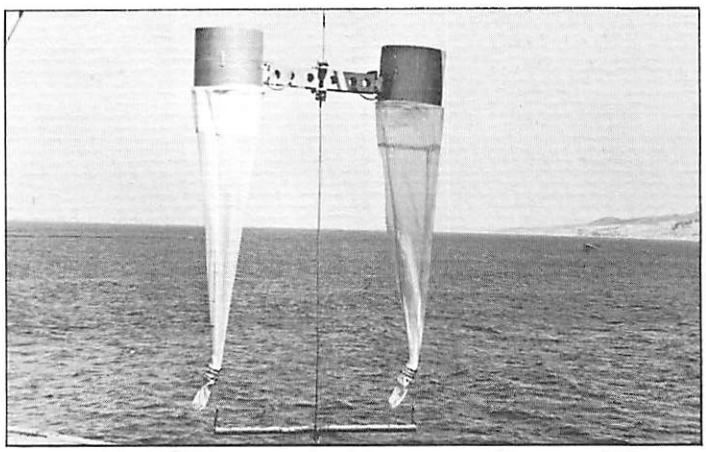
"bloom" of phytoplankton when the copepod population is rapidly increasing, the behavior is as predicted by the computer study. The July data suggest a change in selection pressure: as populations of visually orienting predators (probably primarily fish larvae) increase and primary production decreases, the major reason for vertical migration may, indeed, be avoidance of predators; hence, the copepods waited until after sunset to rise to the surface.

In a field study of this sort, one should always be prepared for the possibility of being right for the wrong reasons. The present interpretation of the data may, of course, be wrong. In any case, however, the data, which so clearly show pre-dusk rise of the copepods, represent a new and significant aspect of vertical migration that must be accounted for by any adequate hypothesis.□

Publications

BROWN, D. M. and H. W. HONEGGER. New rapid-sampling, vertical tow net. For *Marine Technician's Handbook Series, Scripps Institution of Oceanography.* (In press.)

The paper describes the net designed and built for this project, for rapidly taking replicate vertically stratified samples of zooplankton.



New tow net takes replicate, vertically stratified samples of zooplankton.

Future ability to forecase sea surface temperature could depend, in part, on temperature and velocity measurements now being taken in the East Pacific with instruments dropped into surface waters from aboard FLIP, a 355-foot-long floating instrument platform.

San Diego
R/F-6

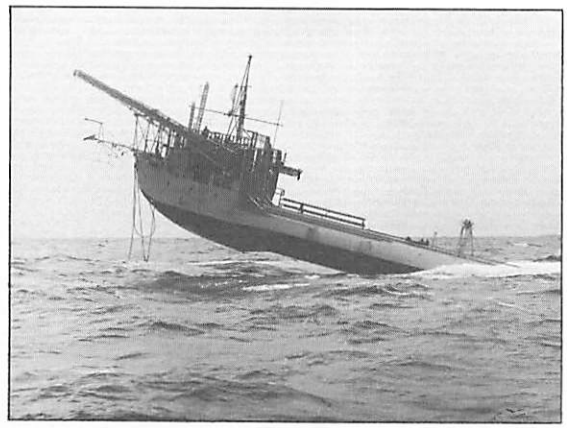
Sea Surface Temperature Prediction

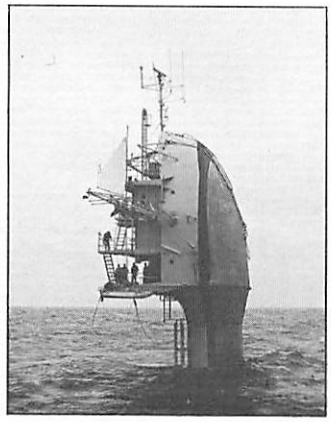
Carl H. Gibson

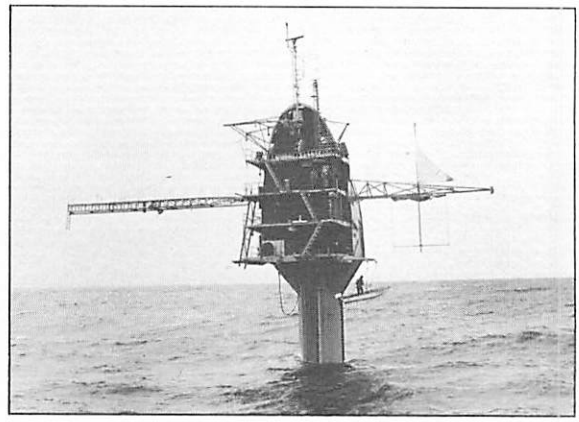
Experimental operations off Ensenada, Mexico

In two experimental operations 60 miles off Ensenada, Mexico, in February and April, 1972, fine-scale measurements of velocity and temperature were made in the mixed layer of the ocean. A four-inch ducted current meter

FLIP, a 355-foot Floating Instrument Platform, was developed by Marine Physical Laboratory at Scripps Institution of Oceanography, University of California, San Diego. She is photographed here while "flipping" from the horizontal to the vertical position where she will act as an extremely stable platform from which scientists will conduct oceanographic studies. FLIP has no motive power of her own and must be towed to a research site in the horizontal position. Once on station, her ballast tanks are flooded and she "flips" vertically, leaving 55 feet above water.







and a constant temperature hot-film anemometer system were used to measure the mean velocity and velocity fluctuations. A platinum cold-film probe was used in an a.c. Wheatstone bridge to measure temperature fluctuations. The film probes had spatial resolution down to 0.13 mm. The probe package was lowered into the mixed layer from FLIP, a 355-foot-long floating instrument platform that tilts from a horizontal to a vertical position and stays essentially motionless in the open ocean. Mean velocity and temperature and velocity fluctuations and their time derivatives were recorded on FM analog tape. One-dimensional temperature power and dissipation spectra apparently show an inertial subrange and a viscous convective subrange at higher wave numbers. Spectral shapes were used to deduce viscous and temperature dissipation rates.□

Data recorded on FM analog tape

Publications

VEGA, L. A., J. P. CLAY, and C. H. GIBSON. Fine scale measurements of velocity and temperature in the mixed layer of the ocean. *Abstract submitted. Twenty-Fifth Annual Meeting for the Division of Fluid Dynamics of the American Physical Society, November 1972.*

About 500 fish from zooplankton samples collected in California coastal waters over the last two decades have been analyzed, and results show a build-up of DDT in the southern California ocean environment. The increase comes from pesticide manufacturing wastes dumped into the Los Angeles sewage system.

Another pollution threat is non-degradable polychlorinated biphenyls (PCBs) used in plastic making. Unlike DDT, which mostly enters the ocean via the sewers, the source of PCBs appears to be atmospheric fallout. PCB concentrations were measured in zooplankton samples taken during 1969.

Chemical Pollutants in the Biota of the California Current

Reuben Lasker and Vance McClure

Inshore zooplankton generally lower in PCBs than offshore

Three hundred twenty-one zooplankton samples taken throughout the California Current in 1969 were analyzed for PCBs (Arochlor 1254 and 1252) and DDTs (DDT + DDE + DDMU). PCBs averaged 33 ppm in hexane-extracted lipid, while the DDTs averaged 2.5 ppm. PCBs in zooplankton taken inshore were usually lower than in those captured offshore in the middle of the Current. The exceptions were in inshore stations off Baja, California (e.g., Vizcaino Bay) where the California Current impinges on the coastline. Coastal upwelling could be a cause of low PCBs in California inshore zooplankton.

Offshore winds deposit PCB fallout

PCB concentrations in zooplankton during the fall of 1969 were highest in areas west and southwest of metropolitan and industrial areas, and the average value for these months over the whole sampling area was twice as high as levels during the rest of the year when offshore winds are less frequent.

35 metric tons of PCBs per year predicted in the LA metropolitan atmosphere

Onshore sea breezes contribute a flux of about 0.2 g/km²/day of DDTs and dieldrin and appear to be a contribution from hot inland agricultural areas whose DDTs are borne aloft by thermals. In February, 1972, fallout of PCBs on La Jolla atmosphere averaged 0.4 g/km²/day. La Jolla is in the lee of Los Angeles much of the year, and a simple model of transport based on Los Angeles as a source correlates well with the measured flux data. The model predicts that 35 metric tons of PCBs will be generated per year in aerosol form by the Los Angeles metropolitan area. San Diego's source strength was calculated to be 7 metric tons per year.

PCBs in seawater samples taken off California and Baja, California averaged 5 parts per trillion. Therefore the coastal water extending from San Francisco to Vizcaino Bay and 250 km offshore to a depth of 200 m contained about 500 metric tons of PCB in 1969. Sewers and runoff seem to contribute no more than 15 metric tons per year. Fallout seems to be the major PCB contributor to the ocean.

Pesticide DDT residue dumped off Palos Verdes for 20-year period

Most of the DDT in the ocean environment off southern California originated from a point source rather than from widespread agricultural activities. This point source is the Los Angeles County sewer system that empties into the ocean off Palos Verdes, and the DDT came from a large manufacturer of the pesticide who dumped manufacturing wastes into the sewer system from about 1950 until 1970. The historical buildup of DDT in

the ocean off southern California is being traced through analyses of specimens of the myctophid fish, *Stenobrachius leucopsarus,* taken on CalCOFI cruises from 1950 until the present. About 500 fish have been analyzed. This phase of the work is about 90 percent complete. Tentative results show that the DDT gradually built up in this species over the 20-year period. DDT concentrations are much higher in fish taken near the point source of contamination and decline away from the source. Also, DDT is the dominant pesticide during the early fifties, but DDE becomes more and more dominant after the mid-fifties, indicating a metabolic breakdown of DDT in the ecosystem of the Los Angeles Bight.□

Metabolic breakdown of DDT

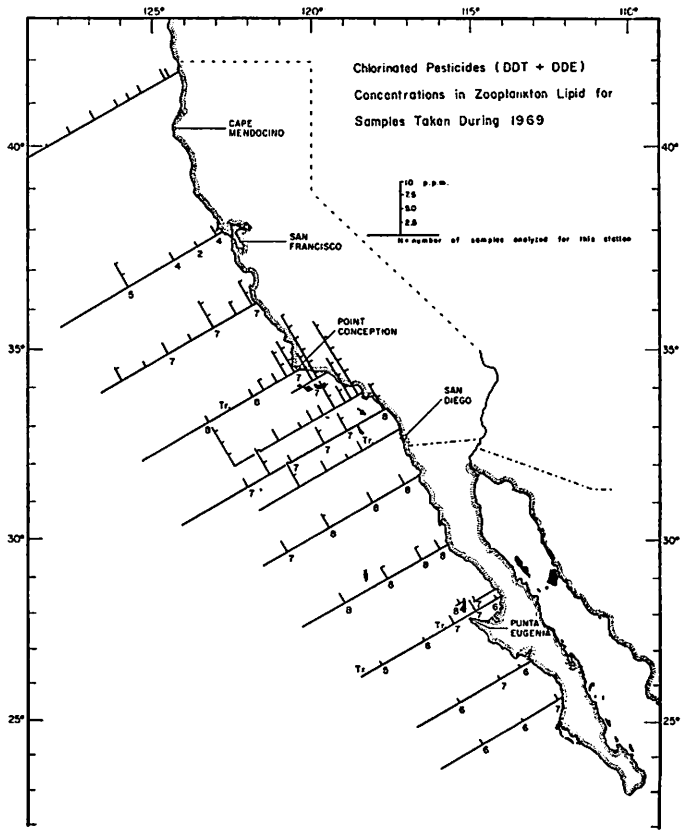
Publications

McCLURE, V. E. Precisely deactivated adsorbents applied to the separation of chlorinated hydrocarbons. *Journal of Chromatography.* v. 70, 1972. pp. 168-170.

A method of preparation of adsorbents for liquid-solid chromatography is described. The method is applicable to adsorbents usually deactivated with water (silica-gel, silicic acid, alumina, and fluoracil) and involved the equilibration of the activated adsorbent with a solution of a strongly adsorbed material in an appropriate solvent. Elution is then performed with a solvent that is incapable of removing the strongly adsorbed material from the adsorbent bed.

Cooperating Organizations

Southwest Fisheries Center, National Marine Fisheries Service, La Jolla, California



Map shows distribution of chlorinated pesticides in zooplankton of the California Current throughout 1969. Note the large quantities of DDT in organisms near Los Angeles. This is correlated with dumping of pesticide manufacturing wastes into the sewer outfall off Palos Verdes.

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Total California spiny lobster landings in 1971 were 224,486, the lowest on record since 1942. Relative abundance of lobsters is a third the 1947 population size. Diminishing stocks never get a chance to recover because of overfishing and capture of short-sized lobsters. Marine biologists have tried to learn what the effects of this improper harvesting are on lobster population dynamics. Among other things, they have found that short females produce fewer eggs than legal-sized ones.

Cal State, San Diego
R/F-8

Evaluation of the California Spiny Lobster Fishery and Related Population Characteristics During a Period of Reduced Fishing

David A. Farris

New license fee, stricter law enforcement expected to increase landings

Total California spiny lobster landings fell to a new postwar low in 1971. Only 224,486 pounds were landed, the lowest since 1942 and about 1,113 pounds less than in 1970. Total effort, however, remained about the same as in 1970—1,669 trip-ticket days were recorded. Of the 128 boats operating in the fishery in 1970, only 107 fished in 1971. Many of these failed to recover the cost of the new $100 license fee and are expected to leave the fishery. Although the California Department of Fish and Game has succeeded in arraigning several violators in the 1970-71 interval, the capture and sale of short-sized lobsters continues to be a major obstacle in the recovery of the stocks. As this source of premature fishing mortality is abated by better policing, landings are expected to rise, for these catches will then appear on the statistical record. Just how much this traffic totals is unknown.

Fecundity studies

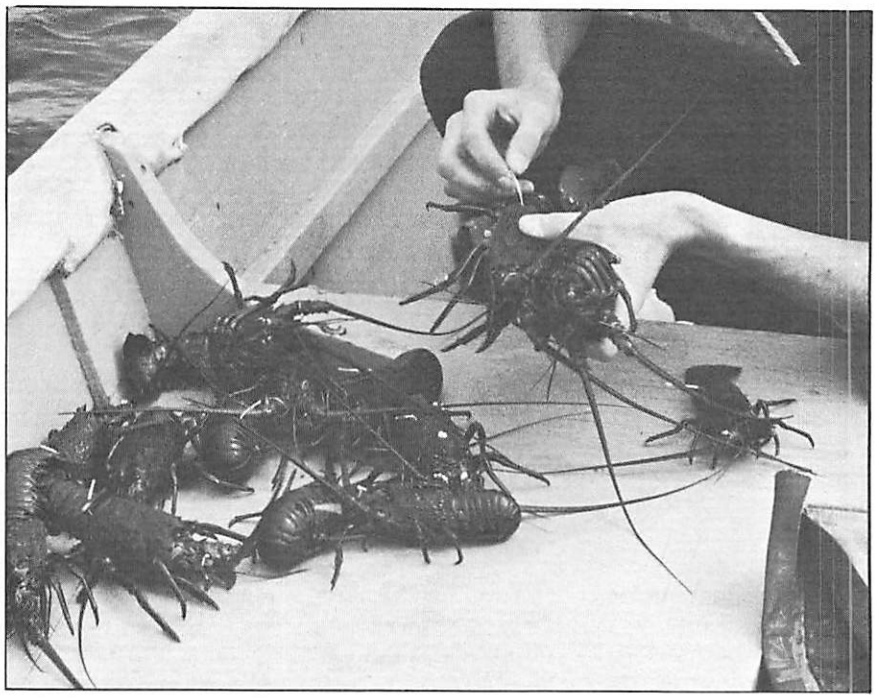
Fecundity estimates were completed on 13 egg-bearing females ranging from 68.1 mm to 84.7 mm Carapace Length. Proportional samples were weighed and counted and related to the total egg mass weight to yield estimated total counts; all samples were fitted by least-squares regression. "Short" females at 70 mm C.L. were estimated to produce about 140,000 eggs, whereas legal females at 82 mm C.L. would produce about 180,000 eggs. Egg diameters were measured also. Average diameter is about 0.58 mm, but the standard deviation is about 0.3 mm. This high degree of variability could be associated with the rather poor survival of the early phylosoma stages. On the other hand, egg size variation appears to have little effect on hatchability, as virtually all eggs have been observed to hatch.

Experimental trapping

Experimental trapping was continued from June to August, 1971. Peak catches exceeding 40 lobsters per trap were observed at the end of July. Monthly peaks were observed in association with the full moon, whereas catch rates always dropped during periods of heavy swell and surf. Two types of bait were used — frozen bonito chunks and sculpin trimmings. Little difference in catch rates was noted between the two baits. Our traps were frequently tampered with, a situation which the fishermen often complained about.

Fertilization found to occur in early summer

The trapping data indicated that the females apparently receive the spermatophore and bear eggs in deep water early in the summer prior to moving toward the beach. Although the evidence is circumstantial, it appears that not all mature females produce eggs each year. The egg-bearing females incubate the eggs in rocky ledges beneath the surf line in about two months and then return to deep water. Females having just released phyllosomes can be recognized by the mass of empty egg membranes retained on the setae of the pleopods. The relative frequency of this condition and the low



Marine biologists tag California lobsters before releasing them into the ocean for studies on population dynamics.

Females may not spawn yearly

relative frequency of females containing eggs earlier in the year poses a question as to whether each female spawns every year. Size at first maturity is about 67 mm C.L.

The past four years of study have shown conclusively that the California spiny lobster fishery is in a severely depressed state, with the Santa Barbara and Los Angeles regions suffering the major part of this decline. Imposing the $100 license fee and strengthening legal restrictions should contribute to a small but significant rise in annual landings in a few years. Nevertheless, barring further degradation of the coastal zone environment, catches are expected to fluctuate between 300,000 and 600,000 pounds annually. The remainder of the market demand must therefore be satisfied by imports.□

Surprisingly little is known about early stages in the life cycle of California spiny lobsters. The greatest number of larvae seem to settle in shallow-water eel grass beds in early August. They have changed from transparent floating creatures into dark reddish-brown bottom-dwellers and will spend about two years in their self-chosen nursery before moving to subtidal areas.

Recent aquarium tests on juveniles completing one molt cycle showed that optimal temperature for increased biomass should probably be around 24°C (about 75°F) — information helpful in aquaculture experiments.

Cal State, San Diego
R/F-9

Studies of Recruitment and Growth of Puerulus and Juveniles of the California Spiny Lobster

Deborah M. Dexter

Inability to negotiate a license agreement with the San Diego Gas and Electric Company until July 20, 1972, precluded carrying forth the high-emperature/accelerated growth studies at the Encina Power Plant site. Field experiments were to have built upon the previous work in closed recirculating aquaria at California State University, San Diego. Nonetheless, considerable progress was achieved by two graduate students.

Recruitment and habitat preference of puerulus larvae

Kenneth P. Parker completed a field study of recruitment and habitat preference of California spiny lobster puerulus larvae. Vital life history information was obtained on morphological and behavioral changes of puerulus larvae, and subtidal recruitment and habitat preferences of juveniles were elucidated. Peak settlement of the larvae occurred in early August, generally in *Phyllospadix* beds. Juveniles apparently remain in these shallow nursery habitats for about two years before moving to subtidal areas. This study fills a void in the basic life history of the California spiny lobster and now permits closer examination of recruitment of the wild stock under natural conditions.

Closed-system thermal studies

Three temperature regimes

James B. Blecha completed a laboratory study of the energetics of spiny lobsters under different thermal regimes. His work was carried out in closed system aquaria under rather difficult conditions. Metabolic rates, assimilation efficiency, and energy input rates were computed for juvenile lobsters captured in the field ranging from 18-34 mm Carapace Length and 10-60 gms net weight. The animals were held at three temperature regimes — 16, 22, and 27°C. Total amount of food ingested and growth was measured, standard metabolic rates were computed, and values for rejecta (feces plus nitrogenous excretions) were estimated. With all the above factors considered, including mortality rates, the optimal temperature for increased biomass production of California spiny lobsters in an aquaculture program appears to be around 24°C.□

Publications:

BLECHA, James B. The effects of temperature on biomass production of juvenile California spiny lobster. *Panulirus interruptus* (Randall). California State University, San Diego. Master's. 1972. (Thesis completed.)

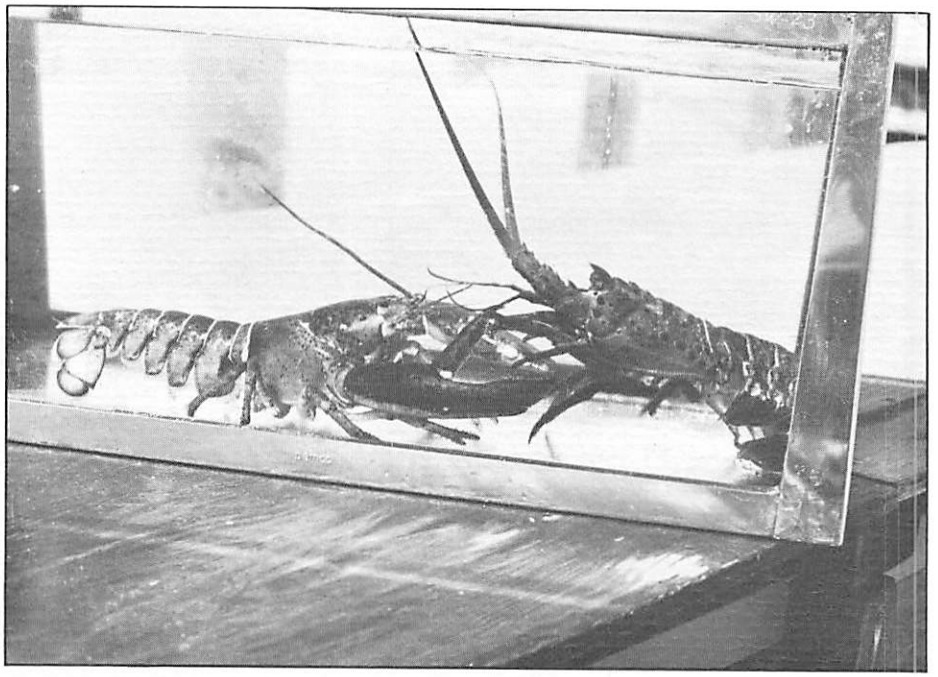
The basis of this study involved quantification of the factors in the equation: Ingestion = Respiration + Rejecta, plus the effect of temperature upon these factors (particularly growth) for juvenile California spiny lobster. *Panulirus interruptus.*

DEXTER, Deborah M. Molting and growth in laboratory reared phyllosomes of the California spiny lobster, *Panulirus interruptus. California Fish and Game.* v. 58, no. 2, 1972. pp. 107-115.

PARKER, Kenneth P. Recruitment and behavior of puerulus larvae and juveniles of the California spiny lobster, *Panulirus interruptus* (Randall). California State University, San Diego. Master's. 1972. (Thesis completed.)

In this investigation of recruitment and behavior of puerulus and juvenile *P. interruptus,* a program of study was undertaken involving: (1) puerulus settlement, (2) puerulus habitat preference, (3) puerulus metamorphosis, including morphological and behavioral changes, (4) juvenile habitat preference, and (5) juvenile recruitment into subtidal habitats.

American lobster (left) approaches California Spiny lobster. Both species are in typical aggressive postures.



Cal State, San Diego
R/F-10

Could the American lobster, native to the East Coast, be introduced to the West Coast to supplement stocks of the California spiny lobster?

Cannibalism has been the greatest problem in hatching and culturing quantities of young lobsters for field introduction. After the fifth pelagic stage of development (reached in the laboratory after 10 or 12 days), the inch-long juveniles attack each other if not moved from mass-rearing tanks to individual containers.

Although ecological studies show that transplanted East Coast juveniles could continue to grow off the California coast, interaction with indigenous species may cause trouble. The American lobster has displayed aggressive tendencies in the laboratory by beating the California spiny lobster in competitions for food and space and by instigating trouble with motionless rock crabs.

An Evaluation of the Potential for Developing an American Lobster *Homarus americanus*, Fishery in California

Richard F. Ford and Charles O. Krekorian

There is interest in the possibility of introducing *Homarus americanus* on the Pacific Coast as a fishery resource. Thus, investigations began at California State University, San Diego, in 1970 to provide a comprehensive evaluation of the feasibility, as well as the potential benefits and dangers, of establishing a *Homarus* population in California.

Studies applicable also to commercial aquaculture

A hatchery laboratory at Scripps Institution of Oceanography, UC, San Diego, is being used to evaluate larval and juvenile culturing techniques and to produce large numbers of young for experimental purposes. While these studies are concerned primarily with evaluating culturing and production problems that would be involved in a field introduction, most of the results are equally applicable to commercial aquaculture in which the product is a lobster of marketable size. For this reason, we have provided informal advisory services to several individuals and companies interested in lobster aquaculture.

Brood females carefully held as egg source

A program of brood female management is necessary in order to raise large numbers of juvenile or adult *Homarus* on the West Coast. Manipulation and staggering of egg hatching time is possible by holding the berried females at different temperatures. We have been able to reduce by about four months the time normally required for hatching by holding egg-bearing females in 72°F water during the winter months. The reproductive cycle of molting, mating, and egg deposition in female *Homarus* took place under ambient temperature conditions in our laboratory, and we are now confident that the problem of brood stock management would not be a serious obstacle to West Coast culture of the American lobster.

Best rearing tanks selected

After hatching, larvae are reared through the four pelagic stages in slightly modified versions of 15-gallon culture containers and circulators developed by John T. Hughes of the Massachusetts State Lobster Hatchery, Martha's Vineyard. Our evaluation of other culture containers has shown that the Hughes system is the most efficient and practical.

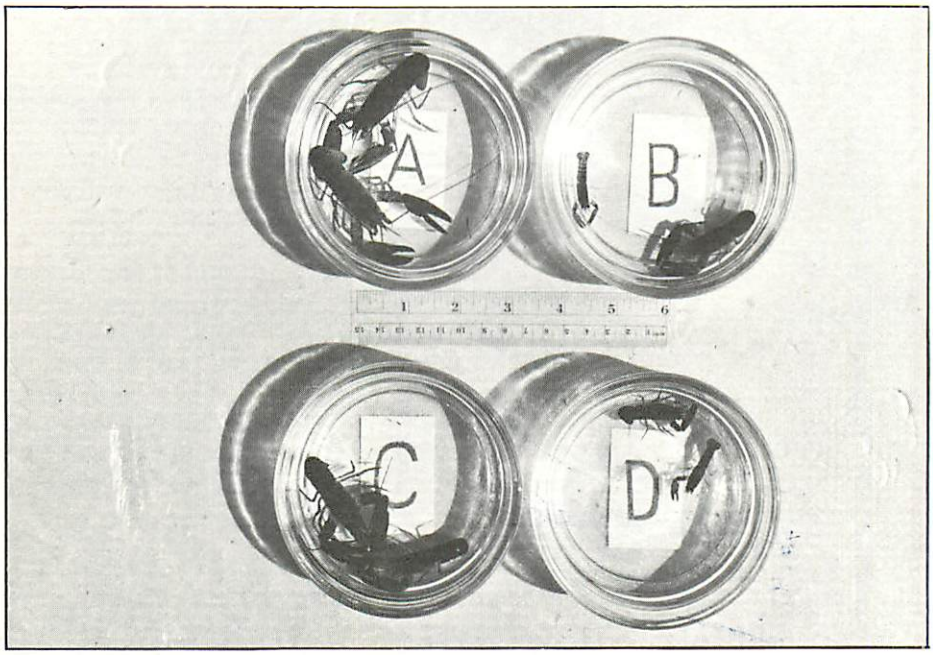
Live food superior to frozen

At 72°F, larvae molt into the fourth stage in 10 to 12 days. By feeding them with live brine shrimp at three-hour intervals, using automated feeding units developed in our laboratory, we have achieved as high as 93 percent survival through the fourth stage. Some problems have been encountered with a bacterial infection identified as *Leucothrix* sp., which can be controlled with common antibiotics, such as streptomycin. Our work on larval feeding and survival suggests that live brine shrimp have enough advantages over frozen brine shrimp and other non-living foods to be worth the added cost. Our results suggest that larval culture, like the management of brood females, will not be a limiting factor in commercial lobster culture or transplant operations.

Cannibalism

Rearing of juveniles, on the other hand, presents some difficulties that we have been unable to solve with existing techniques. Shortly before reaching the fifth stage, the juveniles settle to the bottom of the culture containers and at this time are removed from and placed in various types of grow-out tanks. Cannibalism becomes a major problem at this point, and it is toward this problem that much of our aquaculture research has been directed this year.

Mortality has been high in all of our culture systems, due primarily to cannibalism in mass-rearing tanks and to fouling and waste build-up in small individual containers. After about five months, the carrying capacity of rock substrate (averaging 44 lobsters per square meter) was highest; next in order were oyster shell (37/m²), PVC (polyvinyl chloride) tubing (26/m), and sand (11/m²).



American lobster, *Homarus americanus*, juveniles (all approximately five months old) were cultured in (A) individual containers, (B) mass-rearing tanks with PVC tube habitats, (C) mass-rearing tanks with oyster shell substrates, and (D) mass rearing tanks with sand substrates. Lobsters raised individually are largest and most uniform in size.

Individual holding more time consuming

The equivalent of about 16 one-inch juvenile lobsters per square meter can be reared in individual holding containers. While maintenance and feeding of individually held lobsters was much more time consuming, they grew to an average carapace length of 16.3 mm in five months, while those in

the various mass-rearing trays attained an average carapace length of only 12 mm during the same period.

The size range of lobsters grown in the mass-rearing trays (6-22 mm Carapace Length) was greater than for those grown in individual containers (13-18 mm) because some attacked others, maiming them and inhibiting their growth. The sizes of lobsters held in single containers, free from intraspecific interactions, were much more uniform. It is still unclear whether mass rearing or individual rearing is the more economical and practical approach, and we are continuing to evaluate this question.

Culture system materials analyzed for toxicity

Analyses were conducted to determine the relative levels of chlorinated hydrocarbon compounds in the plastic materials of which the culturing systems are made, in the laboratory foods being used, and in the larvae and juveniles themselves. Based on this information, the least toxic materials have been selected.

Ecological habitat studies

Ecological studies are being conducted to evaluate habitat and other environmental requirements of the American lobster in light of conditions prevailing along the California coast. Comparative field observations in New England and off San Diego indicate that there are extensive areas of rock-sand habitat on the West Coast that would be suitable for a transplant. These areas also are a marginal habitat for the native California spiny lobster, which could be adversely affected by interactions with the American lobster.

Species interaction studies

Quantitative behavioral studies of several types are being conducted in the laboratory to evaluate potential direct and indirect interactions of *Homarus americanus* with the California spiny lobster, *Panulirus interruptus,* and three crab species of the genus *Cancer (C. antennarius, C. anthonyi,* and *C. productus).*

All are nocturnal feeders

Information obtained thus far indicates that all three species — the American lobster, the California spiny lobster, and the rock crab — are most active at night and, in fact, show the most pronounced activity at the same time at night, during the two-hour period immediately following sunset. More specific automated monitoring indicates that, in contrast to this, each species has a somewhat different period of peak feeding activity. Related information on the intensity of feeding activity indicates that *Panulirus* is the least active, *Homarus* is moderately active, while the *Cancer* species display the greatest activity.

Distinctive feeding habits

Comparative observations of feeding behavior in the American lobster, the California spiny lobster, and the rock crab are being made. The results indicate that each species has a distinct feeding behavior pattern, including an individually stereotyped method of food procurement and a characteristic way in which a given prey is manipulated once it has been captured. When a limited amount of food is introduced into the tank containing an American lobster, a California spiny lobster, or a rock crab, the American lobster usually is the first to locate the food.

Interaction between *Homarus* and *Cancer*

Social encounters between *Homarus* and *Cancer* usually result when *Homarus* approaches and touches a motionless *Cancer.* This leads to agonistic displays (raising and extending the claws to the side) by both animals, causing either a retreat by *Homarus* or a retreat by both animals from the area of encounter.

The frequency of social encounters varies considerably between different individuals held in two species pairs, but is generally quite low. This low frequency of social encounters is due partly to the fact that all of the species studied seldom leave their shelters, even during the hours of peak activity.

Competition for shelter

Other trials have been conducted to evaluate competition for a single shelter between two individuals of different species. *Homarus* were successful in maintaining the shelter 70 percent of the time during these trials and *Panulirus* 8 percent of the time. Individuals of both species occupied the shelter simultaneously 17 percent of the time. In similar trials involving *Homarus* and *Cancer antennarius,* each species occupied the single shelter approximately 50 percent of the time.

Recommend against field introduction

Work then indicates very clearly that, if introduced into southern California waters, the American lobster might have serious adverse effects on the California spiny lobster. Because of this, we do not plan to recommend or proceed with any field introductions of *Homarus americanus,* even on the small-scale pilot basis originally proposed.□

Publications

SERFLING, Steven A. Recruitment, habitat preference, and growth of the puerulus and juvenile stages of the California spiny lobster, *Panulirus interruptus* (Randall). California State University, San Diego. Master's. 1972. (Thesis completed.)

Little is known about the early transitional and benthic life history stages of *Panulirus interruptus* or other spiny lobsters. The purpose of this study was to obtain basic ecological information about these important stages in order that their recruitment, survival, and growth might be better understood and possibly improved through habitat conservation and modification and aquacultural methods.

Cooperating Organizations

Massachusetts State Lobster Hatchery, Martha's Vineyard
San Diego Gas and Electric Company, San Diego, California

Gaffkemia, or "red tail disease," is an infection specific to East Coast lobsters. As the common name of the malady indicates, heavily infected lobsters develop very red tails. Carriers of the infection do not show a color change — they can only be detected by their general weakness and lassitude and, on the dinner table, by the mushiness of their flesh.

Although populations of California spiny lobsters are free of gaffkemia, marine biologists are preparing to fight an accidental introduction by gathering data on artificially infected laboratory animals.

Cal State, San Diego
R/F-11

Protective Measures for Lobster Aquaculture

James H. Mathewson

Severity dependent upon temperature

Preliminary studies indicated a strong temperature dependence of the severity of artificially induced gaffkemia in the California spiny lobster, *Panulirus interruptus.* At water temperatures above mean local summer values (25°C), a significant mortality is observed. Water quality and background infections also appear to have important bearing on the spread of the disease in captive populations. Under the stress of gaffkemia, secondary infections develop which also cause death. During the year a major relocation and expansion of holding and experimental tanks permitted much better control of temperature, light, and water quality.

Secondary infections a threat

Two kinds of successful treatment

In spiny lobsters artificially infected with *Gaffkya homari* at optimal tank conditions at 17°C, clearance of massive infection (10^8 cells/ml) follows a biphasic curve and a high rate of survival is observed. Hemocyte levels drop during the initial rapid clearance of bacteria and then rise back to normal values. This is quite different than the effects observed in *Homarus americanus* or in *P. interruptus* at higher temperatures. Literature references suggest two modes of clearance of bacteremias — phagocytosis (Rabin, 1970) and operation of a bacteriocidin (Evans, *et al.*, 1968). Separation of these two processes and their dependence on environmental conditions is being pursued.

Disease transferred apart from interpersonal contact

During one set of experiments, viable *G. homari* were found on exoskeletons and tank walls after the organisms had cleared injected bacteria. The mode of clearance therefore appears to permit spread of the disease by other than cannibalistic attacks on weak animals (Stewart and Rabin, 1970). This possibility will be investigated further because of the extremely important implications for *H. americanus* penning, holding, and quarantining in aquaculture experiments and commercial operations.

Pollution impact studies

Gill tissue was selected as a vulnerable site for pollutant impact. A membrane-bound carbonic anhydrase has been isolated from gill tissue of *P. interruptus* and characterized; a Michealis Constant of 5 m Molar was determined and classical inhibition by sulfonamide demonstrated. A 50 percent inhibition was 6 micromolar mercuric chloride was found, and severe inhibitions were also observed for copper and DDT. Correlations with total gill sulfhydryl groups and whole organism physiology are now under investigation.

Trace metal contaminants

Monitoring of local spiny lobster populations for trace metal contaminants is in progress. A study of a protected population in San Diego Bay, adjacent to sediments with elevated metal content (100-500 ppm Cu), is in progress. Lobsters appear to stay in the outer portions of the bay away from more contaminated areas. This may reflect natural conditions (tidal flushing) but may reflect avoidance or mortality.□

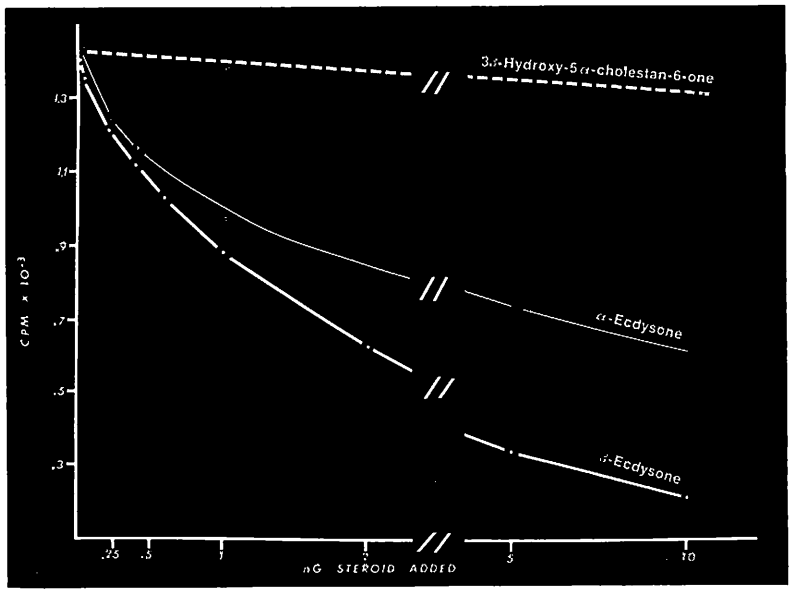


FIGURE 1. **Chart shows inhibition of tritieated β-ecdysone binding by rabbit antiserum in the presence of increasing amounts of various unlabeled steroids.**

Insects periodically shed and regenerate their outer covering, or cuticle, while growing from larvae to adult. Somehow juvenile hormones influence this chain of events by acting in conjunction with the molting hormone, crustecdysone.

Synthetic mimics of juvenile hormones have been manufactured for use in insect control. There has been some concern that these products, when they enter the marine environment, might affect the growth of lobsters and crabs, since they belong to the same phylum as insects (Arthropoda) and go through a similar life cycle. Not until a very sensitive assay was perfected for crustecdysone, however, were researchers able to quantify the molting hormone in lobsters in order to begin monitoring increases in amounts as a reaction to the presence of juvenile hormones. Laboratory tests using juvenile hormone mimics have not yet shown a juvenile hormone-induced increase in ecdysone levels.

Applying juvenile hormone mimics to still another arthropod, the barnacle, seems to cause their larvae to molt prematurely and metamorphose into the adult.

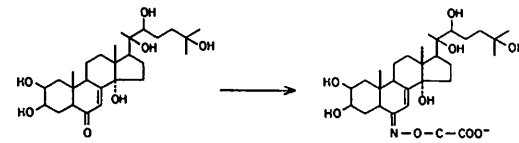
Effects of Juvenilizing Factors on Lobsters

John D. O'Conner and
John D. Faulkner

Unpropitious molting

It has been indicated by several investigators that excessive doses of juvenile hormone can cause arthropods to molt at unpropitious moments. It is important to determine if the juvenile hormone causes an increased titer of the molting hormone, crustecdysone, or acts pharmocologically via a different route. One technical problem that has hindered research in this area has been the lack of a precise physical chemical technique for quantifying crustecdysone titers. We developed a very sensitive radioimmune assay in order to eliminate this technical deficiency. Crustecdysone was derivitized to

Radioimmune assay developed for further studies



the oxime acetic acid ether and subsequently bound to BSA. The conjugate was suspended in Freund's adjuvant and injected into rabbits following a conventional immunization schedule. After six weeks, rabbit serum was collected and assayed for antibodies for ecdysone. As can be seen in Figure 1 the response is maximal with β-ecdysone although a significant response occurs with α-ecdysone. Using this bioassay we have been unable to show a juvenile hormone-induced increase in ecdysone levels.

Juvenile hormones used in crustacean egg maturation experiments

We have also attempted to examine the role of juvenilizing compounds in the maturation of crustacean oocytes. During the course of these investigations we have described a female-specific protein found only in the crustacean ovary and hemolymph. The titers of this protein increase in the eggs as they mature. Attempts to induce such an increase in immature eggs by exposure to juvenile hormones have not been successful. At present we are investigating the site of synthesis of this protein using a radio precipitation technique developed in this laboratory. It is hoped that the metabolism

of this protein within the eggs can be effectively studied using cell/organ culture techniques.

Barnacles metamorphose prematurely

We have tested two juvenile hormone mimics produced by the Zoecon Corporation, ZR512 and ZR515, on the larval stages of the barnacle, *Balanus galeatus*. While ZR515 had no interesting effects, ZR512 caused the premature metamorphosis of cyprid larvae into unattached adults in concentrations as low as 10 ppb (parts per billion). We propose to continue to investigate this surprising result by extending the range of test substances and test organisms.□

Publications

BORST, D. W. and J. D. O'CONNOR. Radioimmune assay for the arthropod molting hormone. *Science*. 1972. (In press.)

A radioimmune assay for the arthropod molting hormone has been developed. The sensitivity of the assay is 200 pg or about 25 times fine maximum sensitivity of the bioassay. Closely related steroids also bind the antibody but with lower affinitives.

FYFFE, W. and J. D. O'CONNOR. Variations in female specific protein concentrations during the crustacean ovarian cycle. *Biological Bulletin*. 1972. (In press.)

Cooperating Organizations

United States Public Health Service
Zoecon Corporation, Palo Alto, California

Biological extracts from various organisms have medicinal properties. Penicillin comes from a mold, and certain fungi and bacteria are known producers of other antibiotics. Marine chemists are now examining physiologically active compounds from the ocean to determine whether they will be of pharmacological importance. So far starfish, sponges, algae, and tunicates have been found to have antibiotic activity.

San Diego
R/B-1

Investigations of Useful Pharmaceuticals in Starfish, Gorgonians, and Other Marine Sources

D. John Faulkner

Starfish extract lyses tumor cells

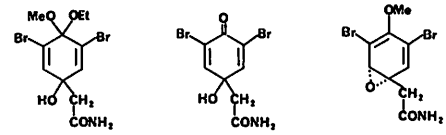
A total of 15 species of starfish were extracted and the saponin fractions purified by a liquid-liquid partition procedure. Samples were submitted to the National Cancer Screening Program. The results from these tests are not promising. However, in work performed here and at the Salk Institute, La Jolla, California, a student has shown that there were significant differences in the ability of the saponin extract to lyse tumor cells and the corresponding normal cells. In particular, the saponin fraction from *Mithrodia bradleyi* will kill SV 3T3 viral transformed mouse fibroblasts at saponin concentrations of 100 μg/ml, but at the same concentration 3T3 normal cells survive. This preparation was equally effective against F_4 DMBA #8 cells but not the normal lymph node lymphocytes. Further *in vivo* tests will be performed. Despite these interesting results it seems unlikely that saponins could be used in cancer chemotherapy without modification to reduce hemolytic properties.

Freshly collected material screened aboard ship

During two recent cruises to the Gulf of California on R/V *Dolphin* we screened 25 species of sponge, 10 species of algae, and 8 species of tunicates for antibiotic activity. All screening was performed on freshly collected material in a shipboard laboratory. We found convincing antibacterial activity in extracts from two sponges *(Verongia thiona* and

Verongia sp. unknown), an alga *(Dictyota flabellata),* and a tunicate *(Polyandrocarpa* sp. unknown). From the unknown species of *Verongia* we isolated a new antibiotic and showed it to be the ketal **1**. We found a known antibiotic **2** in both species of *Verongia.* The discovery of **1** as a mixture of diastereoisomers, leads us to believe that the true antibiotic form species of *Verongia* is the arene oxide **3,** which was transformed during work-up. No arene oxides have yet been found in nature.

Sponge has antibiotic substance



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Due to insufficient material, the antibiotic from *Dictyota flabellata* remains partially characterized. The crude extract from *Polyandrocarpa* contains five closely related antibiotic components. Chemical studies on these extracts and two from local sponges continue.□

Cooperating Organizations
Abbott Laboratories, Chicago, Illinois
Foundation for Ocean Research,
San Diego, California
National Cancer Institute, National Institutes of Health, Bethesda, Maryland
Salk Institute, La Jolla, California

A marine algae extract destroys a plant fungus that attacks avocado trees. Discovery of this new fungicide from *Dictyopteris zonarioides* came after testing more than 40 species of marine plants for materials that might kill bacteria, fungus, insects, or cancer. Chemical analysis of other extracts reveals many new and unusual natural compounds, including the first reported marine compound containing both bromine and chlorine.

Riverside
R/B-2

Natural Compounds from Marine Organisms

**James J. Sims,
William Fenical, and
Phillip Radlick**

The marine plants comprise a very diverse and interesting group of natural organisms. More than 95 percent of these plants are algae, of which more than 15,000 species have been described. The extracts of many of these plants contain substances that are useful in the treatment of disease, so using pharmacological activity as a guide, we collected and evaluated over 40 species of plants.

Materials first dried and pulverized

Chemical evaluation of the marine plants involves drying and pulverizing the material and then extracting it with both aqueous and non-aqueous solvents. All crude extracts are currently being screened for anticancer activity at the National Cancer Institute, National Institutes of Health, under the direction of Dr. Jonathan Hartwell. Crude extracts are then subjected to

various physical and chemical separation techniques aimed at purifying active components. When pure materials are obtained they are then the subject of structural elucidation and thorough biological testing. We have a testing agreement with Merck, Sharp and Dohme Labs, and Dr. Leonard Worthen, Department of Pharmacognosy, University of Rhode Island, is kindly doing antibiotic and antifungal activity testing. At the University of California, Riverside, we are capable of anti-plant fungal testing and insecticidal activity testing.

Bromine and chlorine compound

Fungitoxide

Chemical evaluation of many crude extracts has shown a wealth of new and unusual natural compounds. *Laurencia pacifica* has yielded the first naturally occurring compound that contains both bromine and chlorine. Merck Laboratories is subjecting this and another material from *L. johnstonii* to extensive, 15-month testing. Antibacterial activities have been observed with a new diterpene alcohol from *Pachydictyon coriaceum,* from isomeric hydroquinones from *Dictyopteris zonarioides,* and from many crude extracts, such as *Chondria oppositiclada* and *Zonaria farlowii.* The antibacterial hydroquinones from *Dictyopteris zonarioides* are also found to be very fungitoxic, especially toward *Phytophthora cinnamomi,* a plant fungus responsible for avocado disease. In addition to these results, we isolated many other new materials that are currently being tested or structurally evaluated.□

Publications

SIMS, James J., William FENICAL, Richard M. WING, and Phillip RADLICK. Marine natural products. I. Pacifenol, a rare sesquiterpene containing bromine and chlorine from the red alga, *Laurencia pacific. Journal of the American Chemical Society.* v. 93, no. 15, July 28, 1971. pp. 3774-3775.

The extraction procedure and structural evaluation of pacifenol is presented. Pacifenol is the first naturally occurring compound that contains both bromine and chlorine and contains an unusual tetracyclic ring skeleton. The relationship of this new, unusual material to other natural materials is discussed.

SIMS, James J., William FENICAL, Richard M. WING, and Phillip RADLICK. Marine natural products. III. Johnstonol, an unusual halogenated expoxide from the red alga *Laurencia johnstonii. Tetrahedron Letters.* no. 3, 1972. pp. 195-198.

The methods of extraction, purification, and structural elucidation of johnstonol are described. Johnstonol is related to pacifenol in both its unusual ring structure and its content of both bromine and chlorine.

SIMS, James J., William FENICAL, Richard M. WING, and Phillip RADLICK. Zonarene, a sesquiterpene from the brown seaweed *Dictyopteris zonariodies. Phytochemistry.* v. 11, 1972. pp. 1161-1163.

The extraction, purification, and structural elucidation of zonarene are discussed. Zonarene is the first known example of a conjugated diene in the cadanane series and may be responsible for the iridescence noted with this alga.

SIMS, James J., William FENICAL, Richard M. WING, and Phillip RADLICK. Zonarol and isozonarol. Fungitoxic hydroquinones from the brown seaweed *Dictyopteris zonarioides. The Third International Conference of Fooddrugs from the Sea. University of Rhode Island. Proceedings.* 1972.

The extraction and methods of purification of zonarol and isozonarol are discussed. Structural evaluation and biological activities of these hydroquinones were determined and are presented.

Cooperating Organizations

Merck, Sharp and Dohme Labs, Rathway, New Jersey
National Cancer Institute, National Institutes of Health, Bethesda, Maryland
Searle Laboratores, Chicago, Illinois
University of Rhode Island, School of Pharmacy

ENGINEERING

Introduction

Realizing that most engineering efforts rapidly become expensive when they enter the prototype construction stage, the University of California Sea Grant program carries to completion only such projects that relate to program research already underway. It sponsors other engineering projects through the exploratory stage and then seeks additional funding for continued work. (We are at this point with the artificial upwelling experiments.) Research efforts designed to provide data supplementary to actual engineering construction are encouraged.

Enhancement of marine productivity and mitigation of the thermal pollution created when coastal power plants release heated effluent into the ocean could be positive results of artificially upwelling cold, nutrient-rich deep ocean water to the surface near the power plants. An experiment on Eniwetok, a coral atoll in the West-Central Pacific, attempted to pump deep water up through the atoll, heat it to surface temperatures, and then use it as fertilizer for seawater aquaculture ponds. The experiment, controlled and small in scale, was to be extrapolated to open ocean upwelling and large-scale enhancement of marine productivity at the sites of power stations. Upwelled water would be heated on contact with warm discharge.

Enhancement of Natural Marine Productivity by Artificial Upwelling

John D. Isaacs and Walter R. Schmitt

A year ago we reported on the permeability studies of a coral reef, on the selection of a site for the artificial upwelling program, and on the investigations planned at that site.

Three field trips

This present report deals with the work accomplished during three field trips and with the attendant difficulties that have brought the program to a halt for the time being.

Baseline studies on two potential aquaculture ponds

A team of 11, including a radiation monitor, went to Eniwetok Atoll for two weeks in September, 1971 for a partially structured exploration/work visit. The mission was the design and commencement of studies on the biology, chemistry, and ecology of two semi-submerged nuclear craters to provide baseline data on primary productivity and community structure before nutrient enrichment in the craters' waters would be attempted. Also planned was the locating and pumping of an existing 4,200-foot drill hole 12 miles from the crater. It has been hypothesized that water from such a well would be high in nutrients and could serve as the source for enrichment.

Four months later, in January, 1972, a team of nine extended the baseline survey, which would require continual observations for a minimum of two years to assess the magnitude of natural variability in the system. The drill hole had been located and a pump test proved it plugged.

Radiological hazard stalls baseline survey

Another four months thereafter, in May, 1972, a team of nine went to Eniwetok for the third baseline survey visit, but Runit Island (where the craters are located) was placed off limits three days later for suspicion of unacceptable radiological hazards. However, on this third visit the drill hole was successfully perforated by a contractor and turned into a well for sampling. Seawater was produced from the well in the reef at 2,600 and 3,500-foot depths, and the water from 2,600 feet down was prepared for lab analysis: it is depressed in $PO_4^{=}$ but elevated in NO_2^{-}, NO_3^{-}, and NH_4^{+} over surface water.

Observations

The three Eniwetok visits yielded two team visits to the crater and the perforating of one existing drill hole. The observations made thus far follow.

Crater water nutrient poor

The water that flushes through both craters is extremely low in nutrients and could not be used to rapidly produce a substantial harvestable crop.

Limited phytoplankton growth

Results from enrichment experiments indicate that phytoplankton growth is limited by more than one nutrient element deficiency. Data indicate the nitrogen and phosphorus both severely limit algal growth rates; when both nitrate and phosphate are added to crater water there is substantial growth of algal cells, but it soon declines due to other nutrient deficiencies. Definitive tests were not run to ascertain which other elements become limiting under these conditions, however silicate may also be a limiting nutrient in these waters.

The phytoplankton standing crop in crater water varied from about 0.05 to about 3 μg chlorophyll *a* per liter, which is equivalent to approximately 4 to 225 μg C/1. Most of the phytoplankton crop is accounted for by small unidentified pigmented cells (2-4 μ in diameter) and by small diatom cells of less than 5 to 10 μ in length. There is obviously a very rapid turnover of nutrients in these waters as the assimilation number is fairly high (2 to 10 μg C fixed/μg Chl. *a*/hour). The relatively high ammonia and urea concentrations also support this suggestion, indicating a high grazing rate by the zooplankton populations with resulting recycling of nutrients. There is no significant amount of biological nitrogen fixation occurring in the planktonic community. Nitrogen fixation by filamentous blue-green algae seems to be limited to the benthic environment.

No significant nitrogen fixation

Deep reef water nutrient poor

Samples of fossil water pumped from the 2,600-foot level of the perforated drill hole are very low in nutrients and hence cannot be expected to support much phytoplankton growth. This was substantiated by subsequent nutrient enrichment experiments, which did however show that the fossil water is not toxic.

Species composition of crater communities

Species composition of the plankton communities in the two craters are similar except for a large difference in abundances of *Oithona occulata.* Copepodids of *O. occulata, Centrophages orsini,* and *Pseudodiaptimus comnutus* show some degree of diurnal vertical migration. The phytoplankton standing crop (measured as chlorophyll) appears sufficient to support the zooplankton standing crop.

Eighteen species of benthic algae were identified at least to the genus level. In terms of numbers of species, greens predominate. Uniseriate microscopic blue-greens and encrusting calcareous reds have not been identified beyond those categories. *Derbesia minima* (a green) and *Wordemannia miniata* (a red) appear to be the biomass dominants in both craters, covering extensive portions of the deeper areas. With the exception of *Jania capillacea* (a red found entangled in the *Wurdemannia* turf) and a few blue-green species, all other elements of the flora appear to be sparsely distributed and restricted to the few large rocks found in less than 3 m of water.

Sixty-two species of molluscs were recognized, 42 of which were gastropods (snails) and 20 pelecypods (clams). The most speciose genera were *Conus* (7), *Cypraca* (7), *Strombus* (6), *Terebra* (4), and *Trochus* (4). *Conus* and *Terebra* prey on mobile animals, *Cypraea* prey on sessile animals, and *Strombus* and *Trochus* are herbivores.

There seem to be about 200 species of fishes that permanently reside in the craters, 40 of which are relatively abundant. Most of the crater fishes are those characteristic of quiet waters of the lagoon. Important among these are *Chaetodon lunula* (butterfly fish), *Lutjanus vaigiensis* and *Monotaxis grandoculis* (snappers), and *Acanthurus guttatus* and *A. triostegus* (surgeonfish).

The 20-year-old drill hole was perforated at these depth intervals: 2,605-2,628, 3,468-3,493, 3,654-3,706, and 3,956-3,982 feet below top of the casing. Water was produced from the first two sections independently until elapsed time (pump rate/hole volume), particulate color, and pH indicated arrival of reef fossil water. The results of the nutrient analysis and growth test of the 2,600-foot-deep water are reported above.

Existing drill hole deemed impractical

At the maximum flow possible in the well's seven-inch casing it becomes impractical to pump for fresh, deep, high-nutrient seawater, which must be drawn through one to two miles of reef. That might take 10 to 100 years at 10^5 gph (gallons per hour) depending on assumptions about the reef's permeability and channelization. Moreover, one cannot accurately predict the depth from which the water would be drawn or how the reef might affect the nutrients. A well redirected for open water intake should overcome these difficulties. Since the existing one is 12 miles distant, a new well would also be necessary if the craters are to serve as aquacultural ponds.

Alternate sites, possibly in the Gulf of California, are also being investigated.□

ORB is a 45-by-69-foot Oceanographic Research Buoy designed to carry and service RUM, a Remote Underwater Manipulator that looks like a tractor with a mechanical arm mounted on top. Once towed into position over a research site, ORB opens her center well and RUM drops through to the ocean floor for exploration and collecting operations. RUM remains attached to ORB by a coaxial cable.

In existence since 1959, RUM has been outfitted with new equipment and this year made measurements and collected samples at 17 underwater work sites. Data accumulated on RUM-ORB work performance, effectiveness, and operating costs serve as a basis for designing future sea floor work-vehicle systems.

San Diego
R/E-2

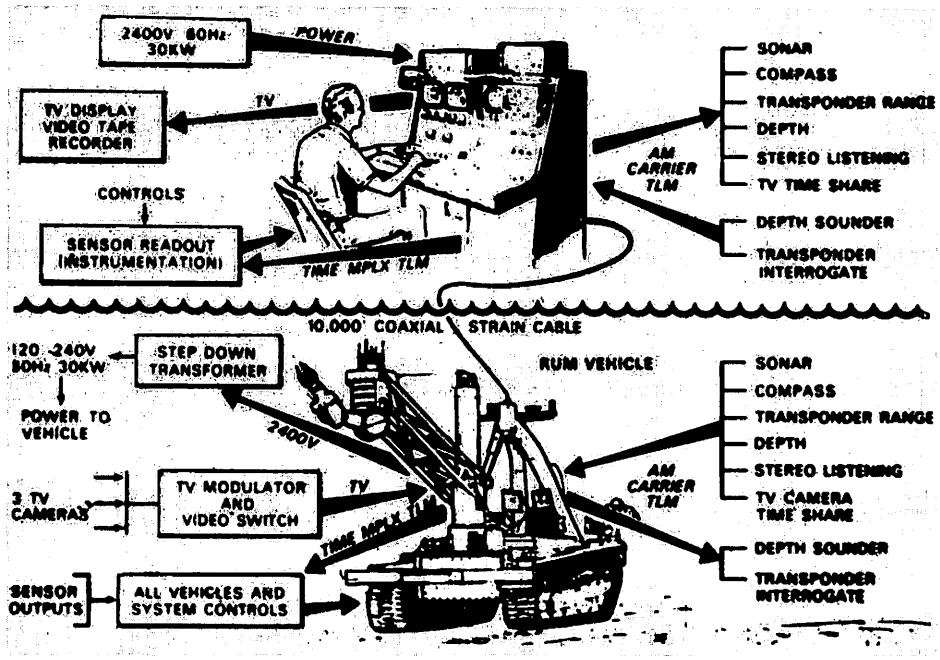
Sea Floor Work Systems

Victor C. Anderson and Daniel K. Gibson

Work off southern California

The ORB-RUM System was at sea a total of 71 days between September 1, 1971 and August 31, 1972. During the six trips to sea ORB was moored over 17 sea floor work sites ranging from 45 to 1900 meters in depth. Work sites, all off the southern California coast, ranged from 1-1/2 to 65 miles off shore and from near the Mexican border north to the Santa Cruz Island area.

Approximately one-third of the total time at sea was spent in transit to and from work sites and in the installation and recovery of moors. More than 280 hours of actual operating experience upon the sea floor was logged in the performance of a variety of tasks.



ORB is a 45-by-69-foot Oceanographic Research Buoy designed to carry and service RUM, a Remote Underwater Manipulator which looks like a tractor with a mechanical arm mounted on top. Once towed into position over a research site, ORB opens her center well and RUM drops through to the ocean floor. RUM remains attached to ORB by a coaxial cable.

From the control room on ORB, scientists operate RUM by sending and receiving electronic messages through the cable. Sea floor operations are continually watched on a series of television screens.
RUM and ORB were developed by Marine Physical Laboratory at Scripps Institution of Oceanography, University of California, San Diego.

Soil mechanics, vehicle trafficability measurements

Soil mechanics and vehicle trafficability measurements were made at 14 of the 17 work sites. Fifty-one sediment core samples were collected. Sixty-seven cone penetrometer profiles and 36 vane shear measurements to a depth of 24 inches below the sea floor surface were made *in situ* to determine sediment strengths. Fifty-nine profiles of vehicle track depressions at various track pressures were recorded. A number of vehicle drawbar pull measurements were attempted, but only two successful ones were obtained. Operating experience with the drawbar pull anchor winch system dictated a redesign. This was completed and a new winch was fabricated.

Cameras and search sonar added

Added to the instrument suite were a pair of camera systems for documenting the sea floor work performed on 35MM and Super 8MM color film. A high-resolution 200-yard search sonar was also added.

Remains of seafloor construction experiment retrieved

During a cooperative sea floor work experiment with the Naval Civil Engineering Laboratory and the Pacific Missile Range, an ocean weather station mooring clump and the remains of a sea floor construction experiment (each weighing over 3,000 pounds) were searched out, picked up, and returned to the surface by RUM from depths of 900 and 1260 meters respectively. A recovery line was fastened to an 18,000-pound foundation at 185 meters depth and tied off to a sub-surface buoy for later recovery. Several long-term sea floor construction experiments were searched out, observed, and photographed to obtain settling, loss of buoyance, and marine growth information.

Benthic biological studies were conducted at two sites near 1150 meters depth in the lee of San Clemente Island. In this work a graduate biologist

Benthic biological studies

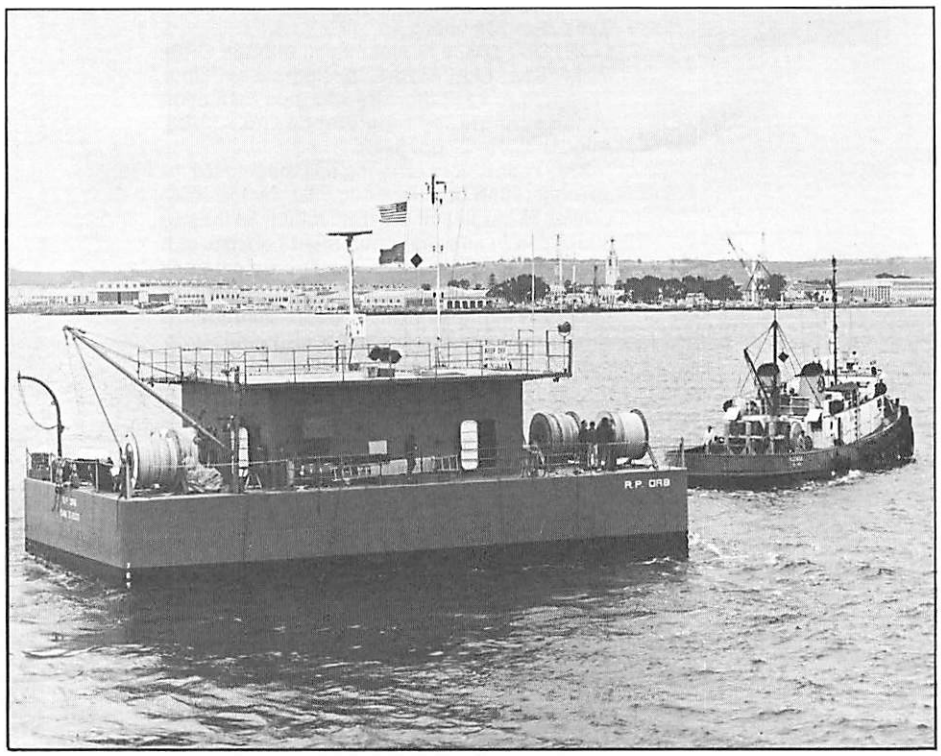
used the TV camera and movie camera on RUM to observe and document behavioral activities of colonies of benthic creatures within fixed areas for periods of several hours per area.

Time budgets recorded

During operations at sea and the performance of this wide variety of tasks, special attention is given to detailed recording of time budgets. The entire operation is broken down into such phases as transit, installation, and recovery of moors, launch-lower-raise and recovery of the vehicle, operating time on the bottom, and maintenance tasks. Time on the bottom is further divided up into the time spent on each activity. Certain activities or tasks, particularly coring, vane shear measurements, and cone penetrometer measurements, are time logged on the basis of phases or sub-tasks. These time studies should form a data base with enough detail to extrapolate for the prediction of performance on new tasks, which can be broken down into similar phases or sub-tasks. This data will also aid in the projection of the effect of possible manipulator, viewing, or other improvements on the work effectiveness of this or other remotely manned work systems. These projections can serve as a guideline for future development in the technology of remote sea floor work systems.

Individual work project projections

Other sea floor work systems



ORB

New report on methodology for economic analysis of sea floor work systems

A small study effort was initiated with Lockheed Corporation to develop a methodology for the economic analysis of sea floor work systems. In this connection a one-day sea floor work session was sponsored by the project. A number of workers in the ocean engineering community — including representatives from private industry, federal government, and universities — participated. All were experienced in sea floor vehicle programs or the requirements for sea floor work. The discussions centered around the general requirements for sea floor work rather than military requirements for search, rescue, and recovery, which have already been covered in extensive studies. An output from the meeting is included in a report on the Lockheed study, which is being duplicated as a Sea Grant technical report.

Six of the 17 RUM work sites this year were near shore at depths of approximately 45, 90, and 180 meters. These sites were selected on the basis of interest expressed by the U.S. Bureau of Reclamation in data from *in situ* soil mechanics measurements and core samplings that may be of value in their reconnaissance survey for an offshore California aquaduct.

All core sediment samples collected are turned over to Dr. Iraj Noorany at California State University, San Diego, for laboratory analysis under a companion Sea Grant project (see Cal State, R/E-3).□

Publications

ANDERSON, V. C., R. CLINTON, D. K. GIBSON, and O. H. KIRSTEN. Instrumenting RUM for *in situ* sub sea soil surveys. *American Society for Testing and Materials. Special Technical Publication 501.* 1972. pp. 216-231.

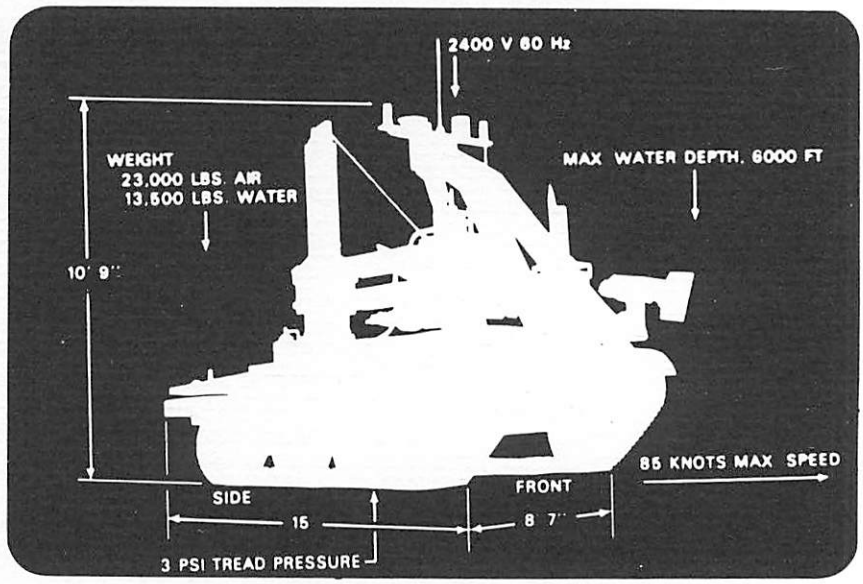
A brief description of the ORB-RUM sea floor work system is presented, whose main emphasis concerns the instrumentation suite developed for *in situ* soil trafficability studies with RUM. RUM has been instrumented for remote operation of a two-foot-long, three-inch-diameter corer, a vane shear meter, 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.

CLINTON, J. R. Soil mechanics with the ORB-RUM Sea Floor Work System. *Sea Floor Technology — Report 44.* Scripps Institution of Oceanography. Reference no. 72-63, August 1, 1972. pp. 1-12.

This report concerns the soil mechanics instrumentation developed for use by the RUM vehicle in studies of the trafficability of the sea floor. The *in situ* test equipment consists of a vane shear meter, cone penetrometer, track depression profiler, and anchor winch system. Each instrument and its operation is described and interpretation of its measurements is discussed. Methods of sample collection and subsequent laboratory analysis are also presented.

Cooperating Organizations

Institute of Geophysics and Planetary Physics, La Jolla, California
Lockheed Corporation, Ocean Laboratory Division, San Diego, California
Office of Naval Research, Washington, D. C.
Royal Norwegian Council for Scientific and Industrial Research, Oslo, Norway
Shell Development Corporation of Houston, Texas.
U. S. Naval Civil Engineering Laboratory, Port Huineme, California
U. S. Naval Undersea Center, Point Loma, California
U. S. Naval Pacific Missile Range, Point Mugu, California



RUM

Cal State, San Diego
R/E-3

As more building takes place in and not just next to the ocean, better data are needed on the engineering properties of submarine clays, the stuff ocean structures rest on.

Findings of studies on sea floor sturdiness are used in developing tidelands and in making nearshore islands, marinas, and recreational facilities. Information related to the continental shelf deposits off the coast of San Diego is immediately related to the U.S. Bureau of Reclamation's work on a possible offshore California aqueduct.

Effect of Sampling on the Engineering Properties of Submarine Clay

Iraj Noorany

Remote underwater manipulator (RUM) used to make *in situ* sediment studies

Part of the project is a continuation of the cooperative work between the Soil Mechanics Laboratory at California State University, San Diego, and the Marine Physical Laboratory of Scripps Institution of Oceanography, UC, San Diego. RUM, a tractor-like Remote Underwater Manipulator (see R/E-2), is used to make in-place observations and measurements of sediment properties and to recover sediment cores to be tested in the laboratory. The results of the laboratory tests and their comparison with the field measurements provide a basis for the evaluation of the effects of sampling on engineering properties of sea floor sediments. Furthermore, the collected data on the engineering properties of these sediments become a much needed source of information for engineers, scientists, and various governmental agencies interested in the condition of the sea floor in the nearshore region of the Pacific. The program of sampling and testing off the coast of San Diego was planned in consultation with the U. S. Bureau of Reclamation to assist the bureau's work in a reconnaissance survey of the feasibility of an offshore California aqueduct.

Vane shear and cone penetrometer tests, trafficability measurements

The *in situ* soil mechanics measurements were conducted by personnel of the Marine Physical Laboratory under the supervision of Victor C. Anderson, Daniel K. Gibson, and Oscar H. Kirsten. In a series of four trips during January, 1972 and July, 1972, *in situ* measurements and sampling operations were carried out in 12 offshore sites in waters ranging from 148 feet to 6,135 feet in depth. The *in situ* tests consisted of vane shear and cone penetrometer tests, as well as measurements of the sea floor trafficability under the tracks of RUM. Sediment cores were taken using RUM's two-foot-long sampler. In addition to the deep water operations in the La Jolla Canyon, the San Diego Trough, and the San Clemente Island areas, four shallow-water sites, west of Point Loma and west of Bird Rock Point, in waters ranging from 148 feet to 717 feet in depth, were explored. The data collected from these shallow-water sites will be of particular interest to the U. S. Bureau of Reclamation.

30 cores analyzed for physical properties of sediments

The laboratory investigations were performed at the Soil Mechanics Laboratory under the supervision of Iraj Noorany with the assistance of Gregory Luke, Barbara Searfoss, and Robert A. Zinser. The analysis of 30 cores were completed, and tests on 12 remaining cores are in progress. Physical properties of the sediments — including water content, unit weight, dry density, specific gravity, grain size distribution, and Atterberg Limits — were determined. The samples were classified in accordance with the Unified Classification System. Vane shear and triaxial compression tests were performed to determine shear strength, and consolidation tests were made to measure the compressibility of the sediments. In addition, as described later, special triaxial compression tests were performed to simulate the effects of sampling.

Comparison between *in situ* measurements and lab tests

Details of the engineering properties of the sea floor sediments from La Jolla Canyon and the data from other sites permit determination of the bearing capacity, settlement characteristics, trafficability, breakout resistance, and penetration resistance of the sea floor. The scatter of data does not yet permit a conclusive statement regarding the comparison between the *in situ* measurements and the laboratory values.

Soil samples recovered by RUM, as well as deep sea clays obtained by Kennecott Explorations, Inc., were used in a testing program planned for simulation of the process of stress removal and disturbance upon sampling of sea floor deposits. In most of these tests the range of water pressures simulating the hydrostatic pressures was limited to 100 psi. Considerable effort was spent in designing a new high-pressure triaxial testing facility for operation at hydrostatic pressures as high as 2,000 psi. This unit was subject to test runs and will be expanded to a larger facility during the next year for testing triaxial samples under hydrostatic pressures up to 10,000 psi.□

Publications

NOORANY, I. Underwater sampling and *in situ* testing: state-of-the-art review. *American Society of Testing and Materials Special Technical Publication STP 501.* March, 1972.

State-of-the-art of underwater sampling and *in situ* testing is covered. Methods of nearsurface 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 that require concentrated research.

NOORANY, I. and G. L. LUKE. Engineering properties of sea-floor sediments off the coast of San Diego. Research Report, Department of Civil Engineering, California State University, San Diego. 1972.

Sea floor sediments recovered from 30 locations in 12 offshore sites at San Diego in waters ranging from 148 feet to 6,135 feet in depth were analyzed. *In situ* measurements and sampling operations were carried out by RUM, the unmanned underwater vehicle of Scripps Institution of Oceanography. The sites include La Jolla Canyon, San Diego Trough, San Clemente Island area, as well as shallow-water regions west of Bird Rock Point and Point Loma. Index properties, vane shear, triaxial shear, and consolidation tests were performed. Laboratory data were compared with those measured by RUM *in situ*.

NOORANY, I. and R. A. ZINSER. Engineering properties of sea-floor sediments from La Jolla Canyon. *13th International Conference on Coastal Engineering, Vancouver, Canada. July 1971. Proceedings.* (In press.)

Nearsurface sea floor sediments were obtained by the tracked underwater vehicle RUM from four locations on the floor of the La Jolla Canyon. The sediments were clayey silts of high plasticity. The engineering properties of the sediments, including grain size, index properties, strength, and compressibility, were determined.

Cooperating Organizations

Kennecott Explorations, Inc., Ocean Operations Division, San Diego, California

U. S. Bureau of Reclamation, Denver, Colorado

An experimental study being made to test the validity of certain approximate methods of calculating wave forces on marine structures may improve future design concepts.

Berkeley
R/E-4

Synthesis of Forces on Marine Structures

John R. Paulling, Jr.

Two pieces of experimental apparatus were designed and constructed, and experiments are currently in progress with each. The first is intended to measure the vertical and horizontal forces on a submerged horizontal cylinder beneath a train of waves. The depth of submergence and wave length are the principle variables.

The second apparatus is designed to measure the vertical and horizontal force and location of the horizontal force resultant on a vertical cylinder or inverted T-shaped assembly of cylinders. It was shown that nearly complete cancellation of the wave forces for such an assembly occurs for certain relations between the horizontal and vertical member dimensions and the wave length. This effect is being investigated in the current experiments.□

The motions of underwater cables used for handling equipment in the deep sea and for mooring deep ocean buoys are predictable. However, a recent review of current methods of computing cable motions revealed that important phenomena had been omitted in the calculations. New defining equations were developed and programmed for a high-speed digital computer.

Berkeley
R/E-5

Underwater Cable Dynamics

William C. Webster

A method was developed for calculating the dynamic response of two-dimensional towed cable systems. This method, which is designed to provide realistic computational times, retains important nonlinearities but uses simplified equations of longitudinal motion.

Elasticity, bending, internal damping considered

General equations of motion including terms due to elasticity, bending, and internal damping were derived. The method of characteristics, which is an especially attractive method for solving these equations, can be used only if the equations are hyperbolic. It was shown that the equations are hyperbolic only if elasticity is included and bending and internal damping are neglected, and that bending and internal damping can be safely neglected for most cases. The excessive computational times required by the large longitudinal characteristic velocity (cable material sonic velocity) can be avoided if only the transverse equations of motion are solved by the method of characteristics.

Excessive computation time avoided

The equations of motion were simplified by a procedure similar to that used in deriving the boundary layer equations. When these higher order terms are neglected, the longitudinal equations of motion reduce to linear equations that are essentially uncoupled from the nonlinear transverse equations of motions. These linear longitudinal equations of motion are solved analytically for suitable linear boundary conditions. Solutions for two sets of boundary conditions were derived. The computational method is based on these analytical solutions and on solution of the transverse equations of motion using the method of characteristics and finite-difference integration. This method is programmed for the CDC 6400 computer.

Computer accuracy demonstrated

A number of computations were made. These serve to demonstrate the accuracy of the computer programs and to illustrate the effect of various parameters, such as external damping and towing velocity on cable motions and tensions. The effect of two sensitive parameters — grid spacing for numerical integration and number of terms used to represent infinite series — were determined.□

Cooperating Organizations
American Bureau of Shipping,
New York, New York

There are other ways to destroy powerful waves than by reflecting them from offshore breakwaters. Submerged manmade reefs in which water depth abruptly alters from deep to shallow back to deep in a longshore direction will reduce passing waves in height by increasing their crest length, and in impact by dispersing the orderly progression of breakers into a confusion of small waves. Waves will also lose much of their energy if they meet patches of near-surface submerged spherical floats that act as resonant drags.

Each of these new wave attenuation systems could provide low-cost wave protection for marinas, anchorages, and offshore structures. The tethered floats would have the additional advantage of being easily set up in water behind dams to prevent over-topping during storms.

Wave Attenuation Studies

John D. Isaacs and
Richard J. Seymour

Shallow portions of reef do the work

In the slotted reef concept, an advancing wave front passes over a manmade reef in which water depth abruptly alternates from deep to shallow to deep in the longshore direction. The reduction in crest propagation speed over the shallow portions results in a phase lag for that portion of the crest and a substantial stretching of the crest length (with a resulting diminishing of the wave height). If the reef is sufficiently long, the wave crest is modified from a line parallel to the beach to a roughly sinusoidal shape. The wave patterns exiting from the reef from such a sinusoidal crestline are analogous to a series of point sources of waves situated at each deep channel and have comparable patterns of interference and reinforcement. The coherence of the advancing wave fronts is disrupted and the reef can easily be made close enough to shore so that the waves cannot again be refracted parallel to shore. The result is that, at model scale, breaking energy is substantially reduced at the shoreline.

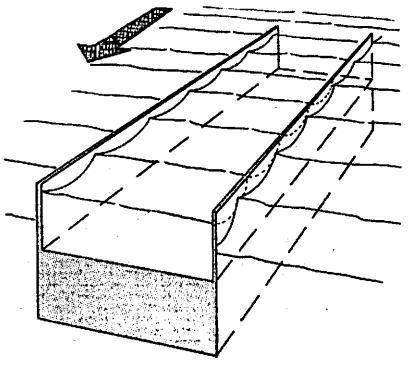
Wave basin models tested

Model experiments were conducted in a wave basin to evaluate phase lag and shoaling characteristics for a range of scale waves. At full scale, for example, a reef to produce a half wavelength phase shift for a 12-second period wave would be about 300 yards long and perpendicular to the beach, if constructed with a depth over the shoal sections of 25 feet and a channel depth of 45 feet.

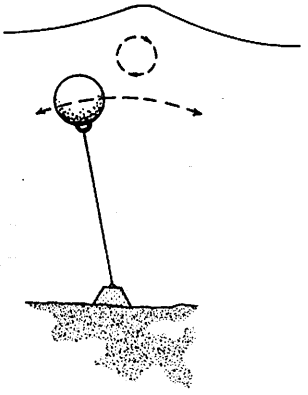
Tethered float patches can remove any fraction of passing wave energy

In the tethered float concept, a patch of buoyant spheres is tethered beneath the surface so that they oscillate in response to horizontal wave forces. By selecting the proper water depth, the tether length will produce a resonant frequency close to that of the predominant storm wave frequency, maximizing float response. Since the float is always out of phase with the surrounding water particle motion, its average speed relative to this water is always high. The resulting drag is greater than that of a similar *fixed* object and extracts more energy from the wave field. If the patch is of sufficient extent, obviously any fraction of the wave's energy can be removed. One of the purposes of this study is to verify that the required patch size is of practical interest.

When advancing wave front passes over manmade slotted reef in which water depth abruptly alternates from deep to shallow to deep in longshore direction, crest propagation speed slows over shallow portions. Phase lag results and ultimately wave height diminishes.



Tethered float is always out of phase with the surrounding water particle motion, so its average speed relative to this water is always high. Resulting drag force extracts energy from the wave field.



Wave basin tests agree with analytical solutions

A series of experiments was conducted in a wave channel in which the response of a tethered sphere was measured when excited by waves of various frequencies and by combinations of three waves of differing frequencies. Float position and surface elevation were recorded on magnetic tape, which allowed subsequent spectral analysis and construction of response function and phase angle curves. These data are in good agreement with the approximate analytical solutions and the exact numerical solutions to the equations of motion. They provide the basis for estimating the performance of a full-scale array of floats used as a wave attenuator.

Tethered floats require deep water

A characteristic of this system is that it requires deep water to function efficiently. Since wave periods much greater than the natural period of oscillation of the system are not attenuated while those of shorter period are, the tether length is turned to the longest period of wave anticipated. The minimum water depth (in feet) to accomplish this is about 1.5 times the square of the maximum wave period (in seconds).

Long-period waves

Short-period waves

A survey was performed of potential sites in California for a full-scale demonstration of a tethered float breakwater. Two kinds of locations are possible. The first is subjected to long-period ocean waves-but where very deep water is available close to shore, as typified by Avalon Harbor in the lee of Catalina Island or Moss Landing where the head of a submarine canyon is very close to shore. The second case involves short-period waves generated on fetch-limited enclosed bodies of water like San Francisco Bay or Lake Tahoe.

Dam protection

Tethered float wave attenuation systems, under investigation for low-cost wave protection for marinas, anchorages, and offshore structures, could also provide wave protection for large dams. At present, when a dam is subject to wind waves generated on its impounded lake, the water level must be kept sufficiently low so that the sum of storm setup and wave runup will not overtop the dam. For flood control dams, this reduces the total amount of

water that can be impounded during spring runoff for use in summer irrigation. Even for regulated hydroelectric dams, it reduces the amount of water that can be released for irrigation without violating minimum head requirements. If waves could be substantially attenuated, the allowance could be appropriately reduced and the resulting increase in volume would be available, at least annually, for irrigation or other uses.

The tethered float system is particularly well suited to the dam application because it is easy to construct in the deep water behind the dam and cannot collect trash as surface-penetrating, rigid systems might.

An instrument to measure the motion of a tethered float driven by ocean waves was designed and is in fabrication. The device continuously measures the inclination angle of the tether in two planes. It will be used in conjunction with Dr. D. L. Inman's SAS System (See San Diego, R/CZ-3a) to provide data recovery and simultaneous wave measurement.□

Cooperating Organizations
State of California Department of Navigation
and Ocean Development,
Sacramento, California

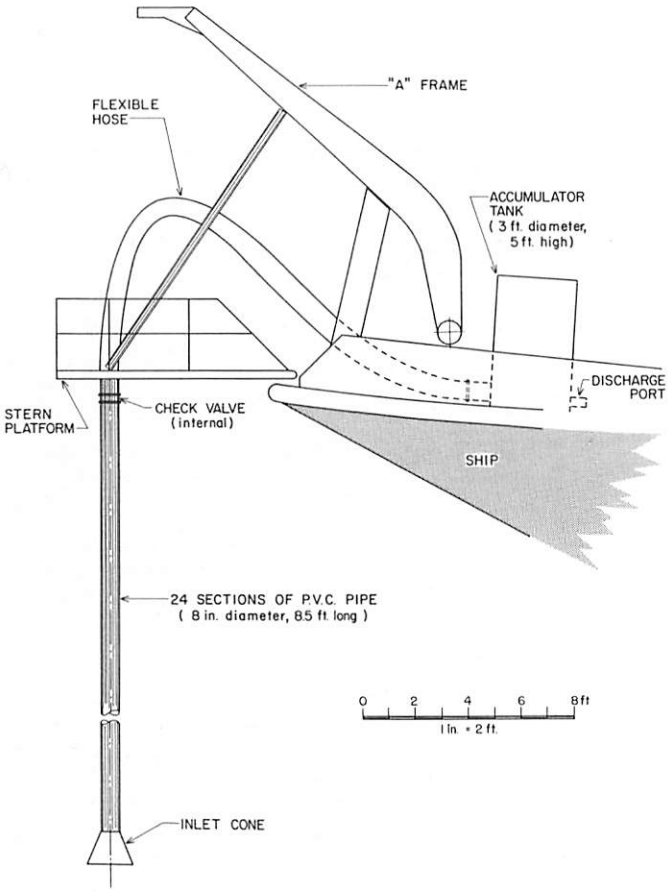


Figure 1. Wave generator system showing stern platform, flexible pipe connection and accumulator.

A surface ship in a seaway commonly has an order of magnitude greater power in its up and down motion than in its propulsion. This observation has led to the development of a new energy generator system powered by the relative motion between a long free-floating vertical pipe and the surrounding water. During that half of a wave cycle when the pipe is positively accelerated downward, water flows up through the pipe into an accumulator tank mounted on a surface buoy atop the pipe. A one-way check valve prevents the water from returning through the pipe during the second half of the wave cycle. When the trapped water then discharges through a turbine, it produces useful work.

Generators of this sort could be used as independent power sources for remote moored bouys and ultimately for non-pollution commercial power generation.

Wave-powered Generator System

John D. Isaacs and David Castel

Ocean wave power calculated to be an order of magnitude greater than former estimates

Although total wave power in the sea has been estimated at 10^6 megawatts, a new analysis of the actual wave power extractable from the sea appears to be an order of magnitude larger. This stems from the fact that the maximum growth *rate* of wave *power* occurs at the stage when waves are of about six seconds in period. Thus a number of the proposed wave power devices can be more effective in harvesting the wave energy of, say, the trade winds than can a single station. The dimensions of the intake pipe are also much reduced by the shorter period, all of which increases the feasibility of ultimate large-scale development.

Small pump constructed

First, a small two-inch-diameter, 40-foot-long pump was build at Scripps Institution of Oceanography, UC, San Diego, in the winter of 1970. The pump, which operated in local water for about six months, confirmed the principle of utilizing wave energy, and its performance was within the expected experimental range.

Marine architects analyze generator system

An extensive analysis of the system was then undertaken by a firm of marine architects (Glosten Associated). This analysis, aided by a computer program, quantifies the energy extraction from ocean waves and the relationship between the system parameters and its performance. An additional analysis carried out at Scripps Institution of Oceanography, UC, San Diego, and aided by an analog computer was found to be in close agreement with the original analysis.

Larger model followed

On the basis of the above results it was decided to further test the idea of a wave-powered generator by building an experimental model.

Pump assembled and towed to position

The actual test of the wave-powered generator was conducted during the period July 22 to July 26, 1972, in the waters off the north leeward side of San Clemente Island. R/V *Oconostota* was selected as a self-propelled buoy from which the model generator would operate. To accommodate the pump a stern platform was constructed to which the pipe was gimbaled. The pump itself consisted of 200 feet of eight-inch-diameter PVC (polyvinyl chloride) pipe (ten 20-foot sections glued together). The pipe was assembled on a gently sloping concrete ramp on the beach at Wilson's Cove at San Clemente Island and, supported by floating buoys, was towed out to the ship anchored approximately 400 feet from the shoreline.

Once the head of the pipe reached the stern platform and was secured to the gimbals, the ship moved out to deep waters while simultaneously lowering the far end of the pipe until it was vertical. Although this method proves satisfactory, it suffers from the inherent disadvantages of being dependent on a shore facility and requiring long towing times to reach a desired station.

Water spouts 20 inches above open end of pipe

Dramatic evidence of the pumping potential became immediately apparent once the ship left the calm waters of Wilson's Cove. During the positive acceleration periods, water would spout in solid columns to levels up to 20 inches above the open end of the pipe.

Coupling fails and test terminates

A flexible pipe coupling was made between the pipe and the accumulator tank, and readings of pressure variations in the tank and volume flow through the discharge port were noted (in lieu of a real turbine). Corresponding pipe acceleration readings were taken continuously. Unfortunately, after only 24 hours of operating time and before the data acquisition system was fully operational, one of the cemented couplings on the PVC pipe failed and the test terminated.

Sufficient data were gathered before failure, however, to establish the fact that even though the analysis appears to be on the conservative side the pump does indeed generally follow predicted performance. In seas of four to five feet at a period of eight to ten seconds, maximum pressure was of the order of 25 psi and the theoretical turbine performance was shown to be approximately .40 hp. For the same conditions, the model predicts a power output of .33 hp. However, data available is insufficient for conclusive determination of the validity of the theoretical model.

Second test with new pipe assembly

A second test to gather additional data is scheduled for mid-November, 1972. This test will differ from the July test primarily in the method of pipe assembly. It is proposed to run a 3/8-inch steel cable through the center of the PVC pipe. The cable will be located by steel spiders spaced at 20-foot intervals inside the pipe. This method will place the pipe assembly under a compressive load and thereby remove all tension on the pipe. Once the gluing operation is eliminated, it will be possible to assemble the pipe aboard ship, independent of shore facilities.

Depending on the outcome of this first phase, it is proposed to hold further tests (incorporating a real turbine) in the trade winds or a similar area.

Closed-system use proposed

Having modified and refined the theoretical analysis using the experimental results and having gained first-hand experience with the operating problems of the wave powered generator, it is proposed to analyze the wave generator further as a closed-system, full-wave rectifier in an attempt to both eliminate the problems of operating with seawater as the working fluid and to extract energy during the upward as well as the downward acceleration periods. At this time further investigations into the practical application and ramifications of the wave-powered generator will be carried out.□

Publications

HUTCHISON, Bruce (Glosten Associates, Seattle, Washington). Calculations pertaining to the extraction of energy from ocean waves. May 1972. (Unpublished report.)

SCHICK, G. B. and J. T. LYONS. Wave powered pump, performance report. January 1971. (Unpublished report.)

Cooperating Organizations

Glosten Associates, Seattle, Washington
Foundation for Ocean Research, San Diego, California.

One of the purposes of an acoustic holographic underwater imaging system is to find and identify objects unknown or lost at sea. It works in the following way: sound waves emitted from a speaker scan a submerged object. As the waves bounce off the object, their interference pattern is picked up by a line of 100 receivers and relayed to electronic equipment (possibly computers) for processing into a light display that exposes a photographic plate.

At this point a sound hologram of the object has been converted to an optical hologram — a photograph. Not until a laser beam is shined through the photograph, however, will the object finally be reconstructed in a recognizable form — a three dimensional image with all planes focusable.

Acoustic Holographic System for Underwater Search

Glen Wade

Model-sized

Mapping use

The current acoustic holographic system for underwater imaging is a model, scaled down in size, of an envisioned ocean-going system for rapid search of both large volumes of water in oceans, lakes, and rivers and of floors of underwater regions, for finding lost objects and for mapping and exploration. The system is characterized by a receiver consisting of a line of 100 discrete transducers and a cylindrical transmitting transducer. The transmitter and the receiver (complete with the 100 electronic processing channels and their respective light-emitting diode display unit) are connected together mechanically, and they scan simultaneously in a direction that is parallel to the cylinder axis and perpendicular to the array of receiving transducers.

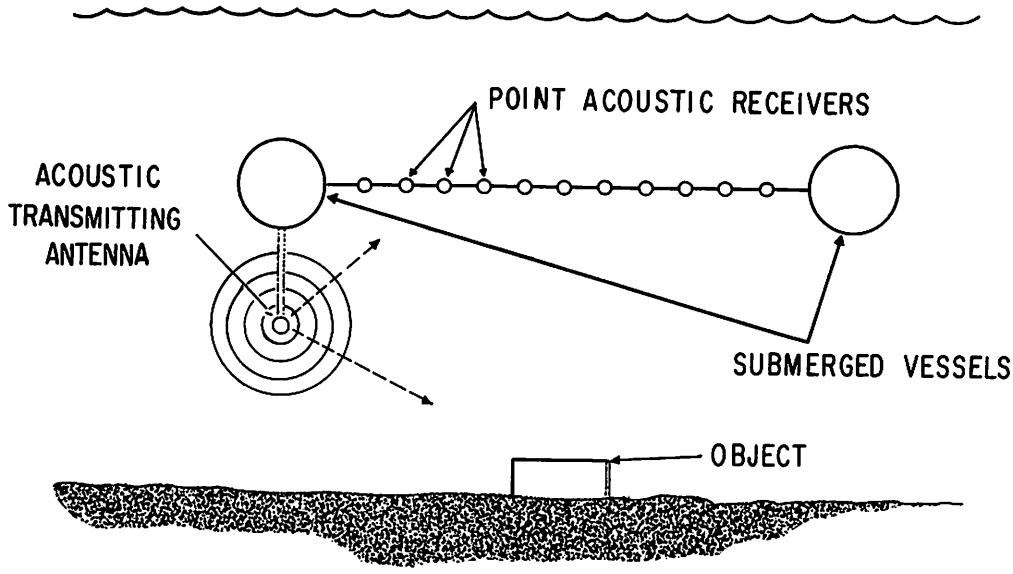
Once all the major components and subsystems were completed, it became a matter of testing each subsystem, connecting them together, and interfacing the various electronic systems. By mid-July all of the aligning of the 100 receiver electronic channels was completed. Also, most of the 200 cables were connected between the receiver electronic processing channels and their respective transducers and light-emitting diodes.

Scan system modifications

At this point, a modification of the mechanical scan system was made. The continuous-drive DC motor was replaced with a stepper motor that provides an accurate method for digitizing the position along the scan. This is important because computer processing and enhancement will be done at a later time. The stepper motor also makes it possible to eliminate the raster-like scan lines generated by the streaking, light-emitting diodes. It is now possible to stop the drive at discrete and precisely controlled intervals and then take data to record holographic information in the form of equally spaced points instead of continuous lines. If the spacing is close enough, no information is lost by the sampling process.

Water tank test produces hologram of a point

The completed system was given a test under pulsed ultrasound operation. A point object was placed at the bottom of the water tank, and the system scanned over it. The hologram itself (not its reconstructed image), of a point, is the familiar Fresnel zone plate. This geometrical form consists of a central circle and a series of concentric circular rings that grow thinner and are more closely spaced with increasing radius. The results of the test were



Acoustic holographic system is for underwater search. Transmitting antenna is cylindrical with axis schematically perpendicular to this page. Receivers form a linear array whose motion sweeps out a planar region parallel to ocean floor. Submerged vessels provide mechanical support for the system and can be used to house electronic and photographic equipment necessary for producing the hologram. During recording, receivers and transmitter move abreast of each other at a known rate.

Complicated objects

successful, producing segments of the theoretically predicted pattern. There were, however, a number of receiver channels with bugs in them, which are now being corrected. All the pulse timing electronics worked perfectly. The next step is to put a more complicated object in the tank and then reconstruct its holographic image.□

New materials that can withstand the saltwater environment are needed for structures built in the ocean. Composite materials seem to be an answer.

Plain and polymer-impregnated concrete samples cut into small bars and slabs and then notched and grooved are being submitted to strain and fatigue tests and experiments on stress-corrosion and cracking. Fracture surfaces will be looked at under a scanning electron microscope.

Composite Materials for Ocean Construction

Alan S. Tetelman and James C. Aleszka

We have received, cut, and begun testing plain and polymer-impregnated concrete samples.

Standard Portland cement composition

The two types of concrete were prepared by the U. S. Department of the Interior, Bureau of Reclamation Engineering and Research Center. Both were prepared using standard Portland cement and cured for 28 days in a fog environment with the polymer-impregnated concrete being characterized by a 9.3 wt. percent of methyl-methacrylate content.

The samples were then sent to UC, Los Angeles where they were cut into suitable shapes for testing. Half of the plain and polymer samples were cut into 3 x ½ x ⅜-inch notched and unnotched charpy bars. The others were cut into 3 x 1¼ x ¼-inch slabs with a ⅛-inch notch in one end and a shallow groove running lengthwise down the sample. The charpy bars are being used to study strain-rate and fatique effects, while the thin slabs are being used for stress-corrosion and crack propagation rates in various environments.

Fracture load data on polymer samples

To date the tests have shown that the polymer concrete exhibits an interesting strain-rate effect. Fracture load decreases with increasing strain-rate (cross head speed) up to a certain point where it then begins to increase again. The data points corresponding to the faster strain-rates were obtained by using an impact hammer at Effects Technology, Inc., while those at the slower strain-rates were obtained through the use of an Instron here at UC, Los Angeles.

Crack propagation rates

We plan to use our MTS machine to generate data at intermediate strain-rates where the effect seems most pronounced. At the slowest strain-rate, there is a substantial difference in the fracture load between the notched and the unnotched polymer-impregnated concrete. Using this strain-rate, the variation of fracture load with notch depth will be examined. We have recently begun measuring crack propagation rates in various environments, but the results are still inconclusive.

Environmental fatigue tests

In the coming months, we will be conducting environmental fatigue tests and studying the fracture surfaces of the samples using our scanning electron microscope to determine cause of failure. We have also received from Maccaferri Gabions, Inc., three samples of their gabion mesh. These people have developed "gabions" as a means of curbing erosion. Gabions consist of polyvinyl chloride-coated wire mesh that has been shaped into rectangular blocks, filled with rocks, and joined together to form a monolithic structure. Up to this time, they have principally been used in fresh water. The first sample has not been exposed to any type of environment, while the second and third were exposed for ten years and five years in ordinary and polluted seawater, respectively, off the coast of Italy. We plan to cut off a small portion of each mesh and examine it under our scanning electron microscope to determine the extent of corrosion. Finally, we have received from Battelle-Northwest Laboratories a third type of concrete known as Wirand® which contains steel fibers intermixed with the cement matrix. The Wirand® will be studied in conjunction with the other two types of concrete to determine which is most suitable for ocean construction.

Corrosion tests on gabion mesh

Cooperating Organizations

Battelle-Northwest Laboratories, Richland, Washington
Effects Technology, Inc., Santa Barbara, California
Maccaferri Gabions, Inc., Flushing, New York
U. S. Department of the Interior, Bureau of Reclamation Engineering and Research Center, Denver, Colorado

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EDUCATION

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Introduction

The University of California Sea Grant program began in 1968 as a program to develop a new graduate curriculum in applied ocean science on the UC, San Diego campus. In subsequent years a pilot program for developing a curriculum in marine biomedicine and a program to train instructors in scientific diving were added at UCSD. A marine technician training program was initiated as a joint effort of UCSD and California State University, San Diego.

A program of Sea Grant Traineeships provides research experience and support of thesis projects for graduate students working on applied topics related to ocean resources. During the past year, the Sea Grant Traineeship program, begun at UCSD, was extended to the UC campuses at Berkeley (5 students), Davis (9 students), Santa Cruz (2 students), and Santa Barbara (33 students). UC, San Diego has 23 Sea Grant student trainees. Because educational programs involving doctorate candidates develop slowly, the thesis projects reported in this section are all from the established UCSD program

Taking research results to the public is also one of Sea Grant's educational goals. For many years the Thomas Wayland Vaughn Aquarium-Museum at Scripps Institution of Oceanography, UC, San Diego, has done this with both public exhibits and educational programs for a limited number of local school classes. The Sea Grant program has assisted the Aquarium-Museum in enlarging its educational program to reach more students.

Graduate Education in Marine Biomedicine

Robert W. Elsner

Two courses taught

Two formal courses were taught during the 1972 winter quarter. One, a seminar course in the comparative physiology of diving and asphyxia, was presented for the second year.

Lectures in diving physiology and related topics were presented in a course in marine vertebrate physiology, administered by Robert Elsner.

Program linked with UCSD School of Medicine

Numerous informal contacts strengthened the ties between the Physiological Research Laboratory at Scripps Institution of Oceanography, UC, San Diego, and the UC, San Diego, School of Medicine. The association will be further advanced in the near future through participation of a student in the graduate program of training in medical physiology.

Diving duration of seals theoretically lengthened

A potentially useful technical advance was achieved through a student-assisted project related to diving physiology. We have established in principle that the maximum diving duration of a seal can be considerably increased by the mechanism of extra-corporeal blood gas exchange. Because of the drastic reduction of circulatory distribution during diving to only the most vital organs, brain and heart, such gas exchange can be made a relatively simple procedure involving small gas quantities. Terrestrial mammals, including man, are known to experience a similar, though less complete, circulatory redistribution. The procedure may, therefore, have applicability as a means of enhancing tolerance to certain kinds of asphyxial insult. The investigation, now in a preliminary state, will continue during the year.□

Relief for asphyxia in humans

Graduate Education in Applied Ocean Science

Victor C. Anderson

Enrollment increases 50 percent over last year

The progress of the graduate education project in Applied Ocean Sciences is becoming more evident as the curriculum gathers momentum. The growth of graduate student enrollment in the program and the appearance of new and wider interest in the ocean science disciplines within this group of students is evidence of the impact of the project. The initial enrollment of 2 students in the first year grew to 11 in the second year, 23 in the third year, and 34 in this, the fourth year. There is a preliminary enrollment of 38 for the fifth year.

New courses

Under the stimulus of this Sea Grant project, several relevant courses were developed. The acoustics course established by Victor Anderson was expanded into two full-year courses, one at the undergraduate and the other at the graduate level, with a related intensive laboratory course offered at each level. Carl Gibson's course in turbulent mixing and transport continues to answer the need of AOS students to know more about those factors important in pollution control in the ocean. Another course stimulated by the program is Douglas Inman's expanded course in inshore processes. This course also has a growing relevance to the environmental pollution control problem facing our nation in the coming years.

Weekly seminars

Practical aspects of working in the ocean are presented to the students through the weekly Applied Ocean Science seminars and through such courses as George Shor's in marine geophysical exploration. Seminars, held on specialized fields, are meant to be close interchanges between students and representatives of other laboratories, universities, and industry.

Although we clarified the formal mechanics for providing an interchange between the ocean engineering curriculum at the Berkeley campus and the San Diego Applied Ocean Sciences curriculum, no personal interchange has occurred to date.

Three theses completed

Three AOS student thesis projects were completed. Reports on the work are included in the summaries that follow.□

San Diego
E/G-4

Resonance and Doppler Structure in Echoes from Pelagic Fish Schools

Dale Vance Holliday

Two new clues for remote classification of fishes

Track and swimming speed

Research directed at the development of two further clues for the remote classification of fish was completed. The first measurement was of the track and swimming speed of fish schools over periods of about an hour. The measurements were made from a minimum range of 500 meters and are thought to represent an undisturbed state of school behavior. A unique measurement of the ship's track and speed, based on the doppler frequency shift of volume reverberation, allowed an accurate estimate of the school mean swimming speed relative to the water column based on track data. Plots of swimming speed as a function of time reveal both cruising and swimming bursts. These data have been used to infer average fish length and swimming endurance for three schools in the Los Angeles Bight.

Doppler spread of acoustic energy in echo from fish school

A second clue, the information contained in the doppler spread of acoustic energy in an echo from a fish school, was also studied. Internal school dynamics was investigated with one-half second acoustic pulses from a 30 kHz sonar. Echoes resulting from these transmissions were analyzed to determine the frequency distribution of echo energy. The observed energy distributions were interpreted as resulting from doppler shifts due to motion in the fish school. Observed doppler structure was divided into that caused by body and tail-related swimming motions, near-side aspect, and behaviorial swimming characteristics, near-tail or head aspect.

Fish length

Side aspect data were used to estimate fish length. Although economic considerations precluded the capture of the schools studied, the swimming speed and the doppler-derived estimates of mean fish size in the schools were consistent. Both estimates were also consistent with fish known to frequent the Los Angeles Bight during the time of the at-sea experiments.

Additionally, tail and head aspect doppler structure data were correlated with echo level, school dimensions, and school swimming speed to demonstrate that the observed doppler structure could have resulted from special swimming behavior. In two cases, the behavior changed the school

dimensions and in a third situation no change in school dimensions was observed.

Research concluded with the award of a Ph.D. in Applied Physics in 1972.□

Publications

HOLLIDAY, D. V. Resonance structure in echoes from schooled pelagic fish. *The Journal of the Acoustical Society of America.* v. 51, no. 4, prt. 2, April 1972. pp. 1322-1332.

San Diego
E/G-4

Underwater Lighting by Low-coherence Submerged Sources

Wayne Havelock Wilson, Jr.

A basic foundation for illuminating engineering in the ocean and other natural water bodies was laid by this study. The procedures and techniques necessary for the efficient design of underwater lighting systems were investigated and sucessfully formulated.

Experimental duplication of optical properties of water

The experimental phase of the study consisted of the duplication of the optical properties of oceanic or other natural waters in an 1,800-gallon tank. The irradiance distribution in the water produced by a small-diameter collimated laser beam was measured as a function of the optical properties of the water. Measurements of this distribution ranged from distances of 2.0 attenuation lengths to 24 attenuation lengths, and from off-axis angles of 0.5 to 100°. The scattering-attenuation ratio of the water varied from 0.60 to 0.83.

Empirical equation for engineering calculations

The irradiance distribution data was fitted with an empirical equation in order to make it more accessible for engineering calculations. A significant scaling of the distribution was accomplished by separating the effects of scattering and absorption on the propagation of the light through the water. The results of the scaling and the empirical equation allow extrapolation of the irradiance data beyond the experimental limits.

The irradiance distribution data is the impulse response of the water to the spatial Dirac delta function represented by the laser beam. By use of the superposition integral, the irradiance distribution produced by a given light source in an arbitrary hydrosol may be calculated. The techniques necessary for the efficient computation of this integral are investigated and outlined.

Sample calculations

Two sample calculations were made using the procedures outlined. One verified the techniques by the comparison of a calculated irradiance distribution with a measured distribution produced by a broad-beam incandescent lamp. The second example illustrates the scope and power of the procedures by showing the different lighting distributions produced by a broad-beam lamp as it is oriented in several directions above the ocean bottom.

Research, sponsored by Sea Grant from 1968 to 1971, concluded in the award of a Ph.D. in Oceanography in 1972.□

San Diego
E/G-4

Measuring Individual Sound Scatters at Sea

Richard Knowles Johnson

The frequency responses and population densities were measured for resonant and nonresonant scatterers (aggregations of biological entities) in the Pacific Ocean near San Diego. Cable-lowered piezoelectric transducers were used to resolve individual targets in the frequency range of 3 to 30 kHz. Three sizes of scatterers with gas bubble structures of 2 to 3 mm radius were observed in the upper 600 meters. Their population densities ranged from 5 to 300 targets in 10,000 cubic meters. Nonresonant frequency responses were measured for three sizes of scatterers with equivalent radii of 2 to 3 cm. They were observed in concentrations of 1 to 25 in 10,000 cubic meters. A population model based on the vertical movements of these six groups of scatterers was developed to explain the diurnal variation of volume reverberation in the upper 600 meters.

Research concluded with the award of a Ph. D. in Engineering Sciences in 1972.□

San Diego
T/G-1
Cal State, San Diego
T/G-2

Undergraduate Training in Marine Technology

Norman E. Anderson
Glenn A. Flittner

Training ashore and at sea

California State University, San Diego, offers a one-semester undergraduate course in marine technician training. Students get practical experience in oceanography at shore installations and at sea. Each semester, upperclassmen trainees go in groups of five to Scripps Institution of Oceanography, UC, San Diego, to work in the Data Collection and Processing Group (DCPG).

Four women and eleven men have participated in three semesters of this program since it began in Fall, 1971. Undergraduate majors represented so far are: biology (7), zoology (3), geology (2), chemistry (1), and physics (2).

Data processing emphasized

The first three to four weeks are spent in classes and cruise preparation. More than half the time goes to learning how to process data, the rest in studying marine chemistry, ocean circulation, and functional structure of the water column.

Early in the project before going to sea on crusies, students choose a library research question and do the research. While at sea they write a paper, which they present to their peers on the last day of class.

Spring semester cruises

Time at sea varies from four to ten weeks, depending on vessel assignments. Spring semester class participated in cruises that were part of two on-going research programs — California Cooperative Oceanic Fisheries Investigations (CalCOFI), sponsored by the State of California, and the North Pacific Buoy Project, sponsored by the Office of Naval Research. All students participated as full working members of the scientific teams.

Specific skills learned

During the course students are introduced to several specific skills: (1) Nansen bottle casts, (2) salinity determinations, (3) oxygen titrations, (4) operation of the Beckman DU spectrophotometer, (5) new tow operations and trawling, (6) biological specimen handling and preservation, (7) weather and sea state determination, (8) buoy mooring and servicing, (9) small boat operations, and (10) general seamanship.

All persons are exposed to routine technician watchstanding, pre-, mid-, and post-cruise data workup, and onshore laboratory assistance. Special student projects are permitted when time allows, and all students are directed to shore activities consonant with their undergraduate major interests.

Learning to live with people in close quarters

Some undefinable learning occurs at sea relative to living in a confined environment for extended periods with the same people. This type of education is difficult to evaluate, yet at the end of his sea time each student knows whether he could work under those conditions in the future.

Each student is individually evaluated on his performance at the end of the course. These evaluations remain on file with DCPG as future job references.

Employment follow-up

Half of the students who have participated in the program since its inception are now employed part or full-time in ocean research laboratories or are pursuing graduate programs in the marine sciences and related areas. The remainder are completing their undergraduate programs.□

San Diego
T/D-1

Scientific Diving Supervisor Training

James Stewart

Seven SCUBA classes

During the past year seven SCUBA classes were conducted with an average enrollment of 12 persons per class. Among the students were individuals from the National Park Service; the U.S. Coast Guard; Duke University; Universidad Autonoma de Baja California; California State University, San Diego and Humboldt; California State Parks and Recreation Department; the Office of Polar Programs (NSF); and Scripps Institution of Oceanography, UC, San Diego.

Scientific diving safety procedures standardized

The *Diving Safety Manual* was completed and distributed. In an effort to seek standards common to the scientific diving groups in general, this publication has been discussed with diving officers from Texas A&M and the University of Michigan, as well as with divers from Washington, Florida, and NOAA.

Hand-Held Sonar, a new tool for underwater recovery operations

The Hand-Held Sonar was used on several recoveries of instruments and human bodies, and a number of persons were instructed in its use, including life guards and national park rangers.

The updating of training equipment and techniques resulted in several papers being presented to the Fourth International Conference for Underwater Education held in Miami in September, 1972. Among those contributing were the diving officers from Scripps; UC, Los Angeles; and UC, Santa Cruz. Stewart presented a paper on emergency ascent procedures.□

Volunteer docents guide a daily average of 250 students through the Vaughan Aquarium-Museum on the campus of Scripps Institution of Oceanography, UC, San Diego.

San Diego
A/CZ-5

Primary, Secondary, and Public Education in Ocean Science

Donald Wilkie

Scripps Aquarium-Museum

The Thomas Wayland Vaughan Aquarium-Museum on the campus of Scripps Institution of Oceanography, UC, San Diego, is a major center for the public dissemination of information about marine sciences. The facilities are open every day of the year.

Three-part educational program for school children

This past year more than 51,000 school children visited the Aquarium-Museum, participating in a three-part educational program. Before the visit, the educational coordinator for the Aquarium-Museum sends teachers instruction materials to familiarize their classes with the world of oceanography. While touring, students are asked to answer questions on a guidesheet by making their own observations and by reading written material on aquarium tanks and on museum displays. A post-visit classroom lesson reinforces and summarizes information gathered during the tour.

Volunteer docents

Over 60 volunteer docents help with the daily average of 250 students. A senior docent meets each visiting class, gives an introductory lecture, and divides the children into groups of ten to be accompanied through the facilities by other docents.

In addition to reaching schools by organizing student tours, the Aquarium-Museum prepares slide and film presentations and educational fact sheets, booklets, and bibliographies on oceanography. One of the widest selections of reading material on ocean science locally available is at the Aquarium-Museum Bookstore.

Summer classes in marine biology and ecology

Each summer classes in marine biology and ecology are offered to elementary and junior high school students. During the last session, more than 120 pupils studied about fishes, invertebrates, marine mammals, and the ecology of tidepools. There is a work-study program for high school and college students interested in careers in oceanography.

Pollution symposium for teachers

One hundred thirty teachers attended an all-day symposium on marine pollution taught by eight research Ph.D.'s. University of California Extension gave one unit of academic credit for the symposium.

Saturday classes are in the planning stage for this school year. There will be films, lab sessions, field trips, and lectures.□

ADVISORY SERVICES

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Introduction

By the term, "advisory services," Sea Grant means the variety of methods used to communicate research results and other specialized knowledge to those in the community who will apply the information in properly utilizing marine resources or managing the marine environment. Information dissemination channels may include the mass media, technical and popular publications, conferences, seminars and demonstrations, and personalized contacts.

Major emphasis of the University of California advisory services program has been to set up marine information channels through an already existing statewide network of county agricultural extension offices. These offices are staffed with university specialists who not only relay research results to the community but also carry user needs back to educators as guidelines for future studies.

While this new combined effort of agricultural and marine sciences is being organized into "Cooperative Extension," other advisory service projects operate separately. There is a project for disseminating advice on handling and processing edible marine products, a project to supply southern California small boat operators with weather and sea condition information, and a geological data center that reports on petroleum resources.

Until the UC Sea Grant Program began setting up its advisory services this year, research results and agency program activities were not taken to consumers in an organized program. The user who needed information had to try to find it among the diverse and often uncommunicative offices and staffs of the universities and government.

Cooperative Extension Project in Marine Advisory Services

Maynard W. Cummings

UC Agricultural Extension Service established in 1914

More than 30 California counties border the Pacific Ocean and the navigable tidewaters extending inland from San Francisco Bay to the deep-water ports of Sacramento and Stockton. In each is a University of California Agricultural Extension Service office. Since 1914 these offices have been disseminating to local audiences technical information on all agricultural, land, and community resources uses.

University academic staff at these county locations have a strong identity as suppliers of immediately available information and as the channel to the University and other sources for solutions to problems. The consultants' good reputation for bringing research attention to local needs, along with their resident status in the community, gives them acceptability and trustworthiness for providing useful information of quality.

Sea Grant Advisory Services new program component

"Cooperative Extension"

Program Coordinator establishes administrative liasons

The established UC Agricultural Extension Service has now accepted responsibility for including Sea Grant Advisory Services as a program component. The coordinator of the new Cooperative Extension program spent this past year establishing liaisons to explain the objectives of Sea Grant and how they fit in with longstanding Extension program areas. He spoke with university Extension administrators, with university vice-presidential level administrators, and with county Extension staff. Response at all levels was very favorable and the coordinator was directed and encouraged to expedite program development to utilize statewide Extension facilities and people. County Extension directors and their staffs are enthusiastic about extending information in new disciplines in marine resources to their local audiences.

Simultaneously, the program coordinator familiarized himself with operational procedures within the Sea Grant administration and research programs. This indoctrination was accomplished through participation with Sea Grant administrators in preparation of proposals and reports, in site visit reviews, and in joint planning of advisory projects. Sea Grant administrators, at the same time, were becoming familiar with how the established Extension Service functions and why this university department is logically suited as a statewide advisory program delivery system.

Administration network

Sea Grant research and teaching programs, individualistic at the participating campus levels, are university-wide, administered through the institute of Marine Resources and Sea Grant administration. Liaison is maintained at all levels with the program coordinator for advisory services informationally responsible to both Extension and Sea Grant administration.

Contacts with industry and government

To insure that advisory programs focus on pertinent needs, close liaison with industry and government is essential. Although attention is given to problems or questions brought by marine resource users directly to the advisory staff or routed to them through county offices, much of the advisory program can be concentrated on established needs if these are known. To accomplish this, the advisory staff will seek industry and government suggestions. This past year, Sea Grant advisory and research personnel met with seafood handling and processing industry leaders to inform them of Sea Grant Program development and to find out their informational need priorities. A continuing committee was established for this industry group.

Coordination with other California Sea Grant institutions

UC established contact with other California institutions having Sea Grant advisory programs. The University of Southern California (USC) was designated a Sea Grant Institution at the same time the University of California received this distinction. California is the only state with two institutional-level programs. Coordination with USC in advisory work has led to understanding how both might function with a maximum of cooperation and a minimum of duplication. USC advisory programs emphasize mass communication of information relating to multiple uses of coastal areas, pollution problems, and recreational developments largely in the urbanized coastal areas.

University of Southern California

Cal State, San Diego and Humboldt

California State University, San Diego, has very limited advisory programs. Since that school's Sea Grant project is contracted through the UC institutional grant, the advisory program coordination is automatic.

California State University, Humboldt, receives advisory program funds on an area grant basis to supply information directly to the Humboldt Bay area fishery and to extend this information elsewhere as needed.

Extension specialists (consultants)

Statewide extension specialists are an important part of Cooperative Extension. They supply general publications and offer consultation on specific problems, using specialist newsletters and workshops to provide detailed subject matter knowledge to the county staff in order to keep them up-to-date on research and other developments.

The need for specialists to program and train county staff is great because every local office cannot be staffed with experts in every field. County staff select and adopt for their situations the overall information supplied to them by the statewide specialist.

Two new recruits in marine science

So far two full-time Sea Grant Extension specialists have been recruited. One of the two specialists functions in fisheries, aquaculture, and general marine resources information. On the job only a short time, he has already established excellent rapport with county Extension staff and is becoming known to some industry segments. Some county staff training has been accomplished by this specialist and more intensive, formalized sessions are planned. A rapid start has been made in youth educational programs. Since UC's Cooperative Extension administers statewide 4-H programs, this is a large immediate audience. The marine resources specialist has adapted Oregon 4-H Sea Grant Literature for California distribution and there already are 4-H marine science projects underway in this state in both coastal and inland counties. Again, the existing Extension staff with its organization and experience could step right into the handling of a new subject-matter area with very little adjustment. Since California 4-H has over 50,000 members, there is tremendous potential for Sea Grant education. This specialist also has submitted manuscripts for additional 4-H publications and for sport-fishing information.

The second full-time specialist will report for duty in January, 1973, and will work in the field of seafood technology.

Other Sea Grant personnel

In addition to these two full-time specialists, two regular Cooperative Extension staff members devote half time to Sea Grant seafood technology and advisory program administration respectively. One half-time technician in food technology is also assigned to Sea Grant.

New California directory of services for boat owners

Among advisory projects accomplished in 1972 was the collection of data for a California directory of services for boat owners. This will complement the directory previously compiled for the North Pacific coast, Oregon to Alaska, and will be available in early 1973. It will list various kinds of services

and where they are located throughout California. Included will be emergency Coast Guard information, weather information, and directions on how to find fuel, repairs, or docking facilities.

Regional projects

The Cooperative Extension coordinator participated in a regional cooperative project called the Pacific Sea Grant Advisory Program (PASGAP). PASGAP, a committee of one representative from each Pacific coast state, Hawaii, and British Columbia, is separately funded by the National Office of Sea Grant. Its purpose is joint effort on programs with regional impact.□

Davis
A/E-2

Handling and Processing of Edible Marine Products

George K. York

Microbial monitoring systems

Microbial monitoring systems, modified from the procedures presently used in the processed red meat and poultry industry, were set up in several fish processsing facilities. The systems involve sampling of processing equipment by swabbing or using contact media prior to operation and at hourly intervals during processing. Thus, both sanitation efficiency and operating procedures can be evaluated. The systems, when properly acted upon, result in improved cleanliness with extended quality during shipping, storage, and retailing. The method has been modified to include assays for indicator bacteria, *Escherichia coli,* and food poisoning bacteria, *Staphylococcus aureus* and *Vibrio parahaemolyticus.*

Improved cleanliness and extended quality

Food poisoning incidents investigated

As a consultant to the Bureau of Food and Drugs, California Department of Public Health, York participated in the investigation of several outbreaks of food-borne illness where seafoods may have been involved. In an outbreak of botulism, he confirmed the absence of neurotoxin in a variety of commercially frozen and smoked fish products that were implicated by the press as a possible source of the outbreak. He examined and confirmed the presence of *V. parahaemolyticus* in shellfish involved in an outbreak of gastroenteritis and implicated pseudomonad spoilage in a case of scromboid poisoning.

These investigations were a part of the program for extending technical information for solving problems of individual processors and for associations of processors. Additional problems that were investigated included discoloration fo frozen fish, contamination of salmonellae in fish meal, and contamination of a processing facility with indicator bacteria.

Consumer education

A number of meetings, workshops, conferences, and seminars were given for consumer education. The groups represented such agencies as regional sections of the California Home Economics Association, California Dietetics Council, California Nutrition Council, American Association of University Women, as well as cooperatives and volunteer organizations. Much of the information extended during these meetings was about the nutritional aspects of fish and seafood, proper handling, storage, and preservation, and the problem of accumulation of heavy metals in certain types of fish.

Seminars, workshops on sanitation and fish processing

York participated with other members of the Pacific Area Sea Grant Advisory Program in seminars and workshops on sanitation and smoking and processing fish. The audience included processors and fishermen in northern California, Oregon, and Washington. These types of programs will be continued on a regular basis with changes in subject matter to cover the entire field of the technology of edible marine products.

Waste management information

York participated in applied and demonstration research and consulted with various agencies on the topic of food processing waste management, including fish and seafood processing wastes. A project was started to prepare a review of the procedures used in fish processing waste treatment and disposal and to make this available to the industry. This also includes the field of odor control in fish processing. This work included participation in the Second Symposium on Food Processing Wastes.□

Cooperating Organizations

Anthony's Sea Foods, San Diego, California
California
California Department of Fish and Game, Sacramento
California Department of Public Health
California Seafood Institute, San Francisco
Federal Food and Drug Administration
Lazio's Fish Company, Eureka, California
Meredith Fish Company, Sacramento, California
National Canners Association, Berkeley California, and Seattle, Washington
Star-Kist, Terminal Island, California
Van Camp Sea Foods, Terminal Island California

Cal State, San Diego
A/E-3

Marine Advisory Services Expansion

Glenn A. Flittner and Donald I. Eidemiller

Weather, sea condition info for small boat owners

Southern California sport fishermen and other small boat operators need near-offshore weather and sea condition reports similar to the reports that distant, deepwater albacore fishermen receive from La Jolla, broadcast by the National Marine Fisheries Service. KPBS-TV and FM facilities at California State University, San Diego, could relay the needed information if it were available.

New data network terminals installed

Naval Environmental Data Network (NEDN) terminal facilities were installed in the Geography Department and became operational January 1, 1972. Existing National Weather Service (NWS) landline facsimile terminal facilities were modified to copy selected charts on a 24-hour basis. NEDN and NWS map products were used extensively in the Introductory Meteorology lecture class (105 students) to give insight into present and forecast weather conditions. The NEDN prognostic charts were found to be extremely useful and exceptionally reliable. Lively student map discussions resulted in a better understanding of modern meteorology.

Students use facilities for classroom projects

The meteorology laboratory classes used NEDN and NWS data and analyses in six laboratory exercises. The use of modern computer products enabled the students to work with "live" products rather than "canned" ones that generally have no relation to present atmospheric conditions.

The presence of this data facility permits students to be exposed to modern, up-to-date meteorological products. In addition, three graduate students received training in the operation of the data terminal facilities during the year. It is hoped students will be able eventually to run advisory services operations.

Progress slow in setting up working weather service

The lack of a formal statewide structure in which to work and to identify roles slowed progress toward actually implementing the marine advisory services program. Informal discussions were continued by the director, however, on the proposed use of KPBS-TV and FM facilities in conjunction with prospective expansion and upgrading of WWD-HF facilities at Scripps Institution of Oceanography, UC, San Diego.□

San Diego
A/CZ-3

Geological Data Center

Thomas E. Chase

Scripps ships collect data useful to oil companies

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, we do have a public advisory service to render. Research vessels of Scripps Institution of Oceanography (SIO), UC, San Diego, produce information of considerable interest to oil companies throughout the world by conducting geological and geophysical exploration of the deep oceans using pneumatic reflection profiling systems, magnetometers, and echo-sounders. 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 therefore makes it possible to plan better exploration programs.

Pacific Ocean surveys

Initially the center has put only the data of the Pacific Ocean into its information system. The reason for this is that Scripps has collected the greatest amount of data in the Pacific. It is planned to make the Pacific into a workable system and then to expand to the other oceans.

Types of data

The Center handles the following type of geologic data: (1) soundings and bathymetry, (2) magnetic anomolies, and (3) seismic reflection and refraction. Navigational tracks are also prepared to correlate the data to geographical positions.

Soundings and bathymetry

Scripps is equipped to digitize most soundings and navigation at sea. These data undergo extensive editing ashore to ensure no errors are included into the final data tape. The soundings are then compiled onto compilation sheets covering particular geographical areas, with other soundings included. The compilation sheets are Mercator Projection with a scale slightly less than 1:1,000,000. Soundings are in fathoms and generally uncorrected for sound velocity in seawater. In addition to Scripps sounding data, we have soundings of varied quality supplied in the past by other institutions and agencies. This information is also available on the compilation sheets.

Compilation sheets

Magnetic anomolies

As with bathymetry and navigation, magnetic anomolies can be digitized aboard ship. These data will eventually be drafted onto 1:3,000,000-scale charts with anomolies plotted next to the ship's navigational track.

Seismic reflection and refraction

Sub-bottom records are being collected by the air gun system and copied onto microfilm. A continuous photograph of the record is made and placed on 42-by-60-inch Mylar with correlation to 1:3,000,000-scale charts and microfilm rolls. Where seismic reflection and refraction data is extensive, special track charts (1:1,000,000-scale) are also prepared.

Previous published work by members of the Center are available for distribution. Contour charts of particular areas, SIO Reference Series concerning special projects, and interpretation of data by the members will also be made available.

Information readily available

If possible, all requests for data will be filled. However, duplication costs must be carried by the requesting company or individual.□

Sue Price, editor

Gerald Wick, consulting editor

Rex Heftman, design

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