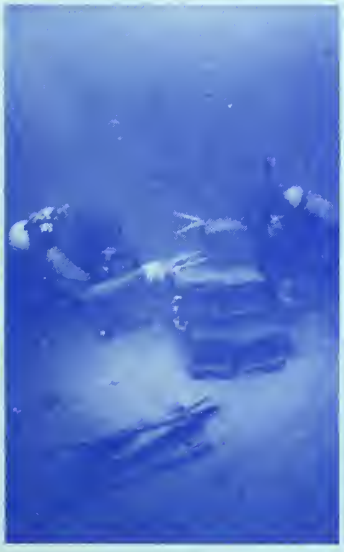
NOAA Undersea Research Program Fiscal Years 1979 and 1980 Report

U.S. DEPARTMENT OF COMMERCE
Research and Development
Special Projects Office



NOAA Undersea Research Program Fiscal Years 1979 and 1980 Report

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U.S. DEPARTMENT OF COMMERCE
Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
John V. Byrne, Administrator

Research and Development Special Projects Office
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CONTENTS

LIST OF ABBREVIATIONS AND ACRONYMS

ADC	Association of Diving Contractors
ADS	Atmosphere Diving Suit
AOML	Atlantic Oceanographic and Meteorological Laboratory
ARC	*Alvin* Review Committee
ATA	Atmospheres, Absolute Pressure
BIP	Balanced Indigenous Population
BT	Bottom Time
BLM	Bureau of Land Management
CMSC	Catalina Marine Science Center
COE	Corps of Engineers (U.S. Army)
COPRDM	Interagency Committee on Ocean Pollution, Research, Development and Monitoring
CRHP	Caribbean Regional Hydrolab Program
CZM	Coastal Zone Management
DOD	Department of Defense
DOE	Department of Energy
DSRV	Deep Sea Research Vehicle
DUMAND	Deep Undersea Muon and Neutrino Detector
EEG	Electro-encephalogram
EMT	Emergency Medical Technician
EPA	Environmental Protection Agency
ERL	Environmental Research Laboratories
FY	Fiscal Year
HBF	Harbor Branch Foundation
HURL	Hawaiian Undersea Research Laboratory
IPHC	International Pacific Halibut Commission
JAMSTEC	Japan Marine Science and Technology Center
LRT	Launch Retrieval and Transport
MGGL	Marine Geology and Geophysics Laboratory
MLC	Main Line Component
MPE	Major Program Element
MSC	Medical Service Corps (U.S. Navy)
MUS&T	Manned Undersea Science and Technology
NDO	NOAA Diving Office
NEFC	Northeast Fisheries Center
NIOSH	National Institute for Occupational Safety and Health
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOS	National Ocean Survey
NSF	National Science Foundation
NTP	Normal Temperature and Pressure
NULS	National Undersea Laboratory System
NURP	NOAA Undersea Research Program
NWAFC	Northwest and Alaska Fisheries Center
OCS	Outer Continental Shelf
ONR	Office of Naval Research

OOE	Office of Ocean Engineering
OSHA	Occupational Safety and Health Administration
OSB	Ocean Sciences Board
OTES	Ocean Technology and Engineering Services
OTEC	Ocean Thermal Energy Conversion
PDP	Program Development Plan
ROV	Remotely Operated Vehicle
R/V	Research Vessel
SCUBA	Self Contained Underwater Breathing Apparatus
SECURE	Southeastern Consortium of Undersea Research Efforts
SEFC	Southeast Fisheries Center
SURF	Southeastern Undersea Research Facility
UDO	Unit Diving Office
UH	University of Hawaii
UJNR	United States-Japan Cooperative Program in Natural Resources
UMS	Undersea Medical Society
UNOLS	University National Oceanographic Laboratory System
URI	University of Rhode Island
USC	University of Southern California
USGS	United States Geological Survey
WHOI	Woods Hole Oceanographic Institution
WRUL	Western Regional Undersea Laboratory
ZID	Zone of Initial Dilution

INTRODUCTION AND SUMMARY

This report of the National Oceanic and Atmospheric Adminstration (NOAA) Undersea Research Program (NURP) presents a general review of the development and management of the program, and of its predecessor program, the Manned Undersea Science and Technology (MUS&T) Program, a summary of significant accomplishments since inception in 1970, and a detailed description of new and ongoing activities in the period October 1978, through September 1980. It is the seventh in a series of formal reports issued on the program. The salient elements of the program are managing integrated undersea research programs which are operated by academic-research institutions, and supporting scientific missions and projects applicable to NOAA research and service requirements.

Although NURP is the successor to the MUS&T, it has been reshaped and redirected to focus on providing undersea research facilities, supporting scientific investigations at those facilities, conducting a diving research and development program, and sponsoring the use of shallow-water and deep-diving submersibles. Other activities previously in the MUS&T Program, including NOAA diving safety, training and certification, systems engineering, and applied technology and advanced concepts (including underwater physics research) have been reassigned to other sectors of NOAA, namely, the newly organized Office of Ocean Technology and Engineering Services and the NOAA Diving Office. For the sake of completeness and consistency, this report covers the activities of both the former MUS&T Office and present NURP Office. To avoid unnecessary complexity, activities which were essentially continuing activities are not broken into segments corresponding to the two organizational entities.

Shortly before the beginning of Fiscal Year 1979, the Oceanlab Program, a congressionally mandated activity intended to provide technology needed to improve the effectiveness of manned underwater research, was redirected to include, in lieu of a single all-purpose facility, a complex of regional facilities providing a diversity of geographical, depth regime, observational, and manipulative capabilities. The evolution of the cooperative regional undersea research program is described in detail in this report.

During FY 1979 and 1980, NOAA continued to participate in partnership with the National Science Foundation and the U.S. Navy in a cost- and use-sharing relationship for support of the deep-sea research submersible *Alvin*. This was accomplished through the MUS&T Office, and later the NURP Office. MUS&T and NURP also supported the use of shallow-water submersibles for a variety of underwater biological, environmental, geological, and other scientific studies, which are summarized in this report.

Activities of FY 1979 and 1980 are described under the following categories: requirements and systems analyses, regional programs, submersible support, diving research and development, diving effectiveness and safety, and applied technology and advanced concepts.

BACKGROUND

The MUS&T Program was created to fulfill part of NOAA's responsibility for significantly increasing our knowledge of the ocean's resources and processes. Impetus for its formation came from recommendations by the National Marine Council, various advisory panels, and the Commission on Marine Science, Engineering, and Resources.

Staffing and planning for MUS&T began in December 1970, and funding was provided beginning in August 1971. Initially, the program was assigned to the NOAA Associate Administrator for Science and Technology; in September 1971, it was transferred to the Associate Administrator for Marine Resources. At the beginning of FY 1977, the MUS&T Program became part of the Office of Ocean Engineering. In March 1980, the Office of Ocean Engineering was merged with the Office of Marine Technology of the National Ocean Survey to form the Office of Ocean Technology and Engineering Services. That portion of the former program which supported the cooperative regional underwater laboratory systems, provided deep-diving and shallow-water submersible services, and managed diving research and development remained under the direction of the Office of Research and Development; this now constitutes the NURP Office.

In past years funds appropriated to the MUS&T Program were budgeted into broad functional categories: operational effectiveness, safety and technical coordination, fisheries research support, environmental research support, support of the submersible *Alvin,* and other scientific research. Manned platforms have been leased through contracts and grants to universities and occasionally to platform operators, based on both competitive and sole-source procurements. By encouraging cooperative involvement and support of other agencies engaged in underwater research, cost effectiveness has been maximized. Scientific and technical programs have been selected from unsolicited proposals, after review by members of the staff and outside reviewers. Program selection has been based on NOAA mission support needs reflecting national research goals and needs.

Currently the NOAA Undersea Research Program is budgeted in somewhat more specific categories: submersible support; diving research and development; the application of advanced techniques to *in situ* research; and undersea science and facilities support, particularly through the regional programs. The missions support NOAA's objectives in marine science, particularly the evaluation, development, and management of our marine resources. Knowledge gained from these projects is also used to plan longer-range marine activities and programs, and to solve day-to-day problems arising from competing interests in coastal and inland waters and the deep ocean.

OBJECTIVES

The goal of the NOAA Undersea Research Program is to promote and enhance manned undersea research and operational capabilities to support NOAA in carrying out its ocean-related mission responsibilities. These mission responsibilities include managing and protecting living resources and their habitats, monitoring marine pollution with studies of its fates and effects, studies of seafloor properties and processes, management of marine sanctuaries, and dissemination of oceanographic predictions.

Undersea research in this context is defined as that body of marine research activities that requires the conduct of complex observational and manipulative tasks using man directly in the sea and extensions of his capabilities through use of submersibles, undersea habitats, remotely controlled vehicles, and special diving systems.

To meet the overall goal of the NOAA Undersea Research Program, the following basic objectives have been established:

- Broaden the support of scientific research involving undersea technology,
- conduct diving research and development,
- provide submersible support for NOAA research missions,
- implement and manage regional undersea research programs.

These objectives are being pursued by a small staff of technical personnel who are well-acquainted with Federal, industrial, and academic underwater programs and interests. The programming and planning endeavors of the staff are guided by the advice and direction of the NOAA Assistant Administrator for Research and Development, the Director of the Special Research Programs Office, of which the NURP Office is a component, and by the suggestions and recommendations of such bodies as NOAA's Undersea Research Policy Committee (internal), the Ocean Sciences Board of the National Academy of Sciences, and the Marine Board of the Assembly of Engineering. The NURP Office also benefits from joint planning on various missions with other Federal agencies, including the U.S. Navy, the National Science Foundation, the U.S. Coast Guard, the Department of Energy, the Environmental Protection Agency, and the National Institute for Occupational Safety and Health, and academia.

NEEDS AND REQUIREMENTS

During FY 1979 and 1980, NOAA conducted and sponsored three significant studies of the Nation's and NOAA's requirements for undersea research, and of the facilities, systems, and organizational entities which might be devised and implemented to satisfy these requirements. The studies, although they were essentially independent, did utilize inputs from studies previously conducted under the aegis of the Manned Undersea Science and Technology Office. The first of these studies was the Oceanlab Concept Review* conducted by a subcommittee of the National Research Council's Ocean Sciences Board. The study was prompted by recognition on the part of NOAA that the Oceanlab concept and program, as it had been defined prior to September 1978, did not fully meet the needs for support of undersea research. The second study, the University National Oceanographic Laboratory System (UNOLS) Committee's Submersible Science Study, was commissioned by NOAA, the National Science Foundation (NSF), and the Office of Naval Research (ONR). Originally this UNOLS study was to determine requirements for a successor to the *Alvin-Lulu* System (the deep-diving submersible *Alvin* and its support ship *Lulu*), but has evolved to include consideration of a wide range of undersea research requirements and submersible systems which might be utilized to satisfy them. Under the overall leadership of Dr. William B. F. Ryan of Lamont-Doherty Geological Observatory, the study is being conducted by the UNOLS Committee, a science panel, and an engineering task force. The third study, NOAA's Undersea Mission Requirements and Scientific Needs, was conducted largely within-house, by four panels of working undersea scientists. It addressed itself to a definition of undersea research requirements in the areas of fisheries, seafloor properties and processes, marine pollution, and ocean services. The panels completed their work and delivered their reports in February 1980.

OCEANLAB CONCEPT REVIEW

As is described in the report of the Manned Undersea Science and Techology Office for FY 1977 and 1978**, an extensive review of the Oceanlab Program was conducted in consultation with the Congress, the Office of Management and Budget, the Department of Commerce, and the undersea scientific community. In September 1978, NOAA decided to redirect the program to include:

- Continuing examination of manned undersea facility requirements with close interactions with the science community,
- analyses of existing U.S. undersea facilities and systems,
- development of requirements for advanced capability systems and technologies,
- expansion of NOAA's cooperative underwater laboratory program on a regional basis, using a number of different systems.

As the first step in analyzing what types of facilities best satisfy research requirements at reasonable cost, NOAA requested the Ocean Sciences Board (OSB) of the National Research Council to conduct a study identifying scientific needs and ocean research topics requiring undersea research activities and to define the types of facilities and techniques that would be needed to support these scientific requirements.

The Ocean Sciences Board formed a subcommittee, under the leadership of Dr. Fred N. Spiess of the Scripps Institution of Oceanography of the University of California, San Diego, to conduct this study. The Oceanlab Program was defined as a program providing facilities for conducting complex undersea observational and manipulative tasks in support of ocean research activities. The study addressed two principal questions: (1) Are there sufficient important scientific problems requiring Oceanlab capabilities and sufficient interest among competent scientists in carrying out the implied research to warrant a multimillion dollar program of this type? (2) If the answer to the first question is affirmative, what general direction should such a program have?

The study concluded that there are, indeed, sufficient important scientific problems requiring Oceanlab capabilities, and sufficient interest among competent scientists in carrying out the research implied. Appropriate research topics emerged in all the subfields of marine science, but the bulk were in the areas of biological oceanography and marine geology and geophysics. The biological problems ranged from studies of near-shore environments through concern with the scarcely known, fragile, gelatinous zooplankton, and plankton and nekton behavior and life cycles, to the need to understand the exotic communities found at active hydrothermal sites on the East Pacific Rise and Galapagos Spreading Center. Problems in geology and geophysics included those concerned with the dynamics of sediment-related processes—deposition, erosion,

*Oceanlab Concept Review. National Academy of Sciences, Washington, D.C., 1980
**Manned Undersea Science and Technology Fiscal Years 1977 and 1978 Report, 1979. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Rockville, Md.

slumping and those concerned with interrelated tectonic, volcanic, and hydrothermal questions. Interdisciplinary problems were also identified: the effects of catastrophic events in the atmosphere and oceans on the geological and biological aspects of the environment; the interactions between bottom sediment and near-bottom currents; and biological intervention into chemical, physical, and geological aspects of the seafloor. Initial insight into most of these questions has been derived in part from use of submersibles and unmanned vehicles, and from diving.

The primary capability required by undersea researchers is the ability to make direct observations, which is immediately coupled with sampling activity.

After sampling come the more complex activities of placing and operating research equipment on the seafloor or in the water column—essentially adapting laboratory experimental techniques for conducting experiments in the ocean environment.

The OSB Panel recommended, as a means of supporting the considerable body of undersea research identified, two parallel, evolutionary, and eventually merging lines for the Oceanlab program, namely:

- The establishment within NOAA of a broad research program exploiting the use of existing facilities, and enhancing present studies, including saturation diving, submersibles and remotely controlled unmanned vehicles.
- The conduct of necessary scientific and engineering studies, development programs, and procurement essential to bring into action the best relevant undersea technology available in the next few years.

The Panel also concluded that the Oceanlab facilities, both in the interim and as eventually constituted, should be operated by selected academic (oceanographic) institutions having interest and capabilities relevant to the types of research required.

UNOLS RESEARCH SUBMERSIBLE FACILITY REQUIREMENTS STUDY

In 1977, NOAA joined with NSF and the Navy's ONR to fund a UNOLS-conducted study of research submersible facility requirements for both short- and long-term needs within the U.S. scientific and technical community. For this purpose, *short term* refers to the utilization (or updating) of existing facilities, and *long term* refers to the replacement of or identification and procurement of new facilities.

This work was begun by the *Alvin* Review Committee (ARC), a part of UNOLS. The ARC, in conjunction with representatives from ONR, NSF's Office of Oceanographic Facilities and Support, and the Manned Undersea Science and Technology (MUS&T) Office of NOAA, established requirements for and the means for carrying out the study. In September 1979, a grant sponsored by NOAA, NSF, and ONR was awarded to Lamont-Doherty Geological Observatory to act as the project coordination office for the study. The study team, under the overall direction of Dr. William B. F. Ryan, consisted of three components: A Project Office, a Submersible Science Assessment Panel, and a Submersible Science Facilities Planning Task Force.

The purpose of the science study was to assess the current and projected requirements for UNOLS submersible science facilities, to review the alternatives that might be employed to meet these ends, and to recommend specific systems, for both short and long terms, along with priorities and associated costs. The major responsibility of the Science Panel in this effort was to assess the role submersible science plays in the larger context of ocean science and technology research, and to define the short- and long-term requirements for a UNOLS submersible facility. The Science Panel consisted of active researchers in the fields of biological, geological, physical and chemical oceanography, and of representatives from Government laboratories and academic institutions. In assessing scientific requirements, the panel considered the continental shelf and slope, deep ocean, and water column environments.

At this writing, the final report of the UNOLS Submersible Science Study has not been issued. The preliminary report of the Science Panel has concluded that:

- In the short term, UNOLS research utilizing deep-diving submersibles will depend on the use of *Alvin*.
- The present capabilities of *Alvin* with respect to sample collection, precise navigation, and the placement and observation of instruments on the seafloor can be profitably augmented while *Alvin* remains in use.
- The most pressing requirement for continued deep-submersible operations is replacement of *Lulu*, the present *Alvin* support ship.
- In the long term, *Alvin* should be replaced by a deep-diving submersible with significantly broader capabilities.
- Conducting required undersea scientific research dictates provision of an adequate shallow-water submersible system, including both submersible and support vessel, in addition to the deep submersible system. It is not effective to use the *Alvin-Lulu* system for shallow-water research.

Table 1.—Comparison of Basic Performance Requirements for *Alvin* and a Replacement Submersible.

	Alvin	New Submersible
Total Space	2.13 m sphere 3 people and controls and instrumentation	3 people and controls and instrumentation
Maximum Depth	4,000 m.	6,000 m.
Forward Speed	1.5 knots (max.) 1.0 knots (cruise)	
Descent, Ascent Speed	30 m/min	To allow approx. 6 hrs bottom time at 6,000 m
Payload	136 kg	453.6 kg
Viewports	3	5
Maneuverability	Up, down, backward, forward, rotation on vertical axis	Equal to *Alvin* or better; anchoring to bottom or vertical wall

The specific scientific capabilities needed to carry out the research identified requiring the use of deep-diving submersibles in the next decade include: direct visual observation; sample collection; sophisticated and precise

Alvin on launching well of support ship *Lulu*.

navigation system; instrumentation for *in situ* measurements; and placement and observation of instruments on the seafloor. The present capabilities of *Alvin* in these respects can be profitably augmented for the short term.

The Science Panel concluded that the most pressing requirement with respect to continued deep submersible operations is replacement of the *Lulu*, the *Alvin* support vessel. The replacement support ship should have a range of operations of 3,000 nautical miles, with 30-day cruise legs, the ability to launch and recover the submersible in sea state 4, accommodations for a scientific party of 14, and adequate scientific laboratory and scientific storage space.

The Submersible Facilities Planning Task Force is endeavoring to translate the scientific requirements for a deep-diving submersible including its support vessel and the requirements for a shallow-water submersible system into a set of realizable performance specifications with predicted costs. These will include specifications of systems for scientific data gathering instrumentation for the present *Alvin*, specification of pressure-hull materials, batteries, and other systems for a long-term replacement deep-submersible, and a definition of a desirable shallow-submersible system.

NOAA'S UNDERSEA MISSION REQUIREMENTS AND SCIENTIFIC NEEDS

In pursuing its undersea research program, both internally and extramurally through grants, contracts, and cooperative agreements with universities and industry, NOAA is repeatedly asked two questions: first, "How do you know that you are allocating limited resources to the highest priority activities?"; and, second, "What are the areas of greatest interest to NOAA so that proposals submitted will be considered responsive to a mission agency's needs?". Any effort to set priorities is difficult and in research it takes on a particular risk. Accordingly, priorities should not be used to limit the scope of legitimate research activities pursued or sponsored by NOAA, but rather to establish an emphasis in areas deemed to be of highest relevance as determined both by need and potential payoff.

To determine the needs and requirements of NOAA in performing its undersea research-oriented missions, four working groups were established late in November 1979 to address the areas of ocean services, fisheries research, marine pollution, and seafloor properties and processes. Each group was to provide, and if possible to prioritize,

research scenarios identifying needs and requirements of researchers as well as future salient problem areas and research opportunities within the 5- to 10-year time frame.* Specific tasks and projects were not to be designated. Instead, broad strategies for NOAA's research requiring the use of undersea technology were developed. The four areas were not mutually exclusive but interrelated and in many instances complemented one another.

These strategies and scenarios formed a basis for an integrated NOAA undersea program and were used for internal program planning and budgeting purposes. They provided criteria and guidance for requesting science proposals, reviewing these proposals, and relating their need to available regional facilities. They were not program development plans and were therefore neither exhaustive nor complete; nor were the identified tasks assured of support or implementation.

The membership of each group was purposely kept small, consisting of scientists and researchers from academia, research institutions, and NOAA. Each member was experienced in undersea operations, marine research, and NOAA's programs.

The specific terms of reference and method of developing the research scenarios for the four groups were developed independently by each. The major areas of the ocean services category that required or could benefit most from use of undersea technology were determined to be: assessment of marine sanctuaries, locating and characterizing outer continental shelf obstructions, and research and development in oceanographic prediction.

The fisheries research category included four major areas: fishery systems assessment and dynamics, ecosystem response to habitat alterations, evaluation and improvement of harvesting methods, and habitat enchancement and aquaculture. The term *fisheries*, as used in these four areas, refers to living resources in the marine environment including marine mammals, fish, shellfish, invertebrates, coral, and algae.

In the marine pollution category two areas were emphasized: first, the fates of pollutants—addressing the mode of transport (i.e., advection, diffusion, dispersion, etc.); and second, the effects of pollutants—investigating community structure change, habitat alteration, and behavioral changes. Using the priority for research called forth in the "Federal Plan for Ocean Pollution Research, Development, and Monitoring, FY 1979 - 83,"** each area was addressed with respect to its process, use of undersea technology, and importance.

In seafloor properties and processes, five basic categories of major geological research were identified: seafloor surveys, seafloor stability studies, geodynamic research, sediment dynamics research, and seafloor fluxes—both chemical and thermal.

These groupings or categorizations were viewed as NOAA's first attempt at identifying and determining both its present and future undersea mission requirements and technology needs. The categories and outputs will periodically be reviewed and updated as new needs and inputs surface.

THE NOAA UNDERSEA RESEARCH PROGRAM

Based on analyses of its mission requirements for undersea scientific research, inputs from the Reports of the Subcommittee of the Ocean Sciences Board, preliminary results of the UNOLS Research Facility Requirements Study, and the results of ongoing scientific research, NOAA set forth the following policies and goals for its Undersea Research Program:

- Facilities capable of performing undersea research and of providing research services will be supported by NOAA.
- Support for undersea facilities will be determined by NOAA scientific research needs and priorities.
- Responsibility for operational management of these facilities generally will be in universities or oceanographic institutions.
- Funding support for the necessary facilities will be integrated with the funding of the scientific research proposals.
- An on-going interactive process will be established with experts in ocean engineering to ensure that new facilities employing the best available technology will be considered to satisfy research requirements.

This policy was established in a report*** submitted to the Congress on March 31, 1980, and resulted in the establishment of three new cooperative regional undersea research programs. These new programs are in addition to NOAA's existing Caribbean Regional Hydrolab Program (CRHP), at St. Croix, U.S. Virgin Islands. This policy also maintained NOAA support of the deep-diving research submersible *Alvin* and of missions utilizing small research submersibles. In addition, NOAA will continue to support diving research and development. These efforts are directed and coordinated by the NURP Office.

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*The Undersea Research Program of the National Oceanic and Atmospheric Administration, Appendix II; 31 March 1980; U.S. Department of Commerce, NOAA

**Report of Interagency Committee on Ocean Pollution, Research, Development, and Monitoring (COPRDM), Chairman, James P. Walsh, NOAA, December 1979.

***The Undersea Research Program of the National Oceanic and Atmospheric Administration. U.S. Department of Commerce, NOAA, May 31, 1980.

NOAA'S REGIONAL UNDERSEA RESEARCH PROGRAM—INTRODUCTION

NOAA was given the mandate to establish programs for the assessment, protection, development, and utilization of U.S. Coastal Zone resources. To address this mandate, NOAA's Manned Undersea Science and Technology (MUS&T) Office initiated, in 1977, the NOAA Undersea Laboratory System (NULS) program. Funds for the program were provided in the FY 1978 appropriation to NOAA for continuation of the Oceanlab Project; the Senate Appropriations Committee report of June 1977 stated that funds in the appropriation were to be used for "cooperative undersea programs, including habitats in shallow and intermediate depths."

The purpose of the program was, and is, to provide manned underwater facilities and research support to investigations of U.S. coastal marine environmental, biological, geological, and ecological problems. Initial program emphasis was on the provision of seafloor laboratories and the advanced technology needed for safe saturation-diving operations in support of scientific missions.

The first phase of the program was formulated in such a way as to permit a focusing of scientific interest on marine problems solvable by *in situ* research during the development, construction, and initial operation of a Mobile Underwater Laboratory System (Oceanlab), planned for the period 1977-82. The purpose of this phase of the program was to develop techniques, knowledge, and expertise in operations and safety which might later be used effectively in more complex advanced coastal and deeper water systems. In addition, undersea research was to be accomplished.

As discussed in more detail in the following section, this first phase was implemented by the establishment of the first regional cooperative undersea facility, then called NULS-1, operated for NOAA by the West Indies Laboratory of Fairleigh Dickinson University, and using the undersea habitat, *Hydrolab*.

The overall goals of the NULS program were to:

- Acquire basic scientific information about the marine ecology and environment applicable to conditions existing in U.S. coastal areas.
- Support research efforts requiring advanced underwater laboratories and saturation-diving operations in pursuit of solutions to marine environmental problems.
- Demonstrate that safe manned underwater operations can significantly enhance the ability of researchers to successfully complete selected tasks and that classical land-based laboratory scientific methods can be extended to the seafloor.
- Provide a mechanism to ensure continuity of effort and long-range funding for otherwise infeasible *in situ* research efforts.
- Provide the training and facilities to develop a cadre of scientific personnel proficient in the use of underwater laboratory systems and advanced underwater research techniques.

In September 1978, the Oceanlab Program was redirected. As part of the newly constituted program, NOAA decided that the cooperative underwater program should be expanded to provide, in several regions, undersea laboratories using different systems. "Letters of interest," indicating possible collaboration in establishing and maintaining regional laboratories and conducting scientific research programs using them, were solicited from over 400 academic institutions. Initially, it was contemplated that the second step in the program would consist of the establishment of a second undersea laboratory and program, tentatively called NULS-2. Fifteen positive responses were received. After screening, nine of these were selected as representing potentially viable candidates. The institutions that had submitted these nine were asked to develop detailed feasibility studies, setting forth the proposed facilities, the scientific programs envisaged, and means for operation and control. The nine feasibility studies were completed by March 1, 1979, and were evaluated by a panel of scientists and engineers experienced in undersea marine research.

Of the nine, three were selected as superior. These were submitted by the University of Hawaii, the University of Southern California, and the University of North Carolina at Wilmington. The evaluation criteria used by the panel emphasized not only the candidates' experience in undersea operations and past marine scientific activities, but also their proposed science programs and how well these programs related to the use of the facilities proposed.

Each of the three institutions was asked to submit a formal proposal discussing in detail the development and operation of the regional undersea research program. A second evaluation panel was set up consisting of engineers and scientists experienced in undersea operations, marine science programs, and NOAA's mission requirements. This panel reviewed the proposals in detail and provided recommendations on how the programs should be implemented.

In July 1980, separate contractual cooperative agreements were awarded to the three universities by NOAA, authorizing the implementation of their undersea facilities

Map showing respective locations of regional programs.

and programs. These programs and facilities, along with the ongoing *Hydrolab* program, are described in more detail in the following sections.

CARIBBEAN REGIONAL HYDROLAB PROGRAM

The first segment of the Regional Undersea Research Program to be implemented was the Caribbean Program, which is operated for NOAA by the West Indies Laboratory of Fairleigh Dickinson University. The centerpiece of the program is the seafloor habitat *Hydrolab*, which was purchased from its builder, Perry Oceanographics, Inc., of West Palm Beach, Fla., in 1977. The habitat was refurbished and placed on the ocean floor in the Salt River Canyon off the north central coast of St. Croix, U.S. Virgin Islands.

Description

Hydrolab is 4.88 m long and 2.44 m in diameter and is equipped to support four divers for as long as 14 days. It rests at a depth of 15.2 m, but aquanauts (saturated divers) using it have made excursion dives within Salt River Canyon to a maximum depth of 46 m.

During the period May 1, 1978, through August 10, 1980, the *Hydrolab* facility has supported 24 scientific projects, involving 56 investigator/aquanauts from 33 different organizations (mostly academic institutions).

The specific goals of the Caribbean Regional Hydrolab Program are to:

- Acquire, via *in situ* study, scientific information about the marine environment, in particular that prevailing in the Salt River Canyon and similar locations.
- Provide a national underwater facility for preliminary and advanced training of marine scientists in underwater research techniques and saturation diving.
- Develop new and improved underwater scientific research and engineering techniques, oceanographic instrumentation, and diving equipment.
- Provide a facility for the open-sea test and evaluation of underwater procedures tested in shore-based hyperbaric laboratories.

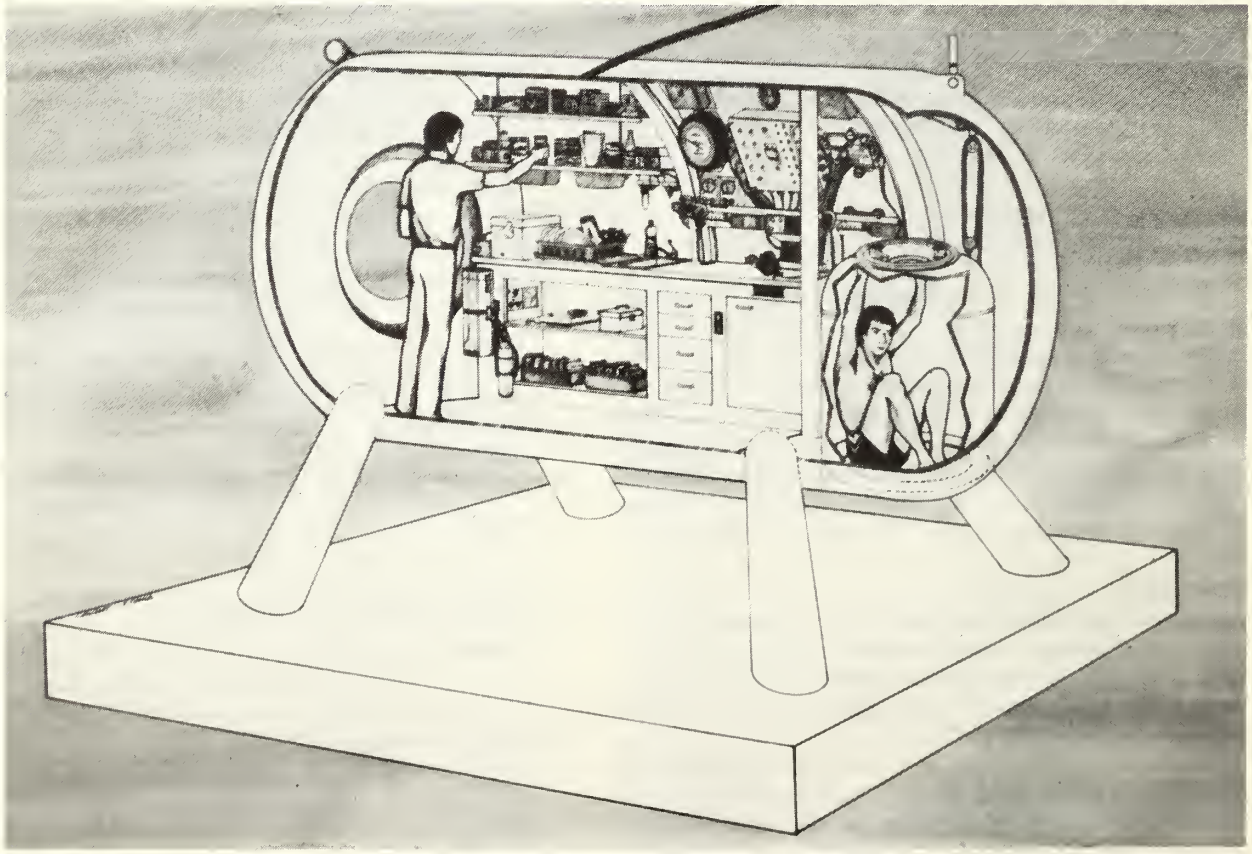
Although each of these objectives is being met in this program, the scientific research program is the *raison d'etre* for the program as a whole.

Program Science Missions

Scientific missions are selected by a Peer Review Board from proposals submitted by the academic community. This Board is chaired by a member of the staff of NOAA's Undersea Research Program Office.

The Report of the Manned Undersea Science and Technology Office for FY 1977 and 1978 lists the missions accomplished using *Hydrolab* during FY 1978, the first year of the facility's operation, and also gives abstracts of

Hydrolab located in Salt River marine canyon off St. Croix.



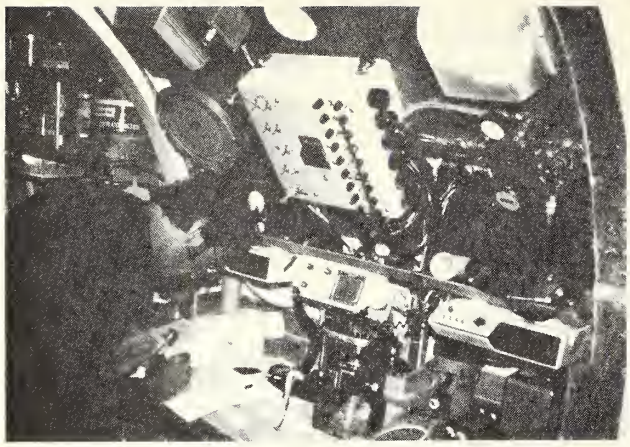
Artist's pictorial cutaway of inside of *Hydrolab*.

the results of nine scientific investigations accomplished in these missions.

Table 2, following, lists 16 scientific missions that were accomplished during FY 1979 and 1980. Following the table, the objectives, scientific personnel involved, and accomplishments of 15 of these missions are given in the abstracts of the Quick Look Reports required at the completion of each research mission at the *Hydrolab* site.

Table 2.—Virgin Islands Regional Program Hydrolab FY 1979-80 Scientific Missions

Investigating Institution	Date	Project
University of West Florida, Rutgers University	Oct 21-Nov 4 1978	Quantification of Reef Fishes
College of the Virgin Islands University of West Florida	Oct 22-Nov 4 1978	Oxygen Consumption of Reef Fishes During Quiescent Periods of Their Circadian Activity Cycles
West Indies Laboratory of Fairleigh-Dickinson Univeristy	Dec 12-18 1978	Sediment Transport Processes of Salt River Submarine Canyon, St. Croix, U.S. Virgin Islands
West Indies Laboratory of Fairleigh-Dickinson University	July 7-14 1979	The Settlement and Recruitment of Post-Larval Fishes into the Coral Reef Community
West Indies Laboratory of Fairleigh-Dickinson University	July 17-28 1979	Geologic Development of Salt River Submarine Canyon
University of Cincinnati University of Michigan	Aug 12-25 1979	The Comparative Feeding Behavior of Crinoids and Ophiuroids
University of Puerto Rico	Sep 15-27 1979	Manipulation of Large External Isopods on Brown and Blue Chromis
Department of Conservation and Cultural Affairs, USVI	Oct 1-11 1979	Optimum Yield for Virgin Islands Black Coral Fishery
West Indies Laboratory of Fairleigh-Dickinson University	Oct 16-24 1979	Structure of the Planktivorous Fish Community Along a Depth Gradient
University of California, Davis	Feb 9-16 1980	Social Behavior and Foraging Ecology of Caribbean Chaetodontids
Moss Landing Laboratories	Mar 24-Apr 6 1980	The Sources, Dispersal, and Utilization of Benthic Drifting Plants in the Salt River Submarine Canyon
State University of New York, Buffalo	Apr 17-23 1980	Resource Availability and Suspension Feeding by Gorgonians
College of the Virgin Islands	May 13-20 1980	In Situ Oxygen Consumption of Reef Fishes During Quiescence (Part II)
West Indies Laboratory of Fairleigh-Dickinson University	May 27-Jun 3 1980	Influence of Sediment Bioturbators on the Success of Seagrass Communities
University of Maryland	July 7-18 1980	An Experimental Analysis of Ecological Processes that Structure Fish and Invertebrate Reef Communities
Moss Landing Laboratories	July 27-Aug 9 1980	The Sources, Dispersal, and Utilization of Benthic Drifting Plants in the Salt River Submarine Canyon



Scientist at work in *Hydrolab*.

Collecting fish to measure their activity.

Quantification of Reef Fishes

Date: October 21—November 4, 1978

Purpose: Compare methods of quantifying reef fish populations (Report No. 78-8a).

Participants: University of West Florida:
Stephen A. Bortone,
Principal Investigator
Rutgers University: R.W. Hastings
University of West Florida: D. Siegel
University of West Florida: R.J. Bolton

Accomplishments: Two 100-meter transects were laid out running north to south, one each along the east and west walls of the Salt River Canyon. Each transect was marked off in 10-meter intervals. The methods used were the following: *Quadrate*: Stations were established at 10 m intervals along each transect. The diver would count and estimate the size of each individual fish which entered an imaginary 2x2x2 meter cube. *Random Swim*: Each diver would swim randomly but slowly in the vicinity of the transect and record species seen in a 50-minute sampling period. *Transect*: Two divers positioned themselves on either side of the origin and the transect line. The divers would then swim along the transect and record the number of each species seen. There were three approaches to photography. (1) *Movie (Cinetransect)*: A super 8 mm movie camera with day-night film was utilized. One diver would swim at a leisurely pace for 50 m while exposing 2.75 minutes of movie film, aiming on the transect line. This was done during both day and night. (2) *Movie (Turret)*: Again, a super 8 mm movie camera was employed. A diver would expose film while slowly panning in a circular fashion (clockwise) for 2 minutes (360°). Each transect was exposed at each end and center of the study area during daylight. (3) *Still Photography*: A diver would expose four frames of ASA-64 Kodachrome film in each of four compass directions. Each transect consisted of ten stations with four frames each. Preliminary findings indicate that each of the methods contributes a specific and necessary amount of information on the population level of reef fishes. The random-swim technique was the easiest to employ and probably the least sensitive to error. It became very obvious at the outset that any method that requires a diver to count fishes has a great amount of potential error inherent in it. It may be reasonable to see that, once the relative species abundance has been discerned, some effort may be made toward standardizing the population figures to absolute abundance levels. A prior assumption concerning photographic techniques seems to be invalid in our opinion. It is doubtful that even the most careful analysis will correct for a diver's *in situ* ability to identify fish. This study has reinforced some assumptions made in certain collecting techniques. The preliminary analysis indicates that some method which permits the diver to inspect all areas of the reef is essential to comparing reefs on the basis of their fish populations. Methods which restrict the observations of divers significantly underestimate the species diversity levels of reefs. Future attempts will be made to combine both quantitative and qualitative methodology to make efficient use of the type of information each of these provides.

Oxygen Consumption of Reef Fishes During Quiescent Periods of their Circadian Activity Cycles

Date: October 22—November 4, 1978

Purpose: Measure oxygen consumption of reef fishes (Report No. 78-8b).

Participants: College of the Virgin Islands:
Paul Winkler, Principal Investigator
University of West Florida:
R. I. Bolton, Jr.

Accomplishments: The standard or resting metabolic rate of fishes has proven difficult to measure under laboratory conditions. Fishes unaccustomed to visual restrictions, particularly during active segments of diel behavioral rhythms, tend to elevate oxygen consumption through spontaneous random and directed movement. The introduction of the fish, then, into an enclosure with water of a strange chemical milieu, would significantly increase the metabolic rate above basal levels. The decreased handling, transport, and acclimation procedures made available by field measurements, and the assurance of water with a familiar chemical milieu, temperature, and pressure, would

perhaps lend itself to a more accurate measure of standard metabolism. Oxygen consumption of diurnally active and nocturnally active fishes was measured using their corresponding quiescent periods. Fishes were captured and placed in the respirometer several hours before measurements were begun. Oxygen consumption was calculated. At the conclusion of the test, fishes were removed, preserved, and weighed. Water samples were analyzed for dissolved oxygen by the Winkler Method. Data for the bicolor damselfish (*Eupomacentrus partitus*) show a weight-oxygen consumption regression. Respiration values for larger fish are similar to those reported in the literature for tropical species. However, the data for smaller fish are not as well correlated. In general, cardinal fishes demonstrate a much higher level of awareness and activity during quiescent periods than diurnally active species. Individual variation among cardinal fishes appears to be quite high and, at this point, unpredictable.

Sediment Transport Processes of Salt River Submarine Canyon St. Croix, U.S. Virgin Islands

Date: December 12-18, 1978

Purpose: To determine sediment transport processes (Report No. 78-9)

Participants: West Indies Laboratory
Fairleigh Dickinson University: Dennis K. Hubbard,
Principal Investigator
Fairleigh Dickinson University: J. Sadd
Fairleigh Dickinson University:
H. Tonnemacher
University of Sydney, Australia: C. Phips

Accomplishments: Sixteen short-core (15-cm) sediment samples were taken from the canyon floor to determine the nature of the canyon fill. The coarsest sand occurred near the base of the west wall, confirming that this low trough was a zone of higher current activity. Other statistical parameters showed little systematic variation and no trends are readily apparent at this time. Measurements were also made to characterize wall "roughness." The data show that there are systematic changes in wall roughness along either wall, from wall to wall, and with depth. In general, the west wall is more irregular than the east with the majority of the wall roughness being confined to the upper transect. Experiments were also set up to measure directly the sediment transport rates during both storm and nonstorm conditions. Eight sediment traps were attached to the canyon walls at various sites to collect the sediment entering the canyon from the adjacent shelf. On the canyon floor, four bedload traps were buried at a depth of 30 m along the excursion limit line. As part of an ongoing West Indies Laboratory study in Salt River Canyon, five sediment tracer experiments were monitored before, during, and/or after the mission. At each site, sand was removed, washed, dried, and impregnated with a fluorescent material. The sediment was then reintroduced and allowed to move for a given length of time. The data from these experiments will be used to calculate daily transport values for the east and west canyon walls and the canyon floor. Based on these data, daily and annual transport rates will be calculated and a sediment transport model constructed. While analysis is incomplete, some conclusions can be made. First, the major areas of transport certainly vary from storm to nonstorm conditions. During nonstorm conditions, most of the sediment introduced to the canyon comes down the west wall. Furthermore, sediment appears to be stored in the canyon during nonstorm conditions. In contrast, during storms most of the sediment is introduced over the east wall in response to the dominant northeast swell and seas. Storm surges are dominant movers of sediment in Salt River Canyon. During storm conditions (5 to 14 days per year, on the average), 11,000 to 35,000 kg are introduced to the canyon and moved seaward through its axis. During the other 351 to 360 days of the year, only twice that amount is moved. The data seem to support our premise that storm events are extremely important and should be closely observed.

Unfortunately, the time period during which storms occur was later than usual in 1978, and did not coincide with the "time-window" set for the mission. Because the storms did not occur as anticipated, the mission was used to determine base-line data for the Canyon and to set up experimental traps to be monitored by surface-based divers during later storms. An attempt will be made to schedule a mission at a later date during a storm period.

The Settlement and Recruitment of Postlarval Fishes into the Coral Reef Community

Date: July 7-14, 1979

Purpose: Observe colonization of reefs by postlarval fish to describe the events of settlement and determine their role in shaping the eventual composition of the developing fish community (Report No. 79-1)

Participants: Fairleigh Dickinson University
West Indies Laboratory: John C. Ogden,
Principal Investigator
West Indies Laboratory: S. Miller
Cornell University:
W. McFarland and N. Wolf
University of Washington: M. J. Shulman
University of Massachusetts:
J. P. Ebersole

Accomplishments: Thirty artificial reefs were constructed on the sand floor of the Salt River Canyon at three different times: June 7, June 22, and July 7. Adult damselfish (*Eupomacentrus variabilis* or *E. leucostictus*) were transplanted to replicates of each time series. The reefs were monitored twice weekly prior to and several times daily during the mission. A transect on the east wall of the Salt River Canyon was also investigated for larval fish during the mission. Observations were made of interactions between settling postlarval fish, resident damselfish, and transient predators. Transfers of various species onto reefs were carried out to examine the effect of one species

on another. Preliminary results have indicated that interactions between postlarval fish are important in determining where fish will settle and the chances of their survival (e.g., presence of juvenile snappers (*Lutjanus mahogoni* and *L. buccanela)* prevents the settlement of postlarval grunts (Family *Pomadasyidae*)). Adult territorial fish also affect recruitment (e.g., adult damselfish lowered recruitment of surgeonfish (*Acanthurus bahianus* and *A. chirurgus*). The presence of an established fish community decreases recruitment of postlarval fish. Older reefs had significantly fewer settling fish than reefs that had just been built. Plankton tows were conducted at surface and midwater levels while aquanauts made tows at 2-3 meters above the canyon floor at regular intervals throughout the day and night. These established that there was an increase in the number of larval fish in surface and midwater plankton during the night, with a peak about an hour before dawn. An initial impression is that postlarval fish first appear on reefs at dawn.

Geologic Development of Salt River Canyon

Date: July 17-28, 1979

Purpose: To study the geologic development of Salt River Submarine Canyon by obtaining cores from horizontal holes drilled into the reef walls (Report 79-2)

Participants: Fairleigh Dickinson University
West Indies Laboratory:
Dennis K. Hubbard,
Principal Investigator
West Indies Laboratory: S. McGowan
West Indies Laboratory: H. Tonnemacher
University of Texas: J. Sadd

Accomplishments: The principal objective of this mission was to accomplish the drilling of a number of holes horizontally into the reef wall of Salt River Canyon, a process previously considered impossible, to obtain material which might throw light on the geologic development of the Canyon. Drilling operations ran in two-man shifts. During the 6 days of the saturation mission, four holes were drilled in the west wall. Total length of core penetration was over 13.7 m with an average recovery rate of 50 percent (this means that of the 13.7 m of core, half was solid rock and half was either sand, rubble, or void space in the wall). The deepest hole penetrated 5.4 m into the wall. This is the first time any extensive horizontal drilling of this type has been attempted, and one of the holes represents the deepest lateral penetration into deep reef framework on record. The cores have been split in half and the core-logging is underway. Samples have been sent to the University of Texas for radiocarbon dating. The preliminary results are speculative at this point. The wall was highly porous and the voids well-connected. The short-term turbid plume was observed on various occasions to emerge at sites away from the drilling operation. If it was easier for the turbid water to pass through the wall and emerge elsewhere than to return to the drill hole, then a free and open pore network is indicated. The coral samples collected were remarkably fresh. If they are Pleistocene in age (say 120,000 years b.p.), then this preservation is noteworthy. If they are Holocene (20,000-30,000 years b.p.), then one of the holes drilled records the thickest accumulation of Holocene material found to date.

The Comparative Feeding Behavior of Crinoids and Ophiuroids

Date: August 12-25, 1979

Purpose: Make repeated samplings of echinoderm food preferences and ambient supply of suspended food material. Document the crinoid distribution in the area, study the possible cause of their cryptic behavior, and make comparative samplings of nocturnally emergent plankton from various reef substrata (Report No. 79-3)

Participants: University of Cincinnati: David L. Meyer, Principal Investigator
University of Cincinnati: G. A. Minnery
Smithsonian Institution: C. G. Messing
University of Michigan: L. H. Somers

Accomplishments: The color patterns, living habitats, morphology, and depth distribution of four crinoids (*Nemaster rubiginosa, Nemaster discoida, Comactinia echinoptera* and an additional color form belonging to the genus *Nemaster*) were examined on the east and west walls of the Salt River submarine canyon. The three Nemaster species were sampled for gut contents in order to determine their feeding preferences. An ambient plankton sampling was taken concurrently with 64 micron mesh net. Insufficient numbers of crinoids at the site prevented the taking of a series of nocturnal feeding samples which would have enabled the times of maximum feeding activity to be documented. Data was collected for this population on the degree of nocturnal emergence, which appeared to be slight. The cryptic behavior of these crinoids was also observed. Two individuals of the yellow-tipped

Securing Crinoid for predator study.

Nemaster were attached to fiberglass screening covering a weighted plexiglass tray during the day. The tray was left in the open in the natural habitat, preventing the crinoids from crawling back into the normal semicryptic living position. Insufficient numbers of suspension feeding ophiuroids were found to compare to crinoids on the basis of feeding behavior and diet preferences. A single adult basket-star (*Astrophyton nuricatum*) was found on a night excursion along the west wall, but this individual was not in the normal feeding posture. A few juvenile basket-stars were also observed. Despite the abundance of sponges in the study area, the ophiuroid *Ophiothrix suensonii* was not common. A few individuals associated with the tube sponges were found along the west wall. The nocturnal suspension feeding ophiuroid *Ophiopsila* was found but is not common. The nocturnal emergence of demersal plankton from interstices of the reef may influence the day-night differences in feeding behavior of reef-dwelling suspension feeders. Because the crinoid study site was located 350 m from the underwater laboratory, the plankton sampling was conducted in closer proximity to the laboratory. Four traps (each covering 0.25 m x 0.25 m) were used to sample plankton emerging from several types of substrata (coral, sand, rubble, and *Halphila* grass on sand). Samples from these substrata were obtained over a variety of sampling periods, day and night. The samples will be analyzed in the laboratory and compared to results obtained from other reef areas.

Photographic study of research site at *Hydrolab*.

Manipulation of Large External Isopods (Genus Anilocra) on Brown and Blue Chromis

Date: September 15-27, 1979

Purpose: Transfer the large, external isopod *Anilocra* (which occurs under the eye of the brown chromis *Chromis multilineatus*, and the blue chromis *Chromis cyanea*) from infested brown chromis to noninfested brown and blue chromis. This method is new and has only been previously tested in aquaria (Report No. 79-4)

Participants: University of Puerto Rico: Ernest H. Williams, Principal Investigator
University of Puerto Rico: J. J. Kimmel
University of Puerto Rico: R. Waldner
University of Puerto Rico: L. B. Williams

Accomplishments: Uninfested brown and blue chromis were collected from an experimental reef at storage depth with quinaldine. Brown chromis infested with isopods were also collected at storage depth with quinaldine from the west wall of the canyon. Fishes were held individually in plastic aquarium bags inside dive bags on the tank rack for no more than 2 hours before transfers. The uninfested fishes were removed from plastic bags in an aquarium. They were then tagged in one or more areas just beneath the scales with an injection of acrylic paint, and held in contact with an isopod from a donor fish in the appropriate location (beneath one eye) until the isopod attached. They were then placed in a plastic bag, suspended in a dive bag for no more than 1 hour, returned to the experimental reef, and released into the field. The donor fishes were released in the areas in which they were initially collected. In the first 2 days, 15 brown and 13 blue chromis isopod transfers were released in the experimental area. During days four and five, five brown and five blue chromis and four blue and two brown chromis transfers, respectively, were released in the area of the experimental reef. During the final observations at the end of day six, 14 of the brown and 14 of the blue chromis were observed from the 22 brown and blue chromis released.

Transferring isopods between fishes was successfully accomplished during the study. Infested individuals were observed in the field throughout the study. The new method promises to be a very useful device for studying parasitism of marine fishes.

Optimum Yield for Virgin Islands Black Coral Fishery

Date: October 1-11, 1979

Purpose: Provide data on black coral growth and mortality to be used in the preparation of an optimum yield estimation for the Virgin Islands Black Coral resource (Report No. 79-5)

Participants: V. I. Department of Conservation and Cultural Affairs: David A. Olsen, Principal Investigator
V. I. Department of Conservation and Cultural Affairs: K. Turbe
Pressure Limited: B. Friedman

Accomplishments: 300 black coral colonies of two species were observed. They ranged in size from 0.5 mm to 47 mm basal diameter. The length and the width of 100 colonies were measured. The initial plotting of the data indicates that there may be size classes which may represent year classes. These data will also permit an initial estimate of the growth rate equation. Over 95 percent of the colonies in the areas of study were measured on the east slope and west walls. These areas consisted of approximately 130 meters of slope/wall area and were north of the standard excursion areas. The colony density will be estimated from

the standard figures of the area. During a followup mission, coral colonies will be remeasured, estimates of recruitment figured, and mortality calculated.

Structure of the Planktivorous Fish Community Along a Depth Gradient

Date: October 16-24, 1979

Purpose: To study the structure of the planktivorous fish community along a depth gradient (Report No. 79-6)

Participants: West Indies Laboratory
Fairleigh Dickinson University:
W. B. Gladfelter, Principal Investigator
Goucher College: W. S. Johnson,
Co-Principal Investigator
National Institutes of Health:
Jeffery Davidson

Accomplishments: The plankton feeding fishes (*Clepticus, Chromis cyanea, multilineata, C. insulata* and *Eupomacentrus partitus*) were investigated along three 50 m transects at a study area located along the east wall of the Salt River Submarine Canyon. These transects were located along the 15.2, 30.5, 100 and 45.7 m depth contours. The number and locations of these fishes were recorded in five excursions. A diver-towed plankton net was used to collect plankton along the same transect. Ten specimens were collected for further study. The results were preliminary requiring more definitive fish and plankton identifications.

Social Behavior and Foraging Ecology of Caribbean Chaetodontids

Date: February 9-16, 1980

Purpose: To obtain quantitative, behavioral, distribution, reproductive, and foraging data for certain Caribbean Chaetodontids and other fishes (Report No. 80-1)

Participants: University of California—Davis:
Steve Neudecker, Principal Investigator
University of California:—Davis:
W. J. Hamilton
Harvard University: P. S. Lobel

Accomplishments: The four 100-meter transects on the east slope and west wall of Salt River Canyon, established during NULS Mission 1 (1978), were sampled for a comparison of chaetodontid distribution, abundance, and foraging patterns. Abundance of chaetodontids and pomacanthids was measured by divers swimming along the transect lines and counting all relevant species seen within 1 meter to either side and within 2 meters above the transect. As in 1978, *Chaetodon capistratus* and *C. aculeatus* were the most abundant chaetodontid fishes. *Chaetodontid striatus* was counted on the east slope transect during this mission and not previously. *Chaetodon sedentarius* was observed only twice and did not occur in any transect survey. For a dietary comparison to the data taken in 1978, six individuals of *Chaetodon capistratus* and *C. aculeatus* were observed at each transect. Foraging behavior and prey selection were quantified by following individuals for 5-minute periods and consecutively tallying the number of bites on each prey item. Individual fish were not followed over successive 5-minute periods.

During evening crepuscular observations on the east slope, several pairs of *Hypoplectrus guttavarius* (shy Hamlet) were found spawning regularly in the vicinity of the east slope tank drop site. Observations of fishes at dusk have revealed that a majority of reef fishes spawn at this time. Hamlets spawn in pairs, above a towering structure. Such orientation may be advantageous to fish because it enables the adults to remain close to refuge (if a predator attacks), and puts the eggs relatively high into the water, out of the grasp of benthic dwelling planktivores. The crepuscular period is the general time of peak predation by reef piscivores and fishes exposed at this time risk higher mortality than at other times. However, at this time, eggs released in the water column have a low risk of mortality, since by dusk most reef planktivores have descended to the reef for the night and any remaining active may be quickly satiated. The relative influence of predators upon spawning reef fishes was also investigated. Several pairs of *H. guttavarius* were selected for study, and a baseline on their natural spawning activity was obtained for each pair. The following data were recorded: the time of each spawning clasp; the location and structure (coral, gorgonian, etc.) over which spawning occurred; height over the structure and height over the bottom where spawning occurred; and the movements of the spawning pair. The aquanauts then acted like potential predators by not allowing the pairs to spawn (each time fish attempted to spawn, a diver rushed in). The fish have two alternative reactions: they may cease spawning (which is the reaction of certain pomacanthids), or they may continue to attempt spawning regardless of the risk.

The results of this experiment will enable contrasting between the reproductive behavior of Hamlets and that of other reef fishes. It will also provide an experimental evaluation of the response of Hamlets to predators.

The Sources, Dispersal, and Utilization of Benthic Drifting Plants in the Salt River Submarine Canyon

Date: March 24—April 6, 1980

Purpose: Determine the sources, export and dispersal of shallow, near-shore benthic vegetation to deeper, offshore areas via the Salt River Submarine Canyon. Also determine the role of the drift accumulating on the canyon floor (additional habitat or food for demersal organisms) (Report No. 80-2)

Participants: MOSS Landing Marine Laboratories:
Ann C. Hurley, Principal Investigator
MOSS Landing Marine Laboratories:
Mike Josselyn, Co-Principal Investigator
MOSS Landing Marine Laboratories:
R. Cowen
MOSS Landing Marine Laboratories:
S. Hawes
MOSS Landing Marine Laboratories:
G. Cailliet
San Francisco State University:
T. Niessen
University of California-Berkeley:
J. Connor

Accomplishments: Little research has focused on the interactions between shallow coastal lagoons, nearby offshore reefs, and deeper waters. Submarine canyons may be important in the drifts of seagrasses and seaweeds from the shallow lagoon areas to deeper water. The drift material's role as an energy and habitat source must be determined in order to understand the coral reef ecosystem. Tropical seagrass beds and their associated seaweeds are among the most productive systems in the world, but it is not known how much of this productivity reaches the surrounding waters in forms readily used by the resident fauna. If this transport is significant, shore developments and other human influences on tropical lagoonal systems could have unpredicted consequences in the adjacent coral reef and deeper habitats.

Several methods were used, including vegetation surveys, drift studies, tagging experiments, and a survey of organisms utilizing the drift. Surface divers explored the Salt River Bay, the coral reef at the mouth of the bay, and the head waters of the submarine canyon to identify the possible drift vegetation sources to the submarine canyon area. Bottom drifters were set in several locations at the beginning of the mission in order to monitor possible avenues of drift dispersal. Surface divers set 150 drifters in the lagoon, the main channel, and at the head of the canyon. Habitat divers set the remaining 50 in the main axis of the canyon. Repeated sightings of these drifters were monitored to detect bottom currents and to suggest probable movement patterns of drift plants. Seven drift collecting nets were placed in and around the canyon to collect drift seaweed and seagrasses. Four of these were placed and sampled daily by the aquanauts. The remaining three were placed at the head of the canyon by surface divers and checked daily. Plants and animals in the net samples were sorted, identified, weighed, and enumerated. Species composition of drift algae is valuable in assessing the most likely source of the drift. Naturally occurring clumps of drift plants in the canyon were also collected, sorted, identified, weighed, and enumerated at the shore-based laboratory. Numerous transects within the canyon were taken to assess the distribution and abundance of drift plants and their potential associates and/or grazers.

A preliminary assessment of the role played by drift in the life history of its occupants was conducted. Information on animals in net drift and drift clumps suggests further investigations to be carried out in the second phase of the project (e.g., actual utilization of the drift).

Resource Availability and Suspension Feeding by Gorgonians

Date: April 17-23, 1980

Purpose: Determine whether gorgonians are capable of suspension feeding and the abundance and nature of particulate matter naturally available on the reef of Salt River Canyon (Report No. 80-3)

Participants: State University of New York—Buffalo:
Howard R. Lasker,
Principal Investigator
University of Miami—RSMAS:
M. A. Russel
University of Miami—RSMAS:
M. Gottfried
University of Miami—RSMAS:
D. Gordon

Accomplishments: The reef fauna of the east slope of Salt River Canyon is dominated by gorgonian soft corals. This domination can be related to the water quality (particulate rich), resuspension rate, and current. However, the autoecology of these species is not well known. Suspension feeding is of particular interest as gorgonians are almost incapable of capturing zooplankton. Like the reef corals, gorgonians also obtain nutrition from their algal symbionts, but it is likely that energetic and micronutrient requirements must be met through some additional mode of nutrition. The comparison of gross primary production and suspension feeding between species from shallow- and deep-water habitats is therefore of use in determining whether deep water and light species have adapted to their environments via photoadaptation or changes in particulate feeding. The work accomplished can be divided into three components: characterization of particulate resources, suspension feeding experiments, and measurement of photosynthetic rates. The greatest effort was directed at the first two components.

Resource availability will be determined from day and night water samples collected at 15.2 m and 27.4 m on each of the 5 days of experiments, with hand-held Niskin bottles. Samples were taken to determine particulate weight, chlorophyll, Carbon-Hydrogen-Nitrogen (C:H:N) composition, and the presence and abundance of mucous flocs and of proteinaceous particles. Additional samples were preserved to determine bacterial density and dissolved organic content. Zooplankton abundances also were measured and collections designed to provide a broad overview of zooplankton availability. Water and zooplankton samples do not characterize the temporal pattern of resource availability, and the water samples may not represent an "average" condition. Samples are, however, intended as an initial characterization of resource availability which may be useful in a comparative sense.

Feeding experiments were designed to measure capabilities for filtering unbound particles and mucus from the water column. The feeding capabilities of two *Plexaura spp.* were compared (one was most abundant in 24-30 m, and the other at 15.2 m, and both were among the dominant species at their respective depths). Branch tips from each of the species were clipped from a colony and reciprocal transplants made between 27.4 m and 16.8 m sites. During the experiment, the branch tips were enclosed in a plexiglass chamber providing natural light and natural water movement via oscillations of the flexible side walls. Ten-liter and 1.5-liter chambers were used. The colonies' behavior remained normal in the chamber. Hydrated sephadex heads were injected into the 10 liter chamber and colonies allowed to feed for 10 minutes. They were then placed in plastic bags and immediately preserved by injecting formalin. The colonies were tested in pairs (one from each species and four replicate experiments per site). Particle feeding experiments were conducted at both sites at approximately 1030 hours and at the shallow site at

2130 hours. Mucus feeding experiments were conducted using alcian blue stained mucus from *Porites spp.* as a prey item. At each site three branch tips of the "native" species were placed in the 1.5 liter chamber and the particles injected. Two replicate experiments were conducted at each site. In all, 112 feeding experiments were conducted. Polyps from each of the 260 branch tips collected will be examined for the presence, abundance, and size of food particles.

Photosynthetic rates were determined by measuring oxygen flux of groups of three branch tips enclosed in the 1.5-liter chambers. Initial and final 50 ml water samples were removed from each chamber and dissolved oxygen measured on the surface. Light was simultaneously monitored using Liquantum flux sensors. At the 27.4 m site, readings were integrated over the entire experimental period and an average determined. Spot readings were taken with a meter at the shallow site spot. Measures of afternoon net primary production and light level were made on each of 4 days.

In Situ Oxygen Consumption of Reef Fishes During Quiescence

Date: May 13-20, 1980

Purpose: Monitor the oxygen consumption of reef fishes during quiescence (Report No. 80-4)

Participants: College of the Virgin Islands:
Paul Winkler, Principal Investigator
College of the Virgin Islands: I. Szurley
College of the Virgin Islands: L. Greiner

Accomplishments: The oxygen consumption of bicolored damselfish *(Eupomacentrus partitus)*, a diurnally active reef resident, and various cardinal-fishes, nocturnally active residents, was measured by "sealed-vessel" respirometry during periods of quiescent behavior. Glass and plastic aquaria of various sizes with glass tops were used as respirometers, weighted with gravel, and supplied with plastic shelters in the larger damselfish tanks. Fish were collected while they were active and held in respirometers fitted with netting for 7 to 10 hours prior to testing. At the beginning of quiescence, the netting was replaced with weighted glass tops. Fishes were then run for 10 to 13 hours at which time water samples were taken from the respirometers by the evacuation of air from standard BOD bottles. Dissolved oxygen was measured with a YSI model 544 oxygen meter. Preliminary laboratory studies amply demonstrated the superiority of this method over the originally proposed "flow-through" system, which significantly raised the metabolism of laboratory fish. The long incubation times and larger respirometers used in this study allowed the fishes to "settle down" in their containers and perhaps, therefore, approach a measure of standard (resting) metabolism. In general, the respirometers functioned properly (i.e., fishes removed oxygen from the water according to their size). However, a larger damselfish respirometer without a plastic shelter (thus exposing the fish) consistently produced abnormally high metabolic rates. This was caused by piscivorous predators striking at the metabolism chamber. The situation was corrected using adequate shelter, and the metabolic rates declined. Sampling methods were improved, as was the reliability of the oxygen meter. During the study, a source of water with a predictable oxygen content was used to calibrate the meter.

Influence of Sediment Bioturbators on the Success of Seagrass Communities

Date: May 27—June 3, 1980

Purpose: Determine the influence of sediment bioturbators (specifically ghost shrimp of the genus *Callianassa*) on the grass beds and sediments in Salt River Canyon (Report No. 80-5)

Participants: Fairleigh Dickinson University
West Indies Laboratory:
Thomas H. Suchanek,
Principal Investigator
West Indies Laboratory: D. O. Duggins
West Indies Laboratory: B. R. Rivest
West Indies Laboratory: P. C. Banko

Accomplishments: Density surveys (10 m x 10 m) were performed at four depths from 15.2 m to 38.1 m. *Callianassa* were found to be patchily distributed. Two common *Callianassa* types were identified: mound builders (assumed to be *C. rathbunae,* or *C. quadracuta*) and hole dwellers (identified as *C. longiventris*).

Plankton collections were made during the day and at night to determine the diurnal behavioral patterns and distribution of larval *Callianassa*. In addition, emergent larval traps were placed over *Callianassa* mounds and the contents collected at three equal periods during the night for four nights centering on the full moon (the presumed period of larval release).

Burrow morphologies were analyzed by pouring fiberglass resin into open burrows and extracting the hardened resin. Burrows are shown to consist of surface-oriented tubes connected to subsurface chambers. The function of these chambers remains unknown.

An Experimental Analysis of Ecological Processes That Structure Fish and Invertebrate Reef Communities

Date: July 7-18, 1980

Purpose: Establish experimental reefs to be colonized by fish and invertebrates, census early fish colonists of these reefs, and sample plankton providing stock for recruitment to reefs in this environment (Report No. 80-6)

Participants: University of Maryland:
Marjorie L. Reaka,
Principal Investigator
University of Maryland: C. VanZant
Cornell University: N. Wolf
Fairleigh Dickinson University
West Indies Laboratory: F. Pecora
West Indies Laboratory: J. Lansteiner

Accomplishments: Fifteen artificial reefs were established along a 150-meter transect along the east wall of Salt River Canyon. The reefs were 10 meters apart and 10

Construction of artificial reefs for fish colonization studies.

meters west of the rubble along the east wall. Reefs for fish colonization were constructed of cinder blocks aged in seawater and held in place by rebars. Artificial reefs were established for invertebrates by placing pieces of normal coral rubble (sun dried in order to provide unoccupied space for settling cryptic organisms) at a given reef site. The artificial reef was established by impaling each piece of rubble on a short rebar. In addition, four small houses made of ceramic clay and plexiglass were around each piece of rubble, thus allowing the observation of the invertebrates settling in the holes of these houses through the plexiglass base. Three experimental conditions were established among the shallow reefs: five (Type A) reefs were constructed of both cinder blocks and sites for invertebrate colonization (rubble, ceramic houses); five (Type B) reefs provided only sites for fish (cinder blocks); and five (Type C) reefs were comprised of only sites for invertebrates (coral, rubble, ceramic houses). The reefs were placed in an A,B,C,A etc., sequence along the transect. Five artificial reefs were also constructed for fish and invertebrates (cinder blocks, coral rubble, ceramic houses) along the 33.5 m depth contour across the mouth of the Salt River Canyon. These reefs were initiated 20 meters west of the east wall, and placed 10 meters apart. Five Type A reefs were constructed in very shallow water (6 m), using surface diving techniques on the back reef of Salt River Canyon as a control for the deeper sites.

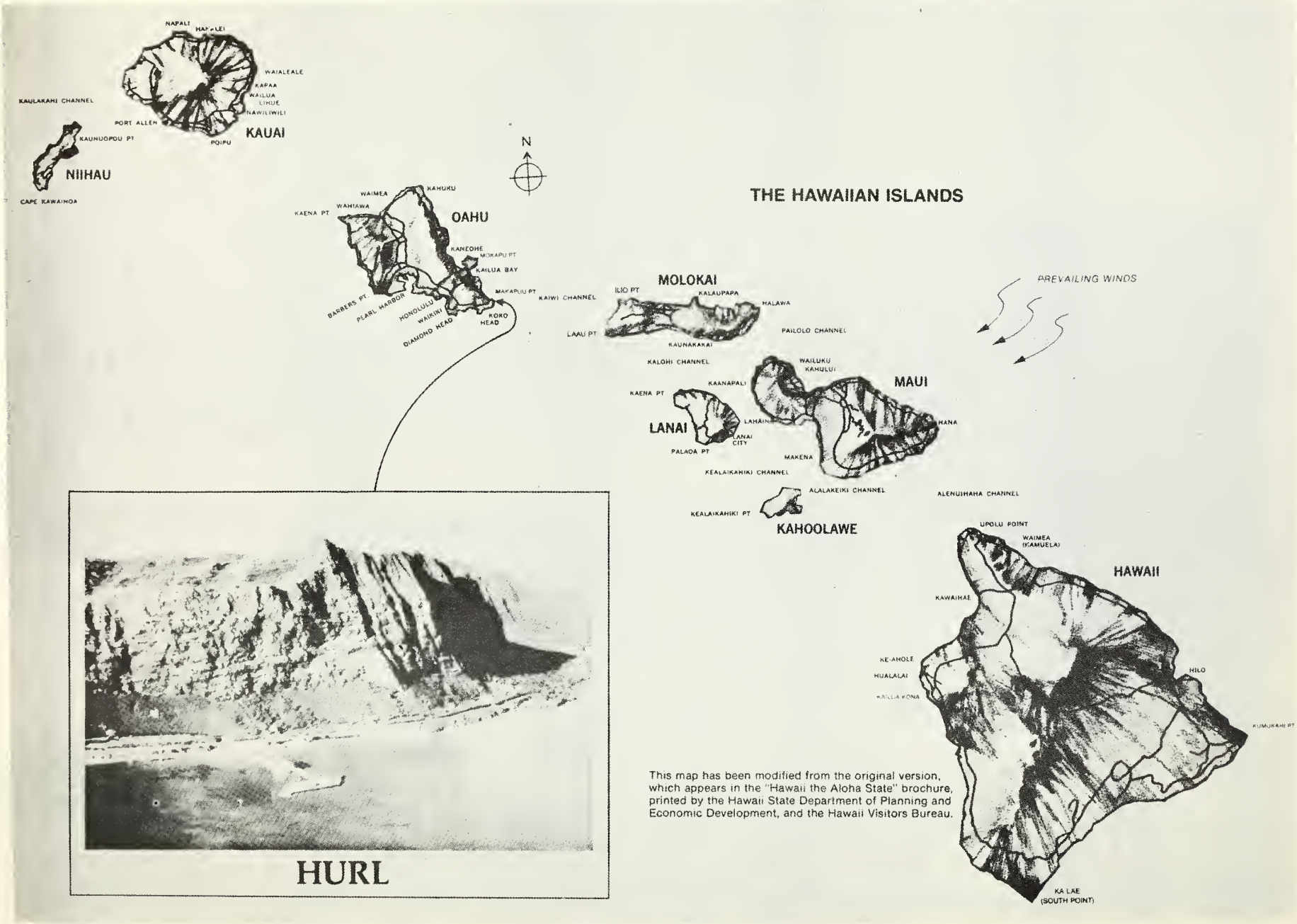
Ten pieces of naturally occurring coral rubble were collected along the east wall adjacent to each artificial reef containing sites for colonization by invertebrates. Ten pieces were also collected along the east wall, adjacent to the reefs at 33.5 m. These pieces of coral rubble were isolated in plastic bags and sent to the surface. Each piece was then chiseled into fine pieces and sieved so that all cryptic fauna could be preserved, recovered, and quantitatively analyzed. These measurements will provide a control for seasonal effects and indicate which cryptic species are available to colonize the artificial reef. On three separate nights, one plankton sample was collected near the light of the habitat and two samples were taken away from the habitat and near the artificial reef sites along the 18.3 m transect.

This study will provide the first comprehensive analysis of colonization of fish and invertebrates at deep 33.5 m, moderate 18.3 m, and shallow 6 m sites. The patterns of colonization and variations in the resultant community structure will be identified in detail during the next two missions. This fauna is almost totally different in species composition from that found in very shallow habitats. The assemblage undoubtedly contains undescribed species and probably undescribed genera. All of these samples will be identified and quantified, with the help of Smithsonian specialists for certain taxa.

HAWAIIAN UNDERSEA RESEARCH LABORATORY PROGRAM (HURL)

As the second segment of NOAA's regional undersea research program, the University of Hawaii is developing a regional undersea program for the Pacific region that is centered in Hawaii and capitalizes on existing Hawaiian facilities, organizations, and programs. Among the organizations involved are: the Hawaii Institute of Geophysics, Hawaii Institute of Marine Biology, the Bishop Museum, the Waikiki Aquarium, Sea Life Park, Oceanic Institute, Brigham Young University, the Community Colleges, State of Hawaii Fish and Game, National Marine Fisheries, Hawaii National Energy Laboratory (OTEC), University of Hawaii, Naval Underseas Center, Look Laboratory, and the Army Corps of Engineers. The program will include research missions of marine scientists on a national basis.

The scientific objectives of the HURL program are closely alined with those of NOAA. At the University of Hawaii, research is dominated by marine-related projects, with the State actively supporting programs in aquaculture, fisheries management, OTEC, and marine resource utilization. The four areas of research priorities are categorized



This map has been modified from the original version, which appears in the "Hawaii the Aloha State" brochure, printed by the Hawaii State Department of Planning and Economic Development, and the Hawaii Visitors Bureau.

HURL program research areas.

as (1) Marine Fisheries, (2) Pollution, (3) Geological Processes, and (4) Ocean Services. In addition, ongoing research within the State of Hawaii is being directed towards these areas of interest. The most important projects are considered to be those which deal with evaluation and development of natural resources, including energy, and those which aid in the better understanding of environmental processes relevant to improved management of marine ecosystems. The following list summarizes Hawaii's proposed initial undersea science program.

	Topic	*Examples*
I.	FISHERIES	
a.	Stock assessment	Shrimp, precious coral, bottom fish, Kona crab
b.	Gear improvement	Nets, traps with light, sound, odor
c.	Trophic dynamics	Ecosystem modeling
d.	Behavior	In connection with gear improvement
e.	Impacts of fishing	Major species
f.	Habitat improvement	Artificial reefs and aggregation buoys
II.	POLLUTION	
a.	Ocean dumping impacts	Deep sites (15): Zone of Initial Dilution (ZID), Balanced Indigenous Population (BIP)
b.	Ocean outfall impacts	4 sites, ZID, BIP
c.	Area of BIP and ZID	Outfalls and dump sites
d.	Mining impacts	*In situ*, refinery
e.	OTEC	Keahole Site
f.	Land use practices	Sedimentation-reefs
g.	Radioactive wastes	Fates and effects at Eniwetok
h.	Hydrothermal vents	East of Hawaii
III.	SEAFLOOR PROPERTIES AND PROCESSES	
a.	Sediment transport	Shelves, slopes, canyons
b.	Seafloor stability	Shelves, slopes
c.	Mineral resources	Sand, manganese crusts, and nodules
IV.	TECHNOLOGY AND OCEAN SERVICES	
a.	Medical and diving physiology	Bends, bone necrosis, and bubble formation
b.	Training	All uses
c.	Engineering	Hardware performance
d.	DUMAND	Neutrino detectors at 3,000 m to 5,500 m

Solicitation and selection of scientific proposals on both regional and national levels will be conducted through a Science Review Committee. Research missions will be scheduled for projects deemed worthy of study as established by NOAA's research priorities.

The existing facilities that the State of Hawaii has committed to the HURL program consist of the manned undersea habitat *Aegir*, the submersible *Makalii* (the former *Star II*), the Launch-Recovery-and-Transport vehicle (LRT), and the Makai Research Pier. Several support vessels are owned and/or operated by the University of Hawaii through the Marine Expeditionary Center located at Snug Harbor, Hawaii, and would be available to the HURL program on a daily lease basis. Additionally, at least two commercially owned vessels are available for lease, the *Holokai* and the *El Greco*. All essential facilities and resources for a sophisticated and flexible marine laboratory exist and are included in the proposed program.

The *Aegir* is a safe, simple, spacious, and inexpensive habitat complete with living quarters, control center, and work space which includes galley and laboratory facilities. Its maximum depth capability is 177 m but it would only be used to a maximum depth of 61 m in this program. There are comfortable accommodations for up to six scientists/aquanauts with adequate storage space for scientific instrumentation and equipment. The *Aegir* is a mobile system and can be towed easily on the surface

Aegir in storage at Makai Research Pier.

from one research site to another. It also has the capability of being quickly brought to the surface and towed to shelter should severe weather conditions develop.

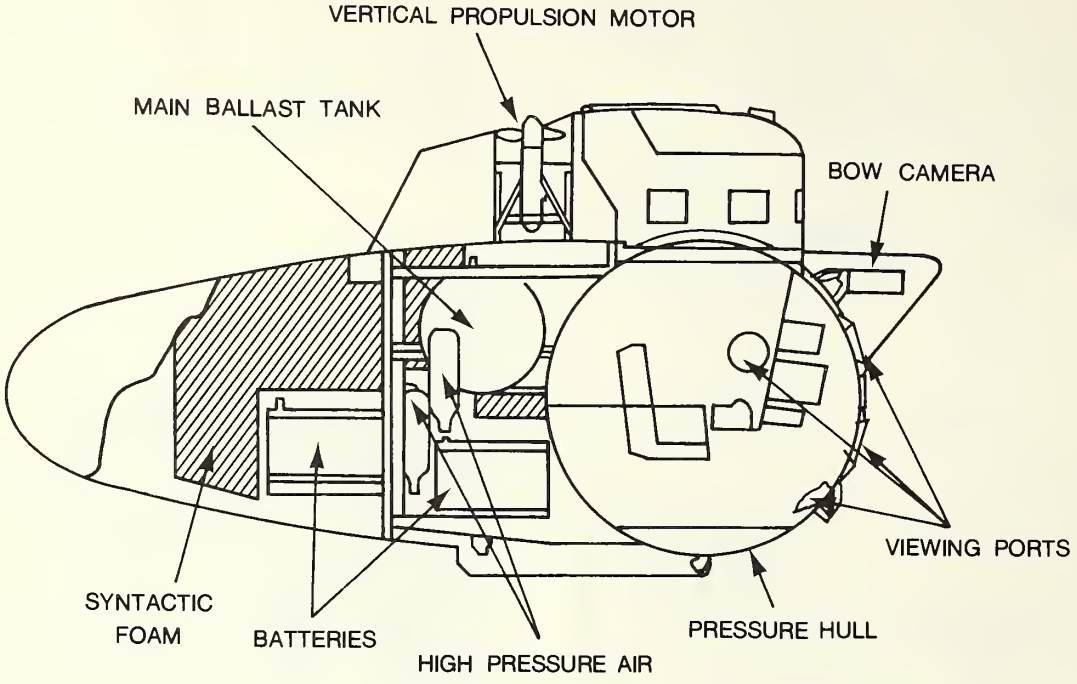
The *Makalii* is a two-man, one-atmosphere submersible with an operating depth of 366 m. It has completed more than 800 operational dives. It is included as a facility for the HURL program since certain research projects will require deeper working capabilities than will be available through the use of the *Aegir* or conventional diving techniques.

The LRT vehicle was designed specifically for launching and retrieving the *Makalii* in rough Hawaiian waters and is in itself a towed wet submersible controlled by scuba divers. It submerges with the *Makalii* to a depth of about 15.2 to 30.5 m, releases the submersible in the calm subsurface, and then resurfaces. When the submersible returns from its mission, the LRT is towed to its position, resubmerges, and the submersible lands on deck, is secured, and then the LRT resurfaces with the submersible. This vehicle may also be used for diver support, salvage, or for launching other oceanographic equipment in rough water where cranes become dangerous.

Both the *Aegir* and the *Makalii* will be operated from and maintained at the Makai Research Pier which is administered by the Research Corporation of the University of Hawaii. The research pier has ample space to support

both the HURL operations and additional scientific programs. At present, a commercial firm, Makai Ocean Engineering, is leasing office and shop space at the pier. This arrangement will continue in the future and will prove invaluable in providing engineering and support services on a contractual basis.

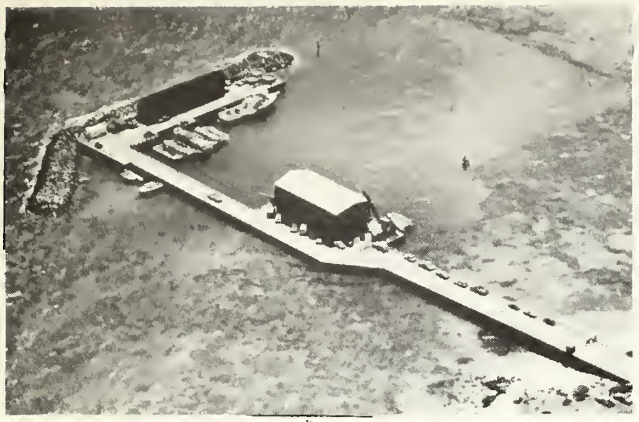
NOAA awarded a grant for a cooperative agreement to the University of Hawaii on July 1, 1980, for implementing the HURL program. It is anticipated that the *Makalii* scientific operations will begin by spring 1981. The *Aegir* is being considered for refurbishment and operation at a later date.



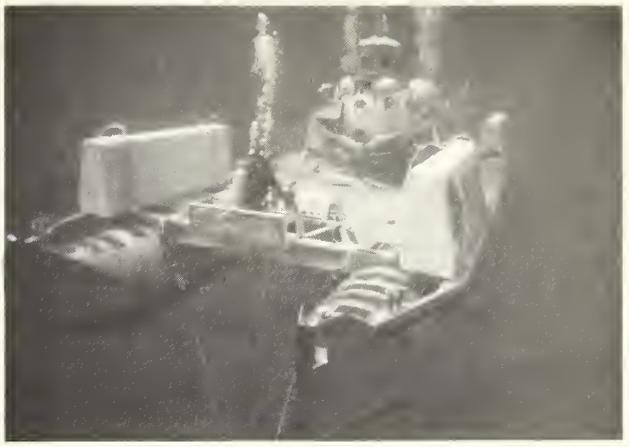
Makalii specifications.

LENGTH:	17.75 ft
BEAM:	5.3 ft
HEIGHT:	7.7 ft
DRAFT:	4.9 ft
WEIGHT (DRY):	5 tons
OPERATING DEPTH:	1,200 ft
COLLAPSE DEPTH:	2,400 ft
LAUNCH DATE:	1966
HATCH DIAMETER:	20 in.
LIFE SUPPORT (MAX):	48 man-hr
TOTAL POWER:	14.8 kWh
SPEED (KNOTS): CRUISE	1/10 hr
MAX	3/1.5 hr
CREW: PILOTS	1
OBSERVERS	1
PAYLOAD:	250 lb

PRESSURE HULL: Spherical shape, 5-ft ID, 5/8 in. thick, of HY-80 steel
BALLAST/BUOYANCY: Main ballast tank of 500-lb capacity is blown by four tanks of compressed air at 2,250 psi. Auxiliary seawater ballast tank of 130-lb capacity is used to obtain buoyancy adjustments when submerged. Two blocks of syntactic foam (30-pcf density) are carried fore and aft to provide additional positive buoyancy.
PROPULSION/CONTROL: Main propulsion is provided by two propellers mounted aft on stabilizing fins and driven by a reversible 2-hp, DC motor at 900 rpm. Immediately behind the hatch is a vertical thruster with characteristics similar to those of the main propulsion units. Electrically driven rudder controls underway lateral maneuvering.
TRIM: No systems provided.
POWER SOURCE: Main power is derived from externally mounted, pressure-compensated lead-acid batteries (Exide 3-FN-17) providing 180 amp-hr at 115 VDC.
LIFE SUPPORT: Gaseous O_2 is carried within the hull. CO_2 is removed by soda sorb.
VIEWING: Six viewports 5-in. ID, 9-in. OD and 0.625 in. thick. A smaller viewport (2-in. ID) is located in the hatch cover.
OPERATING/SCIENTIFIC EQUIPMENT: UQC, CB radio, still camera, TV, pinger, Magnesyn compass, altitude/depth echo sounder, depth gage.
MANIPULATORS: One.
SAFETY FEATURES: Droppable skid (300 lb). Emergency battery pack in pressure hull. Scuba regulator in pressure hull provides emergency breathing by drawing off the deballasting air supply. Hull can be flooded for emergency egress.

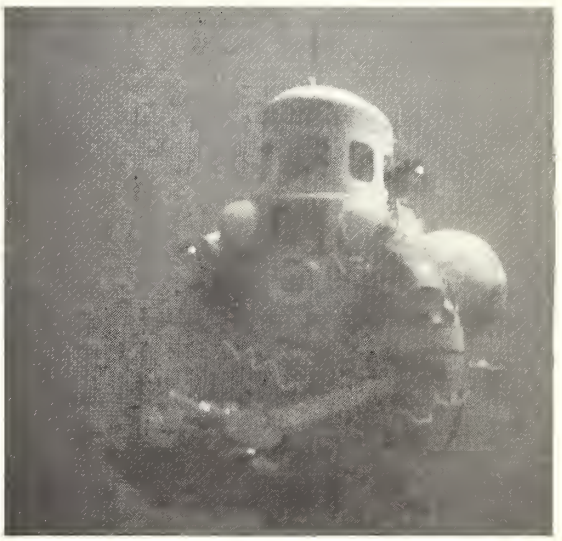


Makai Research Pier on Makapuu Point, Oahu—Support Base for *Makalii* and *Aegir* operations.

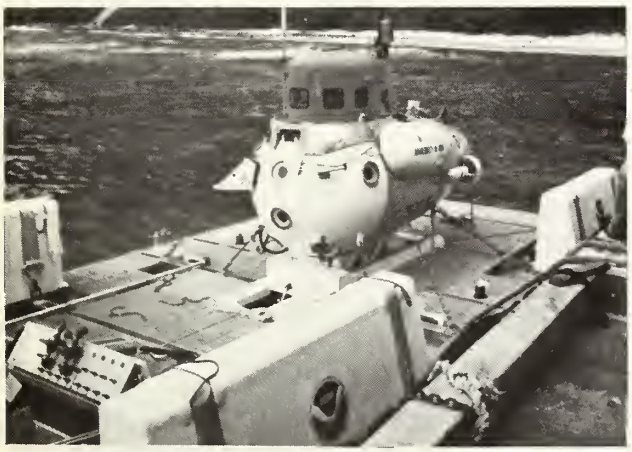


Makalii being released by divers from diver-controlled LRT.

Makalii submerging on its Launch, Retrieval and Transport (LRT) vehicle off coast of Oahu.



Makalii carrying samples back to LRT.



Submersible *Makalii* secured to the LRT.

Diver viewing pink coral off Oahu.

WESTERN REGIONAL UNDERSEA LABORATORY PROGRAM (WRUL)

The third segment of NOAA's regional undersea research program will be the Western Regional Undersea Laboratory Program (WRUL), which is being developed by the University of Southern California (USC) under a cooperative agreement between NOAA and the University awarded on July 1, 1980. It will become operational at USC's Catalina Marine Science Center (CMSC) located on Catalina Island, 25 miles offshore from Los Angeles, Calif.

The program will be integrated into the existing multidisciplinary marine science program at CMSC stressing the use of saturation diving as a scientific and research tool, and is intended to satisfy the research requirements existing between the practical working depths of SCUBA and the need for deep diving submersible vehicles. The Catalina location allows for temperate water experience and activities, complementing the usual tropical locations of past undersea habitat activities. The need for this capability has been supported and encouraged at national undersea workshops as well as by a large number of active scientist-divers representing the entire U.S. West Coast. The added underwater time allowed by saturation diving and continuity of location over a number of years facilitates long-term behavioral observations, diurnal studies, discrete sampling programs, and *in situ* experiments. Although the major emphasis will be biological, studies in oceanography, human physiology, near-shore geological processes, equipment development and testing, and scientist training would be pursued.

The primary undersea sites will be located within 400 meters offshore, in a depth range of 16 to 28 meters, amid a lush bed of giant kelp, and adjacent to an extensive rocky reef and biologically productive softbottoms of shelly sand. This is one of the most productive, yet least studied, of all major undersea biomes—a dynamic three-dimensional entity supporting a number of biological communities.

The proposed USC science program alines itself with NOAA's undersea mission needs. Within marine fisheries, several specific areas of fishery research will benefit from use of undersea saturated habitats. These areas include sampling gear development, ecology, behavior and niche definition, and harvesting methods as well as ecosystem response and habitat alteration which are all extremely important to nearshore resource management.

Marine pollution has implications far beyond the limited scope of nearshore, habitat-based activities. However certain localized effects on bottom-dwelling organisms could be studied from a manned habitat using small-scale experiments with judicious application of pollutants.

In addition to such experiments, habitat-based saturation capability would offer scientists time to: (1) develop and test new methodology for sampling impacted areas; (2) observe and modify surface-oriented gear to obtain

Research site at Catalina Marine Science Center at Big Fisherman's Cove, Catalina Island.

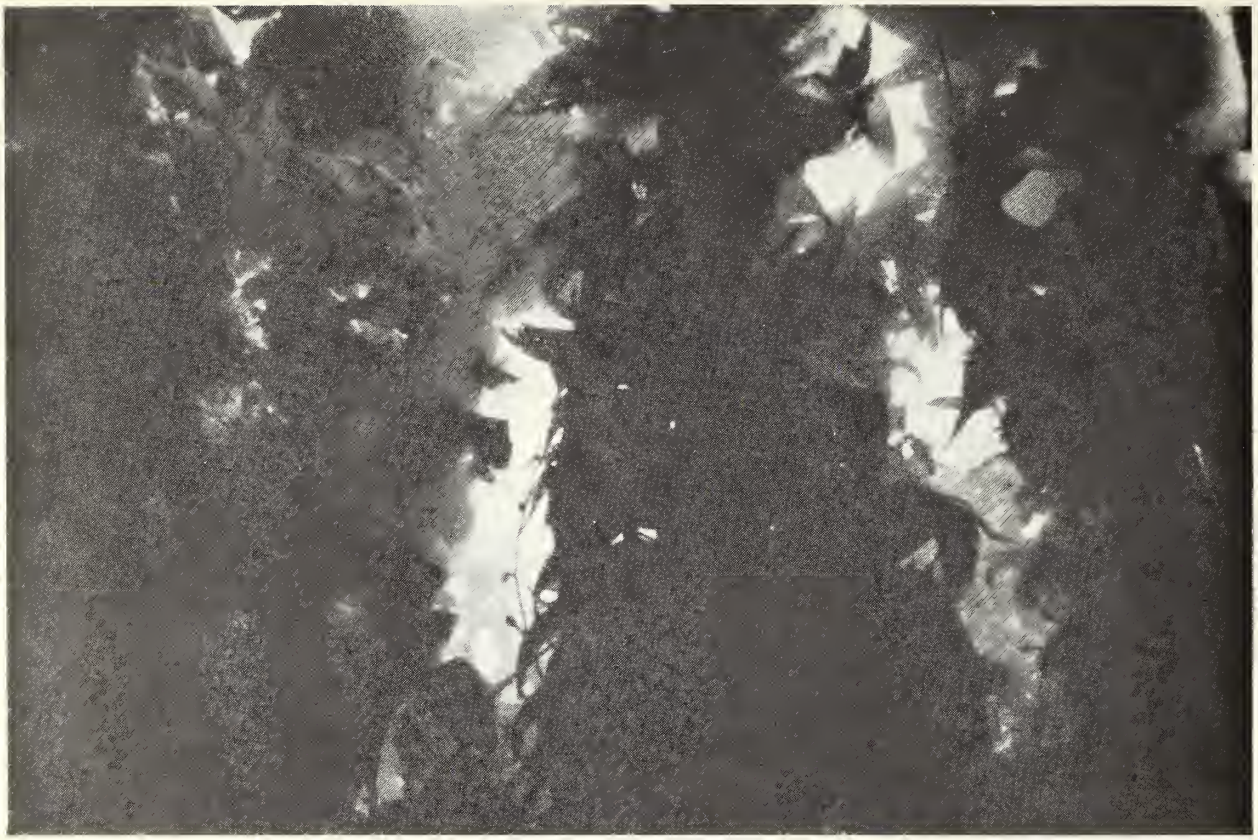
Plankton net being towed by diver through kelp bed.

the most accurate sampling possible; (3) study in great detail the soft-bottom biological communities and possibly define certain assemblages as indicators for assessment of "bottom health".

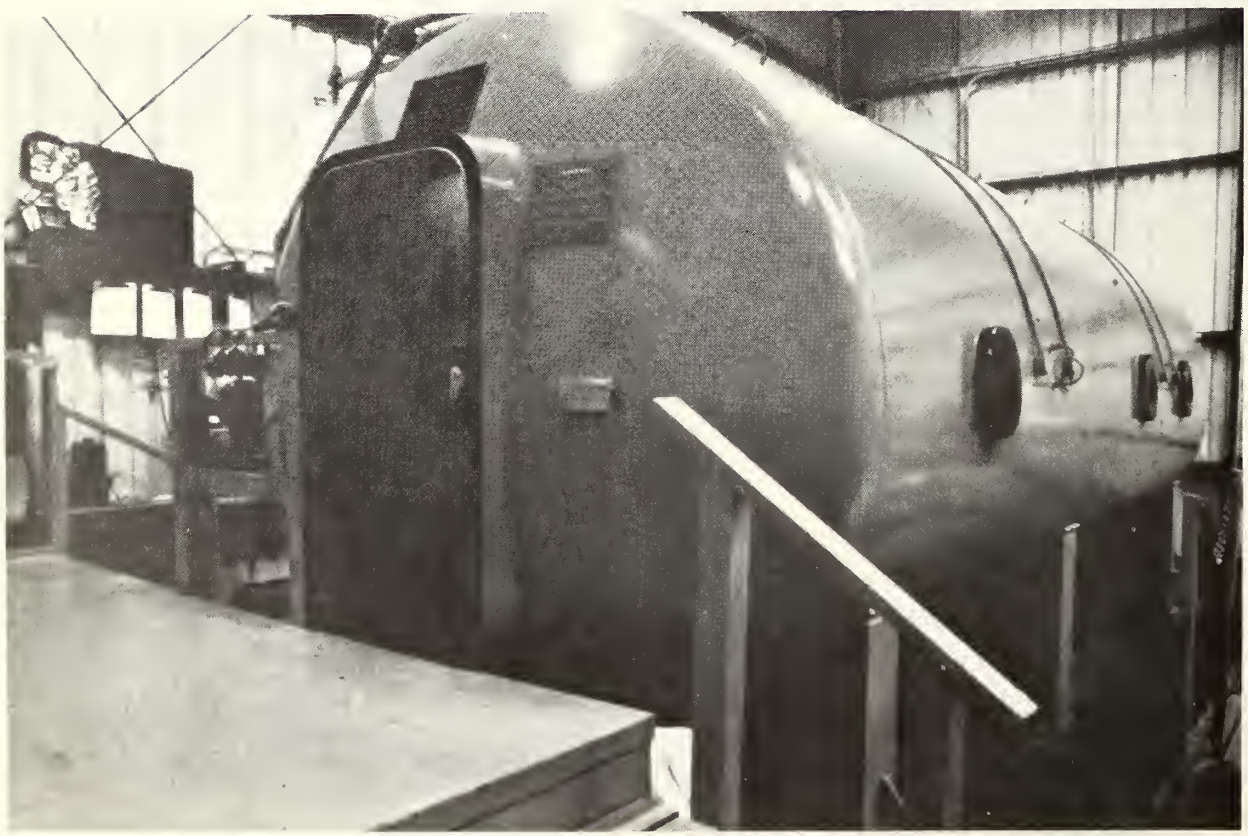
Using a manned habitat system, seafloor properties and processes can be investigated from small-scale nearshore events. These would include scouring, *in situ* observation of biogenic activity and bioturbation, "soil" accumulation in newly exposed surfaces, and chemical properties of substrates and their effects on biological activities.

The following list identifies the scope and breadth of opportunities offered to undersea science by saturation diving and the WRUL program.

1. *Biology*
   a. Comparative studies between selected species of fishes and invertebrates.
   b. Behavioral interactions between selected species of fishes and invertebrates.
   c. Studies on the dynamics of the rock-sand ecotone community.
   d. Documentation of the diurnal-nocturnal changes in the biota of the kelp bed, rock substrate, and soft bottom.
   e. Discrete sampling of the subsurface plankton and its relationship to the sessile and motile resident species.
2. *Geology*
   a. Experimental investigation of the processes contributing to the formation of a shelly debris substrate.
   b. The importance of physical scouring at the sand-rock interface and its implications in sediment formation.
   c. Comparative studies of bioturbation in muddy sand and shelly debris.
   d. Studies in nearshore sediment processes and transport mechanisms.
3. *Oceanography*
   a. Development and testing of micro-oceanographic instruments and methodology.
   b. Detailed documentation of the habitat reef water mass.
   c. Dye studies of water movement at water-sand and water-rock interfaces.
4. *Human Physiology*
   a. Long-term oxygen toxicity studies.
   b. Body temperature changes associated with prolonged saturation diving.
   c. In-water nitrogen narcosis studies.
   d. Work performance limitations during excursion diving.
5. *Nautical Archaeology*
   a. Training and techniques of saturation diving, as it applies to underwater archaeology.
   b. Design, development, testing, and modification of equipment and recovery and documentation methods specifically developed for underwater archaeology.
   c. Discovery, documentation, and recovery of actual Indian artifacts and sites located in the WRUL area (in conjunction with terrestrial shoreside investigations).



Giant kelp ecosystems.



Operational hyperbaric chamber used for treating diving related injuries.

The proposed USC undersea facility consists of a transportable seafloor habitat capable of remaining at the experimental site for extended periods of time receiving shore support by an umbilical supplying power, water, communications, high- and low-pressure air, and data transmission capabilities. The habitat will be capable of working at other locations independent of the shore by using a surface support buoy.

Detailed plans and specifications for the new habitat are being developed. In the conceptual stage, the basic habitat will be a steel cylinder approximately 8 meters long and 3 meters in diameter, with a pressure rating to allow *in situ* operations to 37 meters. The system will be a double-lock chamber capable of both bottom and surface decompression with an internal pressure capability of 61 meters for the emergency treatment of diving accidents. It will be divided into "wet" and "dry" areas, both with laboratory facilities, living quarters, and a diver staging area. Two large observation ports and several smaller ports will be placed in strategic locations.

Additional CMSC resources available to this program include: (1) dormitories, apartments, and a cafeteria, (2) a diving locker, (3) helipad, pier, and dock, (4) boats and vehicles, (5) a machine shop, (6) a 2,800 square-meter equipped laboratory building, and (7) an on-site hyperbaric chamber.

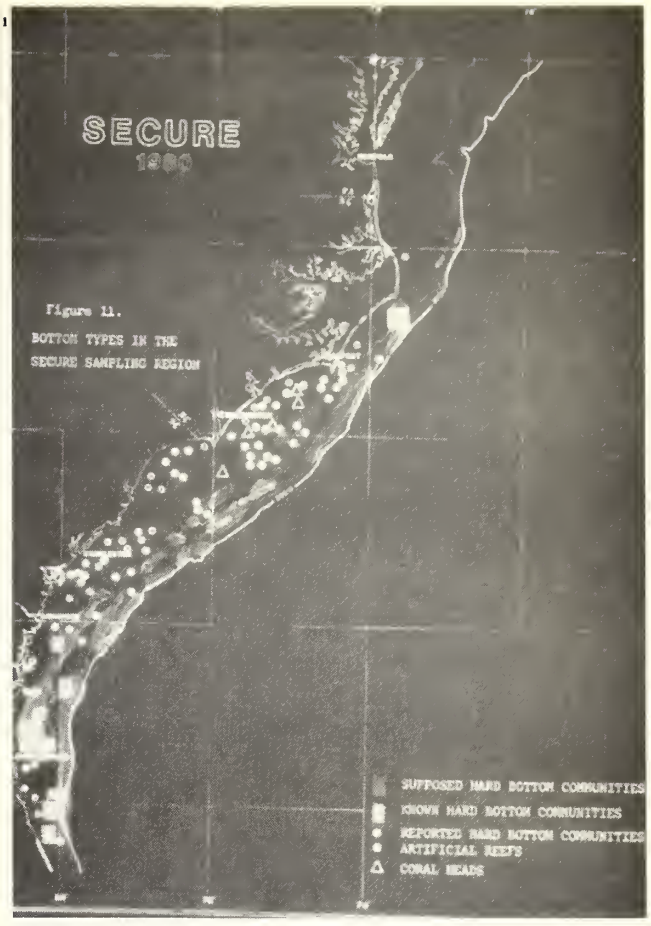
The habitat system is presently under development in its conceptual design phase. Once operational, 12 to 16 scientific missions are planned to be conducted per year.

SOUTHEASTERN UNDERSEA RESEARCH FACILITY PROGRAM (SURF)

The University of North Carolina at Wilmington is developing an undersea research facility program which will be the fourth segment of NOAA's regional undersea research program. This program, the Southeastern Undersea Research Facility program (SURF), is sponsored by a four-State consortium known as the Southeastern Consortium for Undersea Research Efforts (SECURE). This consortium consists of academic organizations, research institutions, and government agencies from the States of Virginia, North Carolina, South Carolina, and Georgia. SECURE's objective is to develop a unique undersea research diving system designed to accommodate a wide range of research needs through a phased-growth diving and scientific-diver training program; expanding from SCUBA, surface demand, and open bell systems through a bell saturation system or a lockout submersible. The program was initiated by NOAA's awarding a grant on July 1, 1980, for a cooperative agreement with the University of North Carolina.

In addressing NOAA's major goals and the objectives of its undersea program and regional needs and goals, the consortium has developed the following research objectives, contingent upon establishment of appropriate facilities:

1. *Marine fisheries:* The collection and analysis of information on important fisheries stocks and habitats, commercial fishing gear use and development, and sea floor obstructions.

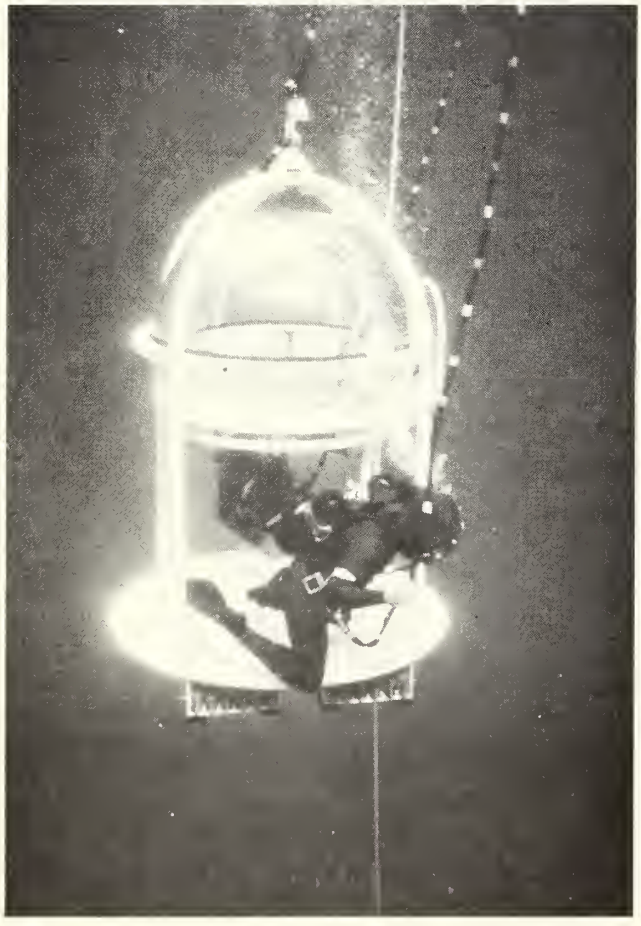


Potential SECURE research sites.

2. *Sea floor processes:*
   a. The development of an accurate system to predict optimal sites for ocean dumping and dredge spoil disposal, concurrent with the determination of methodology for preserving sea floor communities against destruction by these agents.
   b. The collection of ground truth data on energy and mineral resources and their transport across the Continental Shelf.
   c. The analysis of sediment dynamics and critical movement on the Continental Shelf off the Southeastern United States.
3. *Marine pollution:* The collection and analysis of baseline biological data on organisms likely to suffer damage by offshore petroleum development or from other man-initiated pollution sources.
4. *Ocean Services:*
   a. Contributions to the knowledge of human physiology and diving safety as they relate to man-in-the-sea programs.
   b. The identification and preservation of submerged cultural resources through undersea technology.

Proposals for missions using this facility will be solicited on both regional and national scientific levels. A peer review

R/V *Seahawk* prior to conversion for support of diving operations.



Tethered divers swimming out of an open (wet) bell.

process will be developed to evaluate the proposals,determining their applicability to the program. A quantitative evaluation scale will be used in judging scientific merit, applicability to NOAA-SECURE objectives, and adaptability to SURF operational constraints. In light of the fact that undersea scientific research is the driving force behind the program, dissemination and availability of the scientific results will be emphasized.

To accomplish these scientific objectives, the program will begin by acquiring basic diving equipment and training diver-scientists to be effective undersea researchers.

Operations are scheduled to begin in the fall of 1981. A vessel crew and a trained cadre of support diving personnel will be placed aboard the R-V *Seahawk*, a 22 m long, 100-ton (gross) research vessel, to implement the research-diver training program. The vessel will be outfitted for preliminary research missions.

A wet diving bell and surface-supplied air system will be installed on board the vessels, enabling divers to enter and leave the water more easily and enhancing the diving conditions for longer underwater studies.

As the program matures and scientists require greater depth capability, a more sophisticated system will be defined, allowing researchers to remain submerged for extended periods and to depths of about 150 m. Alternate considerations include a closed-bell system and a submersible with the possibility of diver lockout capabilities.

The program will encourage quality research which is responsive to national objectives and carefully balanced over the areas of interest to both NOAA and SECURE. Representatives of the SECURE participating organizations and NOAA will constitute an Advisory Board which will assist the Program Director in the development of the program's policy, emphasis, and direction.

SUBMERSIBLE SUPPORT—INTRODUCTION

NOAA has continued to support the use of research submersibles as a unique scientific tool for projects requiring observations and data which could not be gathered by surface platforms. This support includes several facets:

- Providing research submersibles, along with support vessels and operational systems, to NOAA and other agencies investigating marine resources, environmental problems, and other undersea processes and phenomena.
- Development of technological criteria for the design of submersibles and other platforms.

In past years, NOAA's research submersible activities have devoted considerable effort to feasibility studies and design of underwater research facilities and have made available, through funding sponsorship and lease programs, several submersibles for a variety of scientific missions. During 1979 and 1980, the efforts of the program were concentrated on providing submersibles such as *Alvin* and leased shallow-water research submersibles to marine scientists. Investigations into the utilization of existing systems and need for improved and more advanced new systems are being made by various groups.

Alvin submersible.

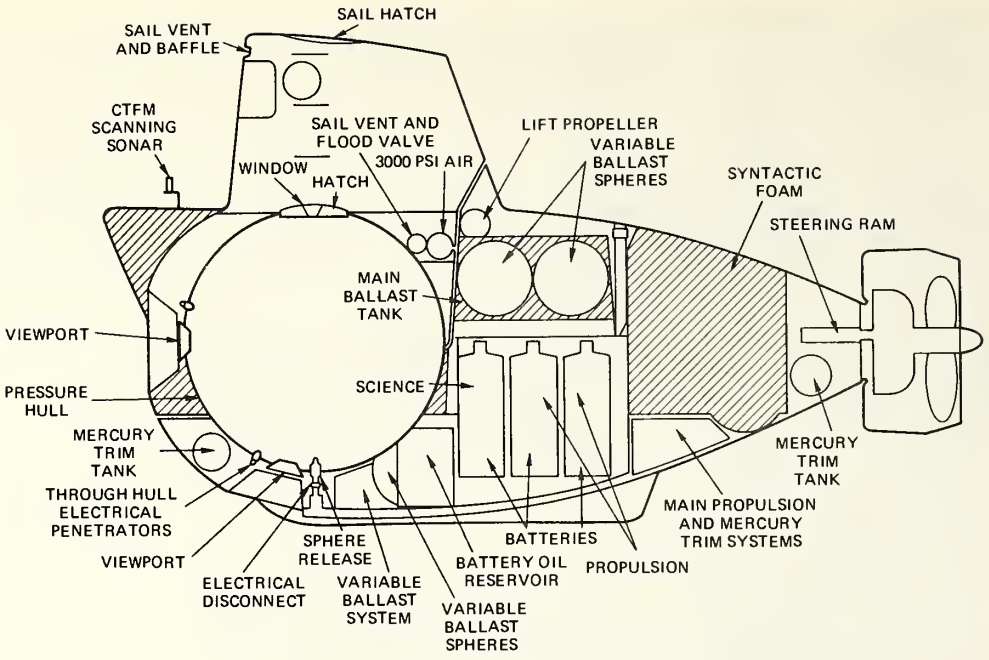
RESEARCH SUBMERSIBLE "ALVIN/LULU" SYSTEM SUPPORT

The U.S. Navy-owned *Alvin/Lulu* deep research submersible and support ship system is operated by the Woods Hole Oceanographic Institution, Deep Submergence Group, under a grant from NSF with support from NOAA and ONR. The 3-year tri-agency agreement to operate the *Alvin/Lulu* system from 1978 through 1980 as a national oceanographic facility under the aegis of the UNOLS committee was renewed for another 3 years (1981-83). The new agreement commits the three agencies to support this research facility for 150-use days per year, with NSF responsible for 90 days and NOAA and ONR for 30 days each.

Science proposals for *Alvin* missions are solicited annually from NOAA's major program elements such as the Atlantic Oceanographic and Meteorological Laboratories and the Pacific Marine Environmental Laboratory of the Environmental Research Laboratories, components of the Office of Research and Development, the National Ocean Survey, and the research centers of the National Marine Fisheries Service. These proposals are evaluated by a submersible research review committee of NOAA scientists with expertise in the major oceanographic disciplines. The proposals are evaluated against the unique capabilities of the *Alvin* system (e.g., depths to 3,660 m) and agency goals and objectives. The results of the NOAA evaluation are provided to the UNOLS *Alvin* Review Committee which meets each spring for scientific evaluation of all proposals for *Alvin* use to determine the calendar year program formulation and scheduling for the subsequent operating year. Supporting agency recommendations, based on in-house reviews, play a key role in formulating the annual schedule.

Table 3.—NOAA-Supported *Alvin* Submersible Activities.

Dates	Scientific Missions	Location	Principal Investigator
	1979		
Aug 21-31	Deep Ocean Mining Environmental Survey	Off California	R. E. Burns, AOML
Nov 25-Dec 15	Galapagos Rift Thermal Vent Area Study	Galapagos	D. Cohen, NMFS
	1980		
Jan 5-21	Submarine Micro-morphology Eastern Galapagos Ridge	Panama Basin	A. Malahoff, NOSS
Aug 15-22	Biological and Geological Studies	Oceanographer Canyon	R. Cooper, NEFC
Oct 1-13	Wilmington Geotechnical Corridor Study	Wilmington Canyon	D.N. Lambert, MGGL, AOML



LENGTH:	25 ft
BEAM:	8 ft
HEIGHT:	13 ft
DRAFT:	7-1/2 ft
WEIGHT (DRY):	16-3/4 tons
OPERATING DEPTH:	12,000 ft
COLLAPSE DEPTH:	18,000 ft
LAUNCH DATE:	1964
HATCH DIAMETER:	19 in.
LIFE SUPPORT (MAX):	216 man-hr
TOTAL POWER:	40-1/2 kWh
SPEED (KNOTS): CRUISE	1/8 hr
MAX	2/2 hr
CREW: PILOTS	1
OBSERVERS	2
PAYLOAD:	1,000 lb

PRESSURE HULL: Spherical shape. Composed of Navy 621.08 titanium, 7-ft OD, 1.97 in. thick to 2-1/2 in. at inserts.
BALLAST/BUOYANCY: MBT's provide 1,500 lbs of surface buoyancy. VBT's consist of hard tanks and pump operable to 12,000 ft, syntactic foam provides approximately 4,000 lbs of positive buoyancy. A 250-lb weight is carried to decrease descent time; it is dropped at the bottom; another 250-lb weight is dropped for ascent.
PROPULSION/CONTROL: Main propulsion is from a 10-hp hydraulic motor driving a 50-in.-diam. propeller trainable 50° left or right. Thrusters are located amidships which are powered by 6-hp hydraulic motors and are rotatable 360° in the vertical plane.
TRIM: Bow angles of <10° are obtained by transferring 450 lb of mercury forward or aft.
POWER SOURCE: Three pressure-compensated boxes of lead-acid batteries. Two boxes supply 30 V, the third supplies 60 V. Four 4-amp-hr nickel-cadmium batteries supply emergency power.
LIFE SUPPORT: Gaseous O_2 in pressure hull. LiOH is used to remove CO_2. O_2 and CO_2 monitors.
VIEWING: Four large viewports forward; these are 3-1/2 in. thick, 5-in. ID and 12-in. OD. A smaller viewport is in the hatch cover which is 2-in. thick, 2-in. ID and 6-in. OD.
OPERATING/SCIENTIFIC EQUIPMENT: UQC with transponder interrogator. Four pressure depth gages, up/down echo sounder, TV, pinger, current meter, CTFM sonar, gyrocompass, two 35-mm still cameras, one 8-mm and one 16-mm cine cameras.
MANIPULATORS: One with six degrees of freedom.
SAFETY FEATURES: Manipulator, batteries (3,400 lb) and specimen basket are attainable. Pressure sphere releasable (2,000 lb of positive buoyancy). Closed circuit emergency breathing off normal O_2 supply. Distress rockets and flares, strobe lights, life vests, radio homing beacon.
SURFACE SUPPORT: Supported by the catamaran *Lulu*, 105 ft LOA, 48-ft beam, 12-ft draft, 450-ton displacement, max. speed 6 knots, propulsion from three 200-hp outboard motors. Seventeen people constitute the system's crew.
OWNER: U.S. Navy. Operated by Woods Hole Oceanographic Institution, Woods Hole, Mass.
BUILDER: General Mills/Litton Industries, Minneapolis, Minn.
REMARKS: Steel pressure hull replaced by titanium hull in 1973, thereby increasing depth range from 6,000 to 12,000 ft.

Alvin characteristics.

Alvin with support ship *Lulu* close by.

Alvin during submerged operations.

In 1979, NOAA scientists utilized the *Alvin/Lulu* system to conduct a biological exploration of the Galapagos rift vents, a micromorphological study of seamount geometry and sedimentation patterns of the Cocos Ridge in the Panama Basin, and research on benthic resedimentation associated with deep ocean mining in the Pacific Ocean. In 1980, the Panama Basin Seamount geometry studies continued. Research was also conducted on the biology and geology of the New England Continental Shelf submarine canyons, and on slope measurements and morphology of both stable and unstable areas in the Wilmington Canyon.

Galapagos Rift Thermal Vent Area Study

Date: November 25—December 15, 1979

Purpose: Characterize both qualitatively and quantitatively the ichthyofauna and examine the role of fishes in the overall thermal vent ecosystem. Observe and collect fishes for subsequent laboratory study.

Participants: NMFS Systematic Laboratory:
D. M. Cohen, Principal Investigator
Smithsonian Institution:
Meredith Jones,
Co-Principal Investigator

Accomplishments: The Galapagos Rift study area contains a unique biota associated with hot springs venting water with temperatures reaching 17°C and containing high concentrations of H_2S with little O_2. The densely populated vent communities may be nourished autotrophically. The fishes associated with the vent area are more mobile and constitute a link with the heterotrophic ecosystems. Dive localities were chosen to include several vent areas, some of which have quantitatively different faunas. Several experimental packages deployed during previous dives in the area were recovered. Approximately 20 species were seen. Apparently only one fish, an undescribed species of the viviparous ophidiform family Bythitidae, lives regularly in warm vent water. Two species of eelpouts, previously observed in time-lapse photographs and found to be relatively abundant, were rare and probably even repelled by *Alvin*. Two species of rattails were common, whereas *C. armatus*, a widely distributed species, was rarely seen. Two of the most commonly observed fishes, previously thought to be rare, were an ophidiid species of the genus *Bassozetus*, and a halosaurid, probably *Halosaurus attenuatus*. Transects made away from vent areas discovered a relatively diverse and locally densely distributed fauna of fishes and larger invertebrates. Observations were made of crabs and giant pogonophoran tube worms and samples collected for subsequent laboratory study.

Submarine Micromorphology—Panama Basin—A Detailed Study of Ridge Axis, Fracture Zone, and Seamount Geometry and Sedimentation Patterns of the Eastern Galapagos Ridge

Date: January 5-21, 1980

Purpose: To investigate the geometry of ridge, fracture zone, and seamount construction along the Galapagos Ridge and the influence that ridge topography has on sedimentation and mineralization patterns on the flanks, the base, and the surrounding region of the ridge.

Participants: National Ocean Survey:
Alexander Malahoff,
Principal Investigator
National Ocean Survey: R. Embley
Lamont-Doherty Geological
Observatory: D. Fornari

Accomplishments: Multibeam surface ship surveys of the Galapagos and the Gorda Ridges supported by a transponder navigation system aboard *Alvin* were used to delineate the kinematics of ridge-fracture zone interaction along the eastern end of the Galapagos Ridge.

The Galapagos Ridge terminates abruptly at longitude 85°23'W along a north-south striking fracture zone. Surface-controlled bottom transponders and camera tows, as well as the DSRV *Alvin*, were used to conduct the visual observations. A detailed multibeam surveying bathymetric net was used as a base to develop a volcanic and tectonic view of the interaction between the ridge and the fracture zone. Detailed studies of the crest and flanks of the Galapagos Ridge between 86°05'W and 85°22'W carried out during the nine-dive expedition show a predominance of tectonic over volcanic activity to the east. Activity along the crest of the ridge takes place between depths of 2,500-2,600 m in the form of a series of volcanic centers characterized by a median rift valley frequently filled with fresh pillow lavas and dissected by anastomosing fissures. The median rift valley narrows eastward. The Galapagos rift terminates at 85°23'W, where the east-west lineations observed along the axis of the rift change sharply into the north-south lineations of the fracture zone. Actively faulted scarps up to 100 m in height are observed along a 500-meter wide plate boundary of the fracture zone. Extensive sulfide mineralization in the form of stacks presently exists along the lateral faults of the rift valley and MnO mineralization is found along segments of the fracture zone where no current volcanism was observed. The boundary between the fracture zone and the rift is very sharply defined and simple in its tectonic pattern.

Sampling clam shells around thermal mound using *Alvin* at 2,400 m.

Sampling using *Alvin* manipulator by thermal vent.

Oceanographer Canyon Study

Date: August 15-22, 1980

Purpose: Conduct biological and geological studies of the Oceanographer Canyon axis and slopes over the depth range 200-400 m.

Participants: National Marine Fisheries Service:
Richard Cooper, Principal Investigator
NEFC, Woods Hole: J. R. Uzmann
U.S.G.S.: P. Valentine
NEFC, Woods Hole: R. Langton

Accomplishments: Oceanographer Canyon was identified as an important and relatively unimpacted canyon environment in which to monitor both short- and long-term biological productivity. The selection of Oceanographer Canyon was based on its relative degree of isolation from coastal zone pollutants.

Mission objectives included: (1) quantitative definitions of baseline conditions of epibenthic fauna and their habitats-shelters at site-specific locations within the benthic boundary layer, (2) quantitative definitions of baseline levels (concentrations) of various pollutants in the tissues-organisms of key indicator species and their associated substrates, (3) comparison of the above biotic and abiotic features of the ocean floor environment, and (4) definitions of certain environmental features, quantitatively, that are likely to reflect man's impact, if any, on the living resources and their habitats of Georges Bank and the Georges Bank Submarine Canyons.

During the period August 18-20, 1980, three of a scheduled series of eight dives were completed at Oceanographer Canyon. Two dives traversed the upper canyon axis and west wall, respectively. The third dive was a revisitation of an area traversed in 1978 for the specific purpose of sampling octocorals and core sampling of bedded outcrops, talus blocks, etc. The first two dives were designated as Ocean Pulse station transects 7 and 8 which will be rerun in alternate years assuming continued availability of *Alvin* dive time. In addition, specific shallow water (200-400 meters) sites along these transects will be marked with bottom pingers, as at stations 5 and 6 at Lydonia Canyon, for more frequent revisitation (minimum of once annually—midsummer) beginning in 1981.

Census methodology was time-lapse photography utilizing paired fixed-focus external cameras and strobe unit fired automatically at 10-12 second intervals. Each photograph includes a data frame providing time in seconds, depth in meters, dive number, and true heading. The system also includes a frame counter and override control of the intervalometer to allow the observer scientist to photograph a setting on a subjective, rather than random, basis; in such cases, the particular frame number(s) is noted. With the *Alvin* submersible tending bottom with a bow-mounted skid and trimmed to horizontal attitude, the camera field analysis of photographs for density estimates of identifiable organisms simply required computation of the mean number of given organisms per photograph and extrapolation to a larger unit area.

The recency of the Oceanographer Canyon cruise has not permitted complete analysis of all the accumulated data. However, the first analysis shows that the transect data closely reflect the major species composition and rank order of abundance described from our earlier investigations (Valentine, Uzmann, Cooper, 1980). Although the depth ranges of the two transects overlap to a degree, the substrates transected differed markedly which explains the differences in rank order of species within the range of overlap (200-400 m).

"Ghost Pot"—abandoned fishing pot in Oceanographer's Canyon (Depth: 500 m).

Wilmington Geotechnical Corridor Study

Date: October 1-13, 1980

Purpose: To collect *in situ* geotechnical data on a variety of seafloor sedimentary features and features created by the mass wasting of sediment in specific areas of the seafloor.

Participants: Atlantic Oceanographic and Meteorological Laboratories:
Douglas N. Lambert, Principal Investigator
AOML: William L. Stubblefield
AOML: George F. Merrill
AOML: Evan B. Forde
AOML: Alvyn M. Meyer

Accomplishments: Seven dives were made during the cruise in the following areas of the Wilmington Geotechnical Corridor: a large slump block northeast of Wilmington Canyon; the main channel of Wilmington Canyon; a small, deeply incised valley on the midslope northeast of the Wilmington slump block; a ridge field within South Wilmington Canyon; a debris flow deposit on the upper rise; the axis of Wilmington Canyon; and the north wall of the main canyon channel. Although weather conditions were other than ideal, 75 percent of all objectives were accomplished. Various sedimentary features associated with mass movement of sediments were investigated in eight different geotechnical stations. These measurements will provide *in situ* data for comparison with laboratory data previously completed on sediment cores. All three of the instruments used (the resistivity probe, the cone penetrometer, and the inclinometer) provided valuable data to be used in modeling sediment stability or instability in specific areas of the seafloor. Rock and semiconsolidated sediment samples collected from the floor of South Wilmington Canyon and the wall of a large slump block should provide an understanding of the formation and evolution of this large feature. Meanders and relic channels, discovered and mapped on the floor of Wilmington Canyon, should provide important new information on the processes of canyon formation and evolution. Thousands of frames of film taken of the seafloor will increase understanding of the benthic biological activity on the seafloor's stability. The success of the probes has proven that *in situ* geotechnical measurements are possible, giving extremely detailed sets of data. These instruments will serve as prototypes of a larger instrument array that can be deployed easily from a surface ship for surveys over larger areas of the seafloor to determine sediment stability. The Sandia miniature piezometer was tested, and the electronics and mechanical performance were evaluated at moderately high ambient pressure and during insertion into the sediment.

SHALLOW WATER RESEARCH SUBMERSIBLE ACTIVITIES

For a number of years, NOAA has provided shallow-water submersibles and associated support vessels for underwater research in the coastal zone. Missions have included surveys of the effects of ocean dumping, surveys of dumpsites, studies of fauna and their habitats, assessments of fisheries potential, and investigations of marine geologic features and processes. These activities continued during FY 1979 and 1980.

The submersibles used are the *Johnson Sea-Link*, owned and operated by the Harbor Branch Foundation in Fort Pierce, Florida, and the *Nekton Gamma*, owned and operated by General Oceanographics Inc. of Newport Beach, California.

NOAA and the Harbor Branch Foundation have had cooperative agreements over the past few years for conducting underwater research. Scientific missions, using the submersible *Johnson Sea-Link* and other Harbor Branch facilities, have emphasized research areas of interest to both NOAA and Harbor Branch, with the results being made available to the scientific community through technical publications. In this unique relationship, Harbor Branch has supported NOAA's program with both cooperative funding and use of laboratory and field resources.

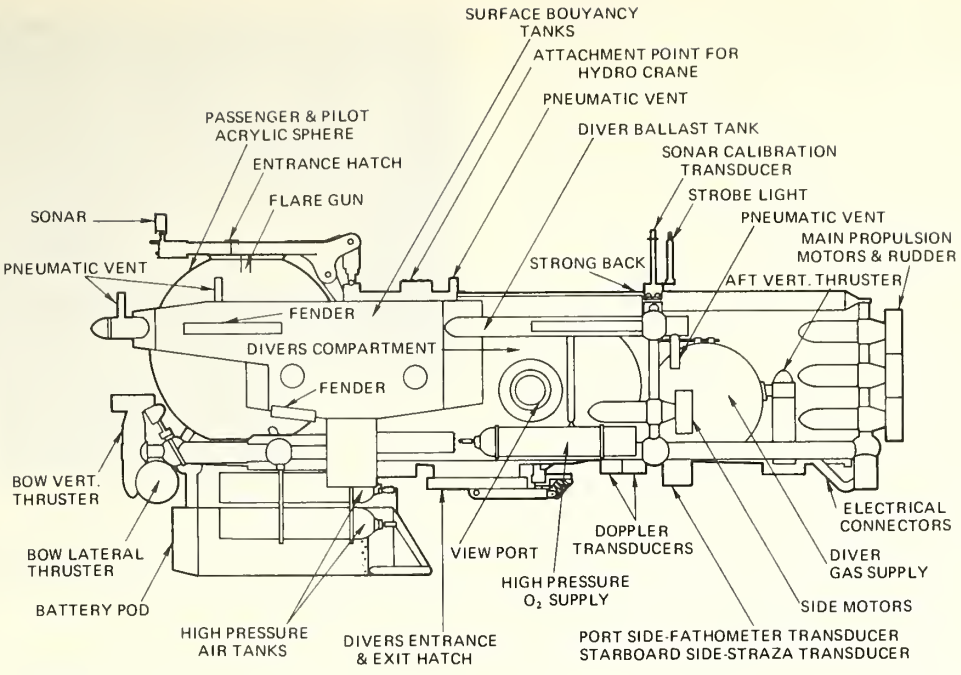
Table 4.—NOAA Supported Shallow Water Submersible Activities.

Dates	Support Ship Submersible	Location	Principal Investigator
	1979		
Jul 11-Aug 21	*Atlantic Twin/ Nekton Gamma*	Georges Bank	R. Cooper, NEFC, Woods Hole
Aug 23-Aug 27	*Atlantic Twin/ Nekton Gamma*	Georges Bank	C. B. Grimes/ K. W. Able, Rutgers University
Aug 30-Sep 6	*Atlantic Twin/ Nekton Gamma*	Off Cape Hatteras	P. Parker, SEFC, Beaufort, NC
Sep 6-18	*Atlantic Twin/ Nekton Gamma*	Norfolk Canyon	R. Embley, NOS
Oct	*R/V Johnson Johnson Sea-Link*	Bahamas	K. Stehling, NOAA
	1980		
May 14	*R/V Johnson Johnson Sea-Link*	Bahamas	K. Stehling, NOAA
Jul 14-Aug 10	*Gold N. Cloud Nekton Gamma*	S.E. Alaska	W. High, NWAFC, Seattle R. Cooper, NEFC
Jul 24-Aug 9	*R-V Johnson Johnson Sea-Link*	Georges Bank	C. B. Grimes/ K. W. Able, Rutgers

Nekton/Gamma submersible during recovery after mission.

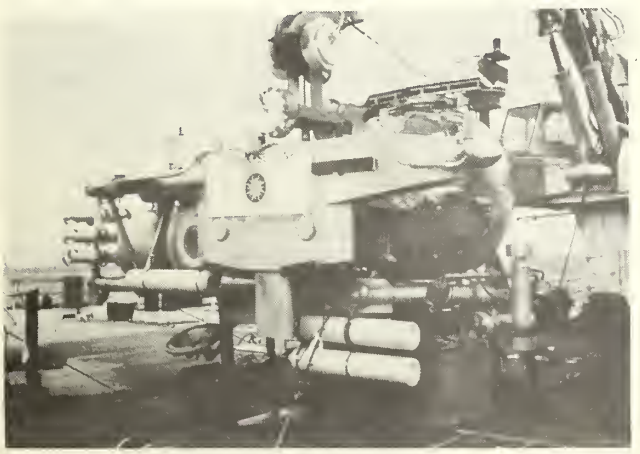
NEKTON ALPHA, BETA, GAMMA

LENGTH:	15.5 ft	HATCH DIAMETER:	18 in.
BEAM:	5 ft	LIFE SUPPORT (MAX):	48 man-hr
HEIGHT:	6 ft	TOTAL POWER:	4.5 kWh
DRAFT:	4 ft	SPEED (KNOTS): CRUISE	1.5/3.5 hr
WEIGHT (DRY):	2.35 tons	MAX	2.5/1 hr
OPERATING DEPTH:	1,000 ft	CREW: PILOTS	1
COLLAPSE DEPTH:	2,500 ft	OBSERVERS	1
LAUNCH DATE:	1968, 70, 71	PAYLOAD:	450 lb



LENGTH:	23 ft
BEAM:	7.9 ft
HEIGHT:	10.8 ft
DRAFT:	7.1 ft
WEIGHT (DRY):	9.5 tons
OPERATING DEPTH:	1,000 ft
COLLAPSE DEPTH:	DIVER 6,000 ft
	PILOT 6,000 ft
LAUNCH DATE:	1971
HATCH DIAMETER:	24 in.
LIFE SUPPORT (MAX):	72 man-hr
TOTAL POWER:	32 kWh
SPEED (KNOTS): CRUISE	0.75
MAX	1.75
CREW: PILOTS	1
OBSERVERS	3
PAYLOAD:	1,100 lb

Characteristics of *Johnson Sea-Link* submersible.



Johnson Sea-Link submersible.

Johnson Sea-Link being launched from support ship R/V *Johnson*.

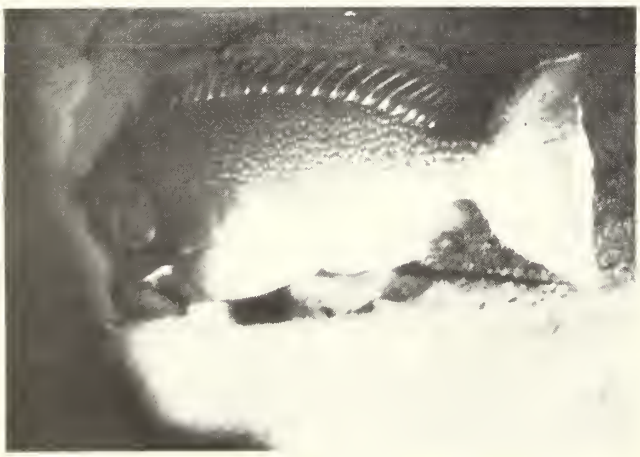
Tilefish Ecology—Commercial Longline Gear Evaluation ("Atlantic Twin/Nekton Gamma")

Date: August 23, 1979

Purpose: To determine the ecological role of tilefish in outer continental shelf ecosystems and to evaluate the effectiveness of commercial longline gear.

Participants: Rutgers University: C. B. Grimes
Rutgers University: K. W. Able

Accomplishments: Working with the crew of the commercial fishing vessel *Lori-L*, the effectiveness of commercial longline fishing gear was evaluated. Two miles of marked longline were observed and photodocumented. One mile of longline (450 hooks) was set with brightly colored vinyl covered snoods (short pieces of line) designed to break away when taken by a fish, thus tagging the individual. Rutgers research personnel aboard the *Lori-L* observed and recorded the location, size, sex, etc., of the catch on retrieved marked longline to compare with *in situ* observations. Approximately 80 break-off hooks and snoods were missing from the longline when retrieved and are assumed to have tagged fish. Final verification of this tagging method depends upon the recapture of and reporting on the marked fish by commercial fishermen. Tilefish distribution, abundance, and habitat preference were also studied. Eight dives, in depths ranging from 73 m to 275 m were made in 3 days and yielded 22 hours of personal observations, 5 hours of video, 8 hours of audio, and 2,000 photographic frames. Preliminary observations show that tilefish occupy large crater-burrow habitats on the flanks of the submarine canyons. Continued analysis will provide a preliminary estimate of the density of tilefish and associated species and may begin to explain the variation and abundance of tilefish relative to habitat. The ecological role of tilefish in establishing and maintaining these outer-continental-shelf communities will also be studied. Information on the distribution and behavior of juvenile tilefish was obtained. Detailed reports describing gear evaluation and the unique tilefish crater-burrow habitat and its associate community will be produced in the near future.



Tilefish entering cave in Veatch Canyon.

Reef inhabitant.

Research Submersible Observations of the Off-Shore North Carolina Reef Ichthyofauna ("Atlantic Twin/Nekton Gamma")

Date: August 30—September 2, 1979

Purpose: Study the reef Ichthyofauna.

Participants: National Marine Fisheries Service, SEFC: Peter Parker, Principal Investigator
National Marine Fisheries Service, SEFC: D. Dawkins
National Marine Fisheries Service, SEFC: S. W. Ross

Accomplishments: Eighteen dives at 13 sites on hard substrate reefs were made in Raleigh, Onslow, and Long Bays, North Carolina. Depths ranged from 27.5 m to 153 m. Reefs with the highest profile and in depths of 30.5 m-91.5 m exhibited the greatest species diversity and biomass systems while adjacent sandy areas were noticeably void of species and biomass. A total of 100 fish species (31 families) were observed, dominated by the families Serranidae, Holocentridae, Sparidae, Chaetodontidae, Pomacentridae, and Labridae. Many tropical species previously thought to be rare in this region were abundant. Reef fish biomass estimates made during these observations will be combined with surveys of the amount of reef habitat conducted from the R/V *Oregon II* to provide estimates of the total amount of reef fish important in the recreational and commercial catches. This estimate will, in turn, be used to estimate potential yield of reef fish.

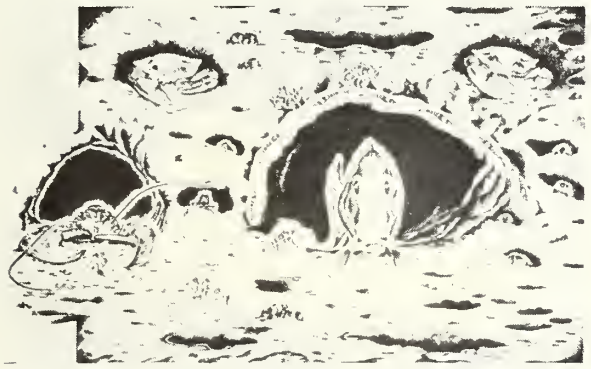
Norfolk Canyon Study

Date: September 7-13, 1979

Purpose: To investigate the seafloor geology and dynamic sedimentation processes of the shallow part of Norfolk Canyon.

Participants: National Ocean Survey: Robert Embley, Principal Investigator
Atlantic Oceanographic and Meteorological Laboratory: E. Forde

Accomplishments: Seven dives were made during the cruise, one of which was terminated due to technical difficulties. The following areas of Norfolk Canyon were examined: the north wall, the head of the Canyon, a small channel which runs from the Franklin shore into a deeper part of the Canyon, and the steep portion of the Canyon's south wall. Some southwest-northeast current lineations were observed at the 107 m-122 m level on the north wall. No outcrops or rocks were observed there, although a terrace was traversed. On a steep section of the north wall the sediment was sand with shelly material. At 180 m, the first of a series of large rocks was seen. The rocks ranged widely in sizes and shapes. Some were as large as, or larger than, the submersible. Many were in unstable positions. The rocks were often undermined by burrowing crab and fish, and supported a large and varied fish, crab, and anemone population. Subsequent rock nests in the area were covered with anemones and served as habitats for groupers and other fish and lobsters. Some of the rocks were incongruous with the location, but the presence of anemones indicated a hard substratum. The area represents a definite outcrop zone, but the rocks were weathered by currents and biological activity and creep downslope. A sample of rocks was retrieved at a depth of 168 m. The head of Norfolk Canyon was examined for the presence or absence of an active transport channel. A large amount of particulate matter in the near-bottom water column was observed. The visibility ranging from 1 m to 3 m. There was also a strong up-canyon current. Similar bottom conditions were encountered in the small channel running from the Franklin shore into the deeper part of the Canyon. The visibility was poor, and the current was strong though running down-canyon at that time. The topography of the steep portion of the Canyon's south wall suggested that the Canyon had eroded through hard substrata in this area. The bottom was silty sand with a low density of large shells on the surface. In the 116-183 m depth range, a moderately high density of small rocks was seen on the surface. These appeared to be of various shapes and a mixed lithology. Many were habitats for small crabs and anemones. The initial bottom type was pinkish silty sand. At the slope break, descending off the small plateau onto a steeper slope, the bottom lithology changed, becoming a more compact, grayish sand. Most of the rocks were also concentrated in the upper part of this slope.



Biological community in a marine canyon off the New England Atlantic Coast.

Dive site on Mid-Atlantic Continental Shelf missions.

Effect of Longline Fishing on Behavior of Marine Animals

Date: July 17-August 11, 1980

Purpose: Observe the behavior of marine animals within the influence of longline fishing gear. Determine the source and consequences of predation upon bait and hooked fish. Investigate the distribution and abundance of adult and juvenile rockfish, and collect samples of juvenile rockfish.

Participants: NMFS, Seattle: William L. High, Principal Investigator
NMFS, Seattle: R. Loghry
IPHC, Seattle: G. Peltonen

Accomplishments: A total of 42 submersible dives were made during 16 days along the west coast of Dall Island near Dixon Entrance, Whale Bay on Baranof Island, Sitka Sound, and Slocum Arm off Chichagof Island. Fish were observed within the influence of longline gear, and the cause and rate of bait loss were documented. Three typical halibut baits—Pacific herring, sablefish, and pink salmon—were compared. More than 2,000 individual hooks were observed. Schools of juvenile rockfish (Sebastes) were observed at offshore stations which were characterized by large bare outcrops. Juvenile rockfish were most abundant at 73 m to 110 m. Several unsuccessful attempts were made to capture juvenile rockfish specimens with a gill net, a trap, and chemicals. Finally, fish jigs were attached to the submersible to capture adult fish seen to feed on small fish. Twelve adult rockfish were captured by the jigs. Two partly digested juvenile rockfish were removed from their stomachs. Scuba divers working from the submersible tender vessel *Gold N. Cloud* were able to collect several juvenile rockfish specimens at 34 m.

Georges Bank Submarine Canyon Oil and Gas Drilling and Monitoring Program

Date: July 24-August 9, 1980

Purpose: Establish predrilling baselines for bottom-oriented fishes and crustaceans, habitat types and available shelters, and pollutant levels in the bodies of key indicator species and bottom substrate.

Participants: National Marine Fisheries Service: Richard Cooper, Principal Investigator
Rutgers University: C. B. Grimes
Rutgers University: K. W. Able

Accomplishments: Twenty-two dives totalling 50 hours of bottom time were logged at 6 stations on Georges Bank, within Lydonia Canyon and the Mud Patch dive stations. The Mud Patch, 60 nautical miles south of Nantucket Island, is characterized by fine-grained sediments and is theorized to be the recipient area of much of the fine-grained particulates that break free of the Georges Bank gyre. Four long-term monitoring stations were established to relate animal and substrate bound levels of pollutants to absolute abundance, community structure, and behavior of macrobenthic fauna (lobsters, crabs, tilefish, starfish, eelpout, conger eel, hakes, rosefish, flounders, skates, goosefish, cusk, anemones, etc.) Stations were marked with 37 kHz pingers which will permit high resolution, site specific studies, and monitoring for a 5-year period. Two stations are located in the center of the proposed drilling area and two in Lydonia Canyon. Between 800 and 1,000 bottom photographs were taken at each station along 600 m transects running north, south, east and west from the station marking pinger. The 35 mm color photographs were calibrated quantitatively for linear distance on depth and field of view. Samples of the surface substrate (2-3 cm) and associated macrobenthic fauna were collected for an assessment of egg pollution load. The diver lock-out capability proved to be very effective for finite sample collection and will be used in the future. Additional observations, photographic documentation, and sample collection was conducted at a 1977 drilling site on Georges Bank. Box core sediment samples were collected at the Mud Patch area. Observations were also made on the operation of a current meter and sediment trap array and on the attraction of marine life to the array. Extensive observations and photographic documentation were accomplished on the abundance, population structure, and general ecology of the tilefish at Lydonia Canyon. This cooperative cruise was highly successful and has laid the predrilling, macrobenthic fauna, and habitat groundwork for monitoring effects of oil and gas exploration and production in a fishing area.

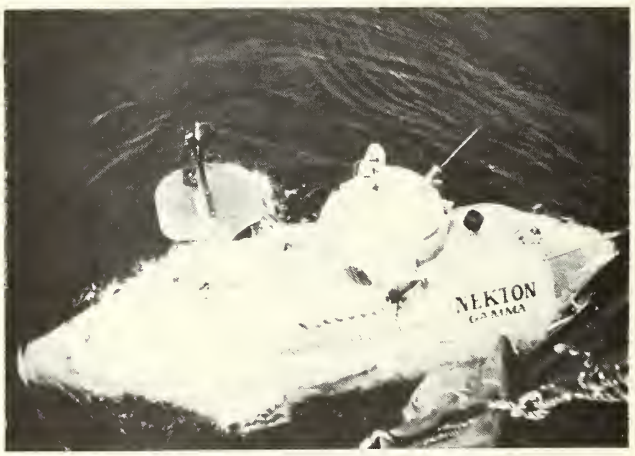
UTILIZATION AND STATUS OF RESEARCH SUBMERSIBLES AND HABITATS

Although the continuing exploitation of offshore oil and gas resources in ever-increasing depths of water has brought about an increased demand for use of manned undersea facilities, there has been a shift from the use of the manned one-atmosphere submersibles to the use of observation-work bells, atmospheric diving suits, and lock-out vehicles. As can be seen in Table 5, a comparison of U.S. civilian submersible utilization by numbers of dives for FY 1976 through FY 1979, use of submersibles in the oil and gas industry rose from 42 dive-days in 1976 to a plateau of 169-171 the two following years, but plunged to 6 dive-days in 1979. Even though the use of these submersibles for scientific (chiefly biological and geological) missions rose appreciably in 1979, total dive-days declined from 510 in 1978 to 371. Table 6 lists dives and dive-days, by mission, for operating civilian submersibles in this country in 1979.

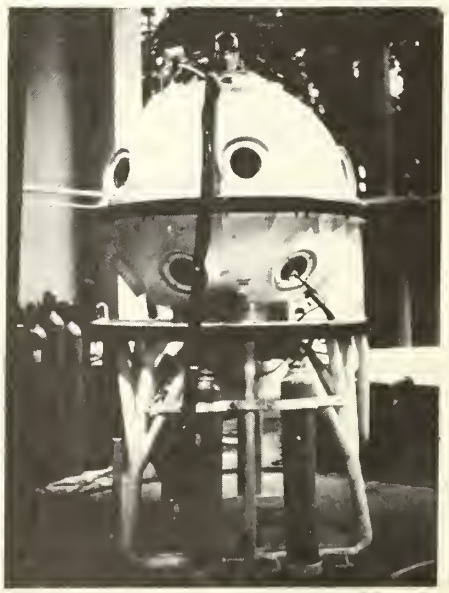
Four basic types of manned submersibles are used today:

a. One-Atmosphere Vehicles: Self supported, mobile vehicles in which a crew of two or three are supported in a one-atmosphere environment. Maximum operating depth: 6,000 m.

b. Observation/Work Bells: One-atmosphere or ambient, surface-supported or self powered vehicles which operate within a limited radius from a surface umbilical capable of high and manipulative dexterity. Crews number two or three. Maximum operating depth: 1,000 m.

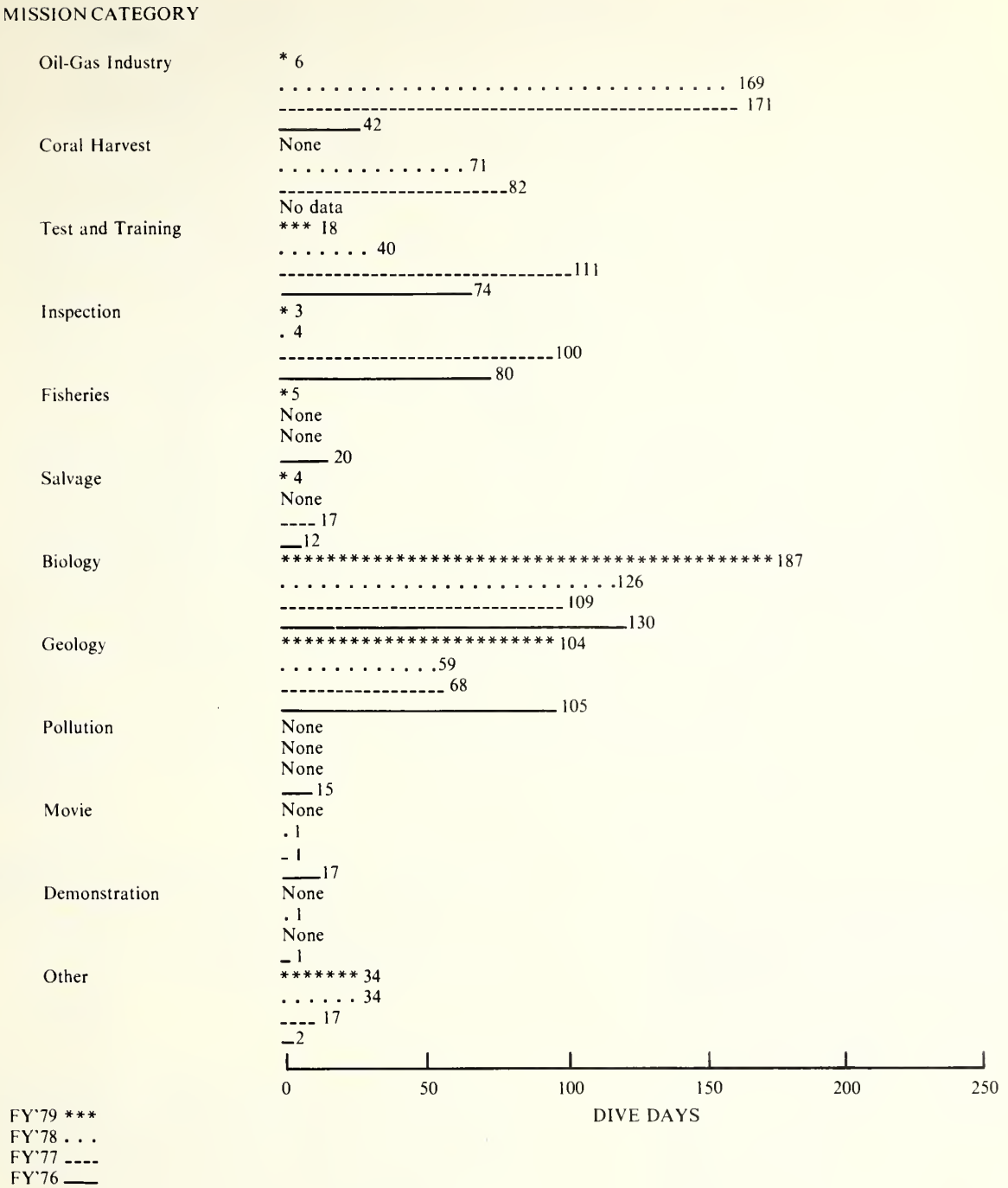


One atmosphere-vehicle *Nekton*.



Observational bell.

Table 5.—U.S. Civilian Submersible Utilization by Number of Dive-Days, FY '76, '77, '78, '79.



c. Atmospheric Diving Suits (ADS): Surface-supported systems carrying a crew of one at one-atmosphere pressure and capable of providing a high degree of manipulative dexterity and maneuverability to perform detailed work in undersea hardware. Maximum operating depth: 610 m.

d. Lockout Vehicles: Self supported, mobile vehicles consisting of a one-atmosphere compartment and a diver lockout compartment which can be pressurized to ambient pressure for release, support, and retrieval of divers. A crew of two is generally carried in the atmospheric compartment, and two to three in the lockout compartment. After a lockout mission with saturated divers, the submersible is hoisted onboard the support ship and mated with a deck decompression chamber (DDC). The divers then transfer into the DDC through a mating hatch to undergo their required decompression routine. Maximum operating depth: 823 m.

Table 6.—U.S. Civilian Submersible Mission Categories
(October 1, 1978 to September 30, 1979)

Mission Category	*Alvin*	*Auguste Piccard*	*Deep Quest*	*Diaphus*	*Johnson Sea-Link I*	*Johnson Sea-Link II*	*Mermaid II*	*Nekton Alpha*	*Nekton Beta*	*Nekton Gamma*	*Snooper*	*Star II*	*Totals*	*Total Percentage of Dive Activities*
Oil-Gas									8		5		13	2
Industry									4		2		6	2
Coral Harvest													0	0
													0	0
Test and	1					20				14			35	6
Training	1					8				9			18	5
Inspection										5			5	1
										3			3	1
Fisheries										22			22	4
										15			15	4
Salvage	2										6		8	1
	2										2		4	1
Biology	57			24	107	79				51	6		324	54
	52			15	44	42				32	2		187	50
Geology	68			23	10					22			123	21
	68			15	6					15			104	28
Pollution													0	0
													0	0
Cable Bury													0	0
													0	0
Movie													0	0
													0	0
Demonstration													0	0
													0	0
Other			7		49	10							66	11
			7		21	6							34	9
Total Dives	128	0	7	47	166	109	0	0	8	114	17	0	596	100
Total Dive Days	123	0	7	30	71	56	0	0	4	74	6	0	371	100

00 Dives (upper number)
00 Dive Days (lower number)

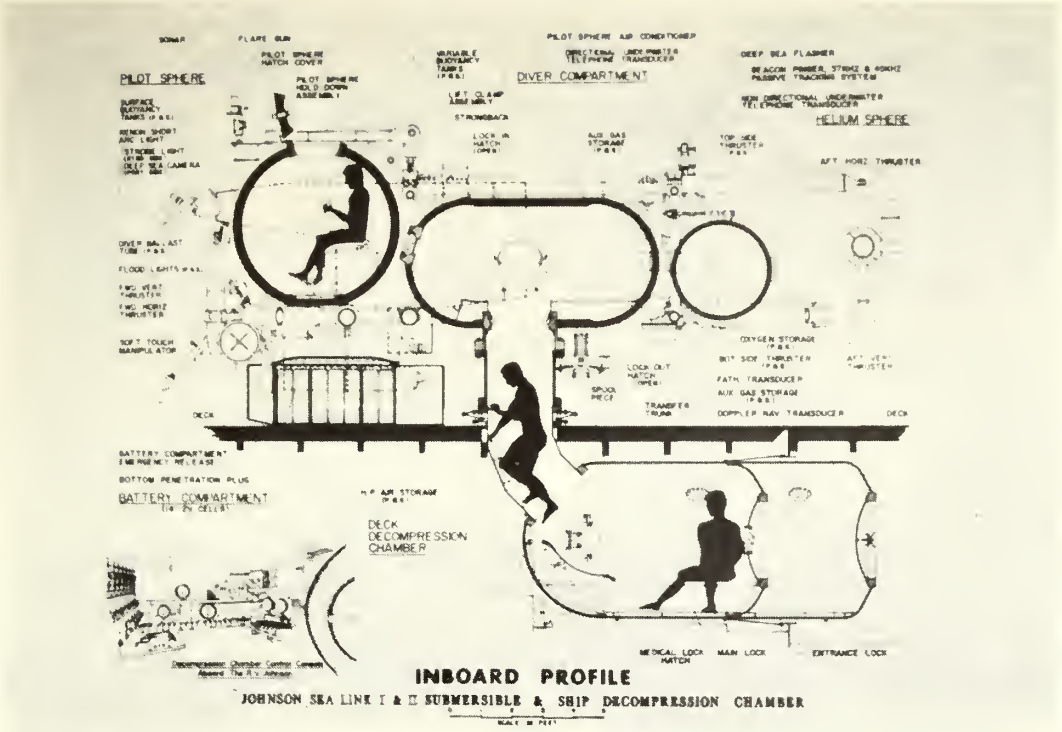
Atmospheric diving suit JIM.

The existing 131 manned submersibles with depth capability of 200 meters and greater are categorized as follows:

One-Atmosphere Vehicles	69
Observation-Work Bells	13
Atmospheric Diving Suits	23
Lockout Vehicles	26
	131

Of this total, 104 vehicles are operational, 14 are under construction, two are being refitted, and 11 are inactive. Table 7 lists contemporary manned submersibles, worldwide, with operating depth, builder, operator, and status. This table includes submersibles which are operated by various navies, as well as civilian submersibles.

The growth in the fleet of manned submersibles has remained relatively steady over the past few years. Each year some three to five vehicles are added to the worldwide inventory, and one or two are retired. Because of the demands of the offshore oil and gas industry, most of the recent growth has been in atmospheric diving suits and observation/work bells, which provide capabilities for detailed on-site maneuvering, high manipulative dexterity, and greater electrical power. More recently, vehicles have been developed which offer a combination of capabilities. The Mobile Diving Unit, built by Perry Oceanographics



Lock-out submersible *Johnson Sea-Link*, owned and operated by the Harbor Branch Foundation.

Table 7.—Contemporary Manned Vehicles

Country/Vehicle	Depth (m)	Operating Builder	Operator	Status
BRAZIL				
Lockout Vehicles				
SUPERSUB	300	Perry Oceanographics, Inc. Riviera Beach, FL	Superpesa Transportes M ritimo Ltda, Rio da Janiero	Inactive
CANADA				
1-Atm Vehicles				
AQUARIUS I	335	Hyco Vancouver, BC	Uncommitted	Inactive
AUGUSTE PICCARD	610	Giovanola Bros. Monthey, Switzerland	Gulf Maritime Inc. San Diego, CA	Operational
PISCES IV	2,012	Hyco Vancouver, BC	Institute of Ocean Sciences Sidney, BC	Operational
SEA OTTER	457	Anautics Inc. San Diego, CA	Can-Dive Services Ltd. Vancouver, BC	Operational
Observation/Work Bells				
ARMS IV	457	Can-Diver Services Ltd. Vancouver, BC	Can-Dive Services Ltd. Vancouver, BC	Operational
Lockout Vehicles				
CONSTRUCTOR	488	Deep Diving Systems Ltd. ThunderBay, Ont	CanSub Inc. Ottawa, Ont	Operational
SDL-1	610	Hyco Vancouver, BC	Canadian Armed Forces Halifax, NS	Operational
FRANCE				
1-Atm Vehicles				
CYANA	3,000	CEMA Marseille	Genavir Z.P. de Bregaillon, LaSeyne	Operational
GLOBULE	200	Comex Industries Marseille	Comex Services Marseille	Operational
GRIFFON	600	CERTSM Toulon	French Navy Toulon	Operational
MOANA III	400	Comex Industries Marseille	Comex Services Marseille	Operational
PC-8	244	Perry Oceanographics Inc. Riviera Beach, FL	Intersub Marseille	Operational

Table 7.—Contemporary Manned Vehicles—Continued

Country/Vehicle	Depth (m)	Operating Builder	Operator	Status
PC-1201, 03	305	Perry Oceanographics Inc. Riviera Beach, FL	Intersub Marseille	Operational
PC-1204, 05	366	Perry Oceanographics Inc. Riviera Beach, FL	Intersub Marseille	Operational
PC-16	914	Perry Oceanographics Inc. Riviera Beach, FL	Intersub Marseille	Operational
PISCES V	2,012	Hyco Vancouver, BC	Intersub Marseille	Operational
SEA CAT MK I	150	SAS Marseille	SAS Marseille	Operational
SM-97	6,000	CNEXO Paris	CNEXO Toulon	Design
Observation/Work Bells				
MOB 501	500	Comex Industries Marseille	Comex Services Marseille	Operational
MOB 1001/1002	1,000	Comex Industries Marseille	Comex Services Marseille	Operational
Lockout Vehicles				
LICORNE	300	CERTSM Toulon	French Navy Toulon	Construction
PC-1202	305	Perry Oceanographics Inc. Riviera Beach, FL	Intersub Marseille	Operational
PC-1801/1802/1804	305	Perry Oceanographics Inc. Riviera Beach, FL	Intersub Marseille	Operational
SHELF DIVER	244	Perry Oceanographics Inc. Riviera Beach, FL	Intersub Marseille	Inactive
ITALY				
1-Atm Vehicles				
LEO 1	610	Hyco Vancouver, BC	Sub Sea Oil Services SPA Milan	Refit
MSM-1	600	Cantiere Navale Breda Venice	Italian Navy	Construction
PC5-C	366	Perry Oceanographics Inc. Riviera Beach, FL	Sub Sea Oil Services SPA Milan	Inactive
PC-1602	914	Perry Oceanographics Inc. Riviera Beach, FL	Saipem Milan	Operational
PS-2	312	Perry Oceanographics Inc. Riviera Beach, FL	Sub Sea Oil Services SPA Milan	Operational
Observation/Work Bells				
AWOC-300	300	Drass	Sub Sea Oil Services SPA	Construction (300)
AWOC-650	650	Zingonia	Milan	Operational (650)
OMB-I	914	Perry Oceanographics Riviera Beach, FL	Saipem Milan	Operational
JAPAN				
1-Atm Vehicles				
DSV-2K	2,000	Mitsubishi Heavy Industry Yokosuka	JAMSTEC Yokosuka	Construction
HAKUYO	300	Kawasaki Heavy Industries Kobe	Ocean Systems Japan Ltd. Tokyo	Operational
Observation/Work Bells				
TANKAI	200	Nippon Nokan KK Tokyo	Fukada Salvage and Marine Works Co. Ltd., Tokyo	Operational
JUGOSLAVIA				
Lockout Vehicles				
MERMAID VI A/B/C/D	600	Bruker Meerestechnik GmbH Karlsruhe, West Germany	Jugoslavian Government	Operational (A/B) Construction (C/D)
NORWAY				
1-Atm Vehicles				
P10	1,000	Hyco Vancouver, BC	Dolphin Services A/S Tananger	Operational
Observation/Work Bells				
CHECKMATE	325	A/S Mollerodden	A/S Mollerodden	Operational
Lockout Vehicles				
LR 4	457	Slingsby Engineering Ltd. Kirbymoorside, Yorkshire	Dolphin Services A/S Tananger	Operational

Inc., combines the capabilities of the tethered observation/work bell with those of a submersible to provide a lockout-type vehicle with high maneuverability and power.

Undersea vehicle applications have become both numerous and varied. Although different units—commercial, military, or scientific—have requirements unique to their missions, the actual tasks conducted can be categorized into specific areas, such as:

- *Observation:* Monitoring, photographing, and providing direction to tasks, such as pile driving, grouting, pipelaying; observation of features and scientific processes.
- *Inspection:* Direct or remote examination of structures and terrain.
- *Repair:* Cutting, welding, grinding, and finishing.
- *Manipulation:* Turning valves, rigging, connecting, water jetting, setting up experiments.
- *Testing/cleaning:* Nondestructive testing; structure cleaning.
- *Survey/Sampling:* Route and site surveys for pipelines, cables, structures, subbottom conditions; broad-area geological reconnaissance; sampling and specimen collection.
- *Salvage/Debris Clearance:* Assistance in attaching lines; explosive attachments; object location, identification, and retrieval.
- *Drilling Assistance:* Equipment observation, drill hole abandonment; re-entry assistance.
- *Diver Support:* Transportation and support of ambient-pressure divers at the work-site.
- *Trenching:* Examination and trenching of undersea pipelines and cables.
- *Instrument Emplacement:* Emplacement and retrieval of scientific instruments.

In contrast to the increased use of manned submersibles, the use of fixed habitats has decreased during the past 2 years. In FY 1977-78, two fixed habitats were known to be operating worldwide: *Helgoland* (by the Federal Republic of Germany) and NOAA's *Hydrolab*. It was reported in the Manned Undersea Science and Technology Office Report for FY 1977-78 that the *Aegir*, owned by the University of Hawaii, was capable of operating on short notice, and that *Tektite*, last used at St. Johns, U.S. Virgin Islands, in 1970, was being refurbished for use off the coast of California. *Aegir* and *Tektite* are still inactive; *Aegir* is, however, being considered for use in NOAA's Regional Undersea Research Program at the University of Hawaii.

Fixed habitats have been used primarily for scientific research. Habitats are towed or otherwise transported to a dive site and lowered to the bottom, where they remain immobile until the specific operation is over, or may be left in place for succeeding operations. The occupants live at ambient pressure for the duration of their dive and can exit or enter at their discretion. Work tools and instruments are carried in or are attached to the habitat. Electrical power is supplied from the surface, as are additional life support system supplies and components. Observations can be made of the surrounding environment through viewports, and limited laboratory experiments can be conducted within the habitat itself.

At the present time, *Hydrolab* is the only working habitat in operation for scientific purposes. A small habitat is used by Mr. John Perry for relaxation; it is situated off Lee Stocking Island, Bahama. The University of Southern California habitat system, being developed for use at the Catalina Marine Science Center, will represent the next generation of habitat capability.

REMOTELY OPERATED VEHICLES

The extraction of offshore oil and natural gas from deep, cold, and hostile ocean regions has encouraged the development of a wide variety of underwater support systems. Of all these systems, perhaps the most dramatic increase in numbers and utilization has occurred in remotely operated vehicles (ROVs). Although ROVs were first developed and used in the underwater community over 26 years ago, it was not until the past 4 years that they were widely used in industry. By the end of 1974, 20 ROVs had been constructed; by the end of 1979 at least 139 of the tethered, free-swimming type had been constructed.

In 1978, R. Frank Busby Associates conducted a survey for NOAA to identify the types and capabilities of ROVs in operation and under development. The survey identified the types of work that ROVs are being used for, assessed their performance, located and described current research related to ROV technology, and recommended research and development programs for improving present and future ROV performance in both industrial and scientific applications. The results of this survey were embodied in a comprehensive report issued in August, 1979.*

Four types of ROVs in use were identified as:

- tethered and free swimming (the most prevalent)
- bottom-crawling
- towed
- untethered

Table 8 lists the ROVs in use, worldwide, at the time the survey was made along with their depth capability, manufacturer, and operator. Table 9 gives generalized characteristics of each category, and Table 10 lists the types of work for which vehicles of each category are suited.

The dominant user of ROVs is the offshore oil and gas industry, followed by the military sector and the scientific community. Over 90 percent of all tethered, free-swimming vehicles perform observation and video-photographic documentation. Manipulative tasks account for less than 5 percent of their work. It is likely that the use of ROVs for manipulative tasks may increase as more sophisticated and more capable systems are developed for ROVs. As ROVs become more available and the underwater community more familiar with their capabilities, their application to scientific research will increase.

**Remotely Operated Vehicles*, prepared by R. Frank Busby Associates, Inc. U.S. Department of Commerce, NOAA, Rockville, Md., 151 pp plus appendices.

Table 8.—Remotely Operated Vehicles—Depth Capabilities, Manufacturer and Operator by Category.

TETHERED, FREE-SWIMMING VEHICLES

Vehicle	Depth (ft/m)	Manufacturer	Operator
ANGUS 002	984/300	Heriot-Watt University	Same
ANGUS 003	1,000/305	Heriot-Watt University	Same
BOCTOPUS	2,170/661	British Oxygen Co., Ltd.	Same
CETUS	1,500/457	ULS Marine Ltd.	Same
CONSUB 1	2,000/610	Institute of Geological Sciences	British Aircraft Corp.
CONSUB 201	2,000/610	British Aircraft Corp.	Sub Sea Surveys Ltd.
CONSUB 202	2,000/610	British Aircraft Corp.	Same
CORD I	1,500/457	Harbor Branch Foundation	Same
CURV II	2,500/762	Naval Ocean Systems Center	Same
CURV II	2,500/762	Naval Ocean Systems Center	Naval Torpedo Station
CURV III	10,000/3,048	Naval Ocean Systems Center	Same
DART	1,200/366	International Submarine Engineering Ltd.	Same
DEEP DRONE	2,000/610	Supervisor of Salvage (USN)	Ametek Straza
ERIC II	19,685/6,000	C.E.R.T.S.M.	French Navy
ERIC 10	1,640/500	C.E.R.T.S.M.	French Navy
EV-1	1,500/457	Kraft Tank Co.	Same
FILIPPD	984/300	Gay Underwater Products	Same
FILIPPD	984/300	Gay Underwater Products	Nereides, Orsay, France
FILIPPD	984/300	Gay Underwater Products	Uncommitted
IZE	1,640/500	Sub Sea Surveys Ltd.	Same
MANTA 1.5	4,921/1,500	Institute of Oceanology USSR	Same
MURS-100	328/100	Mitsui Ocean Development and Engineering Co.	Same
MURS-300	984/100	Mitsui Ocean Development and Engineering Co.	Same
OBSERVER DL1	600/183	C. G. Doris	Same
OBSERVER III	984/300	C. G. Doris	Same
ORCA I	2,297/700	Saab-Scania	Oceaneering International
PAP-104	328/100	Society ECA	Various Nato Navies
PHOCAS II	1,000/305	Geologinen Tutkimuslaitos	Same
PINGUIN A1	330/100	VFW Fokker	Same
PINGUIN B6	6,500/1,981	VFW Fokker	Same
RCV-150	6,000/1,829	Hydro Products	Martech International
*RCV-225	6,600/2,012	Hydro Products	Seaway Oiving
RCV-225	6,600/2,012	Hydro Products	Martech International
RCV-225	6,600/2,012	Hydro Products	SESAM
RCV-225	6,600/2,012	Hydro Products	Esso Australia Ltd.
RCV-225	6,600/2,012	Hydro Products	Taylor Oiving and Salvage
RCV-225	6,600/2,012	Hydro Products	Wharton Williams
RCV-225	6,600/2,012	Hydro Products	Oceaneering International
RCV-225	6,600/2,012	Hydro Products	Japanese Navy
RCV-225	6,600/2,012	Hydro Products	Same
RCV-225	6,600/2,012	Hydro Products	Santa Fe Construction Co.
RCV-225	6,600/2,012	Hydro Products	Uncommitted
RECON II	1,500/457	Perry Oceanographics	Hunting Surveys Ltd.
RECDN III	600/181	Perry Oceanographics	Oceanics Ltd.
RECON V	1,200/366	Perry Oceanographics	Same
RUWS	20,000/6,096	Naval Ocean Systems Center	Same
SCAN	328/100	Underwater Maintenance Co., Ltd	Same
SCARAB I & II	6,000/1,829	Ametek Straza	AT&T Long Lines
SCORPID	3,000/914	Ametek Straza	Stolt-Nielsen Rederi A/S
SCORPIO	3,000/914	Ametek Straza	Israel - Government
SCORPIO	3,000/914	Ametek Straza	Same
SEA INSPECTOR	3,280/1,000	Rebikoff Underwater Products	Same
SEA SPY	1,000/105	Admiralty Underwater Weapons Establishment	Underwater and Marine Equipment, Ltd.
SEA SURVEYOR	660/200	Rebikoff Underwater Products	Same
SMARTIE	984/300	Marine Unit Technology, Ltd.	Marine Unit Holdings, Ltd.
SMIT SUB-1000	3,280/1,000	Smit Tak International	Same
SMT 1 & 2	1,200/366	International Submarine Engineering Ltd.	Sonarmarine Ltd.
SNDOPY	1,500/457	Naval Ocean Systems Center	Same
SNOOPY	1,500/457	Naval Ocean Systems Center	Naval Facilities Command
SNURRE	3,280/1,000	Continental Shelf Institute	Same
SPIDER	820/250	Myrens Verkstad A/S	Same
TELESUB	2,000/610	Remote Ocean Systems	Same
TOM 300	984/300	COMEX	Same
TREC 1, 2, 3	1,200/366	International Submarine Engineering Ltd.	Martech International
TREC 4	1,200/366	International Submarine Engineering Ltd.	Horton Maritime Explorations
TREC 5, 6	1,200/366	International Submarine Engineering Ltd.	Ocean Systems Inc.

*No RCV-225 has a cable longer than 1,212 ft (400m), but the vehicle is designed for 6,600 ft operating depth.

TETHERED, FREE-SWIMMING VEHICLES (Continued)

Vehicle	Depth (ft/m)	Manufacturer	Operator
TREC 7, 8	1,200/366	International Submarine Engineering Ltd.	Sub Sea International
TREC 9	1,200/366	International Submarine Engineering Ltd.	Uncommitted
TROV B-1	1,200/366	International Submarine Engineering Ltd.	National Water Resources Institute
TROV O-1	1,200/366	International Submarine Engineering Ltd.	(Not resolved)
TROV E-3	1,200/366	International Submarine Engineering Ltd.	J. Ray McDermott
TROV S-4, 6, 7	3,000/914	International Submarine Engineering Ltd.	Ocean Systems Inc.
TRDV S-8	3,000/914	International Submarine Engineering Ltd.	Intersub
UFD 300	984/300	Submersible Television Surveys	Winn Technology
UTAS 478	1,312/400	General Video System	Same

BOTTOM-CRAWLING VEHICLES

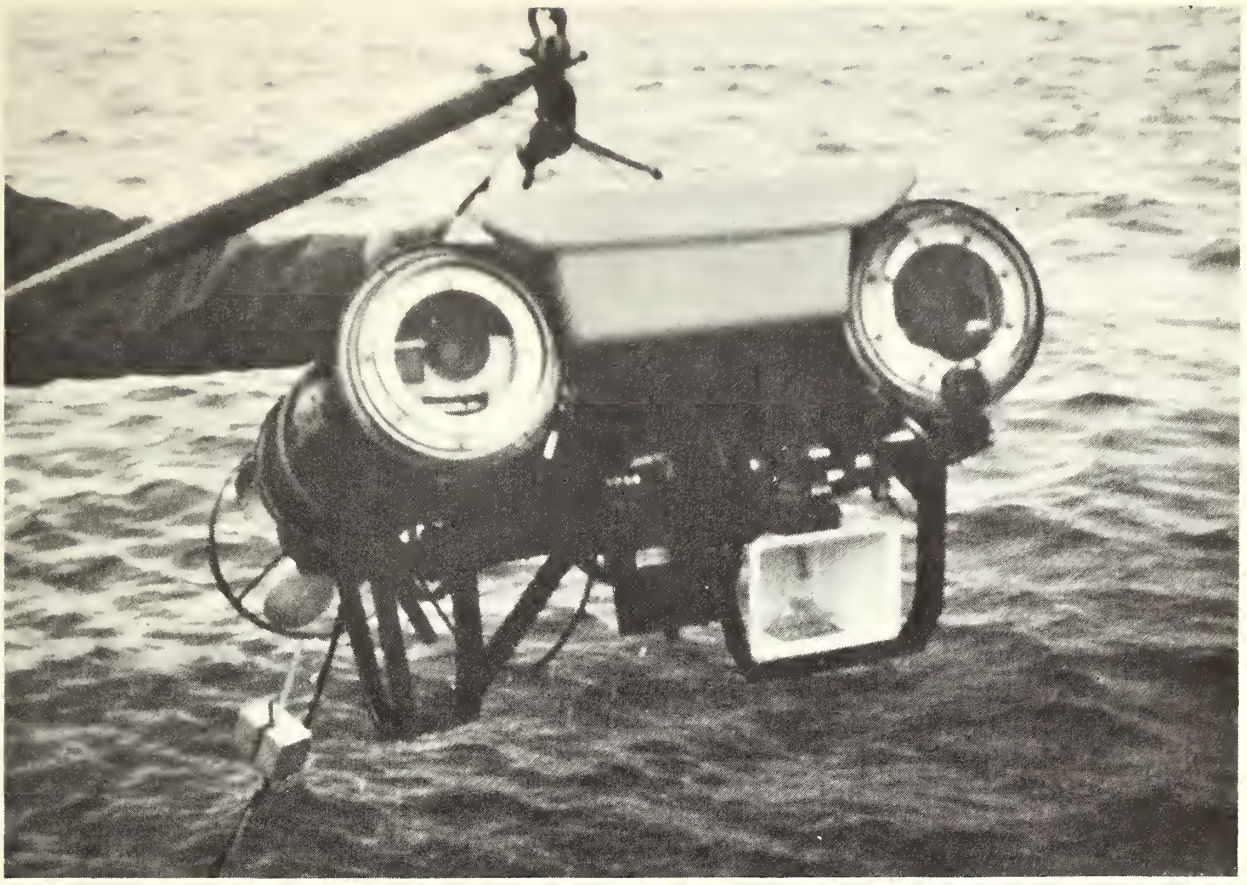
Vehicle	Depth (ft/m)	Manufacturer	Operator
GRANSEOLA	150/46	INCOP, Ancona, Italy	Same
JU 160	197/60	Hitachi Construction	Same
KVAENER MYREN TRENCHING SYSTEM	1,640/500	Kvaerner Brug A/S	Same
PBM	420/128	Sub Sea Oil Services	Same
RUM	6,158/1,877	Marine Physical Laboratory	Same
SEABUG 1	1,000/306	UDI Ltd.	Same
SEACAT	656/200	Vickers Oceanics Ltd.	Same
SL 3	164/50	Land and Marine Engineering	Same
SUBTRACTOR	150/46	Maui Divers of Hawaii Ltd.	Same
TALPA	150/46	INCOP, Ancona, Italy	Same
TALPETTA	150/46	INCOP, Ancona, Italy	Same
TM-102	660/201	Techomare S.p.A.	Same
TM III, IV	246/75	Land and Marine Engineering	Same
TRAMP	(Not available)	Winn Technology Ltd.	Same
UNDERWATER BULLDOZER	23/7	Komatsu Ltd.	Same
UNDERWATER TRENCHER	70/21	Sumitomo Heavy Industries	Same

TOWED VEHICLES

Vehicle	Depth (ft/m)	Manufacturer	Operator
ANGUS	7,874/2,300	Woods Hold Oceanographics Institute	Same
BATFISH	650/198	Bedford Institute of Oceanography	Same
CRAB	13,123/4,000	Institute of Oceanology	Same
DEEP TOW	20,000/6,096	Marine Physics Laboratory	Same
DIGITOW	19,685/6,000	Jet Propulsion Laboratory	Same
DSS-125	20,000/6,096	Hydro Products	One Japanese and One German Industrial firm
GUSTAV	19,685/6,000	Dornier System GmbH	Same
MANKA 01	21,325/6,500	GPK Karlsruhe	Same
NRL System	20,000/6,096	Naval Research Laboratory	Same
RAIE I	19,685/6,000	CNEXD	Same
RAIE II	19,685/6,000	CNEXO	Same
RUFAS I	600/183	NMFS	Same
RUFAS II	2,400/731	NMFS	Same
S^3	6,000/1,829	University of Georgia	Same
SEP	19,685/6,000	Dornier System GmbH	Same
TELEPROBE	20,000/6,096	Naval Oceanographic Office	Same

UNTETHERED REMOTELY OPERATED VEHICLES

Vehicle	Depth (ft/m)	Manufacturer	Operator
EPAULARD	19,685/6,000	CNEXO	Same
OSR V & H	820/250	Mitsui Ocean Development and Engineering Co.	Same
ROVER	984/300	Heriot-Watt University	Same
SPURV I	12,000/1,650	Applied Physics Laboratory	Same
SPURV II	5,000/1,524	Applied Physics Laboratory	Same
UARS	1,500/457	Applied Physics Laboratory	Same
UFSS	1,500/457	Naval Research Laboratory	Same
Unnamed	2,000/610	Naval Ocean Systems Center	Same
Unnamed	3,000/914	University of New Hampshire	Same



Tethered ROV *Snoopy*.

Table 9.—General Vehicle Characteristics.

	Operating Depth (m)	Weight in Air (kg)	Speed (knots)	Operating Duration	Electrical Power	Maneuvering Capability	Propulsion	System Components
Tethered Free-Swimming	1,053	592	1.6	Unlimited	Cable	3 Dimensions	Thrusters	Vehicle, umbilical cable, control/ display console, power generator
Bottom-Crawling	118[1]	49,000[2]	N/A	Unlimited	Cable	3 Dimensions	Tracks	Same
Towed	4,712	1,488		Unlimited	Cable	3 Dimensions	Surface	Same
Untethered	1,643	948		4-6 hours	Batteries	3 Dimensions	Thrusters	Vehicle, control/ display console

[1]Does not include general purpose vehicles which have an average depth capability of 1,184 m.
[2]Does not include general purpose and cable burial vehicles which average 1,900 kg

Table 10.—ROV Work Capabilities.

TETHERED, FREE-SWIMMING VEHICLES

Industrial	*Military*	*Scientific/Research*
Inspection	Inspection	Inspection
Monitoring	Search/Identification	Survey
Survey	Installation/Retrieval	Installation/Retrieval
Diver Assistance		
Search/Identification		
Installation/Retrieval		
Cleaning		

BOTTOM CRAWLING VEHICLES

Industrial	*Military*	*Scientific/Research*
Bulldozing	Drilling	None
Trenching	Trenching	
Inspection		
Manipulation		

TOWED VEHICLES

Industrial	*Military*	*Scientific/Research*
Survey	Search/Identification/ Location	Geological/Geophysical Investigations
	Survey	Broad Area Reconnaissance
	Fine-grained Mapping	Water Analysis
	Water Sampling	Biological/Geological Sampling
	Radiation Measurements	Bio-assay
		Manganese Nodule Survey/Study

UNTETHERED VEHICLES

Industrial	*Military*	*Scientific/Research*
None	Conductivity/Temperature/ Pressure Profiling	Bathymetry
	Wake Turbulence Measurements	Photography
	Under-ice Acoustic Profiling	

DIVING RESEARCH AND DEVELOPMENT—INTRODUCTION

In the 8 years of its existence, the MUS&T Office had concerned itself in almost equal proportions with submersibles, habitats, and the diver. Until the establishment of a separate NOAA Diving Office in 1979, the MUS&T Office was responsible for the development, support, and management of a NOAA diving program to assure safe diving and more efficient operations for prolonged manned missions in coastal waters and on the Continental Shelf. These responsibilities included not only training, safety, and certification of NOAA divers, but also the conduct of diving research and development, in both medical and technological aspects. The office addressed, in conjunction with the NOAA Diving Safety Board and the NOAA Diving Medical Review Board, the development of training and operational policies, medical qualifications, and reporting requirements. Since the reorganization of the Diving Office, MUS&T and its successor, NURP, have been responsible for diving research and development.

Diving research and development covers a wide range of activities, from identification of needs in equipment and technology, physiology and medicine, and training, to the development of equipment and procedures. It concentrates on improvements in diving safety and the treatment of diving-related casualties and disease. It also includes the dissemination of information on such improvements to NOAA divers and to the scientific, commercial, and recreational diving communities and the incorporation of diving tables, procedures, and the like in authoritative publications such as the *NOAA Diving Manual*.

The efforts of the MUS&T and NURP Offices in promoting, facilitating, accomplishing, and promulgating the results of diving research and development have been greatly assisted by the active cooperation of the Undersea Medical Society, the National Institute for Occupational Safety and Health, the Department of the Navy, and the Department of Energy, as well as other agencies in this country and abroad.

PHYSIOLOGY AND MEDICINE AND DIVING SAFETY

As part of the diving research activities, NOAA has actively supported efforts in furthering research in human hyperbaric physiology as applied to operational and scientific diving and in training physicians in the unique medical aspects of diving-related emergencies. Increasing the awareness for diving safety and emergency procedures and the development of applicable programs has been emphasized by NOAA. Following are examples of programs initiated by NOAA pertaining to these areas.

Microbial Hazards Associated With Diving In Polluted Waters

In 1977, NOAA initiated a research project to study the microbiological hazards to divers conducting operations in polluted waters, and the medical consequences of such diving. This study was also designed to lay the groundwork for the development of effective medical and technological countermeasures for such hazards.

In addition to NOAA, the University of Maryland, and the Naval Medical Research Institute are involved in this research effort along with the U.S. Coast Guard, and the Veterans Administration. Leading investigators have been Dr. Otis P. Daily, LCDR, MSC, U.S. Navy, of the Medical Microbiology Branch, Naval Medical Research Institute, and Dr. Rita R. Colwell, Department of Microbiology, University of Maryland. The project is an outstanding example of a continuing, cooperative effort between two federal agencies and a university.

A search of the literature prior to initiation of the study revealed a serious lack of information on the hazards posed to divers by pathogens in polluted waters, as in waters contaminated by sewage disposal. Active field investigations began in early 1978 and have continued since that time in the Anacostia River and the New York Bight. A number of pathogens to date have been isolated including *Aeromonas hydrophilia, Aeromonas sobria, Vibrio cholerae* and three strains of *salmonella*.

During an early mission, a U.S. Navy diver developed an infection and tissue abscess that clearly and unequivocally resulted from invasion of a puncture wound by *Aeromonas hydrophilia* and *Aeromonas sobria*. These organisms are resistant to antibiotics. Further, *Aeromonas* infections are often misdiagnosed by clinicians, with the result that prescribed treatments may be ineffective. Finding that divers are subject to such infections is considered significant.

In the most recent series of tests, several diving masks were evaluated for their potential to protect divers from colonization by bacteria. Sixteen NOAA divers participated in the study. They used four different masks: (1) Divator-AGA; (2) Kirby Super-Light 17 (LT-17); (3) Kirby-Morgan MK-1; and (4) SCUBA. Although only three divers used SCUBA, the majority of bacterial colonization occurred on these divers. On the basis of these limited results, it was concluded that the use of the SCUBA in polluted water environments is hazardous to the diver and provides marginal protection against bacteria. The AGA, Kirby-Morgan, and LT-17 mask, all full-face masks covering the entire face, appear to afford excellent protection.

NOAA divers working.

Preliminary results of the characterization of 17 isolates identified as *Aeromonas Hydrophilia* and *A. sobria* in this most recent experiment, indicate that 5 isolates appear to be cytotoxic for Y-1 adrenal cells, and 10 of 13 tested so far demonstrate enterotoxic activity.

NOAA plans to continue this research effort, including microbial ecology studies to define the incidence, and seasonal and spatial distribution of pathogens in the water. Complementary medical microbiological studies will be done to assist in defining the persistence and pathogenicity of microorganisms isolated from water and sediment samples and from divers working in such areas. Particular emphasis will be placed on determining the practical efficiency of procedures now employed for decontamination of divers and diving equipment. Work will also be done to determine the effectiveness of present recommended procedures for immunization prophylaxis. The results of these investigations will be included in a future edition of the *NOAA Diving Manual.*

Training of Physicians in Hyperbaric Medicine

In 1976, the Undersea Medical Society issued a "National Plan for the Safety and Health of Divers in their Quest for Subsea Energy." The development of this plan was supported by the National Institute for Occupational Safety and Health (NIOSH) and by NOAA. The plan was a comprehensive program for ensuring the continuing health and safety of divers involved in the development of offshore oil resources and other subsea energy sources. One of the top priorities identified was the need for physicians trained to treat diving casualties.

To meet this need, NOAA, with financial support from the Department of Energy, developed the curriculum for a course in hyperbaric medicine, and made it available to physicians. Since early 1977, five separate courses have been given, the first three in cooperation with the U.S. Naval School of Diving and Salvage, Washington, D. C.; the last two were at the NOAA diving facility in Miami, Florida. The latter now has three types of recompression chambers among its facilities, which allows the physician students to gain wider experience in chamber operations.

Over 50 physicians have taken this training since the inception of the program. Most of these physicians have become instrumental in establishing means of handling diving emergencies and casualties in their communities or have become actively involved in treatment of diving accidents resulting from commercial and recreational diving activities. Many will participate in the new National Accident Management Network being managed by NOAA and National Institute For Occupational Safety and Health. Most of the trained physicians maintain a close relationship with the NOAA Diving Office. Some have participated in Government sponsored activities as diving medical officers, instructors, examining physicians, and advisors.

Biomedical Advisory Services

The Biomedical Advisory Services program was established to provide NOAA with timely advice on diving training, diving medicine, and diving procedures. This advice is provided by the Undersea Medical Society, an organization numbering some 1,400 physicians, divers, and other professionals, and comes in the form of special reports, proceedings of workshops convened to address specific problems, and bibliographical services.

In the past, a number of workshops have been held covering such topics as marine pharmacology, emergency ascent training, and delayed treatment of decompression sickness. The Glossary of Hyperbaric and Diving Terms* was completed and published in FY 1978; it now serves as a standard reference for diving terminology and units of measurement. Other workshops have been sponsored jointly with the Navy and other agencies.

It is anticipated that this program will continue with support from both NOAA and the Department of Energy. Future activities include:

- Analyses, evaluation, and dissemination of information relevant to research in the biomedical aspects of hyperbaric activities.
- Special literature searches, analyses, and annotated bibliographies relative to diving activities and publications.
- Organization and management of workshops and symposia, including the selection of medical and scientific advisors, provision of necessary logistics, and preparation, publication, and distribution of proceedings.
- Selection of scientific advisors capable of review of research proposals, and preparation, publication, and distribution of research evaluation documents.

Outer Continental Shelf Diving Research Program

In September 1978, the Outer Continental Shelf Lands Act Amendment of 1978 was enacted as Public Law 95-372. Section 21(e) of Section 208 of Title II of this Act tasks the Secretary of Commerce to "Conduct studies of underwater diving techniques and equipment suitable for protection of human safety and improvement of diver performance." This responsibility was assigned to NOAA by the Secretary of Commerce in February 1979. NOAA, with the assistance of representatives of seven other Federal agencies, prepared a program development plan (PDP). This plan, entitled "Program Development Plan for Studies of Underwater Diving Techniques and Equipment Suitable for Protection of Human Safety and Improvement of Diver Performance," was published in April 1980.

The PDP was developed by NOAA, the U.S. Coast Guard, and the National Institute for Occupational Safety and Health (NIOSH), with the assistance of the Navy, the Occupational Safety and Health Administration (OSHA), the National Heart, Lung and Blood Institute,

**Glossary of Diving and Hyperbaric Terms*, Undersea Medical Society, Bethesda, Md., 1978

the Department of Interior, and the Department of Energy. The commercial diving industry, working primarily through the Association of Diving Contractors, participated fully in the workshops held to formulate the PDP. Representatives of organized labor (from the United Brotherhood of Carpenters and Joiners, who represent divers), and physicians qualified in diving medicine also participated.

The plan outlines a comprehensive set of research and development studies which should be undertaken to meet the long-range safety and operational aspects of diving and diving support systems. This set includes (not in any order of priority):

Equipment

- Compatible mating equipment for diving bells, recompression chambers, and emergency evacuation systems.
- Safe load requirements for primary and backup handling systems; requirements imposed in meeting extreme heat and cold, and effects of external pressure.
- CO_2 scrubber system improvements.

Training Curricula

- Specialized training for diving and diver support personnel.
- Training of scientists and engineers in techniques of deepwater diving and use of diving equipment.

Biomedical

- Practical developments for improvement of diver health and safety.
- Diving accident management.
- Inclusion of training in diving medicine in emergency medical specialist training.
- Effect of individual physiological differences on diving physical examination procedures.
- Epidemiological study of long-range health problems associated with diving, effectiveness of different decompression sickness regimes, and causes of fatal diving accidents.
- Establishment and maintenance of National Diving Data Center (by NIOSH).
- Air/nitrogen-oxygen saturation diving: development of repetitive dive schedules, decompression procedures, and procedures for using helium-oxygen when making excursion dives from a saturation breathing mixture of air/nitrogen-oxygen.
- Microbiological hazards for divers, including the effects of hyperbaric conditions on the permeability of chemicals in microbial processes, the microbial metabolism of organic and inorganic compounds, enzyme activity, and protein synthesis.
- Use of routine drugs under pressure.
- Medical and surgical treatment under hyperbaric pressure.
- Means of alleviating effects of delayed treatment of decompression sickness.
- Medical considerations of special regard to female divers.
- Posttreatment care and return-to-work schedule for diving casualities.

Many of these studies will be carried out by the agencies having direct responsibilities for specific areas, and some workshops are already being held. To ensure that the studies recommended in the PDP are carried out and that their results are disseminated and implemented, a National Diving Advisory Committee composed of representatives of Federal agencies, the diving industry, and academia may be formed.

National Accident Management Network

Recognizing the widespread diving activity within the United States today, the minimal number of physicians experienced in diving medicine, and the treatment of diving accidents, NOAA, with the financial support of the Department of Energy and the National Institute for Occupational Safety and Health (NIOSH), is establishing a nationwide Diving Accident Management Network with the assistance of the Undersea Medical Society (UMS).

The purpose of the Network is to provide a means of rapid, efficient response to diving accidents. This response includes furnishing appropriate medical services, making recompression facilities available, and arranging transport of diving casualties to these facilities. The Network is intended to serve those individuals who experience diving accidents and organizations and individuals responsible for emergency handling of diving-related casualties. A secondary objective is to gather data on diver morbidity and mortality and the causes of accidents for use in planning and initiating preventive procedures.

As a first step, the United States and its territories were divided administratively into seven cohesive geographical regions, each with a regional director. In each region, a facility has been selected, based on the qualifications of available professionals in the field in the region, and its capability to direct or manage the treatment of diving casualties.

The seven regional networks, each with their identified facility, are functioning. Plans have been completed to provide a national entry point to the Network, which can be reached by telephone (in a manner similar to providing toll-free "800" numbers). The present number is (919) 684-8111 and can be called collect in an emergency. This national entry point will be manned 24 hours a day, 365 days of the year, and will inform those who seek assistance where that assistance can be obtained and the mechanism for obtaining it. The Network will be managed by Duke University under a contract to NOAA. To promulgate the existence of the Network, and the focal facilities for treatment, informational posters will be distributed to hospital emergency rooms, diving societies, operating companies, and other appropriate centers.

Commercial Diver Training

With support from NOAA, the Department of Energy, the State of Florida, and private groups, a Commercial Diver Training Program was established in January 1976 at the Florida Institute of Technology, Jensen Beach, Florida. Under this program, students are offered a 2-year course of instruction leading to the award of an Associate of Science Degree in Underwater Technology.

The purposes of the program are to:

- Provide the diving industry with trained underwater technicians.
- Serve as a model program for other institutions who might want to offer similar training.
- Provide students who successfully complete the courses with a high probability of employment.

The program was founded because of the need to provide the offshore industry and the scientific community with well-qualified underwater technicians, knowledgeable in physics, electronics, pneumatics, hydraulics, life support systems and the complexities of the underwater world. With the assistance of the Association of Diving Contractors, the diving industry projected the needs for specific skills and the numbers of technicians required.

NOAA provided funds for the conversion of a U.S. Navy-donated landing craft into a suitable surface-supply diving vessel equipped with modern operating diving gear.

To date, three classes have been trained and all graduates have been placed. The program's reputation is excellent in the commercial diving industry.

Recent developments in the offshore oil industry, along with the requirement for compliance with new OSHA and U.S. Coast Guard regulations, have substantially increased the management requirements of the diving industry. Accordingly, Florida Institute of Technology has increased enrollment in the course to 125 students per year. Plans have been made to upgrade the quality of the program by the purchase of underwater photography equipment, the construction of a gas mixing and analysis system (to eliminate the need to purchase premixed helium and oxygen cylinders), and the replacement of an aging high-pressure compressor.

United States—Japan Cooperative Research on Saturation Diving

Since 1972, NOAA has carried out, in cooperation with Japan, the United States-Japan Cooperative Program in Natural Resources (UJNR). At the first meeting of the UJNR Panel on Diving Physiology and Technology, the need for developing a cooperative research program in the field of diving and hyperbaric physiology and technology was recognized. Subsequently, such a program was developed between the University of Hawaii (UH) and the Japan Marine Science and Technology Center (JAMSTEC). Three cooperative saturation dives were carried out, namely:

- Saturation dive at 7 Atmospheres Absolute (ATA) (Seatopia) in 1973. JAMSTEC sponsored this dive and four UH scientists participated.
- Saturation dive at 18.6 ATA (Hana Kai II) in 1975. UH sponsored this dive and four JAMSTEC scientists participated.
- Saturation dive at 11 ATA (Seatopia) in 1975. JAMSTEC sponsored this dive and six UH scientists participated.

These dives were designed to study the effects of a prolonged stay in the hyperbaric helium-oxygen environment on certain physiological functions (e.g., energy exchange, body fluid exchange, and cardiorespiratory functions), and resulted in the publication of some six scientific papers.

A fourth cooperative dive experiment was conducted at JAMSTEC during the period July 27—September 5, 1979. Four Japanese divers participated. They remained at a pressure of 31 ATA for 14 days.

The major focus of this study was to document various physiological functions during an extended exposure to high pressure, comparing the results to those obtained during pre- and post-dive periods at 1 ATA. Specific studies were conducted on the effects of exposure on energy balance, body fluid balance, cardiac functions, respiratory functions, maximal workload, and minimal aerobic power. The effects of head-out immersion in the thermoneutral waters at 31 ATA on thermal balance, cardio-respiratory functions, and renal functions were also studied. While the divers were at depth, extensive studies were conducted on comprehensive electro-encephalogram (EEG), including "sleep" EEG, evoked potentials and perception, and motor functions.

In addition to this experimental program, technical meetings have been held with the Japanese every 2 years. The most recent joint panel meeting was in Tokyo in October 1979. This was a joint meeting with the UJNR Panel on Marine Facilities. Following each panel meeting, proceedings are published and abstracted in the professional literature.

DIVING INFORMATION

Revision of NOAA Diving Manual

The *NOAA Diving Manual* is a compendium of basic information on diving and data on applied diving technology, including the technology needed to carry out scientific investigations and the many other tasks the working diver is called on to perform. It contains over 500 pages of expository material, tables, equipment lists, procedures, and illustrations covering the following: the physics of diving, diving physiology, the training of divers, diving equipment, breathing media, general and emergency diving procedures, working and scientific diving procedures, regional and special diving, air diving and decompression, mixed gas and oxygen diving, saturation diving, surface support platforms, manned underwater support platforms, hyperbaric chambers, accident management, first aid, and aquatic animals hazardous to divers.

The first edition of the *Diving Manual* was published in August 1975. By February 1979, 24,000 copies had been sold. It is used, along with the *Navy Diving Manual*, as a reference in the OSHA Standard for Commercial Diving Operations, which is now Federal law for the diving industry. The *NOAA Diving Manual* is the authoritative reference for NOAA's scientists and working divers and has wide appeal and acceptance in other Federal and State agencies by scientists and by the sport diving community.

In FY 1978, a major revision of the NOAA Diving Manual was undertaken. Much new information was added, and the information in the first edition was updated where appropriate. Over 90 individuals contributed to the new edition, which was published in May 1980.

It is anticipated that the manual will be revised again in approximately 4 to 5 years.

Diving Fatality Statistics Study

Since 1970, the University of Rhode Island has operated a national underwater accident data center. For 8 years this program was supported by the U.S. Coast Guard and NOAA; and for the past 2 years (FY 1979 and 1980) the National Institute for Occupational Safety and Health (NIOSH) has also been a co-sponsor of the program. The objective of the program is to acquire, compile, and analyze data pertaining to fatal diving accidents within the United States. These analyses are published in annual reports, which are widely used and, in fact, have become the principal reference for information relating to diving accidents.

The reports are prepared from information received by telephone (when verified), autopsy reports, media clipping services, and a variety of other sources. A substantial amount of information is received through unsolicited letters, reflecting the acceptance of the program in the diving community. In the last 2 years, the program has been expanded to include commercial diving accidents, as well as scuba and other sport diving incidents. The data have been computerized to facilitate accomplishment of additional analyses and to accelerate publication of statistics. Many of the conclusions and recommendations of this program have been adopted by various national training agencies and by the diving equipment manufacturing industry. This has resulted in improved safety and in a dramatic reduction in fatalities.

This program has proven to be of great value to NOAA, to the scientific community, diving training organizations, the insurance industry, and the medical profession. Because of the importance of the data and the continuing interest in them, on a nationwide basis, continued support of the program is planned.

International Underwater Physiology Symposia

Over the past 20 years, a series of international underwater physiology symposia have been sponsored by the Office of Naval Research, NOAA, and the University of Pennsylvania. NOAA was co-sponsor for the 1972 and 1975 symposia, with a representative of NOAA serving on the planning and editorial boards for these meetings. Their objective is to bring together, at intervals of 3 to 4 years, the leading experts in the world on underwater physiology and medicine to discuss research accomplished, problems identified, and requirements imposed by current and anticipated operations.

The seventh symposium in the series, held in Athens, Greece, in 1980, attracted international attention. Ninety-six technical papers were presented. Publication of the proceedings of the symposium is available.

It is anticipated that NOAA will continue to co-sponsor, with the Office of Naval Research, these symposia at 3- to 5-year intervals, and that reports of the proceedings will be published after each meeting.

Bibliography of Diving and Undersea Medicine

For the past decade the Undersea Medical Society has been under contract to the Office of Naval Research to prepare and disseminate a selective bibliography of published material related to diving and undersea medicine. NOAA became a joint partner in this endeavor in FY 1977 and has continued its support since that time.

UMS surveys all of the literature published in the field, annotates appropriate articles, and prints abstracts of them in hardbound volumes. An average of 110 abstracts is prepared each month. These abstracts are available to subscribers through a computerized information retrieval system for a small fee. In addition, periodically, a new compendium of these abstracts called "Underwater Science and Medicine" is issued. Volume IV of this bibliography was published in 1980.

DIVING EFFECTIVENESS AND SAFETY

ADMINISTRATIVE STRUCTURE OF THE NOAA DIVING PROGRAM

During FY 1977 and 1978, the NOAA Diving Program was managed, insofar as policy was concerned, by the Associate Administrator for Research and Development and the Director of the Office of Ocean Engineering (OOE), through the MUS&T Office. At the same time, the management of the diving safety, training, and certification program was vested in the NOAA Diving Coordinator and his assistants.

In April 1979 after a review of the administrative structure and responsibilities of diving activities within NOAA, responsibility for management of the NOAA Diving Program was assigned to the Director, NOAA Diving Office, who now functions under the Associate Director, Office of Marine Operations, of the Office of Oceanic and Atmospheric Services. The material in this report covers the activities of the NOAA Diving Program only during the period when it was under the policy management of the MUS&T Office. However, statistical data on NOAA diving activities are presented for the whole of FY 1979.

The Diving Coordinator (now the Director, NOAA Diving Office) is responsible for the training, safety, and certification of all NOAA divers. He also, in conjunction with the NOAA Diving Medical Review Board, develops and oversees training and operational policies, medical qualifications, and reporting requirements for divers and diving operations.

The NOAA Diving Medical Review Board is responsible for reviewing the medical qualifications of NOAA divers and diver candidates. The Board is made up of physicians skilled in hyperbaric and occupational medicine. Diving medical evaluation criteria used by the Board are updated periodically on the basis of advances achieved in the knowledge of diving physiology.

Diving operations are carried out within NOAA in support of the missions of NOAA's Major Line Components and Major Program Elements (MPEs). Each of the three MPE's that actively use diving as an operational tool has an MPE Diving Officer who represents the MPE on the Diving Safety Board, and who interacts with the Director, NOAA Diving Office, by planning, programming, directing, and reviewing the diving activities within his MPE in such a way as to ensure compliance with overall NOAA policies on underwater operations.

Responsibility for an individual diving operation rests with the Unit Diving Office (UDO) set up in each individual unit within an MPE that may have diving operations. The UDO has direct control of all individual diving operations. Successful use of NOAA divers for NOAA missions and the safety and operational efficiency of dives accomplished depend on the judgment and expertise of the UDO.

NOAA DIVERS

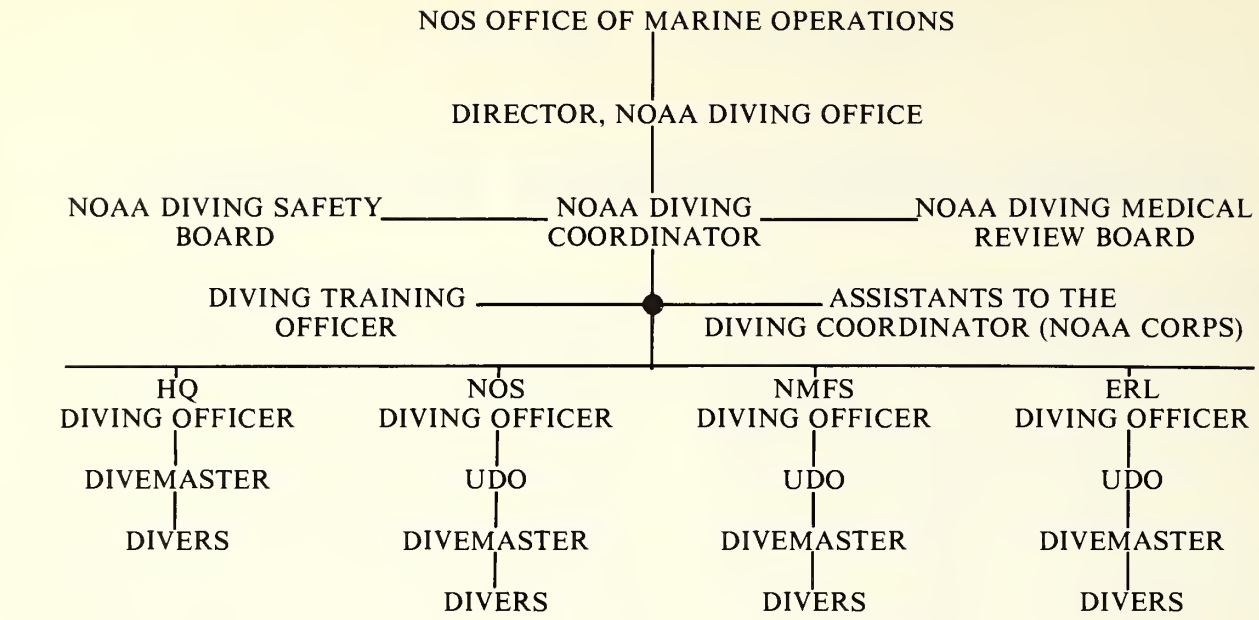
NOAA divers are certified at one of three levels: trainee, limited, or unlimited. There has been a steady increase in the number of certified divers within NOAA since 1972. This number has grown from approximately 100, almost all from the former Bureau of Commercial Fisheries, to approximately 500, of whom about 250 are considered an active diving resource pool. The majority of the NOAA divers are in the National Marine Fisheries Service (NMFS) or the National Ocean Survey (NOS), many being NOAA Corps officers.

Typical NOAA diving activities include: resource ecology, fisheries management, coastal zone and estuarine studies, ecosystems investigations, environmental conservation and assessment, hydrographic and oceanographic surveying, and vessel and installation maintenance. On occasion, NOAA divers assist other Federal agencies, such as the U.S. Coast Guard and the National Transportation Safety Board in search, rescue, and recovery operations.

NOAA diving activities are conducted in all maritime areas in which the United States is active, but the majority are in coastal waters of Alaska, the North Pacific, the Gulf of Mexico, and the North- and Mid-Atlantic, and Caribbean areas. Most NOAA fleet vessels have a complement of divers, and many National Marine Fisheries Service Centers, laboratories, and field stations have resident divers. Diving is a collateral voluntary duty in NOAA, generally performed by qualified individuals whose primary occupation is enhanced by diving activity.

Among NOAA diving activities in recent years have been:

- Assessment of damage to a reef from an oil spill.
- Observation of marine flora and fauna around offshore oil platforms.
- Investigation of the effects of thermal discharge from power plants.
- Investigation of the effects of filling, dredging, and underwater construction.
- Assessment of the effects of nuclear testing on benthic communities.
- Assessment of the inshore marine effects of discharges from sugar mills, sewer outfalls, tuna canneries, and storm drains.



HQ = WASHINGTON AREA DIVERS

NOS = NATIONAL OCEAN SURVEY

NMFS = NATIONAL MARINE FISHERIES SERVICE

ERL = ENVIRONMENTAL RESEARCH LABORATORIES

UDO = UNIT DIVING OFFICER

Organization of NOAA Diving Program

- Analysis of damage to the marine environment from cargo in wrecks.
- Study of herring egg bed dynamics.
- Study of the prey-predator relationships between baitfish and tuna.
- Observation of octopus den occupancy.
- Ground truth observations for aircraft and satellite overflights.
- Search and delineation of submerged obstructions.
- Analyses of sediment flux by observing movement of dyed sand.
- Study of the attraction of pelagic fish to artificial structures.
- Fisheries resource assessment.
- Pearl oyster surveys.
- Assessment of damage by Crown of Thorns starfish.
- Sediment and water sampling.
- Determination of least depths for hydrography.
- Study of juvenile salmon behavior and net reaction.
- Tridacnid clam survey and collection.
- Fish trap emplacement.
- Installation, inspection and servicing of current and temperature sensors and tide gauges.
- Installation of plankton nets in reef and seagrass areas.
- Search and recovery of lost gear.
- Installation and repair of salt water pumps.
- Installation of instrument packages for tsunami research.
- Observation of midwater trawls using towed sleds.
- Observation of harvesting gear dynamics.
- Evaluation of trap effectiveness.
- Observation of the behavior of animals inside captive gear (e.g., king and dungeness crabs).
- Monitoring of an underwater pyranometer while underway.
- Untangling nets and wires from propellers.
- Cleaning of viewports, propellers, sonar sea strainers, etc.
- Effecting emergency repairs.

Table 11 summarizes NOAA diving activity for FY 1979, listing dives accomplished by NMFS, NOS, and ERL for each major type, along with percentage of total in each category. The table also categorizes the 5,959 dives made during the year by location.

Table 12 gives total number of dives logged, with bottom time, by the Major Line Component/Major Program Elements in NOAA, and Table 13 gives data on the depth range of the dives accomplished.

Table 11.—NOAA Diving Activity by Purpose and Location, Fiscal Year 1979.

	NMFS	NOS	ERL	TOTAL	%
I. **Working Dives**					
1. Biological Survey	1527	48	47	1622	27.2
2. Geological Survey	10	18	0	28	.5
3. Oceanographic Survey	39	112	15	166	2.8
4. Physiological	1	0	5	6	.1
5. Maintenance/Repair	383	540	24	947	15.9
6. Search/Recovery	261	332	19	612	10.3
7. Test/Evaluation	458	122	23	603	10.1
TOTAL				3984	66.9
II. **Training Dives**					
8. Training	426	645	21	1092	18.3
III. **Miscellaneous Dives**					
9. Miscellaneous	555	298	30	883	14.8
Total Dives in NOAA				5959	100.0
Dives by Location					
North Atlantic Coastal	417	98	5	520	8.7
Mid-Atlantic Coastal	298	148	29	475	8.0
South Atlantic Coastal	122	475	42	639	10.7
Gulf of Mexico Coastal	511	162	7	680	11.4
Puerto Rico, USVI, Canal Zone	43	57	24	124	2.1
Alaska Coastal	993	256	2	1251	21.0
North Pacific Coastal	434	463	18	915	15.4
Mid-Pacific Coastal	32	1	0	33	.6
South Pacific Coastal	157	78	0	235	3.9
Hawaii Coastal	80	71	0	151	2.5
Pacific Territories and Trustees	123	21	2	146	2.5
Great Lakes Waters	0	87	55	142	2.4
Other Inland Waters	295	57	0	352	5.9
Foreign Coastal Waters	91	49	0	140	2.3
Deep Ocean Waters—Beyond the Continental Shelf	49	34	0	83	1.4
Other	15	58	0	73	1.2

Table 12.—NOAA Diving Activity, Fiscal Year 1979.

MLC/MPE	Dives Logged		BT* Logged		Logs Received		Logs With Diving Activity		Logs Without Diving Activity		Average BT/Drive for MLC/MPE
NMFS	3660	(61.4%)	101475	(60.7%)	1001	(53.6%)	681	(51.5%)	315	(58.3%)	27:73
NOS	2115	(35.4%)	61756	(37.0%)	812	(43.5%)	595	(45.0%)	217	(40.2%)	29:20
ERL	184	(3.2%)	3820	(2.3%)	54	(3.0%)	46	(1.5%)	8	(1.5%)	20.76
Total	5959		167051		1867		1322		540		Average BT/Dive NOAA Wide: 25:89

*BT: Bottom Time in Minutes

Table 13.—Depth Range of Dives.

	0-10 m (48.3%)	10-20 m (31.8%)	20-30 m (12.3%)	31 m ° (7.6%)
NMFS	1581	1181	543	355
NOS	1247	616	167	85
ERL	50	97	24	13
Total	2878	1894	734	453

DIVING INFORMATION

The NOAA Diving Office has continued the periodic publication of the *NOAA Diver*. This newsletter is designed to provide timely information on new technical developments, diving equipment, legislation, diving procedures, and other general information pertaining to diving which is of interest and enhances the effectiveness and operational safety of diving operations. The *NOAA Diver* is circulated to all NOAA divers and to many in the outside diving community. Three to four issues are published annually.

In addition, the NOAA Diving Office publishes, as the occasion dictates, NOAA Diving Safety Bulletins, which are intended to call to the attention of NOAA divers instances of safety procedure infractions, difficulties encountered with equipment, and changes or proposed changes in diving procedures.

Applied Technology and Advanced Concepts

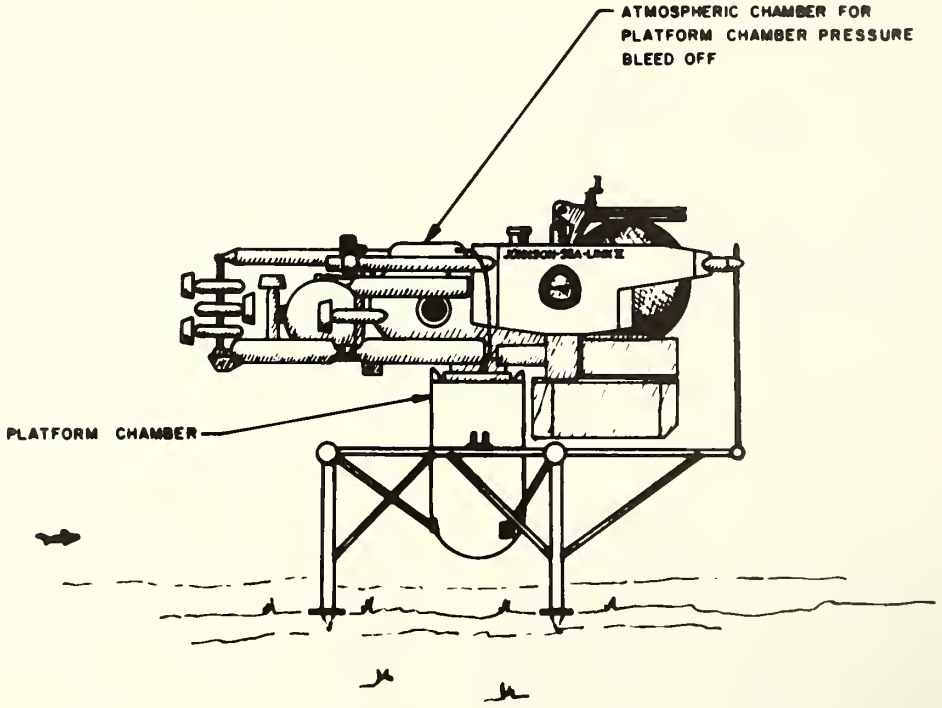
In early 1977, an agreement was reached between NOAA and the Harbor Branch Foundation of Fort Pierce, Florida, to use Harbor Branch's *Johnson Sea-Link* submersible for experiments in which sensitive photographic emulsion stacks were to be used for the detection of cosmic ray muons. The waters of the ocean act as a homogeneous and isotropic filter eliminating most unwanted "noise" and nuclear and extra-nuclear particles, leaving only the muons (mu-mesons) and neutrinos at depths below about 305 m. Over the years, researchers have attempted to detect muons and neutrinos in deep mines or well shafts. Use of a submersible to carry detection instruments, or to emplace them on the seafloor for extended exposure periods, offers the advantages of deployment of detectors in a medium which is not only homogeneous and isotropic, but also relatively free of natural radioactivity.

In the first series of experiments, described in the report "A Submersible Physics Laboratory Experiment,"* two emulsion stacks in glass cassettes were prepared in the *Johnson Sea-Link* and deployed, via dry lockout, one at 305 m and the other at 122 m. In March 1978, the 122 m cassette was retrieved and locked into the *Johnson Sea-Link* where the emulsions were developed *in situ*. The 305 m emulsions were retrieved and developed in the same manner later in October 1978.

Upon development and scanning via special microscopes, the developed photographic emulsions revealed tracks of muon interactions with silver and other nuclei in the emulsions. The experiments sought to measure the range-flux and angular distribution of undersea muons and the intensity of stopping muons. They were also designed to classify the nuclear cascades for multiplicity of protons, fast pions (pi-mesons), and slow pions as a function of depth, and to study inelastic muon-nucleon interactions.

Concurrently with the successful use of nuclear track sensitive photographic emulsion stacks (in glass spheres which were prepared, deployed, and eventually developed at depth), the attention was drawn to the possible advantages of using a photomultiplier detector tube for direct measurements. A three-photomultiplier detector system, with associated miniaturized digital electronic circuitry

*NOAA Technical Report OOE 1, "Submersible Physics Laboratory Experiment," by Kurt R. Stehling, January 1979.



Schematic of submersible and platform chamber for dry transfer of pellicle plates.

suitable for operation at a depth of 610 m, was developed by Western Washington University and made available for the *Johnson Sea-Link* through the Office of Naval Research. In October 1979, an engineering shakedown cruise was undertaken with a dive to 305 m off Grand Bahama. The three-photomultiplier, which has been named Cyclops, was installed. The Cyclops was able to detect light pulses in the microsecond range, and although there were minor engineering problems, such as interference from background noise, the demonstration was entirely successful.

Accordingly, in May 1980, an operational cruise was undertaken in which the *Johnson Sea-Link*, with Cyclops installed, made a 610 m dive off Grand Bahama. Both Cerenkov light pulses (in the nanosecond range) and bioluminescence (in the millisecond range) were detected. Significantly, the Cyclops was able to distinguish between the two, using, in some instances, the multiple coincidence technique.

Development of the Cyclops photomultiplier light detector unit with its associated circuitry offers the potential as a species discriminating bioluminescence light detector in the deep ocean. NOAA has funded the Western Washington University for the purchase of a data management unit (DMU) consisting of a processor, floppy disk memory storage, address terminal, discriminator, scaler, etc., all in miniaturized form, suitable for submersible on-board use.

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