NOAA's Office of Undersea Research Fiscal Year 1981 Report

Rockville, Md.
April 1983

U. S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration

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Malcolm Baldrige, Secretary

National Oceanic and Atmospheric Administration
John V. Byrne, Administrator

Office of Oceanic and Atmospheric Research
Ned A. Ostenso, Acting Assistant Administrator

Office of Undersea Research
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List of Abbreviations and Acronyms

ABS	American Bureau of Shipping
CMSC	Catalina Marine Science Center, USC
CRUL	Caribbean Regional Undersea Laboratory
DAN	Diving Accident Network, Duke University Medical Center
FISSHH	First International Saturation Study of Herring and Hydroacoustics
FY	Fiscal Year
HBF	Harbor Branch Foundation
HURL	Hawaiian Undersea Research Laboratory
IOC	Intergovernmental Oceanographic Commission, UNESCO
LRT	Launch, Retrieval, and Transport Vehicle
MPRL	Mid-Pacific Research Laboratory
MUS&T	Manned Undersea Science and Technology Program, NOAA
NIOSH	National Institute for Occupational Safety and Health
NITROX	Nitrogen-Oxygen Breathing Mixture
NMRI	Naval Medical Research Institute
NOAA	National Oceanic and Atmospheric Administration
NSF	National Science Foundation
NULS	NOAA Undersea Laboratory System
ONR	Office of Naval Research
OSB	Ocean Sciences Board
OUR	Office of Undersea Research, NOAA
PTC	Personnel Transfer Capsule
ROV	Remotely Operated Vehicle
R/V	Research Vessel
SCORE	Scientific Cooperation Operational Research Expedition
SECURE	Southeastern Consortium for Undersea Research Efforts
SURF	Southeastern Undersea Research Facility
UJNR	United States–Japan National Resources Program
UMS	Undersea Medical Society
UNC-W	University of North Carolina–Wilmington
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNOLS	University National Oceanographic Laboratory System
USC	University of Southern California
WRUL	Western Regional Undersea Laboratory

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Preface

This report of the National Oceanic and Atmospheric Administration's Office of Undersea Research (OUR) describes OUR's development, achievements, and goals, and emphasizes program activities initiated, continued, or completed in the period October 1, 1980 to September 30, 1981. The report, eighth in the series of annual reports, will underscore the importance of OUR's role in helping NOAA to carry out its Congressionally mandated responsibilities in marine resources management and research. It will also discuss OUR's contributions to such important areas as underwater safety, research and development, interagency and international cooperation, and the nation's undersea research program.

In 1980, NOAA's Manned Undersea Science and Technology (MUS&T) program, which had been active since the establishment of NOAA in 1970, was restructured, and various elements of its program were assigned to the Office of Technology and Engineering Services, the Diving Office, and the Office of Undersea Research. The primary responsibilities of the newly defined OUR progam office are providing the facilities and financial support for underwater research activities involving habitats and submersibles, conducting and supporting research related to diving safety and research and development, participating in and encouraging international underwater research, and ensuring that NOAA's underwater research needs are met in the most integrated and cost-effective manner. In accordance with recommendations made by the Congress, the Office of Management and Budget, the Department of Commerce, and the undersea scientific community, OUR has also supported the development of cooperative regional manned undersea research programs based in the Caribbean, North Carolina, California, and Hawaii. These regional programs, which permit OUR to take maximum advantage of local resources and geographical diversity, are described in detail in this report.

Other topics included in this annual report of OUR activities and goals include: a history and overview of the program; the submersible support program; activities related to diving safety, research, and development; international programs; and future plans.

SECTION I

History and Overview of NOAA'S Undersea Research Programs

BACKGROUND

When the Congress established the National Oceanic and Atmospheric Administration within the Department of Commerce, it assigned several ocean-related responsibilities to the new agency. These legislative mandates included the management and protection of marine resources and their habitats and the responsibility for conducting and monitoring research on the causes and effects of marine pollution, the uses of marine sanctuaries, and the influence of the Earth's oceans on climate and weather. In each of these areas, underwater research plays a central and critical role.

To coordinate and encourage an integrated approach to NOAA's underwater research efforts, the Manned Undersea Science and Technology (MUS&T) Office was established in 1971. In March 1980, the MUS&T Office was reorganized, under the direction of the Office of Research and Development, as the NOAA Office of Undersea Research (OUR). More recently, it has been proposed that the OUR Office be assigned to the Assistant Administrator in charge of the Office of Oceanic and Atmospheric Research. Throughout the first decade of NOAA's existence, both the MUS&T and the OUR offices have helped NOAA to fulfill those of its Congressionally mandated responsibilities specifically related to underwater science and technology.

HISTORICAL OVERVIEW

NOAA has consistently emphasized the importance of marine research involving observation of the natural underwater environment and the use of techniques and equipment, such as habitats, submersibles, and remotely operated vehicles, that permit human divers to observe, record, manipulate, and understand the ocean environment. To achieve these ends, NOAA has joined with other Federal agencies, universities, private institutions, and foreign governments in sponsoring, supporting, and directing manned underwater research.

Submersibles designed both for deep-water and shallow-water operation and underwater habitats have played an important role in these efforts. For example, NOAA has sponsored, in conjunction with the Office of Naval Research (ONR) and the National Science Foundation (NSF), a series of deep research dives involving the deep-diving research submersible *Alvin* (Fig. I-1) and its surface support vessel *Lulu* (Fig. I-2). The Woods Hole Oceanographic Institution operates and maintains the *Lulu-Alvin* underwater research system, which has been used extensively in the past 7 years to carry out several NOAA underwater research missions.

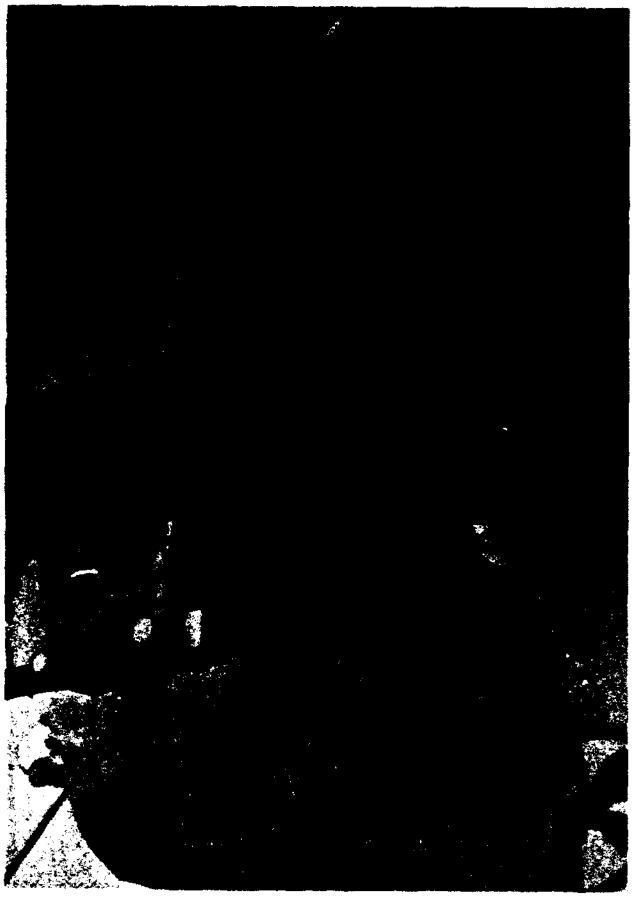


Figure I-1.—Deep-water research submersible *Alvin* being lifted into position

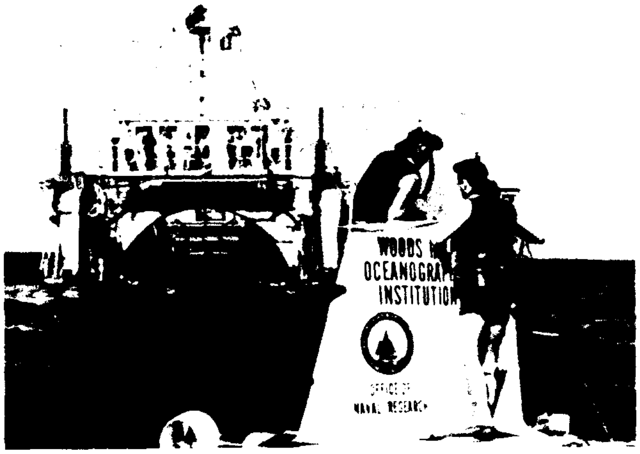


Figure I-2.—Deep-diving research submersible *Alvin* shortly after launch from the support vessel *Lulu* (in background)

In addition, NOAA has been heavily involved in the development of saturation diving techniques, which permit human divers to remain under pressure for extended periods without significantly increasing the length of time they must decompress before being returned to the surface. During the 1970's, using the habitats *Helgoland* (Fig. I-3) and *Hydrolab* (Fig. I-4), NOAA conducted a number of marine research programs that involved both national and international teams of marine scientists. The success of these programs, which included the First International Saturation Study of Herring and Hydroacoustics (FISSHH) and Project SCORE (Scientific Cooperation Operational Research Expedition), led to national and Congressional recognition of the current importance and future potential of manned underwater research.

Oceanlab

In 1975, in response to the request of a member of Congress, NOAA submitted a report entitled, "Concept

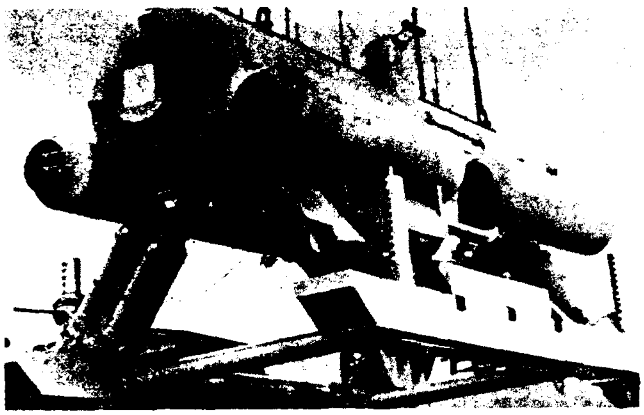


Figure I-3.—Underwater habitat *Helgoland*, used by international teams of underwater scientists

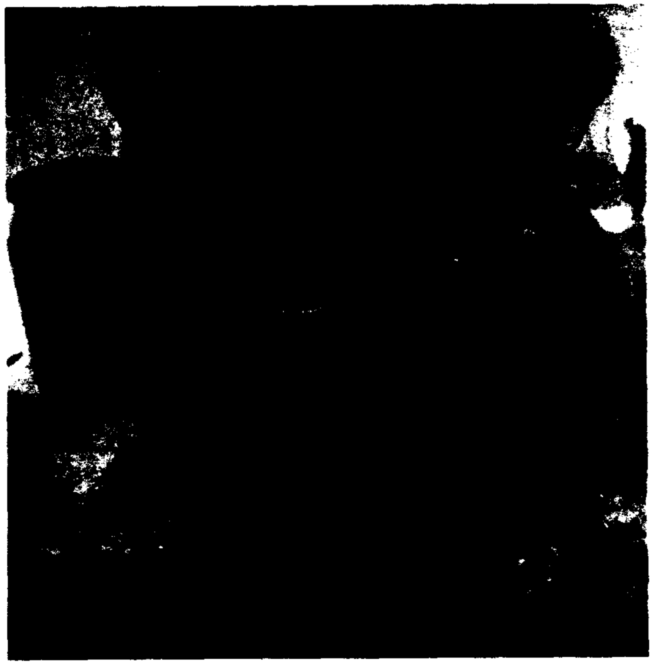


Figure I-4.—Underwater habitat *Hydrolab*, centerpiece of NOAA's Caribbean Undersea Research Program

Paper for the Development and Utilization of an American Underwater Laboratory, *Oceanlab*." This study recommended that a sophisticated mobile undersea laboratory be designed and constructed to provide the capability needed to perform research on the cultivation, conservation, and use of ocean resources.

In the following year, Congress provided funds for several projects related to the development of such a research facility, including a preliminary engineering and design study, a performance requirements analysis, and a review of NOAA's research needs. The Congressional appropriation also specifically designated funding for programs in the areas of diver training, diving physiology, and undersea science and technology. Funds were also set aside for "cooperative undersea programs, including habitats in shallow and intermediate depths necessary to develop safety and expertise in future *Oceanlab* operations."

The purchase of the habitat *Hydrolab*, in 1977, marked the beginning of NOAA's Congressionally mandated cooperative undersea program. The *Hydrolab* program was designed to provide the facilities and research support necessary for NOAA to investigate the nation's coastal marine environmental, biological, geological, and ecological problems. During the 5 years of its operation, the *Hydrolab* facility has permitted scientists to obtain essential information about the marine environment in coastal areas, furthered the use of underwater laboratories and saturation diving in marine research, encouraged *in-situ* studies of the ocean environment, and provided training in investigation techniques unique to underwater research. (Individual *Hydrolab* projects are discussed in detail in Section III of this report.)

As a further response to suggestions made by Congress in 1976, NOAA also began to analyze its research needs for the 1980's. This assessment involved members of the scientific and academic communities, commercial and industrial organizations, Federal agencies, and recreational and environmental groups. The design and performance characteristics of the underwater systems needed to achieve NOAA's underwater research goals were also evaluated, and preliminary cost estimates and development schedules were solicited by procurement. More detailed plans and specifications for a mobile undersea laboratory were also subsequently devised during the System Program Definition phase of the *Oceanlab* program.

By mid-1978, engineering plans for *Oceanlab* were sufficiently complete to permit refined estimates of the costs of constructing a large, all-weather, self-propelled undersea research facility capable of serving as the base for extended and far-reaching research missions. Estimates of the cost of acquiring such a facility were calculated; however, the size of these estimates prompted NOAA and members of the marine science community to reconsider NOAA's underwater research needs with a view to meeting them in a more cost-effective and flexible manner. It became apparent that providing several smaller and more specialized facilities might enable the Agency both to take advantage of local resources and expertise and to conduct several missions at the same time. This regional facility approach also had the advantage of being less costly than the original *Oceanlab* program.

Ocean Sciences Board

In consequence, after consultation with the Congress, the Office of Management and Budget, and the Department of Commerce, NOAA decided in 1978 to redirect the *Oceanlab* program. The first step in this re-evaluation involved requesting the Ocean Sciences Board (OSB) of the National Research Council to undertake a study to define scientific areas requiring undersea research capabilities and to determine the types of facilities and research methods necessary to perform these studies. The OSB concluded in its 1979 report that a significant body of research needed to be done that would require manned undersea studies, complex observational tasks, and manipulative underwater techniques. The OSB recommended that NOAA establish a research program using existing facilities, including saturation diving systems and manned (and unmanned) submersibles, and take advantage of the operational expertise already available at a few oceanographic institutions. The OSB report also urged NOAA to establish new underwater research facilities that incorporate the most advanced and effective underwater technology available.

The second phase of NOAA's research needs reassessment involved commissioning a survey of existing submersibles and underwater technology, which was conducted by the General Electric Company. In addition, NOAA requested organizations interested in conducting underwater research and in operating research submersibles and habitats to submit proposals in support of these interests. NOAA also undertook an overall review of its underwater research programs and their contribution to the achievement of the Agency's goals; results of this review, which primarily involved NOAA staff, are discussed in the research needs and priorities section below.

UNOLS Submersible Science Study

In 1977, NOAA joined with the National Science Foundation and the Office of Naval Research to investigate the immediate and future needs of the Nation's science community for submersible support to conduct underwater research projects. The Submersible Science Study was initiated by the Alvin Review Committee, a part of the University National Oceanographic Laboratory System (UNOLS), and, in 1979, the three supporting organizations awarded a grant to the Lamont-Doherty Geological Observatory to act as the project coordinator for the study.

The study is designed to review past and present technical requirements for manned and unmanned underwater research facilities that permit access to the ocean and to predict future requirements for such submersible vehicles. The study is also structured so that both short- and long-term recommendations can be made and priorities set to achieve immediate and future objectives.

The project team consists of three components: a science panel, a task force, and a project office. The science panel includes research scientists from several scientific disciplines who have themselves used submersibles in their research, and the task force comprises engineers, operators, and designers of submersibles. Administrative and editorial functions for the study are being performed by the project office.

The study team's review of the historical contribution of the submersible to an understanding of the role of volcanic processes and hydrothermal activity in the formation of the ocean's crust stressed the following unique capabilities of manned submersibles: direct visual observation; maneuverability; and manipulative ability. Past submersible research efforts have focused on explorations of the mid-ocean ridge, the ocean's main floor, and the continental margins and on baseline environmental studies and scientific studies of biological, chemical, and oceanographic processes in the water column.

The team has identified several factors that have limited or are presently limiting the usefulness of the

Figure I-5.—*Alvin* on underwater missions

deep submersible *Alvin/Lulu* system. These include the limited operational range, transit speed, and logistical capability of the *Alvin*'s support ship *Lulu*. These limitations have restricted *Alvin* users to operations in certain geographical areas and during the warmer seasons of the year. In addition, the *Alvin* (Fig. I-5) needs improved scanning sonars, additional video cameras, better sampling and manipulative tools, and on-board electronic instrumentation and telemetry. The *Alvin*'s present capabilities are shown in Figure I-6.

Preliminary results of the Submersible Science Study have identified the following long-term needs that will have to be met if submersibles are to continue to play a critical role in the Nation's underwater research:

- Availability of a submersible with a depth limit of 6,000 meters
- Availability of a submersible capable of participating in extended missions.
- Continued research and development of innovative technology applicable to submersibles.

For the immediate future, however, the project team has found that accomplishing the following steps would provide the biggest return for submersible research at the present time:

- Modify *Alvin* to permit a single point lift.
- Replace the support ship *Lulu* with a larger vessel, the *Atlantis II*, with a range of 13,500 nautical miles, a cruising speed of 11.5 knots, and an endurance capability of 30 days without an escort vessel (Fig. I-7).

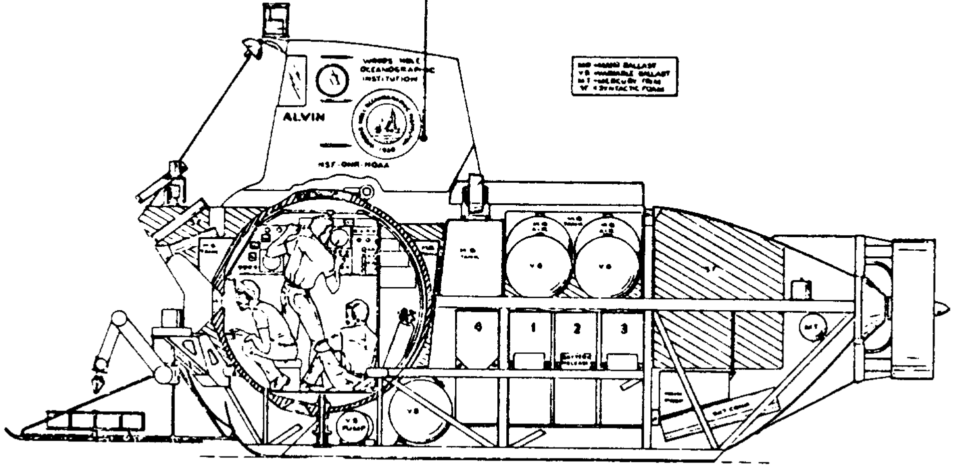
The final report of the Submersible Science Panel is expected to be completed in FY 1982.

NOAA'S RESEARCH NEEDS AND PRIORITIES

Based on the Ocean Sciences Board's report, other surveys and studies, and the results of NOAA's internal review, the following decisions related to the Agency's underwater research program have been made.

- NOAA will support existing underwater research facilities that are used by the marine scientific community.
- The amount of support for these facilities will be determined by NOAA's research needs and priorities.
- Universities and oceanographic institutions will provide the operational management for these facilities.
- Funding for these facilities will be included as an integral part of the funding provided in connection with successful research proposals.
- NOAA will continue to consult with experts in the fields of ocean engineering and marine science to insure that newly developed underwater research facilities, which are equipped with the most advanced technology, are considered in funding decisions.

Research programs supported by the Office of Undersea Research, which include submersible support programs, regional undersea programs, and research and other activities related to diver safety, are described in the sections that follow.



Length: 7.6 meters (25 feet)
Beam: 2.4 meters (8 feet)
Draft: 2.1 meters (7 feet) surfaced
Full Speed: 1 1/2 knots
Cruising Speed: 1 knot
Cruising Range: 5 miles submerged
Displacement: 16 knots
Endurance: 72 hours
Normal Dive Duration: 6-10 hours
Depth Capacity: 4,000 meters (13,120 feet)
Complement: 1 pilot, 2 scientific observers

Propulsion: Large stern propeller, 2 small side lift propellers which can be rotated and separately reversed.

Ownership: The submersible ALVIN is a Navy-owned national oceanographic facility jointly supported by the National Science Foundation, the Office of Naval Research and the National Oceanic and Atmospheric Administration and operated by the Woods Hole Oceanographic Institution.

Navigation: Gyro compass and gyro repeater; magnetic compass; nose mounted horizontal scanning sonar system; indicators for depth, speed, list, trim and variable ballast; echo sounder; battery voltmeters, ammeters and ground detector; five viewpoints.

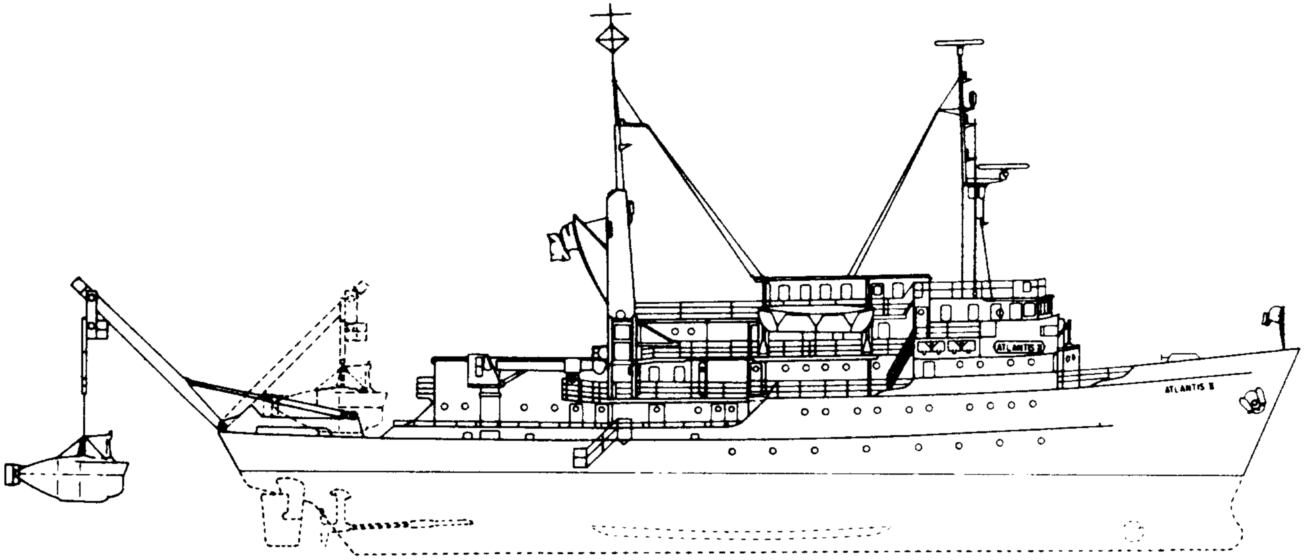
Electrical Power: Three banks of lead-acid batteries, 60 and 30 volt DC systems, 40.5 KWH total. Limited amount of 115 volt 60 cycle AC power.

Communication: Sonar telephone (voice or code); marine band (VHF) radio.

Other Features: The submersible is designed to be versatile with respect to the weight, space and power requirements of portable scientific equipment in order to meet the differing needs of scientists using the vehicle. Scientific equipment which remains on board most of the time includes two remotely controlled mechanical arms and associated sample trays, 35 mm film cameras and associated strobe and incandescent lights, closed circuit vidoe system with recorder, water temperature monitor, current speed and precisions depth indicator.

A precision navigation system is also available which will allow accurate positioning of the submersible at any time during a dive series. This system and other specialized equipment such as hard rock samplers, magnetometer, precision temperature sensors and analog or digital data logging equipment are available for use with ALVIN, but require some additional funding for installation and operation.

Figure I-6.—Description of *Alvin's* capabilities and schematic showing cutaway view



Built: 1963
Length: 210 feet LOA (64 meters)
Beam 44 feet (13 meters)
Draft: 16 feet (5 meters)
Gross Tonnage: 1,529 tons
Displ.: 2,300 L tons
Crew: 25
Scientific Personnel: 25

Main Engines: Two GM 12-567E diesel engines driving through reduction gears with variable speed, hydraulic clutches. 2,000 shp.

*Bow Thruster: 250 hp transverse tunnel thruster. DC motor driving from main gear P.T.O.

Ships Service Generators: Two 480/120 volt AC 300-KW generators driven by CAT 353 diesel engines.

Propellers: Twin screw: 3 fixed blade; bronze.

Ownership: Built under grant from NSF. Conditional title rests with W.H.O.I.

Speed: Cruising: 11.5 knots
Full: 13.5 knots
Minimum: Dead slow

Endurance: 45 days
*Fuel Capacity: 151,000 gallons
Range: 13,5000 miles

Laboratories: wet - 400 square feet
dry (4) - 4,300 square feet

Sewage System: Two type III holding tanks;
Five to ten days endurance.

Ship is equipped for full range of oceanographic observations and work. One trawl winch: 30,000 feet 1/2" cable. One hydrographic winch: 30,000 feet 3/16" wire. One CTD winch 27,000 feet 0.303" cable.

*A proposal pends to add a submersible handling system for ALVIN support, SEA BEAM system, and new 700 h.p. trainable bow thruster. If accomplished, fuel capacity will be reduced to 99,200 gallons and cruising range to 12,000 miles.

Figure I-7.—Description of *Research Vessel Atlantis II's* capabilities

Submersible Support Programs

NOAA's SUBMERSIBLE SUPPORT PROGRAMS

Since its inception, NOAA has encouraged and supported the use of submersible vehicles to perform research projects involving *in-situ* underwater observation and data gathering. Submersibles differ from underwater habitats (see Section III) in that the scientists occupying a submersible remain at surface pressure inside the pressurized vehicle throughout the research mission. Submersibles are used to conduct both deep- and shallow-water missions; their depth capability depends on the strength of their pressure hulls. NOAA has supported research involving the deep submersible *Alvin* and its support ship *Lulu*, as well as shallow-water missions utilizing the *Johnson Sea-Link* and the *Nekton Gamma* submersibles and their respective support ships. NOAA's support has taken the form both of providing the submersible vehicles and their support ships and operating systems and of developing technical criteria for the design of submersibles. In FY 1981, the primary emphasis of the submersible program has been on funding and sponsoring use of the *Alvin* and the shallow-water submersibles.

Figure II-1.—Submersible *Alvin* surfacing after mission

Deep-Water Submersible System *Alvin/Lulu*

The deep-water submersible *Alvin* (Fig. II-1) and its support ship *Lulu* (Fig. II-2) are owned by the U.S. Navy and operated by the Woods Hole Oceanographic Institution under a grant from the National Science Foundation. NOAA's Office of Undersea Research and the Office of Naval Research also provide support for the operation of the *Alvin/Lulu* system. The tri-agency support agreement was extended for an additional 3 years in 1981. Under the terms of this agreement, the submersible system is required to be used for a minimum of 150 use-days per year.

Selection of Science Missions

Research proposals involving use of the *Alvin* are solicited from NOAA's major program elements, e.g., the Atlantic Oceanographic and Meteorological Laboratory, the Pacific Marine Environmental Laboratory,

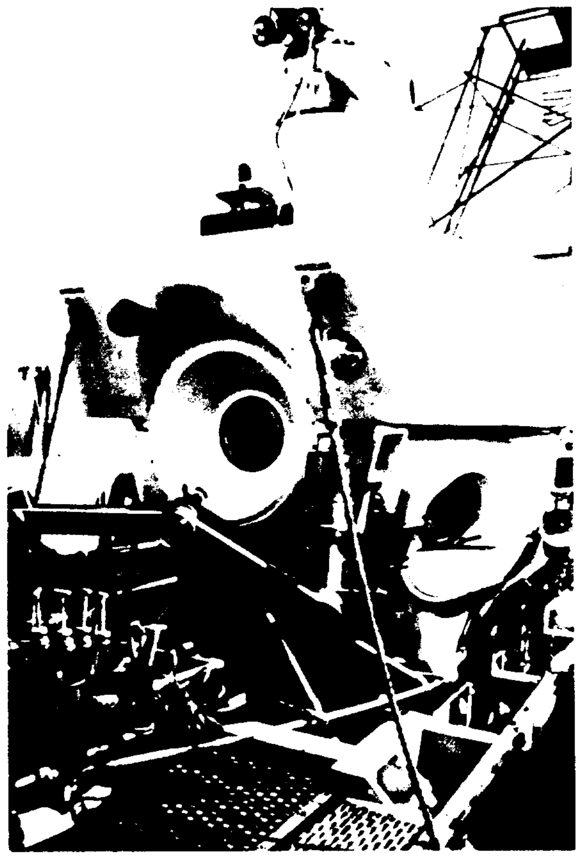


Figure II-2.—Submersible *Alvin* in well of support ship *Lulu*

and from the Office of Research and Development, the National Ocean Survey, and the National Marine Fisheries Service. Proposals are initially evaluated by a NOAA panel of scientists from the major oceanographic disciplines; the principal evaluation criteria are conformance with Agency goals and appropriateness of the research in terms of the *Alvin*'s capabilities. Results of this preliminary review are passed on to the University National Oceanographic Laboratory System (UNOLS) *Alvin* Review Committee, which meets annually to evaluate all *Alvin* proposals and schedule individual projects. Recommendations from the three agencies supporting the *Alvin/Lulu* program are also carefully considered in the proposal review process.

The missions conducted from the *Alvin* since 1979 and supported by NOAA are shown in Table II–1. Submersible research projects have included biological exploration of the Galapagos rift vents, micromorphological investigations of seamount geometry and sedimentation patterns of the Cocos Ridge in the Panama Basin, studies of the benthic resedimentation associated with deep mining in the Pacific Ocean, biological and geological research in the submarine canyons of the New England Continental Shelf, and measurements of the slope and studies of the morphology of the stable and unstable areas of Wilmington Canyon. In 1981, the deep submergence research vessel was involved in two series of dives: one in the Caribbean and one in the Ecuador Rift/Galapagos Rift areas. These research expeditions are briefly described below.

The St. Croix Submersible Expedition

In January and February, 1981, a series of three dives was made in the *Alvin* to depths of 3,500 to 4,000 meters in a basin to the north of St. Croix, U.S. Virgin Islands. The purpose of this project was to investigate the quantity and distribution of shallow-water sediments and biological debris in the deep-water canyon. Another objective of the expedition was to determine how much seagrass reached the basin, how it was used or decomposed, and how much of it was incorporated into the bottom sediments in the form of organic carbon.

During the dives, sediment and grab samples were collected by means of *Alvin*'s manipulator, and samples of biota were taken for gut analysis. The distribution of seagrass was estimated visually, and photographs were also taken during the dives. Sediments derived from shallow water decreased from 93 to 7

TABLE II–1.

NOAA-Supported Deep-Water Submersible Research Projects

Dates	Project	Location	Principal Investigator
		1979	
Aug 21-31	Deep Ocean Mining Environmental Survey	Off California	R. E. Burns, Atlantic Oceanographic and Meteorological Laboratory
Nov 25–Dec 15	Galapagos Rift Thermal Vent Area Study	Galapagos	D. Cohen, National Marine Fisheries Service
		1980	
Jan 5-21	Submarine Micromorphology of Eastern Galapagos Ridge	Panama Basin	A. Malahoff, National Ocean Survey
Aug 15-22	Biological and Geological Studies	Oceanographer Canyon	R. Cooper, Northeast Fisheries Center
Oct 1-13	Wilmington Geotechnical Corridor Study	Wilmington Canyon	D. N. Lambert, Marine Geology and Geophysics Laboratory
		1981	
Jan 30–Feb 2	Fate of Shallow-Water Sediments in a Deep Basin	Off St. Croix	Dennis Hubbard, West Indies Laboratory, Fairleigh Dickinson University
Aug 18–Sep 2	Ecuador Rift/Inca Transform/Galapagos Rift Study	Galapagos	A. Malahoff, National Ocean Survey

percent in a downward slope direction; however, seagrass was more evenly distributed, with average concentrations of 0.1 to 6 blades per square meter of bottom. Organic carbon levels within the sediment were low and can be attributed to the prevailing oxidative conditions and to recycling by aerobic heterotrophs.

The major findings of the St. Croix *Alvin* dive series concerned the fate and distribution of shallow-water sediments in the deep basin. Shallow-water sands and gravels are introduced into the basin as bedload during storms, in contrast to deep-water sediments, which are formed from settled planktonic forms. Cores taken on the mission indicate that deep- and shallow-water sediments are continually mixed, either because of bioturbation or because small storms continually introduce shallow sediments into the area. Once the shallow sediments leave the shelf, their distribution is primarily controlled by gravitation, which causes muds to be carried far out into the basin while sand, gravel, and boulders settle along the slope.

Ecuador Rift-Inca Transform-Galapagos Rift Study

To continue the research initiated in earlier dives along the Galapagos Rift, an additional ten dives were conducted at various points in the Ecuador Rift/Inca Fracture/Galapagos Rift areas during August 1981. The purposes of this *Alvin/Lulu* dive series were to:

- Examine the tectonics of the Inca Fracture Zone/ Ecuador Rift intersection
- Examine the tectonics of the Ecuador Rift
- Determine the area's hydrothermal mineralization potential, particularly for polymetallic sulfide deposits

Six dives were made in the Ecuador Rift Valley and at the Inca Fracture Zone-rift valley intersection, two dives were completed on the southern end of the fracture zone, and two dives were conducted in the Galapagos Rift Valley.

Results of the expedition. Several of the hypotheses developed on the basis of earlier NOAA investigations in the Galapagos area were confirmed during the 1981 research effort. The tectonics of the intersections of the Galapagos Rift and Inca Transform to the south are similar: both have "bends" in the rift valley that point toward the active position of the transform and are directly related to the translation of strain from extensional to strike-ship motion, and both faults are expressed as inward-facing vertical scarps with truncated pillow flows, outcropping, and large talus piles below. Figure II-3 shows a series of submarine fault marks. These dives confirmed that the Galapagos Rift has propagated eastward and short-circuited the southernmost Inca Ridge to create a new transform.

The massive sulfide deposits (Fig. II-4) discovered during the 1980 dive series were examined and mapped more extensively in the 1981 *Alvin* dives. The hypothesis that these deposits were formed in place along the deep-seated boundary faults bordering the rift valley was confirmed. It has been established that at least part of the active hydrothermal phase that created the sulfide deposits occurred during or after the active faulting that created the fault. These stacks are believed to be the largest submarine polymetallic sulfide deposits ever found; they occur over an area at least 1.5 kilometers in length and stand 35 meters high.

In another section of the hydrothermal field, mini-stacks of nontronite, a hydrated iron magnesium aluminum silicate, were discovered covering an extensive area. This mineral was determined to be a low-temperature direct precipitate rather than a secondary product of the sulfides, as previously believed.

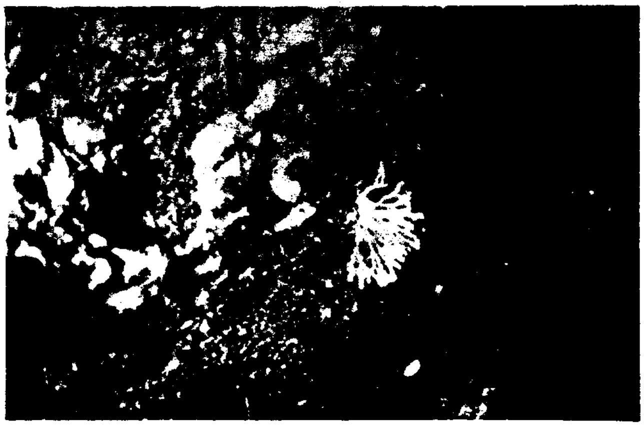


Figure II-3.—Fault marks caused by motion of one side of fault relative to the other

Figure II-4.—Stack of poylmetallic sulfide

The *Alvin*'s extensive depth range, array of scientific equipment (including sonar, still and movie cameras, echo sounders, and closed-circuit television), and versatile manipulators are ideally suited to the type of deep-water observation required in the on-going Galapagos Rift dive series.

Shallow-Water Submersible Programs

NOAA has actively supported underwater research involving the use of shallow-water submersibles in the nation's coastal zones. The submersibles and support ships used in these research projects are the *Johnson Sea-Link* (Fig. II-5) and its support ship *R/V Johnson* (Figs. II-6,7), and the *Nekton-Gamma*, which has been used with different support vessels. The *Johnson Sea-Link* is owned and operated by the Harbor Branch Foundation, and the *Nekton-Gamma* (Fig. II-8) by General Oceanographics. NOAA and the Harbor Branch Foundation have had a cooperative agreement for several years that permits the two organizations to conduct underwater research in areas of interest to them both and to share expenses and resources. Results of these cooperative research efforts are made available in a series of technical publications. In this way, the Harbor Branch Foundation has contributed significantly to NOAA's underwater research program.

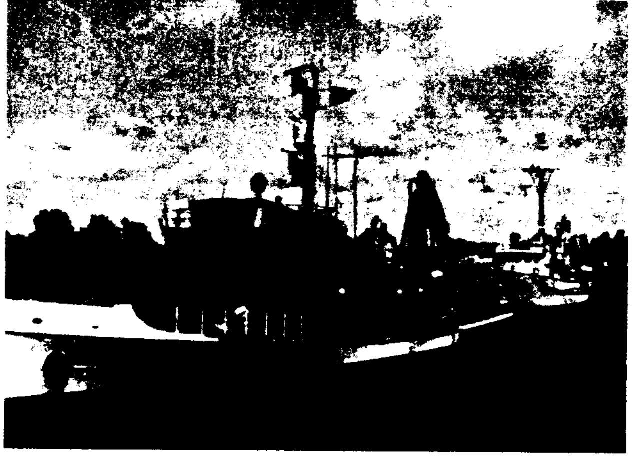
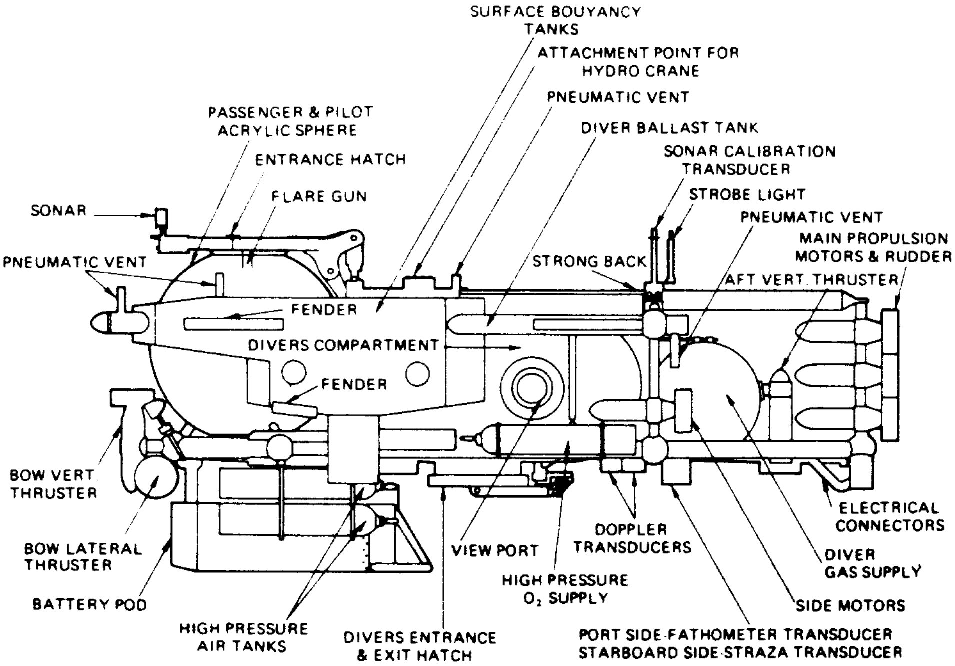


Figure II-6.—*Research Vessel (R/V) Johnson*

Shallow-water submersible expeditions have investigated the effects of ocean dumping, assessed the



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

Figure II-5.—Characteristics and cutaway view of *Johnson Sea-Link* submersible

Figure II-7.—Rear view of *R/V Johnson*, showing pre-launch positioning of submersible *Johnson Sea-Link*

Figure II-8.—Shallow-water submersible *Nekton-Gamma* shortly after launch

potential of various fisheries, surveyed ocean dumpsites, studied the distribution of underwater fauna, and explored marine geology. Shallow-water submersible activities supported by NOAA in the years 1979, 1980, and 1981 are shown in Table II-2.

Shallow-Water Submersible Missions, 1981

NOAA and the Harbor Branch Foundation entered into another in an ongoing series of cooperative agreements in April 1981; this agreement, like its predecessors, provides for the joint funding, use, and staffing of research projects using shallow-water submersibles to conduct investigations of interest to both NOAA and the Foundation.

In FY 1981, one long cruise involving the support ship *R/V Johnson* and the *Johnson Sea-Link* submersible was conducted in the period from July to October. The cruise began in Woods Hole, Massachusetts, and ended off the coast of southeast Florida. It consisted of five individual missions or "legs," each staffed by different personnel, supported by different organizations, and designed to achieve distinct and specific scientific objectives. Figure II-9 is a map of the cruise route, showing the sites of each of the five legs. The individual research missions are briefly described below.

Five-Part Sea-Link Cruise

Leg 1—Georges Bank and Submarine Canyon

Living Resources and Habitat Baselines in Oil and Gas Drilling Areas

Dates: July 11-22

Purpose: Establish quantitative pre-drilling baselines of epibenthic faunal abundance, species diversity, condition, and distribution, and of tissue-bound and substrate-bound levels of contaminants (hydrocarbons, PCB's, and trace metals); compare biotic and abiotic features of the ocean floor; and define environmental features quantitatively that will enable any future impact of offshore drilling on the living resources of Georges Bank to be assessed.

Participants: National Marine Fisheries Service:
Richard Cooper, Principal Investigator
Joseph R. Uzmann

TABLE II-2.
NOAA-Supported Shallow-Water Submersible Research Projects

Dates	Support Ship/ Submersible	Location	Principal Investigator
		1979	
Jul 11-Aug 21	*Atlantic Twin/Nekton Gamma*	Georges Bank	R. Cooper, Northeast Fisheries Center; C. B. Grimes, Woods Hole
Aug 23-27	*Atlantic Twin/Nekton Gamma*	Georges Bank	K. W. Able, Rutgers University
Aug 30-Sep 6	*Atlantic Twin/Nekton Gamma*	Off Cape Hatteras	P. Parker, Southeast Fisheries Center
Sep 6-18	*Atlantic Twin/Nekton Gamma*	Norfolk Canyon	R. Embley, National Ocean Survey
Oct 7-9	*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, Northwest and Alaska Fisheries Center; R. Cooper, Northeast Fisheries Center; C.B. Grimes, Woods Hole
Jul 24-Aug 9	*R/V Johnson/ Johnson Sea-Link*	Georges Bank	K. W. Able, Rutgers
		1981	
Jul 11-22	*R/V Johnson/ Johnson Sea-Link*	Georges Bank, Lydonia Canyon, Oceanographer Canyon, Veatch Canyon	R. Cooper, National Marine Fisheries Center
Jul 23-29	*R/V Johnson/ Johnson Sea-Link*	Lydonia Canyon, Veatch Canyon, Hudson Canyon	C. Grimes, Rutgers University
Aug 1-11	*R/V Johnson/ Johnson Sea-Link*	Baltimore Canyon, Norfolk Canyon	R. Embley, National Ocean Survey
Sep 12-23	*R/V Johnson/ Johnson Sea-Link*	Florida Middle Grounds	W. R. Nelson, National Marine Fisheries Center
Sep 24-Oct 5		Southeast Florida	G. L. Beardsley, National Marine Fisheries Center
Oct 21-22	*R/V Johnson/ Johnson Sea-Link*	West End, Grand Bahama Island	P. Kotzer, Western Washington University; K. Stehling, NOAA

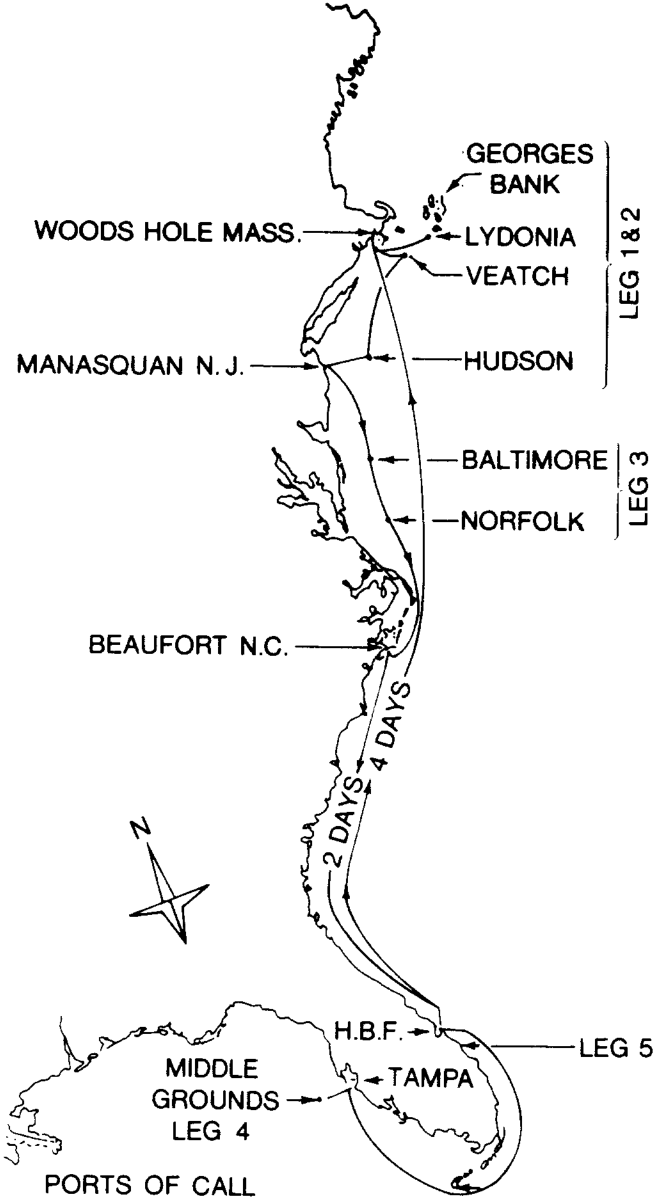


Figure II-9.—Map of the *Johnson Sea-Link's* 1981 cruise route

Accomplishments: During 10 days of shallow-water (75-250 meters) submersible operations, 21 dives were made to six established monitoring stations on Georges Bank and within Lydonia and Oceanographer Canyons, and one additional station was established at Veatch Canyon. Two of the existing stations are located in the center of the proposed gas and oil drilling areas (Lease Sale Nos. 42 and 52 (Fig. II-10)), and other stations are located downstream from these areas. Approximately 10 species were selected as likely indicator species of drilling impact; these include the mud anemone, starfish, sea scallop, cancer crab, ocean pout, white lake, tilefish, black-bellied rosefish, and lobster.

The substrate and fauna at several of the stations were free of PCB's, and hydrocarbons occurred in trace amounts or were not detectable. Trace metals were found at very low levels in sediment and faunal tissues, although copper and zinc occurred in moderately high amounts in crab, scallop, and lobster tissues. Figures II-11 and II-12 are photos taken on this mission.

The submarine canyons in this area have the following characteristics:

- canyon heads consist of erosional areas swept by strong currents of variable direction
- the deeper portions of the canyons serve as repositories for bottom-carried sediments and entrained contaminants
- the longevity of a given particle in any canyon head depends on the canyon's "flush" time, which is not known.

These findings suggest that surface sediments are continuously reworked and redistributed within the upper portions of the canyon by bottom currents.

Publications: Meyer, T.L., R.A. Cooper, and K.J. Pecci. The performance and environmental effects of a hydraulic clam dredge. *Mar. Fish Rev.* 43(9): 14-21, 1981.

Able, K.W., C.B. Grimes, R.A. Cooper, and J.R. Uzmann. Burrow construction and behavior of tilefish, *Lopholatilus chamaeleonticeps*, in Hudson Submarine Canyon. *Env. Biol. Fish* 7(1): 1981.

Leg 2—Lydonia, Veatch, and Hudson Canyons
Tilefish Distribution and Abundance in Relation to Habitat

Dates: July 23-28

Purpose: Determine distribution of tilefish, map areas of distribution, study construction of tilefish burrows, measure burrow sizes, and determine why tilefish prefer Hudson Canyon.

Participants: Rutgers University:
Churchill Grimes
Kenneth Able
Harbor Branch Foundation:
Robert S. Jones

Accomplishments: During 5 days of submersible dives to depths between 450 and 582 feet of seawater, scientists took more than 10,000 photographs of the behavior and habitat of the burrowing tilefish, which is becoming an increasingly important economic resource. Tilefish construct burrows (Fig. II-13) in canyon walls or floors by burrowing through sediments to make a crater-like excavation with one or more central shafts that penetrate to the underlying clay below. Results of these investigations of tilefish populations in certain areas tend to disappear or diminish periodically, and these fluctuations may be explained by data obtained during these missions. In addition, information gathered

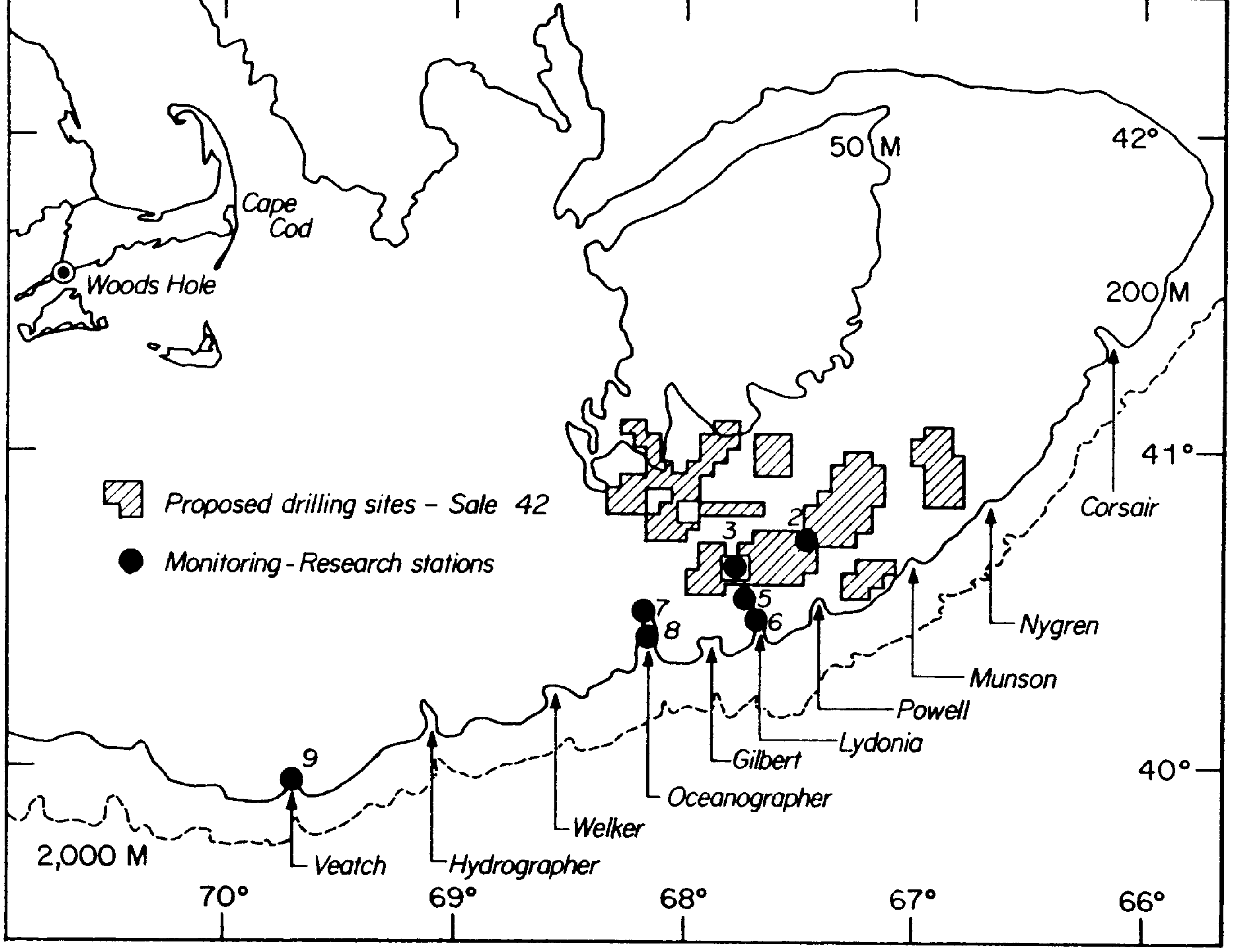


Figure II-10.—Proposed gas and oil drilling areas

Figure II-11.—Head of cusk projecting from a "pueblo village" in Veatch Canyon

Figure II-12.—Lobster near deteriorated lobster trap in Oceanographic Canyon

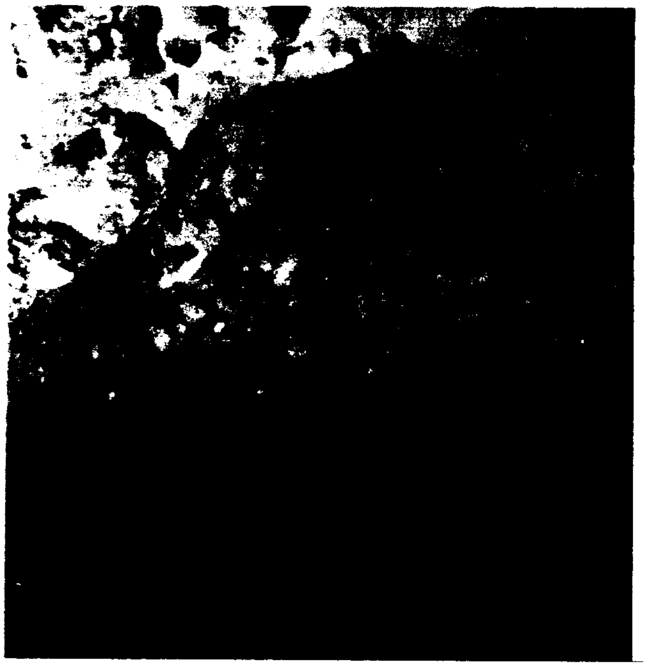


Figure II-13.—Tilefish burrow

during the present pre-oil and gas well drilling phase will establish baselines against which the impact of the drilling activity on tilefish can be assessed.

Leg 3—Norfolk and Baltimore Canyons

Seafloor Geology and Canyon Development

Dates: August 1-6; 7-10

Purpose: Establish any association between bioerosion and submarine canyon development in Norfolk Canyon and study the small-scale morphology of both Norfolk and Baltimore Canyons.

Participants: National Ocean Survey:
Robert Embly, Principal Investigator
Lamont-Dougherty Geological Observatory:
Barbara Hecker, Co-Principal Investigator
Patricia Gibson
Dennis Logan
U.S. Geological Survey:
George Carpenter
Atlantic Oceanographic and Meteorological Laboratory:
Evan Forde

Accomplishments: During a 9-day period in August, a total of 16 dives was made to depths between 640 and 2,000 feet of seawater; two of these were made in the area north of Baltimore Canyon, eight in the head region of Baltimore Canyon, and six in Norfolk Canyon. In the Norfolk Canyon dives, a series of vertical ledges and a vertical outcrop wall on the north wall were traversed, and recent mass wasting, slump scars, and debris were observed. The canyon has been actively eroded by biologic and biochemical agents, and there were large variations in the lithology and weathering of the rock. Dense forests of red coral *Paragorgia arboreta* were seen at depths of 1,000—1,800 feet of seawater, and anemones were prolific in the 550- to 1,000-foot range. Analysis of the rock samples and photographs taken during this portion of the cruise continues, and results are expected to shed further light on the relationship between canyon biology and geology and the formation of East Coast canyons. (Figure II-14 shows different aspects of submarine canyon geomorphology.)

Leg 4—Florida Middle Grounds

Evaluation of Passive Fishing Gear

Dates: September 9-23

Purpose: Evaluate effectiveness of passive fishing gear, compare reef fish population estimates obtained by tagging with those made by observation from the submersible, determine factors responsible for the effectiveness of passive gear, and estimate fish handling and tagging mortality.

Participants: National Marine Fisheries Service:
Walter Nelson, Co-Principal Investigator
Ian Workman
Peter Parker
Elmer Gutherz
Wendy Taylor
Harbor Branch Foundation:
Robert S. Jones, Co-Principal Investigator
South Carolina Marine Research Laboratory:
Charles Wenner

Accomplishments: With the support of the *FRS Oregon II*, the *R/V Johnson* and *Johnson Sea-Link* submersible conducted a reef fish survey at depths of 82 to 132 feet of seawater offshore of the Florida Middle Grounds. During this mission, 42 trap (Fig. II-15), 11 bottom longline (Fig. II-16), and 19 handling stations captured 1550 fish belonging to 21 families, 28 genera, and 36 species. Of these, 630 fish were tagged and released, and 21 tagged specimens were subsequently recaptured. Fifteen submersible dives were made to identify observed fish and to evaluate fishing gear and the responses of fish to different types of gear. Tagging fish using breakaway tags on the bottom longline gear was not successful, both because smaller finfish ate the bait and because baits became tangled in rock or coral outcrops. Large fish apparently did not forage on the bottom, and taglines that hold the bait up off the bottom may prove more successful. Traps were effective in catching fish, which were then tagged with plastic discs. Decompression and tagging mortality were high among vermilion snappers and scamps. Handline fishing was a successful method of obtaining fish for tagging and can be used as an alternative to

Figure II-14 A.—Outcrop showing layers of Pleistocene indurated claystone spalling off in vertical planes

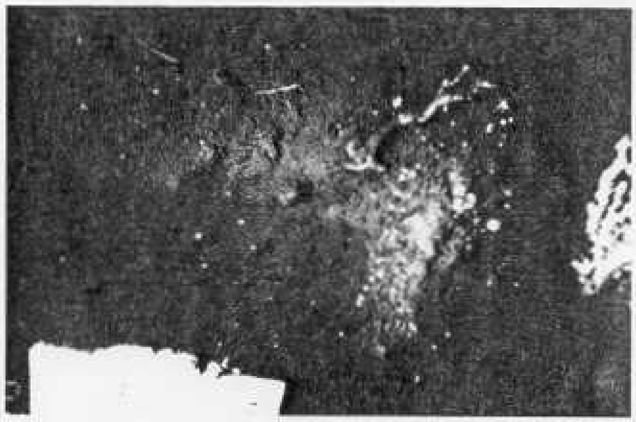


Figure II-14 C.—Geomorphological processes at depths below 220 meters

Figure II-14 B.—Details of wall area showing degrees of colonization

Figure II-14 D.—Disintegrated sandstone outcrop manifested as colonized cobbles

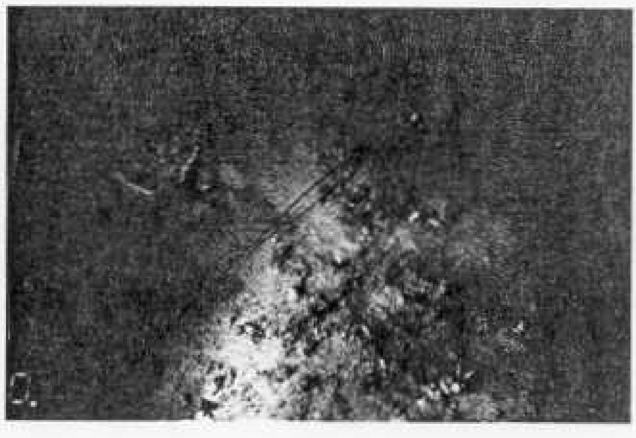


Figure II-15.—Trap used to evaluate effectiveness of various types of passive fishing gear trapping. Submersible observations provided essential information on species composition on the reef, aided in identifying tagged fish, and permitted habitat differences between shallow inshore and deeper offshore reefs to be documented.

Leg 5—Southeast Florida Coast (Tortugas)
Ghost Trap Survey and Reef Fish Census

Dates: September 24 - October 5

Purpose: Establish transect surveys near Tortugas Bank and along the East Florida Shelf to identify ghost traps and assess their effects on reef fishes, and study grouper behavior and colormorphs.

Participants: National Marine Fisheries Service, Southeast Fisheries Center:
Grant Beardsley, Principal Investigator
D. L. Sutherland
Harbor Branch Foundation:
Robert S. Jones, Co-Principal Investigator

Accomplishments: During 16 separate dives involving 43 hours of bottom time, scientists in the *Johnson Sea-Link* traversed trap fishing grounds from Dry Tortugas to Triumph Reef off the coast of Miami to detect lost or abandoned wire fishing traps. Visual observation and the submersible's sonar system were used to identify "ghost" traps (lost traps still capable of catching fish) and derelict traps (lost traps incapable of catching fish because of structural damage or deterioration) (Figs. II-17, 18). Videotape recordings and still photographs were taken of all traps sighted during the dives. A total of 23 derelict and ghost fish traps and 36 lost lobster traps were observed. The derelict traps were too damaged to contain fish. However, when located on sandy bottoms, these traps apparently function as artificial reefs by attracting and sheltering fish and invertebrates. Fish trapped in the ghost traps appeared healthy, and neither the derelict nor ghost traps seemed to have damaged the plants or corals in the vicinity of the traps. Further surveys are needed before an estimate of the total number of ghost traps off southeast Florida can be made.

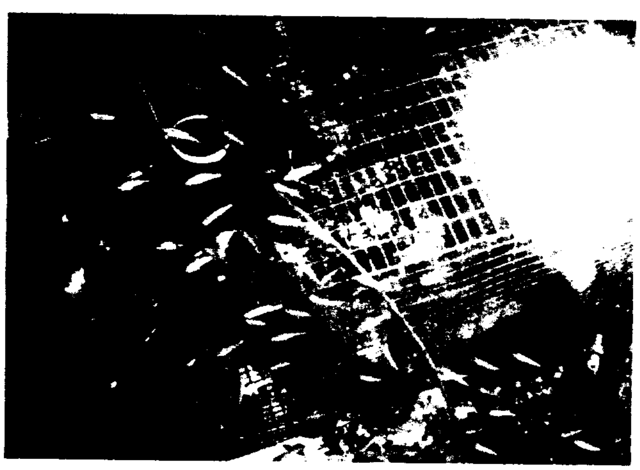


Figure II-16.—Longline fishing gear in place on Florida Middle Grounds seafloor

Figure II-17.—Scientist examining ghost trap located with aid of the *Johnson Sea-Link*'s sonar

Publication: Sutherland, D.L., and G.L. Beardsley. 1981. Results of a preliminary survey of the south Florida fish-trapping grounds using a manned submersible, *Northeast Gulf Science* (in press).

Undersea Radiation Detection

Dates: October 21-22

Purpose: Detect light from bioluminescent organisms and from relativistic particles at various ocean depths.

Participants: Western Washington University:
Peter Kotzer, Principal Investigator
Ocean Technology and Engineering Services, NOAA:
Kurt Stehling, Co-Principal Investigator

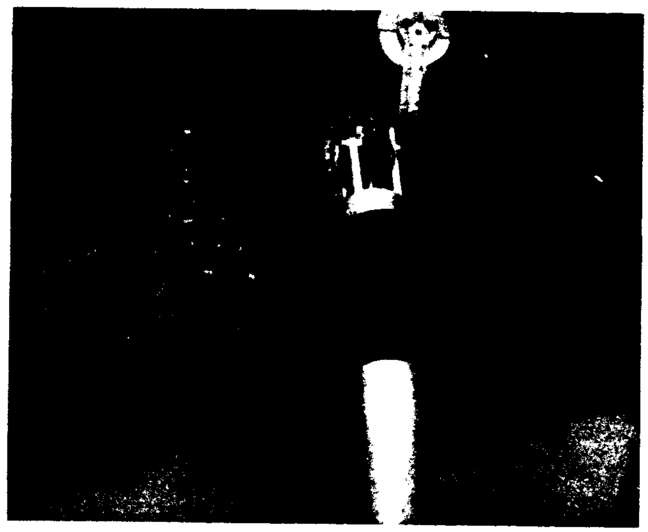


Figure II-18.—Submerged ghost trap near Tortugas Bank

... were made off the west end of Grand Bahama Island during this mission: a shallow-water test dive to 200 feet of seawater (fsw) and a deeper dive to 2,000 fsw. Despite the background photon flux that existed to a depth of 1,100 fsw because of the nearly full moon, a large amount of bioluminescence was detected as star-like greenish dots and flocculi by the "Cyclops" detector. This Cyclops detector consists of an aluminum cylinder containing three photomultiplier tubes with nanosecond resolution. Pulses received by the phototubes are preliminarily processed within the module, which is mounted on a boom extending from the submersible (Fig. II–19). Data are then recorded on diskettes in a data management unit for later analysis on shore (Fig. II–20A, B). It was possible to differentiate pulses emitted by organisms from those associated with Cerenkov radiation and trace radioactive isotopes and therefore to isolate bioluminescent pulses originating from organisms under water. The techniques and equipment developed during this brief mission will permit future investigations to determine the pulse signatures of various bioluminescent species and their respective roles in the marine food chain.

Presentation: Kotzer, P. Preliminary report on bioluminescent organisms at depths to 2000 fsw. Paper presented at the American Physical Society Meeting, Seattle, Washington, 1981.

Figure II-19.—Deck of *Johnson Sea-Link*, showing boom-mounted module used to collect data on underwater bioluminescence

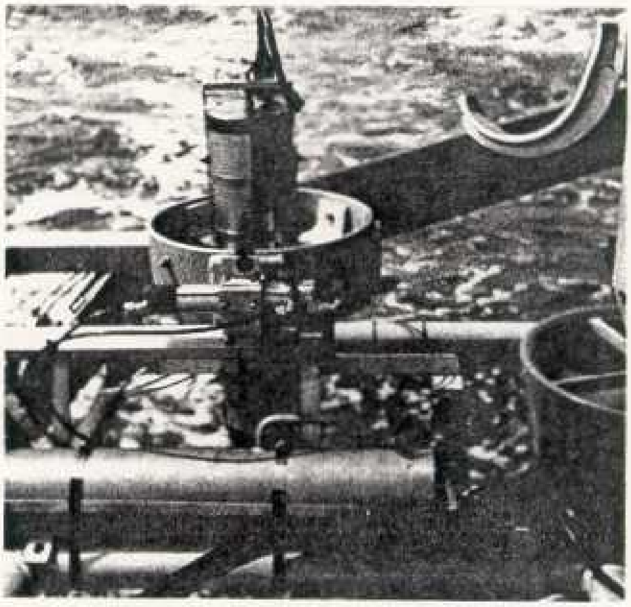


Figure II-20.—A. Close-ups of U.S. Navy furnished photoelectric bioluminescence detector on *Johnson Sea-Link*'s deck

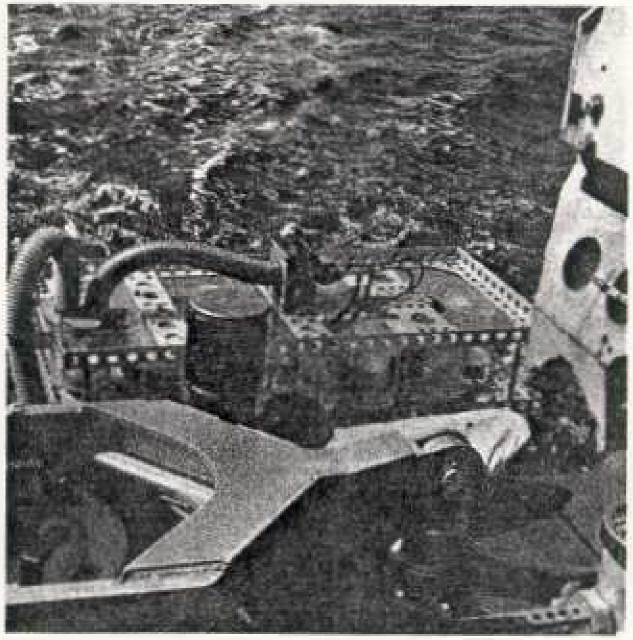


Figure II-20.—B. Close-ups of U.S. Navy physical sample containers mounted on *Johnson Sea-Link*'s deck

SECTION III
Regional Undersea Research Programs

HISTORY

When NOAA was established in 1970, Congress mandated that the new agency assume the responsibility for developing programs for the assessment, protection, development, and utilization of the Coastal Zone resources of the United States. Accordingly, NOAA's Manned Undersea Science and Technology Office, the forerunner of the present Office of Undersea Research, initiated the NOAA Undersea Laboratory System (NULS) program in 1977. Congressional appropriations for FY 1978 included funds to continue the Oceanlab Project (see Section I) and to develop "cooperative undersea programs, including habitats in shallow and intermediate depths."

The purpose of the NULS program, from its inception to the present time, has been to provide manned underwater facilities and other research support for scientific investigations of coastal marine environments, and biological, geological, and ecological problems. The NULS program's first phase was implemented when the first manned regional underwater facility was established in St. Croix, U.S. Virgin Islands, by the West Indies Laboratory of Fairleigh Dickinson University, using the undersea habitat *Hydrolab*.

In 1978, NOAA decided, in response to input from the underwater research and scientific communities, to increase the scientific usefulness and cost-effectiveness of the NULS program by expanding it to include several regional underwater laboratories at scientifically significant locations. Broadening the regional base of the NULS program was designed to take advantage of local personnel and research resources and to develop a more comprehensive understanding of several of the country's coastal zone areas. NOAA advised more than 400 academic institutions of its plans to establish and maintain regional laboratories and their associated research projects; 15 of these institutions submitted letters of interest to the Agency. Nine of the interested institutions were asked to submit detailed feasibility studies, which were then evaluated by a panel of scientists and engineers experienced in undersea marine research.

After careful review and analysis, the University of Hawaii, the University of Southern California, and the University of North Carolina at Wilmington were selected to submit formal proposals describing their approaches to the development, operation, and utilization of a regional underwater research program. Figure III-1 is a map of the locations of OUR's regional underwater facilities. Evaluation and selection criteria emphasized the institution's experience and capability in undersea operations and marine science, the suitability of proposed research projects in terms of NOAA's overall mission requirements, and the scientific merit of the underwater investigations planned for the regional facility. NOAA's evaluation panel made specific recommendations to the three universities on methods of improving and implementing their proposed programs.

In 1980, cooperative agreements authorizing the University of Hawaii, the University of Southern California, and the University of North Carolina at Wilmington to establish undersea research facilities and programs were signed by NOAA and the universities. This action formally established NOAA's Regional Undersea Research Program, which presently consists of the Caribbean Regional Undersea Laboratory at St. Croix, U.S. Virgin Islands; the Hawaiian Undersea Research Laboratory at Oahu; the Southeastern Undersea Research Facility at Wilmington, North Carolina; and the Western Regional Undersea Laboratory at Catalina Island, California. The programs, facilities, and research achievements of each of these programs are described in the sections that follow.

CARIBBEAN REGIONAL UNDERSEA LABORATORY PROGRAM

The first part of NOAA's regional laboratory program to become fully operational was the Caribbean program, operated by the West Indies Laboratory of Fairleigh Dickinson University and located in the U.S. Virgin Islands. The focal point of the Caribbean Regional Undersea Laboratory (CRUL) program was the habitat *Hydrolab*, which was placed on the seafloor in the Salt River Canyon off the north central coast of St. Croix.

In the first 3 years since it became operational, 43 science missions have been conducted using *Hydrolab*'s research facilities. A total of 135 scientists has been saturated at bottom depth for 536 days, without a single

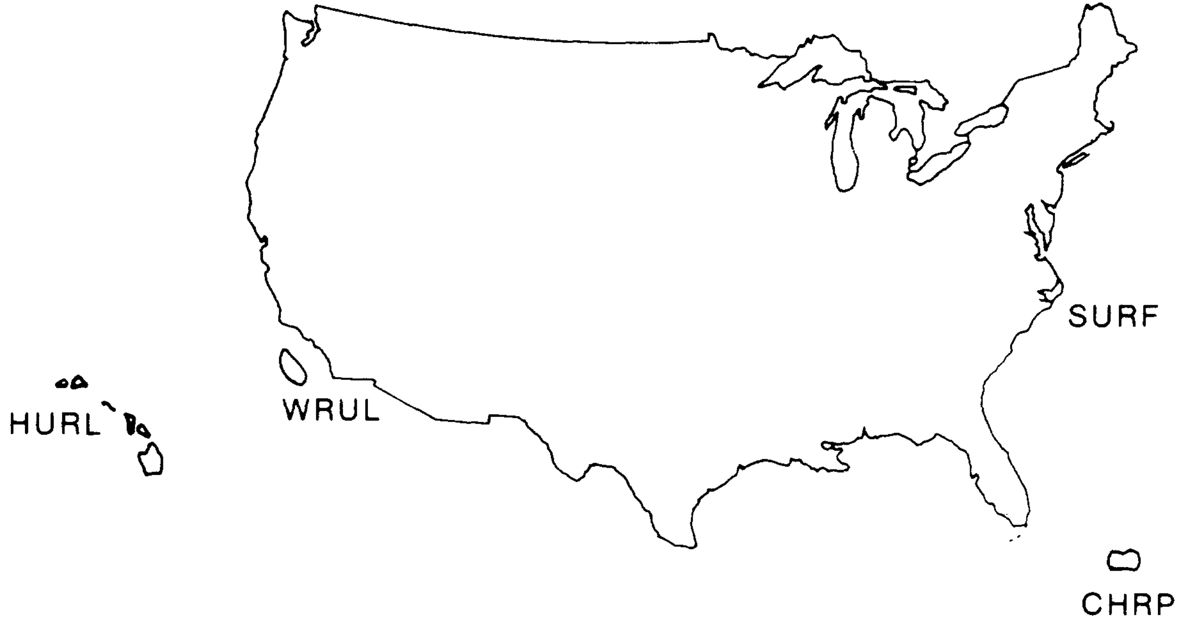


Figure III-1.—Map showing existing and planned underwater regional facilities sponsored by the Office of Undersea Research

Figure III-2.—A. The habitat *Hydrolab* submerged off St. Croix, Virgin Islands: front view

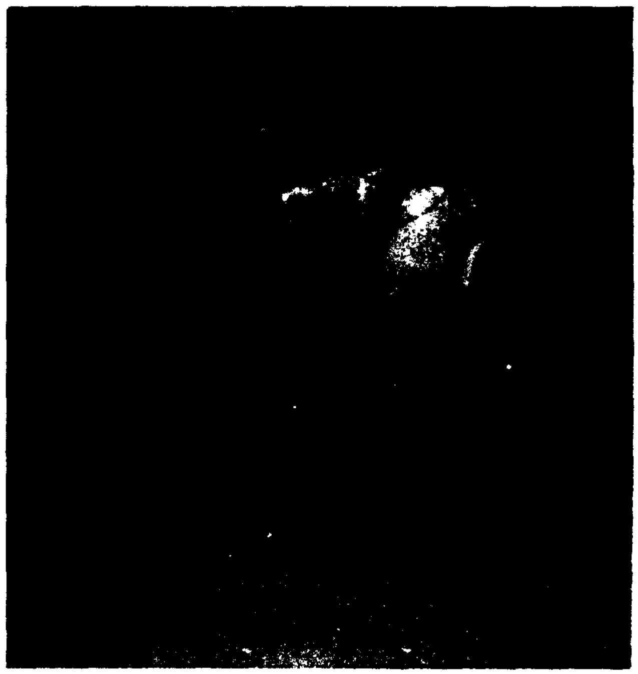


Figure III-2.—B. The habitat *Hydrolab* submerged off St. Croix, Virgin Islands: side view

serious mishap. This safety record is particularly remarkable when one considers that the scientists/aquanauts participating in these research efforts are drawn from many institutions and often have not previously worked together. The safety record and success of the CRUL program are a tribute to the pervasive emphasis on safety underlying all of NOAA's underwater programs and activities and to the rigorous training and certification procedures required for all aquanauts participating in OUR programs.

CRUL Program's Habitat and Research Projects

The habitat *Hydrolab* (Fig. III-2) was built by Perry Oceanographics, Inc., in 1977, and was outfitted by NOAA for research use. *Hydrolab* has been operational since the Spring of 1978. The habitat is about 5 meters long and 2.5 meters in diameter; it is designed to support four saturated divers on projects lasting up to 14 days (Fig. III-3). It is located at a depth of 15.2 meters but can be used as a base for excursion dives to depths of about 40 meters (Fig. III-4). *Hydrolab* has a double-lock entrance compartment and a hatch that is 24 inches in diameter. It has six external viewports and is equipped with a sink, shower, hot plate, trash compactor, air conditioner, heater, and three bunks. Figure III-5 shows a cutaway view of the *Hydrolab*'s interior. The Salt River Canyon in which the habitat is located is an extensive coral reef ecosystem, which provides unique opportunities to study the geological, botanical, and biological aspects and interactions of marine life in tropical waters (Fig. III-6).

In FY 1981, 15 research projects were conducted from the *Hydrolab* facility. The participating institutions, purpose of the projects, and dates of the various science missions conducted in that period are shown in Tables III-1 and III-2. The individual missions are briefly described in the section that follows this table.

Figure III-3.—A. Interior view of *Hydrolab* showing sleeping quarters

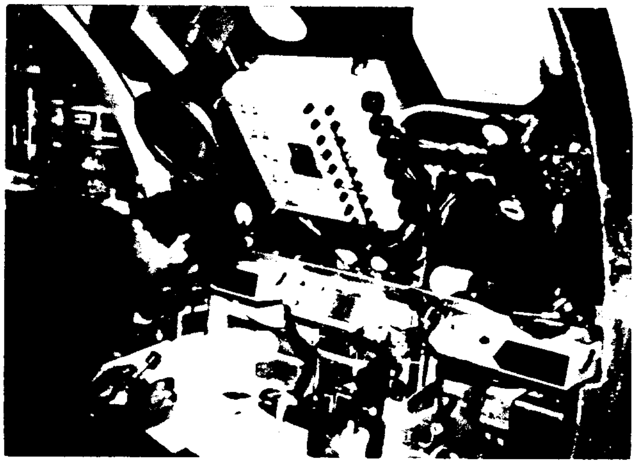


Figure III-3.— B. Interior view of *Hydrolab* showing working quarters

Figure III-4 A.—Tank rack for *Hydrolab* divers

Figure III-4 B.—Diver checking with aquanauts in *Hydrolab*

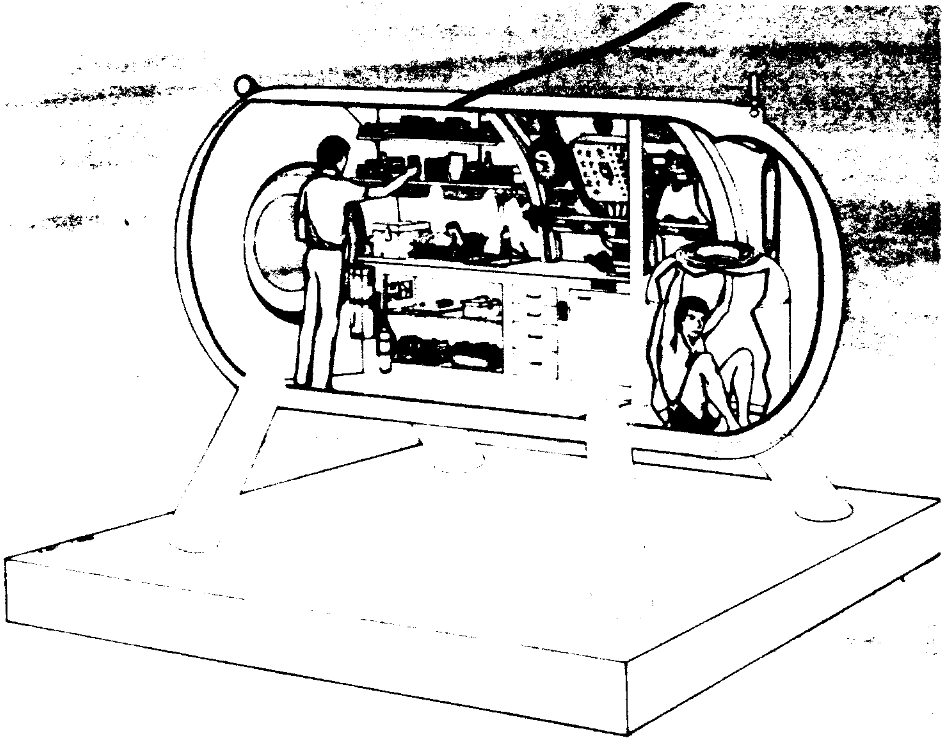


Figure III-5.—Cutaway view of *Hydrolab's* interior

Diel Migrations of *Scarus Guacamaia* and *Scarus Coelestinus*

Dates: October 5–18, 1980

Purpose: To study the behavior of two species of parrotfish and correlate behavior with light levels and position of the sun (Report No. 80-10A).

Participants: University of Puerto Rico:
Ileana E. Clavijo, Principal Investigator
Ana T. Bardales
Luis M. Amador
Jennie Ramirez
Julio Morell
Astrid Mendez

Accomplishments: Two observation stations were established in Salt River Submarine Canyon to observe the arrival and departure of *Scarus (S.) guacamaia* and *S. coelestinus*. One station was located along the west wall at a depth of 18 meters and the other on the east slope at 14 meters. At dawn and dusk, one aquanaut was stationed at each location for a period of about 80 minutes, during which the number of parrotfish and their direction of movement were recorded. A second aquanaut, stationed underwater at a depth of about 17 meters, recorded the time and light intensity data during the observation period. Fish arriving at dusk moved from north to south along the west wall and from east and northeast along the east slope. At dawn, fish were observed to begin feeding within 12 or more minutes of sunrise. At dusk, as many as 12 individual parrotfish entered the canyon within the hour preceding and following sunset, while more than 10 *S. guacamaia* were seen leaving the west wall at dawn. Periods of social interactions occurred both at dawn and at dusk. "Yawn-rushing" behavior, directed principally at smaller individuals of the same species, occurred occasionally during the morning and evening social periods. In general, activity began at first light, at light intensities of less than 0.016 foot candles, and evening activity ceased when levels had again reached this intensity. On several occasions, the same individuals were seen to return to the same shelters each night. Data on frequency of various behaviors, light intensities, daily tidal variations, and atmospheric conditions are being analyzed further.

Social Behavior in *Eupomacentrus Partitus*

Dates: October 5–18, 1980

Purpose: To observe and measure aggressive behavior among groups of the bicolor damsel fish *Eupomacentrus partitus* and to determine the factors responsible for eliciting this behavior (Report No. 80-10B).

Participants: University of Manchester:
Yvonne Sadovy, Principal Investigator
University of Puerto Rico:
Ileana Clavijo, Co-principal Investigator
Humboldt University:
Kimberly Boulon

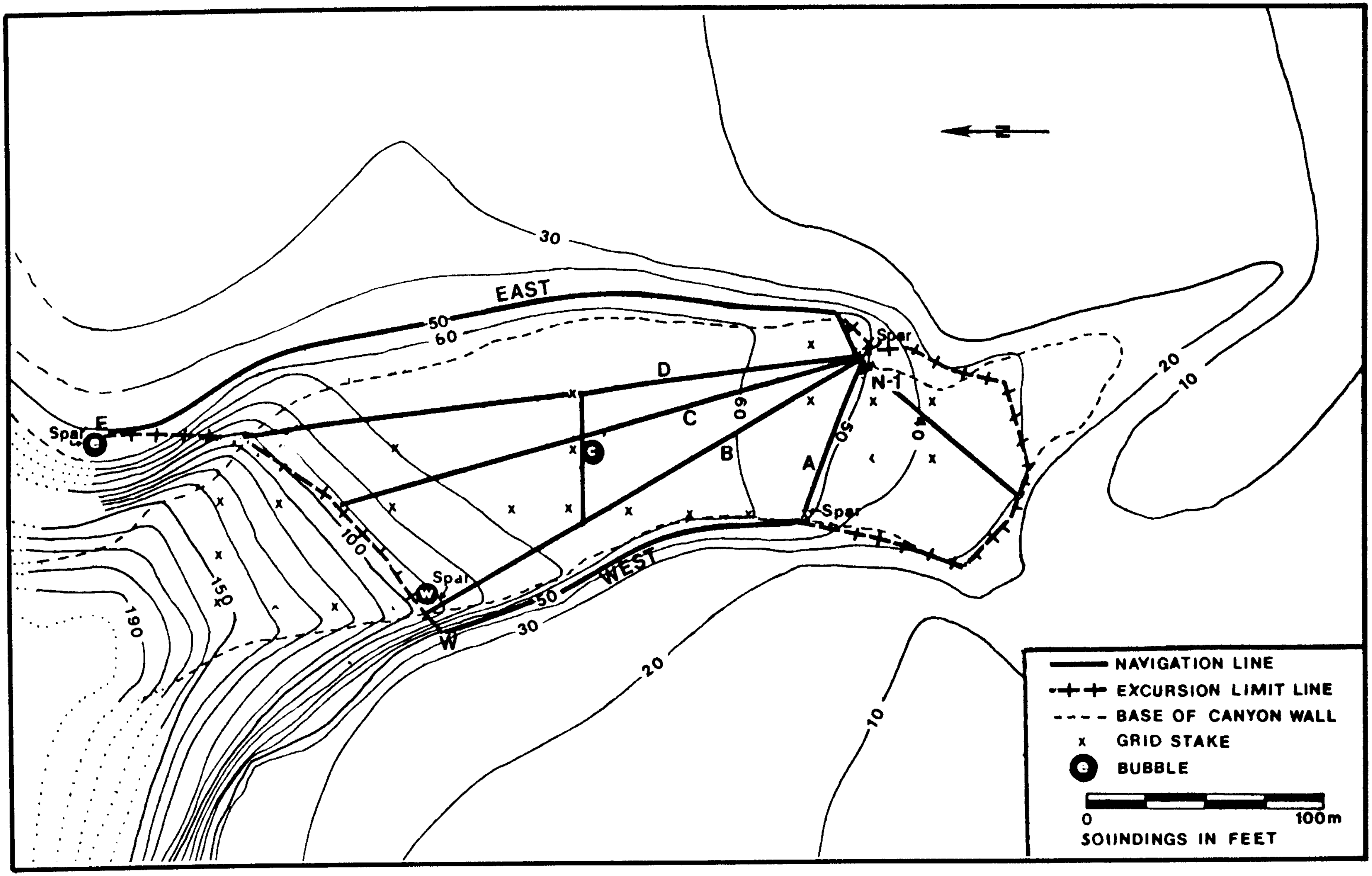


Figure III-6.—Bathymetric map of Salt River Canyon, showing location of *Hydrolab* (N-1), depths and location of navigational lines, limits of excursion dives, research site, and location of bubble way station (e)

TABLE III-1.

FY 1981 Caribbean Regional Undersea Laboratory Projects

Participating Institutions	Dates of Mission	Focus of Mission
University of Puerto Rico	October 5-18, 1980	Diel Migrations of *Scarus guacamaia* and *Scarus coelestinus*
University of Manchester; University of Puerto Rico; Humboldt University	October 5-18, 1980	Social Behavior of *Eupomacentrus partitus*
Goucher College; National Heart, Lung, and Blood Institute; National Aquarium; Whidbey Island Biological Services	October 27—November 8, 1980	Resource Utilization Patterns Within a Deep-Water Planktivorous Fish Community
Department of Conservation and Cultural Affairs, U.S. Virgin Islands; David A. Olsen Associates	November 15-25, 1980	Characteristics of Black Coral Trees in Salt River Canyon
University of Maryland; Cornell University; University of Massachusetts; Fairleigh Dickinson University	January 20-26, 1981	Ecological Processes that Structure Fish and Invertebrate Reef Communities
University of Havana; Cuban Academy of Sciences	February 22—March 7, 1981	Fish Behavior in Relation to Commercial Fish Traps
Department of Conservation and Cultural Affairs, U.S. Virgin Islands	March 14-24, 1981	Relationship of Coral Recruitment and Grazing Intensity to the Distribution of Algae and Corals in Salt River Canyon
University of Georgia	April 1-11, 1981	Trumpetfish Distribution and Predation
University of Puerto Rico; Florida State University; National Oceanic and Atmospheric Administration	April 20—May 2, 1981	Manipulation of Large External Isopods on Brown and Blue Chromis and Coneys
University of Hawaii; University of British Columbia	May 19-26, 1981	Feeding and Space-Related Behavior of Three Species of Pomacanthid Fishes
University of Maryland; Cornell University; University of Manchester; University of Rochester	June 26—July 3, 1981	Ecological Processes that Structure Fish and Invertebrate Reef Communities
University of Massachusetts; Sarah Lawrence College; Fairleigh Dickinson University Woods Hole Oceanographic Institute	July 9-19, 1981	Structure in Coral Reef Fish Communities: Predictability of Taxonomic, Morphological, and Behavior Patterns
Cornell University; University of Maine; Mary Washington College	August 4-11, 1981	Settlement Age, Early Behaviors, and Visual Attributes of Larva and Post-Larval Fishes
University of California, Los Angeles; University of Georgia	August 25—September 1, 1981	Role of Bioluminescence in Communication and the Activity Patterns of the Ostracod *Vargula*
Fairleigh Dickinson University; University of Chicago; University of Rochester; North Dakota Geological Survey	September 12-24, 1981	Geological Development of Salt River Submarine Canyon

TABLE III-2.
Excursion Times and Depths for FY'81 *Hydrolab* Missions

Principal Investigator	No. of Mission	Purpose	Number of Aquanauts	Number of Surface Scientists	Total Man Hours (Aquanauts)	Longest Excursion, hours:min	Average Depth, fsw	Maximum Depth, fsw
Clavijo	80-10A	Animal Behavior	2	3	76	4:00	55	90
Sadovy	80-10B	Animal Behavior	2	3	94	4:00	60	75
Johnson	80-11	Ecology	4	1	135	4:00	130	150
Olsen	80-12	Coral Distrib.	3	0	52	1:63	130	150
Reaka	81-1	Ecology	4	2	102	3:38	65	120
Samson	81-2	Fisheries	4	2	96	2:40	100	100
Rogers	81-3	Ecology	4	1	165	4:00	90	120
Helfman	81-4	Animal Behavior	4	4	110	3:00	66	130
Williams	81-5	Ecology	4	1	166	3:00	50	55
Reese	81-6	Animal Behavior	4	1	177	6:56	85	95
Reaka	81-7	Animal Behavior	4	7	169	4:27	65	150
Ebersole	81-8	Animal Behavior	4	1	147	3:45	60	100
McFarland	81-9	Animal Behavior	4	1	119	2:55	60	120
Morin	81-10	Ecology	4	2	116	3:55	65	120
Hubbard	81-11	Geology	4	2	115	6:21	100	100

Accomplishments: Several factors that may be important determinants of intragroup aggression were evaluated among groups of the damsel fish *Eupomacentrus (E.) partitus*. Factors considered included: size; stage of maturation; hierarchical rank; size in relation to others in any particular size-group; a combination of these factors; and any other observable factor. Eight groups of *E. partitus* were observed for the period of time needed for 50 interactions to occur in the group. Group members were categorized visually by size from 1 (largest) to 6 (smallest). In six groups, individuals that had been chased were anesthetized with quinaldine and removed from the group; the remaining two groups acted as controls. After the objects of the aggressive behavior had been removed from the group, the experimental groups were again observed for 50 interactions. Preliminary data show that the hierarchy among *E. partitus* is not rigidly linear, and that size alone does not determine aggressive behavior. Moreover, when a fish that had been chased was removed from the group, aggressive behavior did not always shift to the next lower individual in the hierarchy. All individuals removed from the group belonged to size rank 3 or 4, and other fish in this size category became the target of aggressive behavior after the first fish had been removed. Further study is needed to determine whether size rank 3 or 4 within the group is the critical determinant of aggressive behavior in this species of damselfish.

Resource Utilization Patterns in a Deep-Water Planktivorous Fish Community at Salt River Canyon

Dates: October 27—November 8, 1980

Purpose: To determine the habitat and resource utilization patterns among plankton-eating fish on the deep (30 to 45 meter) reef slope of Salt River Canyon (Report No. 80-11).

Participants: Goucher College:
William S. Johnson, Principal Investigator
National Heart, Lung, and Blood Institute:
Jeffrey M. Davidson
National Aquarium at Baltimore:
Valerie C. Chase
Whidbey Island Biological Services:
Fred Johnson
Stephen S. Hamilton

Accomplishments: The abundance, habitats, feeding patterns, and feeding preferences of *Chromis (C.) insolata, C. cyanea, C. multilineata,* and *Eupomacentrus (E.) partitus* were determined by visual and photographic censuses. *Chromis insolata* and *C. cyanea* were the dominant deep diurnal feeders, followed by *E. partitus*. *Chromis insolata* inhabited isolated coral heads and rocky outcrops at depths below 40 meters. Adults of *C. insolata* were solitary and territorial, while juveniles of this species grouped together. Different size-classes of fish in this species were also strictly segregated. Members of the *C. cyanea* species were observed less frequently below 40 meters and often fed in a layer above the level inhabited by *C. insolata*. These fish also exhibited greater vertical and horizontal mobility than *C. insolata*. *Chromis multilineata* occurred in abundance at 80 and 90 feet but were not observed below 110 feet. *Eupomacentrus partitus* were numerous at 80 feet and were not seen below a depth of 130 feet. Approximately 60 fish of all species combined were taken to determine feeding preferences. The results of gut analyses performed on these specimens will be reported at a later date.

Characteristics of Black Coral Trees in Salt River Canyon: Management Data

Dates: November 15–25, 1980

Purpose: Measurement of the growth, depth of occurrence, natural mortality, and depth distribution of 292 black coral trees in Salt River Canyon in the interval since October 1979 (Report No. 80-12).

Participants: David A. Olsen and Associates:
- David A. Olsen

Department of Conservation and Cultural Affairs, U.S. Virgin Islands:
- Gerald R. McCrain

Pressure, Ltd.:
- Brian M. Friedman

Accomplishments: Eighty-two percent of the black coral trees of the *Antipathes (A.) pannacea* and *A.* sp. species that had been tagged with plastic bags in Salt River Canyon on an earlier (October 1979) mission were remeasured, and an additional 110 black coral colonies in the same area were tagged and measured for the first time. In the intervening period, three of the original 292 trees had died of natural causes. Mean depth of occurrence of the colonies was 100 feet on the canyon's west wall and 124 feet on the east slope. Depth distributions for both species were similar, but *A. pannacea* was more abundant in both locations. A total of 241 colonies was remeasured, and 294 are now tagged. Growth was very slow, and future research will probably be most effective if sufficient time for colony growth is allotted between missions.

Publication: Olsen, D. A. Investigations of black coral in Salt River Submarine Canyon, St. Croix. U.S. Virgin Islands Fish and Wildlife Reports, July, 1982.

Experimental Analysis of Ecological Processes that Structure Fish and Invertebrate Reef Communities. I.

Dates: January 20–26, 1981

Purpose: Establish 15 artificial reefs to attract fish and invertebrate colonies; remove and examine half of the material from artificial invertebrate reefs established in 1980; collect rubble from the natural reef adjacent to each site to be used as control material; census the fish and invertebrates at the 110-foot site (Report No. 81-1)

Participants: University of Maryland:
- Marjorie L. Reaka, Principal Investigator
- Cheryl Van Zant
- Jane Dominguez
- Hugh Reichardt
- Joe Dineen
- Miriam Smyth

Cornell University:
- Nancy Wolf

University of Massachusetts:
- Eldridge Bermingham

Fairleigh Dickinson University, West Indies Laboratory:
- Frank Pecora

Accomplishments: Fifteen new cinder block and rubble artificial reefs were constructed at 65 feet about 20 meters west of the East Slope of Salt River Canyon. These were in addition to the 15 reefs established at 65 feet during an earlier (July 1980) mission. To assess the effect on fish recruitment of larger fish preying on juveniles populating the artificial reefs, 5 of these 15 reefs were caged. To control for the effect of caging on recruitment, an additional five reefs were surrounded with half-open cages. Figure III-7 shows divers collecting samples in the area of the reefs while Figure III-8 gives a good example of local reef inhabitants. The last five reefs were placed, without any caging, to permit seasonality (January vs. July) and other effects (caging vs. non-caging) to be evaluated. Sixty pieces of rubble that had been colonized for 6 months, along with control pieces of rubble from adjacent natural reefs, were collected at the 10-, 65-, and 110-foot sites established in July 1980. Figure III-9 shows activities conducted at various stages of the experiment. The new reefs were positioned 10 meters apart between the previously established reefs and a line 20 meters from the East Slope. The reef cages were constructed of 1.5-inch mesh hardware cloth and rebar and were equipped with zinc tabs to inhibit algae. Both long sides of each cage could be removed to permit diver access for census and maintenance.

Figure III-7.—Plankton collection, performed by divers towing net 2-3 meters above reef

Figure III-8.—Juvenile olive chromis (blue and yellow)

Stomatopod density and species identification were also measured in the collected material. Six months after caging, stomatopod density for each of the experimental conditions was significantly different; rubble from the natural reef had the lowest stomatopod density, and the artificial block-and-rubble reef had a lower population of adult fish than the natural reef. The highest stomatopod density, and the lowest fish density, occurred in the artificial reefs composed exclusively of rubble. One species of stomatopod previously believed to occur only in deeper rubble was collected from the 65-foot reef; this species is apparently an early colonizer that is later replaced by other species. One stomatopod species collected at 110 feet has been sent to the Smithsonian for identification and appears to be a new species. Sample sorting and analysis are continuing.

Publication: A paper reporting the results of these *Hydrolab* missions was presented at the Mini-Symposium and Workshop on Coral Reef Ecology, held October 16, 1981, at the University of Maryland, College Park.

Fish Behavior in Relation to Commercial Fish Traps

Dates: February 22—March 7, 1981

Purpose: Evaluate influence of fish trap size and shape, and the presence, absence, and type of bait, on the relative effectiveness of the trap (Report No. 81-2).

Participants: University of Havana, Center for Marine Research:
Gaspar Gonzalez Samson
Eugenio Diaz Igleria
Cuban Academy of Sciences:
Alfonso Silva Lee
Juan Pablo Garcia Arteaga

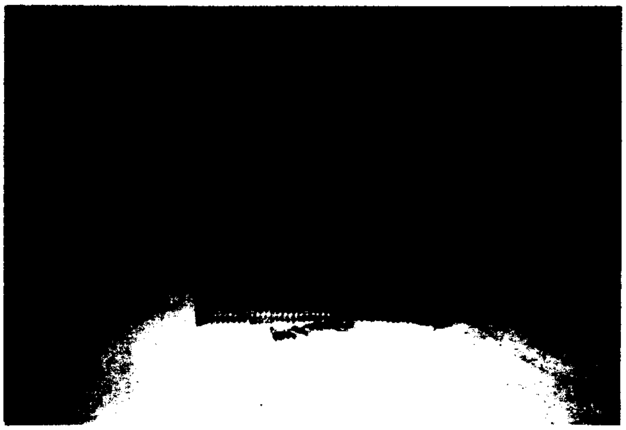


Figure III-9 A.—Cage over artificial reef

Figure III-9 B.—Aquanaut collecting rubble sample

Accomplishments: A total of 12 fish traps of various sizes and shapes and baited with two types of bait or no bait was set out in seven locations in Salt River Canyon, St. Croix, Virgin Islands. The traps included two semi-cylindrical traps, two rectangular traps, three large traps baited first with raw parrotfish, grunt, or surgeonfish and then with the same bait roasted, three large unbaited traps, and two additional large and baited traps. Figure III-10 shows aquanauts examining baited traps. Two series of experiments, each lasting two days, were conducted at each location. Trap catches were recorded at dawn, noon, and dusk. In addition, traps at Locations V, VI, and VII were continually watched to observe fish behavior in the vicinity of the traps. In general, the number of fish caught in any trap was low; the canyon's low fish population and poor visibility caused by bad weather (which is believed to affect trap effectiveness) may have reduced the size of the catch. However, the number of fish caught in baited traps was higher than that in unbaited traps, but no difference was observed in size of catch when roasted rather than raw bait was used. In Locations I through IV, catch was not affected by

Figure III-9 C.—Aquanaut taking data at open (uncaged) reef

Figure III-9 D.—Aquanaut sending buoy with samples to surface crew

trap size or location. At Location V, more fish were caught between sunset and sunrise than between sunrise and sunset. The species caught in small traps in Locations I through IV and in large traps in Location V corresponded well with previously reported species distribution in the canyon. The number of fish caught in small rectangular and semi-cylindrical traps was the same, 0.02 fish per trap-hour; the catch by effort-unit increased when larger traps were used. Near the East Slope bubble, many fish of the *Pomadasyidae* family were seen, while the East Slope favored members of the *Serranidae* family. Species analysis showed that *Holocentrus rufus* was more abundant near the East Slope, and *Miripristis jacobus* was more plentiful in the vicinity of the bubble.

Relationship of Coral Recruitment and Grazing Intensity to the Distribution of Algae and Corals in Salt River Canyon

Dates: March 14–24, 1981

Purpose: Establish settling plates for coral and algae recruitment at 60-, 90-, and 120-foot depths, and survey coral, sea urchin, algae, and fish populations at each depth (Report No. 81-3).

Participants: Department of Conservation and Natural Affairs, U.S. Virgin Islands:
- Caroline S. Rogers, Principal Investigator
- Marcia Gilnack
- Carl Fitz
- Jim Beets
- John Hardin

Accomplishments: Settling plates composed of slabs of dead coral were placed at 60, 90, and 120 feet on both the East and West Wall of Salt River Canyon, St. Croix, Virgin Islands; 24 vertical and 24 horizontal plates were positioned at each location (Fig. III-11). Transects were used to count hard coral species at each depth and on both canyon walls. Data analysis is not yet complete, but preliminary counts show that 26 species of coral were observed in transects on the East and West walls. *Agaricia lamarcki* was abundant at 90 and 120 feet on both walls, and sponges were plentiful at the same depths. Sea urchins were counted in an area 1 to 2 meters wide along the 10-meter long coral diversity lines; urchin

Figure III-10.—Aquanauts examining baited trap

density decreased with depth. Fish surveys were conducted over 50-minute periods at each depth. A total of 84 species was observed along the west wall, and 89 were seen near the east wall. The number of fish decreased with depth, and depth comparisons of the various fish communities are currently being made. Eighteen red algae *(Rhodophyceae)*, four brown algae *(Phaeophyceae)* and six green algae *(Chlorophyceae)* species were collected for later analysis.

Trumpetfish Distribution and Predation

Dates: April 1-11, 1981

Purpose: Investigate the distribution and foraging behavior of trumpetfish, and the reactions of trumpetfish prey to trumpetfish models, in the Salt River Canyon (Report No. 81-4).

Participants: University of Georgia:
Gene S. Helfman, Principal Investigator
Judith L. Meyer
Dorinda G. Dallmeyer
Earl G. Bozeman

Accomplishments: Aquanauts and surface scientific personnel studied the foraging activities, depth distribution, and size and number of Atlantic trumpetfish *(Aulostomus maculatus)* in depths ranging from 50 to 130 feet on the East Wall and from 0 to 50 feet at various locations in the canyon. Diver pairs at assigned depths recorded the size, color, and distinctive spot patterns of individual trumpetfish, which were followed for 10 minutes while the fish's angle of orientation to the substrate, height above the bottom, depth, distance traveled, and foraging activities were observed and recorded. Foraging activities studied included approach to prey, distances from which predatory strikes occurred, sizes of fish and species preyed upon, reactions of prey, frequency of strikes, and frequency of successful strikes. Ninety trumpetfish were observed in this manner. Preliminary data show that trumpetfish at shallow depths and in extensive reef areas are more mobile than those in patchy reef areas but were sighted in the same areas less frequently than individuals at deeper depths. Trumpetfish inhabiting deeper depths participated in more social interactions than those at shallower depths, which may suggest a territory-based social system among these fish. However, depth does not appear to be the primary determinant of social organization and foraging patterns, although additional research is necessary

Figure III-11.—Aquanaut examining settling plates at 90 fsw

to confirm this finding. In contrast, the distribution of color morphs and sizes of trumpetfish may indicate a relationship to depth. All trumpetfish observed at depths greater than 30 feet were brown or reddish-brown, while blue-nose, yellow-nose, silver, and greenish morphs were also seen at shallower depths. The extent to which the predominantly reddish-brown color preference found at shallower depths reflects attempts at camouflage, since these fish hide in reddish-brown gorgonians to catch their prey, is not known. Trumpetfish smaller than 6 inches in length were not seen below 50 feet, while 7 of 9 individuals larger than 18 inches were observed below this depth. Two fiberglass-coated models of formalin-preserved trumpetfish, one 15 inches and one 24 inches in length, were used to study the reactions of bicolor damsel-fish *(Eupomacentrus partitus)* to trumpetfish behavior. Models were presented in different attitudes to damselfish of various sizes. Large models were responded to more frequently and more strongly than small models, and models presented in a vertical posture elicited escape reactions more frequently than those presented horizontally. These results suggest that damselfish responded most strongly to trumpetfish perceived as immediately threatening and of sufficient size to carry out a successful attack.

Publication: Helfman, G. S. Resin-coated fishes: a simple model technique for *in-situ* studies of fish behavior. *Copeia* 1983: No. 2.

Manipulations of Large External Isopods (of the Genus Anilocra) on Brown and Blue Chromis and Coneys

Dates: April 20—May 2, 1981

Purpose: To transfer the isopod parasite (genus *Anilocra* n. sp.) from infested *Chromis multilineatus* and *Chromis cyaneus* to uninfested fish of the same species and to coneys *(Epinephelus ulvus)* (Report No. 81-5).

Participants: University of Puerto Rico:
Ernest H. Williams, Principal Investigator
Lucy B. Williams
Florida State University:
Raymond E. Waldner
National Oceanic and Atmospheric Administration:
Michael J. Dowgiallo

Accomplishments: The large external isopod parasite *Anilocra* (n. sp.), which is attached under the eye of infested hosts of the *Chromis multilineatus* species (brown chromis) in Puerto Rico and the Virgin Islands and of the *Chromis cyaneus* species (blue chromis) in the Bahamas, South Florida, and the Dominican Republic, was transferred manually to uninfested chromis of both species and to coneys *(Epinephelus ulvus)*. Uninfested brown and blue chromis and coneys were collected at the habitat's storage depth using the fish anesthetic quinaldine. Isopods were collected from infested brown chromis, and both donor and recipient fish were held individually in plastic aquarium bags on the tank rack for no more than two hours before transfers were accomplished. Recipients were marked with acrylic paint, held in contact with adult gravid isopods from donor fish until the isopod attached itself beneath the recipient's eye, and returned to the field after a brief observation period. A total of 40 chromis, 20 from each species, and 16 coneys was experimentally infested. Isopods were retained by 10 of the 11 brown chromis observed after release, but none of the 15 blue chromis or 10 coneys from the experimental group later observed in the field retained their parasites for longer than 24 hours.

Isopods were successfully transferred from infested brown chromis to individuals of both the blue and brown chromis species, and to coneys, but only the brown chromis successfully retained these parasites. Two to five days after transfer, 10 of the 11 experimentally infested brown chromis still retained their transferred isopods. These results do not agree with results obtained in aquarium studies, which showed that coneys were predisposed toward isopod parasites from both chromis species. Brown chromis are apparently susceptible to isopod parasitism, while blue chromis and coneys are not. In addition, intraindividual differences in susceptibility to isopods were not observed among experimentally infested brown chromis.

Publications: Williams, L. B., and E. H. Williams Jr. Nine new species of *Anilocra* (Crustacea: Isopoda: Cymothoidae), external parasites of West Indian coral reef fishes. Proceedings of the Biological Society of Washington 94(4): 1005-1047, 1981.

Williams, E. H., Jr. and L. B. Williams. Field experimental transfers of an external cymothoid isopod, *Anilocra chromis* Williams and Williams, on brown and blue chromis. American Zoologist: 21(4), 1981.

Grizzle, J. M., and E. H. Williams, Jr. Dermal fibroma in a redband parrotfish, *Sparisoma aurofrenatum* (Valenciennes). In preparation.

Feeding and Space-Related Behavior of Three Species of Pomacanthid Fishes

Dates: May 19-26, 1981

Purpose: To investigate the feeding ecology, use of space, and social interactions of three species of angelfishes (Report No. 81-6).

Participants: University of Hawaii:
Ernst S. Reese, Principal Investigator
Thomas F. Hourigan
Frank G. Stanton
Bruce Carlson

University of British Columbia:
Philip Motta

Accomplishments: The relationships between feeding ecology, use of space, and social interactions and the reproductive and social organization of three species of angelfish *(Holacanthus (H.) tricolor, Pomacanthus (P.) arcuatus,* and *Pomacanthus paru)* occurring in the Salt River Canyon were studied. Divers counted the number of fish of each species and then followed individuals to observe feeding behavior and social interactions. Seven *H. tricolor* were marked, released, and observed (Fig. III-12). These individuals spent much of their time concealed under ledges but during feeding forays were observed to ingest algal turf and sponges. Home ranges of *H. tricolor* females overlapped each other, and *H. tricolor* males had larger home ranges than the females. Both *P. arcuatus* and *P. paru* species occurred in equal abundance, and paired members of both species apparently frequent large and relatively exclusive home ranges. Members of both species engage in long periods of nonforaging behavior and spend little time in shelters. *H. tricolor* prefers to eat algae and sponges, while *P. arcuatus* and *P. paru* feed on octacorals and sponges primarily. These differences in shelter requirements and food preferences appear to be the primary determinants of the different social systems observed among these angelfish species.

Experimental Analysis of Ecological Processes that Structure Fish and Invertebrate Reef Communities. II.

Dates: June 26—July 3, 1981

Purpose: Observe artificial reef colonization, establish new artificial reef sites, monitor the density of fish inhabiting artificial and natural reefs, determine the influence of time of day on fish density, and establish food preferences of several species of reef fishes (Report No. 81-7).

Participants: University of Maryland:
Marjorie L. Reaka, Principal Investigator
Cheryl VanZant
Jane Dominguez
Valerie Wesner
Mitchell Craig
Cornell University:
Nancy Wolf
University of Massachusetts:
Eldridge Bermingham
Hydrolab:
Bruce Nyden
University of Rochester:
Stephanie Smith

Accomplishments: In previous missions, five type A reefs suitable for colonization by fish and cryptic invertebrates had been established at 10, 65, and 110 feet. In addition, five reefs suitable only for fishes (type B), five reefs inhabitable only by invertebrates (type C), five reefs suitable for both fish and invertebrates but established during the winter to study seasonal effects (type D), five fish-and-invertebrate reefs partially enclosed by wire mesh cages (type E), and five completely enclosed reefs (type F) had been established at 65 feet. In shallow water (10 feet in depth), invertebrates colonized the experimental reefs more slowly than the natural reefs. At the intermediate depth, invertebrates showed various rates of colonization; at 110 feet, however, all taxa of invertebrates colonized the artificial reefs in numbers equal to or greater than those for the control rubble. These results demonstrate for the first time that invertebrates at relatively shallow depths (110 feet) have high rates of colonization, as has been observed for invertebrates in the deep sea. Type C reefs attracted fewer invertebrate-eating fishes than type A reefs. Fewer invertebrates were found in the winter-established reefs than in those emplaced during the summer, and fewer invertebrates inhabited the caged reefs than the type D or E reefs. Herbivorous fish were more abundant at 10 feet but still prevalent at 65 feet, while the number of piscivorous and invertivorous species increased with depth. No species or frequency differences related to time of day were found.

Figure III-12.—Angelfish being captured for sexing and sizing

Structure in Coral Reef Fish Communities: Predictability of Taxonomic, Morphological, and Behavior Patterns

Dates: July 9-19, 1981

Purpose: Investigate the species composition, trophic structure, organizational morphology and behavior, species diversity, and relative abundance of coral reef fish communities on the East and West walls of Salt River Canyon (Report No. 81-8).

Participants: University of Massachusetts:
John P. Ebersole, Principal Investigator
Les Kaufman
Sarah Lawrence College:
Ray Clarke
Fairleigh Dickinson University,
West Indies Laboratory:
Bill Mahan
Woods Hole Oceanographic Institute:
Rod Catanach

Accomplishments: Two teams of two divers each performed censuses on adjacent walls of Salt River Canyon in census areas approximately 50 meters long and located at a depth of 60 feet. Census activity was continued until the number of new species entering the census area fell to 2 or less per 10-minute interval; each census period lasted about 40 to 50 minutes. Modes of swimming and feeding patterns were observed in planktivores and herbivores, and the frequency and intensity of feeding bouts of the major East Wall herbivores were recorded. The species composition differed markedly along the two canyon walls, but there was no significant difference in trophic structure, i.e., number of piscivores, planktivores, and herbivores, between the two walls. Species abundance patterns were also similar for the two walls. The fish communities of Salt River Canyon apparently follow the rules of species packing predicted by the orderly model of community structure, which assumes that different habitat structures will produce specialized species and low niche overlap within the reef community.

Settlement Age, Early Behaviors, and Visual Attributes of Larva and Post-Larval Fishes

Dates: August 4–11, 1981

Purpose: Investigate the factors responsible for the settlement and recruitment of reef fishes to underwater structures, and the early behaviors of free swimming fish larvae (Report No. 81-9).

Participants: Cornell University:
William N. McFarland, Principal Investigator
Edward B. Brothers
University of Maine:
Nancy M. Kotchian
Mary Washington College:
Wendy Prothro

Accomplishments: Twelve artificial reefs built at depths of 55 to 62 feet were censused at different times of day to determine species composition of colonizing fish (Fig. III–13). Some of the fish recruited to the reef were removed periodically, both to prevent their presence from discouraging subsequent recruits and to permit the age of the recruits to be determined accurately. Within 4 hours of reef construction, 10 of the 12 reefs had recruited up to 6 species of small juvenile to adult fishes; most recruitment occurred during daylight hours. Figure III–14 shows a light used to trap ichthyoplankton.

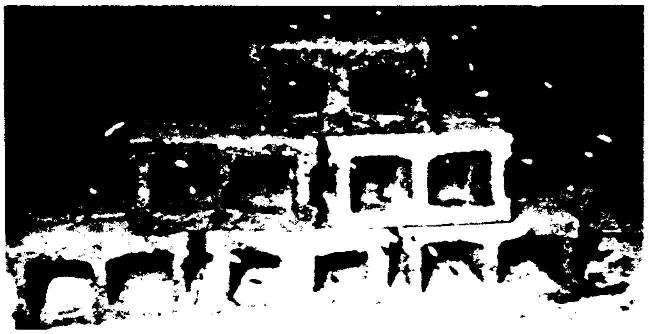


Figure III-13.—Artificial reef in place on reef bottom

Agonistic behavior was common among fish from established reef communities; this behavior apparently aids in establishing feeding territories near the reef. Competition between individual fish for a specific food morsel, however, was not observed among the reef inhabitants, although such competition did occur among fish of several planktivorous species in the water column. Planktivorous fish at a depth of 50 feet were observed to direct their food searches toward the zenith (or lightest photic background), in contrast to the behavior of these species at shallow depths, where they search for food against the darkest photic background. This search strategy was seen in blue and brown chromis, juvenile and adult creole wrasse, and juvenile cottonwick grunts and bogas. The age of the larval fish colonizing the artificial reefs in the vicinity of the habitat are being analyzed by the otolith-aging method and will be reported on at a future date.

Role of Bioluminescence in Communication and Activity Patterns of the Ostracod *Vargula*

Dates: August 25—September 1, 1981

Purpose: Study of the diel patterns of movement of demersal or mero-plankton, observe the movements and luminous display patterns of *Vargula bullae*, survey bioluminescent marine bacteria, and observe the luminescent flashlight fish *(Kryptophaneron alfredi)* (Report No. 81-10).

Participants: University of California, Los Angeles:
James C. Morin, Principal Investigator
Bobette V. Nelson
Richard F. Ambrose
University of Georgia:
Eldridge L. Bermingham

Accomplishments: Samples of mero- and holoplankton species were taken at depths of 30 and 50 feet at dawn, twilight, and various other times during

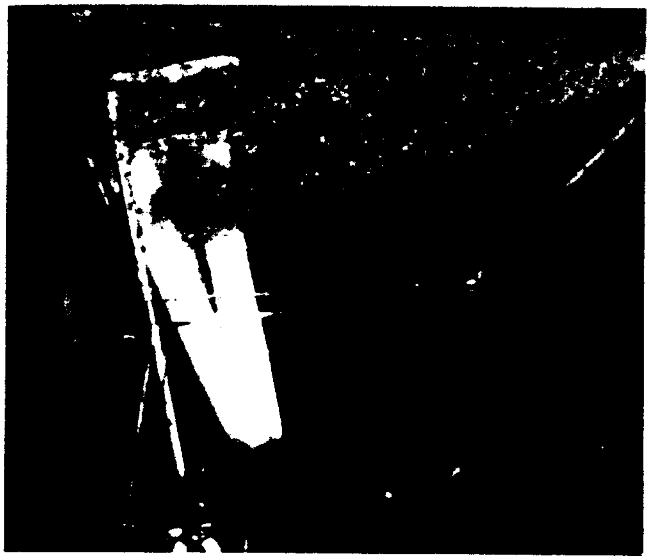


Figure III-14.—Light trap to snare Ichthyoplankton, as seen from *Hydrolab* viewport

Figure III-15.—Divers pushing double mesh plankton net just above the reef

the day and night to obtain information on plankton patchiness, depth effects, and temporal variations (Fig. III-15). Plankton from the samples were counted and recorded, and ostracods were identified by species. Meroplankton appear to migrate from the reef to the water column at twilight, and this migration is progressive as twilight deepens. Migrations of plankton occurred in pulses and followed a species-predictable sequence, which is apparently governed by light level. Migration was particularly pronounced among the cumaceans and ostracods and to a lesser extent among gammarids, isopods, and some mysids. A weaker migration occurred just before dawn. During the daylight hours, holoplankton dominated the water column.

The luminescent ostracods *Vargula bullae* move from the reef into the water column about an hour after sunset. These meroplankton then perform a complicated vertical series of group luminescent displays, which include complex intraspecific signals. The displays are initiated by a bright broad glow lasting more than 10 seconds and are followed within 5 minutes by a communication or calling display initiated by the male. The calling display is then followed by a mating display, involving 10 to 30 short-duration bioluminescent secretions, which become progressively closer together in time. The total vertical line of *Vargula* may be 5 meters long and consist of as many as 20 males, spiralling together vertically. In addition, different clusters of *Vargula* in the same area appear to pulse in synchrony; this area-wide coordination serves intra-species communication purposes and may provide protection against predators. Display patterns among the males are complex and varied; the females do not signal during these periods. Displays are shorter in length and duration in shallower water.

Fish gut and invertebrate samples and material from sediment and water samples were isolated and grown on culture plates. Two days after plating, up to 10 percent of the fish isolates and 5 percent of the sediment cultures consisted of luminescent bacterial colonies. These colonies have been identified preliminarily as *Photobacterium leiognathi* and *Benackea spp.*

One pair of *Kryptophaneron alfredi* was observed on the East Wall at a depth of 60 to 80 feet; one specimen was collected, observed, and analyzed for gut content.

Publication: Morin, J. G., and E. L. Bermingham. Bioluminescent patterns in a tropical ostracod. *Am. Zool.* 20:851, 1981.

Geological Development of Salt River Submarine Canyon

Dates: September 12–14, 1981

Purpose: Describe the Holocene history of Salt River submarine canyon by means of radiocarbon dating (Report No. 81-11).

Participants: Fairleigh Dickinson University, West Indies Laboratory, U.S. Virgin Islands:
Dennis K. Hubbard, Principal Investigator
Jack Westerfield
John Bayes
University of Chicago:
Arnold Miller
University of Rochester:
Ivan Gill
North Dakota Geological Survey:
Randolphe B. Burke

... During this dive, the last of three saturation dives designed to obtain horizontal cores from the East and West Walls of the Canyon, divers obtained seven geological cores. Total core length was 30.6 meters, and the average recovery rate was 44 percent. Hole SR-5, drilled at a depth of 30 meters, was extended from 2.8 meters; carbon dating of material from this core showed that substance from the deepest section was about 5370 years old. Material from this core had slumped from a higher location on the wall, as shown by growth banding patterns. Horizontal reef accretion rates ranged from 0.84 to 1.38 meters per 1000 years, and sedimentation apparently plays a dominant role in reef development. Sedimentation rate in the canyon is also universally proportional to bioerosion rate. In addition, the walls of the canyon are highly porous, and secondary cementation is light.

HAWAIIAN UNDERSEA RESEARCH LABORATORY PROGRAM

The second element in OUR's regional undersea research program is the Hawaiian Undersea Research Laboratory (HURL) program, developed by the University of Hawaii for the Pacific region. Organizations, institutions, and agencies that have actively participated in the design and development of the HURL program include the Hawaii Institute of Geophysics, the Hawaii Institute of Marine Biology, the Bishop Museum, the Waikiki Aquarium, Sea Life Park, the Oceanic Institute, Brigham Young University, the Community Colleges, the State of Hawaii's Fish and Game Department, the National Marine Fisheries, the Hawaiian National Energy Laboratory, the Naval Underseas Center, Look Laboratory, and the Army Corps of Engineers. In addition, individual research missions involve the participation of various interested supporting agencies of the Federal government (see Table III-3).

The HURL program is headquartered at the Makai Research Pier, Makapuu Point, Oahu (Fig. III-16). To support program activities, HURL maintains the two-man submersible *Makali'i* and a Launch Recovery and Transport vehicle (LRT); several other support vessels are available to the program through the Marine Expeditionary Center at Snug Harbor, Hawaii.

The HURL program's principal research focus is directed to the following areas of investigation:

Fisheries, including ecosystem assessment and dynamics, habitat degradation and enhancement, harvesting impact, animal behavior, and gear development;

Pollution, including the manner and physical effects of waste disposal at sea, and the behavioral, biochemical, and physiological responses of marine organisms to pollutants;

Sea floor properties and processes, such as gradients in the water column near the sea floor, sediment transport, and the stability, fluxes, and mineral resources of the water column;

Ocean technology and services, including marine sanctuary monitoring, engineering, equipment testing and recovery, medical and diving physiology, and underwater archaeology.

Research proposals submitted on these or other areas of research are judged on their scientific merit by the HURL program review panel and by peers from the academic, scientific, and government sectors, and proposals showing the greatest scientific merit, conformity with NOAA's overall goals, and cost-effectiveness are selected for funding.

HURL Facilities

Scientists participating in HURL program activities have access to a wide variety of vessels capable of supplying support for dives at various depths and using various diving modes.

Submersible Makali'i. The *Makali'i* is a 5-meter long one-atmosphere submersible with an operating speed of from 1 to 3 knots and a depth range of 380 meters (Fig. III-17). The submersible can accommodate a pilot, an observer/scientist, and a payload of about 200 pounds (95 kilograms). The *Makali'i* is equipped with a still 35-mm camera, a television camera with an audiovideo recorder, lights, and temperature and salinity sensors; current meters, coring devices, water samplers, substrate samplers, and specimen collectors can be operated in connection with the submersible's hydraulic manipulator.

In 1980, the *Makali'i* was completely disassembled as a preliminary step toward ABS certification. After major modifications, including removal of the tail section, relocation of the horizontal thrusters, construction of two syntactic foam blocks for trim stability, installation of a manually operated hydraulic system to permit the manipulator to be jettisoned, and construction of two rebreathers to be used as emergency breathing systems, the submersible successfully completed the ABS Test Dive on July 15, 1981. After a complete review of all documentation, the ABS is expected to issue the *Makali'i* a classification certificate.

Launch Recovery and Transport Vehicle Hiilawe. The LRT *Hiilawe* was specifically designed to transport and deploy the submersible *Makali'i* for ocean research activities (Fig. III-18). The LRT is a wet submersible platform that is controlled by SCUBA divers as it is towed to the site by a surface support vessel. Once on site, the LRT submerges to a depth of about 17 meters to permit the submersible to be landed and secured on its deck, after which the LRT and the submersible resurface. The LRT makes it possible to launch and retrieve the *Makali'i* in the calm waters immediately

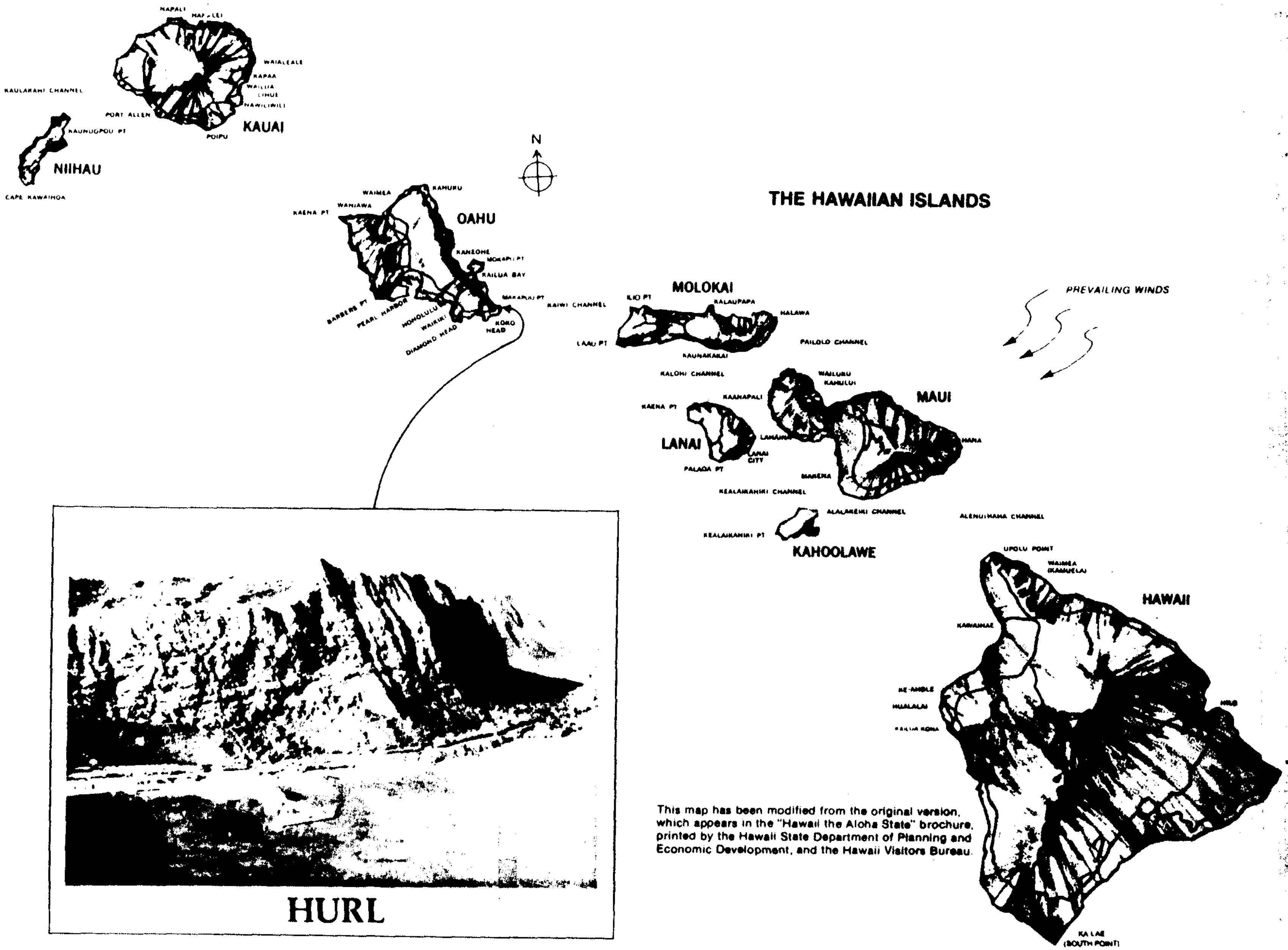
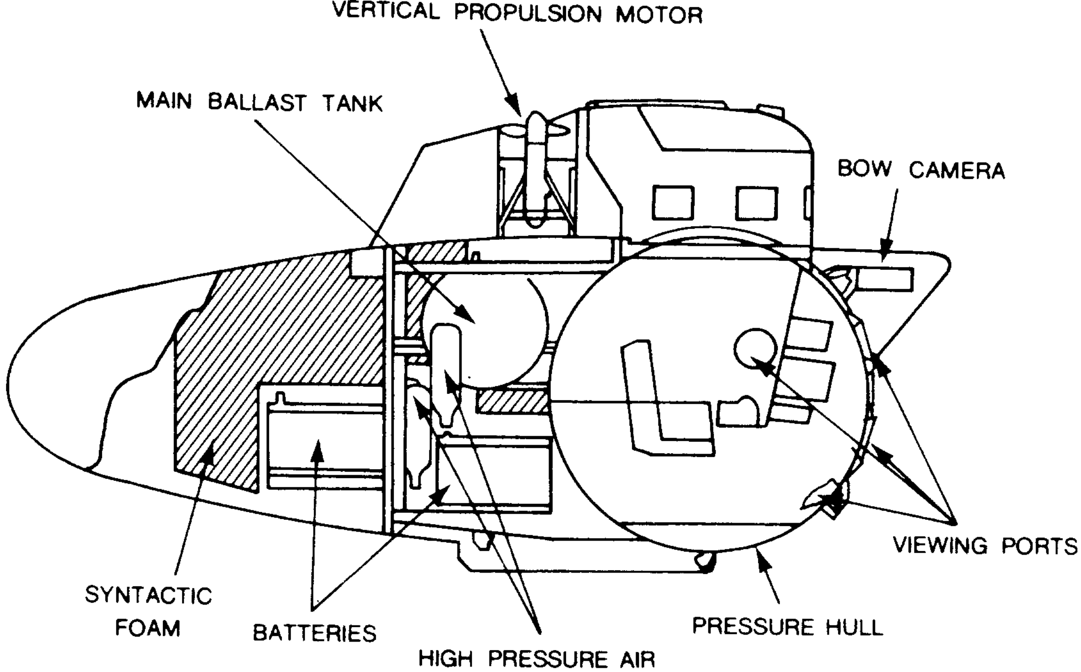


Figure III-16.—HURL program research areas



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

Figure III-17.—Schematic showing *Makali'i*'s specifications

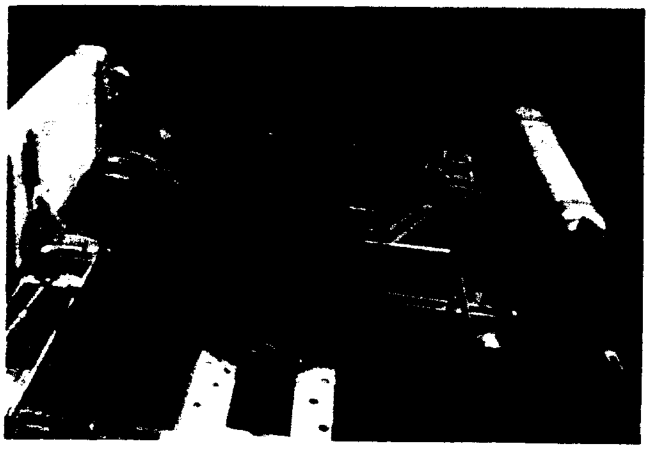


Figure III-18 A.—View of LRT as submersible backs off

Figure III-18 B.—*Makali'i* submerged

below the often turbulent surface water layer. After complete refurbishment, including testing of the buoyancy blocks, overhaul of the gas system, hydrostatic testing of the high-pressure air cylinders, cleaning and calibration of gauges, and installation of emergency decompression equipment, the *Hiilawe* is expected to receive ABS classification as an A-1 barge.

Makai Research Pier Recompression Chamber. In 1981, the recompression chamber at Makai Research Pier was refurbished to prepare it to serve as the on-site treatment facility for HURL crew members and scientist/aquanauts. The chamber will be required to pass the NOAA Diving Safety Board's requirements before it is used to support habitat research programs. Until the Research Pier's chamber meets NOAA's certification requirements, a portable double-lock chamber is available for use by HURL program personnel.

HURL Personnel Training

All diving personnel involved in HURL program activities are certified by the Diving Safety Officer at the University of Hawaii and qualified by the NOAA Diving Safety Coordinator. LRT crew training qualifies personnel as LRT support divers and pilots and as recompression chamber operators. Submersible pilot training, conducted by the senior submersible pilot, includes training in submersible maintenance, repair, piloting, and emergency procedures.

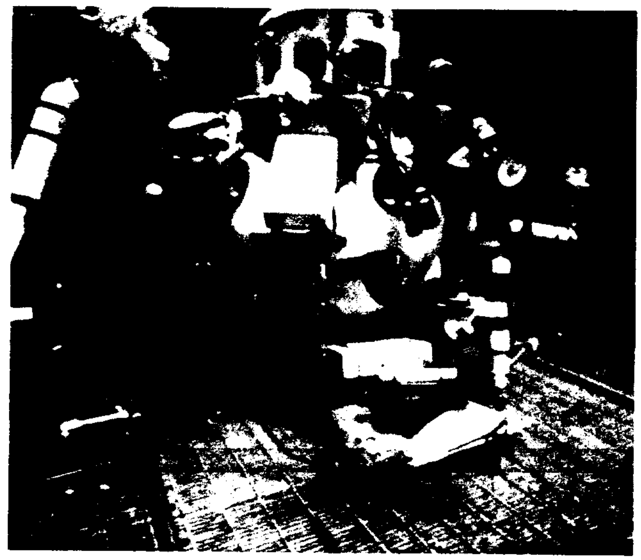


Figure III-18 C.—*Makali'i* on LRT

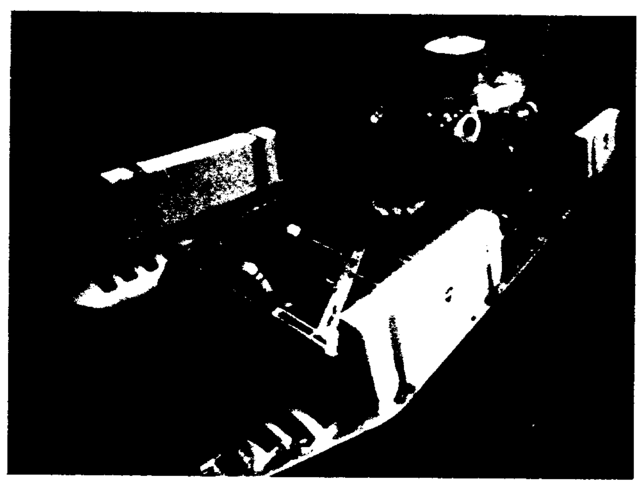


Figure III-18 D.—View of LRT *Hiilawe*

TABLE III-3.

FY 1981 Hawaiian Undersea Research Laboratory Projects

No. of Mission	Month Day Year	Start Time— End Time	Starting Latitude, Ending Latitude; Starting Longitude, Ending Longitude	Purpose, Location, Observer, Organization
81.01	7 13 1981	1400 1700	11 36′ 4″ N 162 6′ 3″ E	Crater Geomorphology Survey Oak Crater Major Robert Couch Defense Nuclear Agency
81.02	7 14 1981	1102 1334	11 36′ 1″ N 162 6′ 2″ E	Crater Geomorphology Survey Oak Crater Major Robert Couch. Defense Nuclear Agency
81.03	7 14 1981	1530 1724	11 36′ 6″ N 162 6′ 7″ E	Crater Geomorphology Survey Oak Crater Major Robert Couch Defense Nuclear Agency
81.04	7 15 1981	1028 1228	11 36′ 4″ N 162 6′ 1″ E	Crater Geomorphology Oak Crater Byron L. Risvet Defense Nuclear Agency
81.05	7 15 1981	1514 1650	11 36′ 4″ N 162 6′ 1″ E	Crater Geomorphology Survey Oak Crater Major Robert Couch Defense Nuclear Agency
81.06	7 16 1981	0933 1151	11 40′ 5″ N 162 11′ 9″ E	Crater Geomorphology Survey KOA Crater Major Robert Couch Defense Nuclear Agency
81.07	7 16 1981	1430 1605	11 38′ 8″ N 162 13′ 0″ E	Benthic, Core Sampling, Dye Dispersion Experiment Lagoon Side, Janet (Enjebi) Rodney Eagle Lawrence Livermore National Laboratory
81.08	7 17 1981	1052 1152	11 38′ 7″ N 162 12′ 7″ E	Benthic Collections, Dye Dispersion Experiment Lagoon Side, Janet (Enjebi) Rodney Eagle Lawrence Livermore National Laboratory
81.09	7 17 1981	1634 1720	11 38′ 7″ N 162 20′ 5″ E	Benthic Collections, Dye Dispersion Experiment Lagoon Side, Runit Rodney Eagle Lawrence Livermore National Laboratory
81.10	7 18 1981	1219 1427	11 21′ 9″ N 162 10′ 7″ E	Survey Fish Populations Ocean Side, James John E. Randall Bishop Museum
81.11	7 18 1981	1545 1735	11 22′ 4″ N 162 10′ 3″ E	Invertebrate/Coral Observation, Collection Ocean Side, James Dennis M. Devaney Bishop Museum
81.12	7 19 1981	1320 1443	11 26′ 9″ N 162 5′ 6″ E	Fish Population Survey Ocean Side, Leroy (Rigili) John E. Randall Bishop Museum
81.13	7 19 1981	1525 1745	11 26′ 9″ N 162 5′ 6″ E	Survey and Collect Coral on Slope Ocean Side, Leroy (Rigili) Dennis M. Devaney Bishop Museum

TABLE III-3.—Continued

FY 1981 Hawaiian Undersea Research Laboratory Projects

No. of Mission	Month Day Year	Start Time—End Time	Starting Latitude, Ending Latitude; Starting Longitude, Ending Longitude	Purpose, Location, Observer, Organization
81.14	7 20 1981	1235 1430	11 20′ 0″ N 162 21′ 0″ E	Fish Collection, Rotonone Experiment Ocean Side, Enewetak John E. Randall Bishop Museum
81.15	7 20 1981	1522 1740	11 29′ 9″ N 162 21′ 0″ E	Benthic Biota Observation/Collection Ocean Side, Enewetak Dennis M. Devaney Bishop Museum
81.16	7 27 1981	1200 1315	11 23′ 3″ N 162 18′ 3″ E	Particulate Radionuclide Distribution Lagoon Station 3, Japan Gary M. McMurtry University of Hawaii
81.17	7 27 1981	1352 1610	11 23′ 3″ N 162 18′ 3″ E	Lagoon Observation Lagoon Side, Japtan Pat Colin Mid-Pacific Research Laboratory
81.18	7 29 1981	1230 1400	11 20′ 7″ N 162 16′ 9″ E	Particulate Radionuclide Distribution Lagoon Station 2, Runit Gary M. McMurtry University of Hawaii
81.19	7 29 1981	1426 1612	11 30′ 7″ N 162 16 9″ E	Lagoon Observation Lagoon Station 2, Runit Pat Colin Mid-Pacific Research Laboratory
81.20	7 31 1981	0946 1130	11 22′ 3″ N 162 20′ 6″ E	Dome Placement & Sampling Test Lagoon Side, Enewetak John Harrison Mid-Pacific Research Laboratory
81.21	7 31 1981	1617 1750	11 22′ 1″ N 162 20′ 3″ E	Dome Emplacement & Sampling Test Lagoon Side, Enewetak John Harrison Mid-Pacific Research Laboratory
81.22	8 1 1981	0945 1052	11 22′ 4″ N 162 20′ 3″ E	Dome Emplacement, Sampling Test Lagoon Side, Enewetak John Harrison Mid-Pacific Research Laboratory
81.23	8 1 1981	1134 1307	11 22′ 1″ N 162 20′ 4″ E	Dome Emplacement, Sampling Test Lagoon Side, Enewetak John Harrison Mid-Pacific Research Laboratory
81.24	8 1 1981	1634 1800	11 22′ 1″ N 162 20′ 4″ E	Lagoon Side, Enewetak John Harrison Mid-Pacific Research Laboratory
81.25	8 3 1981	1000 1200	11 20′ 1″ N 162 19′ 4″ E	Outer Reef Face Geomorphology Channel, Enewetak Pat Colin Mid-Pacific Research Laboratory
81.26	8 22 1981	1447 1700	11 20′ 55″ N 162 21′ 0″ E	Encrusting Invertebrate Distribution Ocean Side, Enewetak Thomas H. Suchanek West Indies Lab., St. Croix

TABLE III-3.—Continued

FY 1981 Hawaiian Undersea Research Laboratory Projects

No. of Mission	Month Day Year	Start Time— End Time	Starting Latitude, Ending Latitude; Starting Longitude, Ending Longitude				Purpose, Location, Observer, Organization
81.27	8 24 1981	0853 1148	11 162	22′ 20′	9″ 21″	N E	Dome Sampling Lagoon Side, Enewetak John Harrison Mid-Pacific Research Laboratory
81.28	8 24 1981	1615 1843	11 162	22′ 20′	9″ 21″	N E	Callianassa Bioturbaton Lagoon Side, Enewetak Thomas H. Suchanek West Indies Lab., St. Croix
81.29	8 25 1981	0900 1018	11 162	22′ 20′	9″ 21″	N E	Dome Sampling Lagoon Side, Enewetak John Harrison Mid-Pacific Research Laboratory
81.30	8 26 1981	0900 1115	11 162	22′ 20′	9″ 21″	N E	Dome Sampling Lagoon Side, Enewetak John Harrison Mid-Pacific Research Laboratory
81.31	8 26 1981	1605 1715	11 162	22′ 20′	21″ 21″	N E	Dome Sampling Lagoon Side, Enewetak Terry Kerby (for John Harrison) Hawaii Undersea Research Laboratory
81.32	8 27 1981	0919 1237	11 162	22′ 20′	9″ 21″	N E	Callianassa Bioturbation Lagoon Side, Enewetak Thomas H. Suchanek West Indies Lab., St. Croix
81.33	8 30 1981	0930 1343	11 162	26′ 24′	8″ 14″	N E	Depth Effect on Fish Distribution Ocean Side, Japtan Ron E. Thresher University of Sidney
81.34	8 31 1981	0923 1145	11 162	26′ 24′	39″ 20″	N E	Encrusting Invertebrate Distribution Ocean Side, Japtan Thomas H. Suchanek West Indies Laboratory, St. Croix
81.35	9 1 1981	1007 1207	11 162	30′ 16′	42″ 12″	N E	Lagoon Side, Runit John Harrison Mid-Pacific Marine Laboratory
81.36	9 1 1981	1509 1734	11 162	30′ 16′	42″ 12″	N E	Calnianassa Bioturbation Lagoon Side, Runit Thomas H. Suchanek West Indies Lab., St. Croix
81.37	9 2 1981	1020 1214	11 162	30′ 16′	42″ 12″	N E	Pilot Training, Dome Sampling Lagoon Side, Runit Terry Kerby (for John Harrison) Mid-Pacific Marine Laboratory
81.38	9 3 1981	1035 1405	11 162	20′ 16′	0″ 6″	N E	Geologic Features of Channel Channel, Enewetak Dan Self University of Austin
81.39	9 4 1981	1004 1245	11 162	21′ 21′	31″ 33″	N E	Deep Reef Coral Communities Ocean Side, Enewetak J. Wellington University of California, Santa Cruz

TABLE III-3.—Continued

FY 1981 Hawaiian Undersea Research Laboratory Projects

No. of Mission	Month Day Year	Start Time— End Time	Starting Latitude, Ending Latitude; Starting Longitude, Ending Longitude	Purpose, Location, Observer, Organization
81.40	9 5 1981	0954 1230	11 23′ 45″ N 162 23′ 00″ E	Deep Reef Coral Communities Ocean Side, Medren Ray Highsmith University of Washington
81.41	9 5 1981	1415 1630	11 24′ 18″ N 162 21′ 00″ E	Deep Water Halimeda Lagoon Side, Medren Lewellyn Hillis-Colenivaux Ohio State University
81.42	9 7 1981	1030 1500	11 22′ 24″ N 162 10′ 00″ E	Deep Water Halimeda Lagoon Side, Medren Lewellyn Hillis-Colenivaux Ohio State University
81.43	9 8 1981	1005 1330	11 23′ 21″ N 162 08′ 49″ E	Deep Reef Coral Communities Ocean Side, Keith (Kidrenen) Jerry Wellington University of California, Santa Cruz
81.44	9 9 1981	0945 1130	11 20′ 14″ N 162 19′ 54″ E	Rotonone Fish Experiment Ocean Side, Enewetak Pat Colin Mid-Pacific Research Laboratory
81.45	9 9 1981	1300 1530	11 20′ 18″ N 162 19′ 51″ E	Deep Reef Coral Communities Ocean Side, Enewetak Ray Highsmith University of Washington
81.46	9 11 1981	1040 1435	11 13′ 00″ N 162 23′ 00″ E	Deep Water Halimeda Ocean Side, Runit Lewellyn Hilles-Colenivaux Ohio State University
81.47	9 12 1981	1015 1230	11 29′ 9″ N 162 24′ 12″ E	Deep Reef Coral Communities Ocean Side, Bruce J. Wellington University of California, Santa Cruz
81.48	9 11 1981	1410 1530	11 30′ 57″ N 162 23′ 3″ E	Deep Reef Coral Communities Ocean Side, Bruce (Boko/Muhjor) J. Wellington University of California, Santa Cruz
81.49	9 15 1981	1104 1304	11 22′ 27″ N 162 22′ 18″ E	Ocean Side, Bokandrotok John Harrison Mid-Pacific Research Laboratory
81.50	9 16 1981	1441 1645	11 22′ 15″ N 162 22′ 15″ E	Deep Reef Coral Communities Ocean Side, Bokandrotok Ray Highsmith University of Washington
81.51	9 16 1981	0937 1115	11 36′ 3″ N 162 5′ 6″ E	Crater Investigations Oak Crater Byron L. Risvet Defense Nuclear Agency
81.52	9 16 1981	1058 1410	11 36′ 21″ N 162 6′ 9″ E	Crater Investigations Oak Crater Byron L. Risvet Defense Nuclear Agency

Enewetak Atoll Project

After the ABS Test Dive, the *Makali'i* and *Hiilawe* were transported 2,500 miles to Enewetak Atoll in the Marshall Islands to support a series of research dives coordinated by the Mid-Pacific Research Laboratory (MPRL). A total of 52 dives was made in the deep lagoon and outer reef slopes in the period from July to September 1981; maximum dive depth was 360 meters. Participating scientists were affiliated with the MPRL, the Defense Nuclear Agency, the Lawrence Livermore National Laboratory, the Bishop Museum in Honolulu, the University of Hawaii, the University of Texas (Austin), the West Indies Laboratory of Fairleigh Dickinson University, the University of Sydney (Australia), the University of Washington, Ohio State University, and the University of California (Santa Cruz). The supporting agencies included NOAA's Office of Undersea Research, the Defense Nuclear Agency, and the Department of Energy.

The Enewetak Atoll Project's principal goals were to study the benthic ecosystems of the atoll at depths from 130 to 1200 feet and particularly to assess the effects of nuclear testing on the recovery rates of organisms living in the nuclear craters, the rates of sediment movement by burrowing invertebrates, the flux of radionuclides in lagoon sediments, and to map the contours of the Oak Crater. In addition, fishery resources on the seaward slopes and the dynamics of atoll formation and erosion were investigated. In the course of these dives, the submersible's hydraulic manipulator was used to collect samples of outer face biota, and more than 2,000 photographs and 100 hours of video tape recordings were made.

Summary of the Enewetak Project's Results. The major finding of the Atoll Submersible Project was the discovery that the underwater craters created by nuclear testing contained large populations of irregular sea urchins and buried invertebrates (callianassids), even at the bottom of the craters. These craters were previously believed to be incapable of supporting life. This breakthrough discovery confirms that bioturbation is all pervasive in the atoll's marine environment and plays a central role in remobilizing the radionuclides from the sediment to the water column. All previous data concerning the distribution of radionuclides in and around these underwater craters will have to be reevaluated in light of these new findings.

Other results of this dive series were the discovery of large scleractinian coral colonies to depths as great as 90 meters and the presence of macroalgae to depths of 145 meters. Highly polished grooves several yards in width were seen at 300 meters; these apparently operate as chutes to transport sediment into deep water.

The results of the Enewetak Atoll Project have attracted national attention and will be presented at a national scientific meeting in 1982. In addition, individual scientist/participants are preparing manuscripts on the various aspects of the mission.

Western Regional Undersea Laboratory Program

On Catalina Island, 25 miles off the shore from Los Angeles, California, the third part of OUR's Regional Undersea Laboratory Program is currently being developed. The program, called the Western Regional Undersea Laboratory (WRUL) program, is directed by the University of Southern California (USC) and located at its Catalina Marine Science Center (CMSC). The WRUL program will form an integral part of USC's multidisciplinary marine science program and will emphasize research in temperate waters using habitat-based saturation diving techniques and capabilities.

Santa Catalina Island is ideally located and equipped to serve as the base for WRUL program activities (Fig. III-19). The Island has well-established transportation, communication, and emergency facilities, and the Catalina Marine Science Center, which houses the program, has laboratory and administration buildings, a dormitory-apartment-cafeteria complex, and a complete waterfront facility, including a new pier and dock, a dockside crane, a day-night heliport, and a multiplace hyperbaric chamber.

The seafloor habitat system, which is currently in the design stage, will be constructed with four principal factors in mind:

- Safety (ABS certification)
- Cost-effectiveness
- Operational simplicity
- Versatility and maximum utilization of available facilities

The basic habitat will be a double-lock chamber capable of both bottom and surface decompression (Fig. III-20). It is designed to be mobile (i.e., towable), with submersible-type ballast tanks and a haul-down sys-

Figure III-19.—Site on Catalina Island near WRUL program headquarters

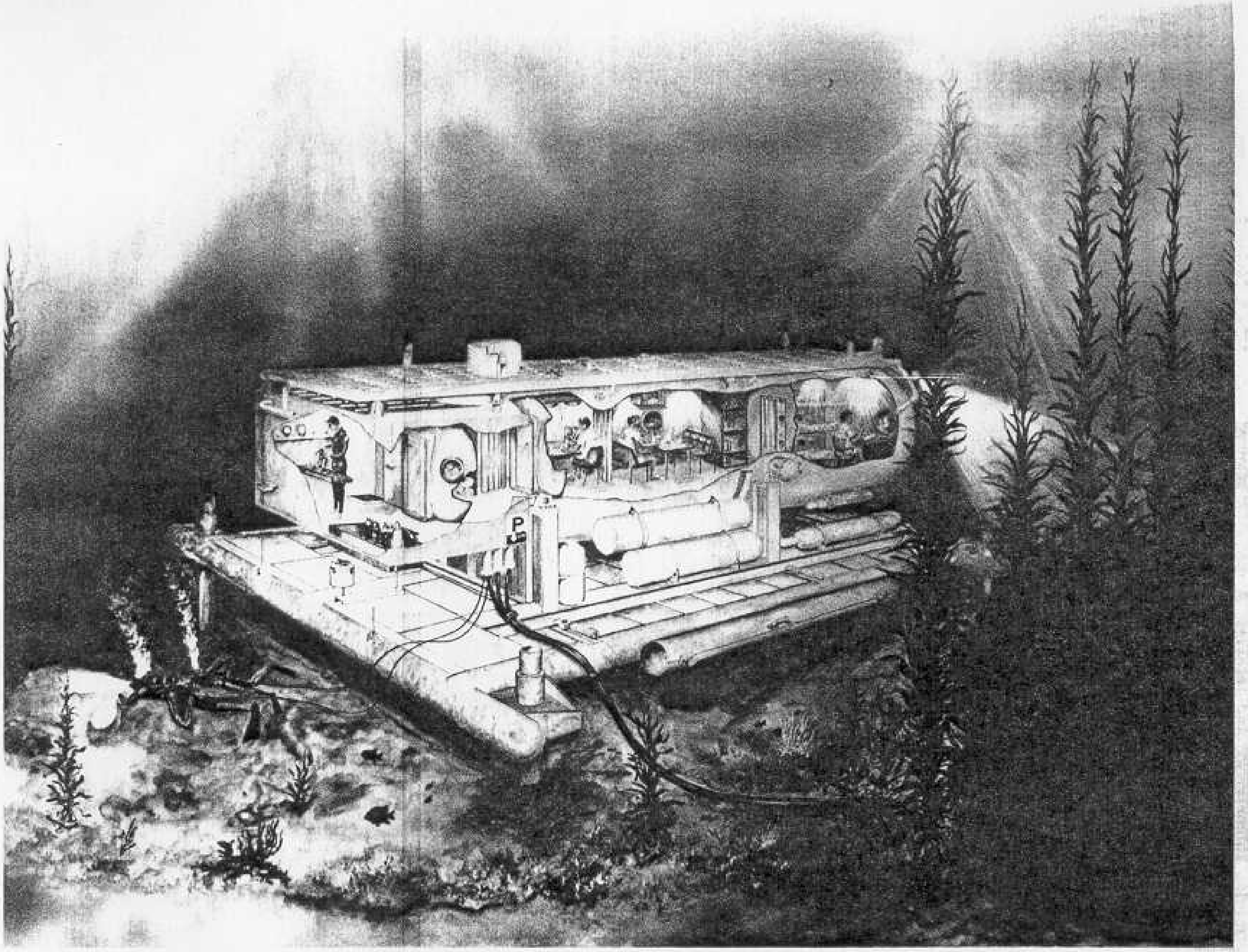


Figure III-20.—Cutaway view of WRUL habitat, currently in design stage tem for routing submergence and recovery. A movable and negatively buoyant base-plate will be implanted on the seafloor at the research site for hauling down and anchoring the habitat. Water, electric power, communications, sewage disposal, heat, and breathing gas will be provided via umbilicals either from shore or a surface support unit. On shore, an operations room will monitor all critical functions and parameters of the operation, with override capability on life-essential functions only. Actual control of all habitat systems and activities within the habitat will be on board, with absolutely no outside or external control. The breathing air mixture will be nitrogen oxygen (NITROX), which will allow the saturation storage depth to vary from 60 to 120 feet of seawater and permit the divers to make excursions to depths greater than 200 fsw. If an aquanaut develops decompression sickness, he or she can be treated right in the habitat. Since the system is a double-lock chamber with an internal pressure capability of 232 fsw, it permits the use of hyperbaric treatment tables. Attached to the system's entrance lock will be a diver's "wet porch," providing an entrance to the sea, along with a "wet lab" sorting tray for collected specimens. Because the habitat will be based in temperate waters, there is the possibility that an aquanaut could acquire an increasing body heat deficit after making repetitive dives in cold water; a diver rewarming tub is therefore also included in the wet porch area.

Inside the main lock, there are sleeping and galley accommodations for six aquanauts, with shower and bathroom facilities in the entrance lock. The main lock will serve not only as an apartment for the aquanauts but will house a marine laboratory. It will have two large 24-inch in diameter viewports, with a number of smaller 8-inch ports. The larger ports will have trays positioned on the water side on which experiments can be set up to be viewed from the inside. An area will be set aside as a dry lab, with appropriate scientific equipment such as microscope balances, dissection equipment, and whatever else is needed. Connected to shore by hardwire will be an onboard computer terminal permitting real-time analysis of data, such as cataloging of samples/specimens and plotting of trend graphs, which should be particularly useful in determining whether the data or approach taken in an experiment is fruitful. Data analysis on the spot will allow experiments or methods not considered appropriate to be modified quickly. In addition, the computer can be used administratively to run the habitat system by monitoring vital parameters, setting off alarms in situations dangerous to the aquanaut (i.e., fire, low PO_2), keeping track of dive profiles and physiological data for each of the aquanauts, and innumerable other tasks.

Once in the water, the aquanaut/scientists will be allowed to work not only in the near vicinity of the habitat itself but at distances far greater than previously allowed under NOAA Diving Regulations, this feat will be accomplished by using diver way-stations. A way-station is actually an open diving bell that consists of a heavy metal base with a plastic bubble or dome mounted above by metal struts. The bubble is continuously filled with NITROX from the main habitat, allowing the divers to enter the station, remove their masks, talk, rest, refill their tanks from a high-pressure air hose, and communicate with the main habitat or the operations base on shore if need be. Breathing gas, power, and communications will be supplied from the main habitat via an umbilical. In an emergency, the way-station could also be used as a diver refuge.

The Marine Science Center operates a double-lock hyperbaric chamber for physiological research, training, and hyperbaric therapy for diving accidents. The chamber is on-call at all times, with a five-man crew on standby. This operation will be available for use by the WRUL program. An intermediate chamber will be attached to the existing chamber to act as the entrance lock for the habitat's personnel transfer capsule (PTC). The PTC acts as a life boat for the habitat and is placed nearby on the seafloor. In the event of an emergency requiring that the habitat be evacuated, the aquanauts would swim to the PTC, climb inside, and rise to the surface, still at the ambient pressure of the habitat. From the surface, the PTC would be transported to and locked onto the chamber on shore, allowing the aquanauts to carry out normal decompression inside the larger chamber.

The program anticipates accommodating 12 to 16 saturation missions per year, each lasting from 7 to 10 days. Construction is planned to begin in the late fall of 1982, with the first mission scheduled for late fall, 1984.

WRUL Research Opportunities

The WRUL program site at Catalina Island offers several unique opportunities for undersea research (Fig. III–21). For the first time, WRUL habitat research projects will permit underwater scientists to explore the flora, fauna, and geology of temperate, rather than tropical, waters using habitat-based saturation diving techniques. In addition, WRUL aquanauts will have the advantage of working in a multi-disciplinary atmosphere devoted exclusively to marine science. Further, diver/scientists will be able to capitalize on the scientifically important but inadequately explored rocky substrate, beds of giant kelp, and surrounding soft bottom unique to the nearshore west coast temperate underwater environment.

The projected WRUL habitat and program are ideally suited to the scientific exploitation of one of the world's major marine biomes. The underwater laboratory will be situated within easy reach of the lush bed of giant kelp that dominates most of California's nearshore areas. In addition to the giant kelp *(Macrocystis)* beds, the spawning ground of one of the largest squid *(Loligo*

Figure III-21 A.—Dome used in oxygen experimentation

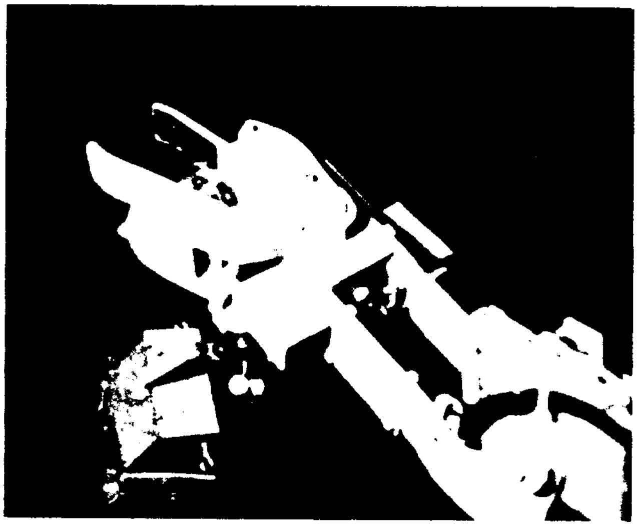


Figure III-21 B.—Submersible arm taking seafloor sample

opalescens) and a bed of the brown luminarion alga *Pelagophycus porra* are also located within close vicinity of the prospective site.

Examples of the types of research projects that will be conducted from the WRUL habitat are described below; these are grouped into three of the research categories deemed by NOAA (see Section I) as most compatible with the Agency's overall goals: 1) marine fisheries, 2) marine pollution, and 3) seafloor properties and processes. All of the research projects described are designed to utilize the WRUL program's distinctive features to the full: a subsea laboratory, temper-

Figure III-21 C.—Manipulator taking seafloor samples

ate waters, and saturation diving techniques. Figure III-22 shows NOAA divers engaged in research activities near Catalina Island.

Marine Fisheries. Several specific areas of fishery research that are vital to nearshore resource management have been proposed as future WRUL projects. These include studies on the ecology, feeding behavior, mortality, predation, and reproductive behavior of the California spring lobster *(Panulirus interruptus)*, one of California's more lucrative marine crops.

Similar information is needed about the abalone *(Italiotis* spp.), another important marine resource; comprehensive data on the seasonality, growth rates, feeding and reproductive behavior, and migratory habits of this large, reef-oriented gastropod mollusk can only be obtained by observing these creatures in their natural habitats over long periods.

Figure III-22 A.—Giant kelp bed near WRUL site

Figure III-22 B.—Divers working on bottom placing algae transect

Results of *in-situ* research into the schooling behavior, reproductive strategies, and responses to stimuli, attractants, and fishing methods of the squid *Loligo opalescens* have direct economic implications as well as significance for neurological research, since these squid have long been important in studies of the responses of giant nerve axons.

Marine Pollution. The seafloor habitat-trained aquanauts/saturation diving combination that is the hallmark of OUR's regional undersea research program is also well suited to studies of the localized effects of pollutants on bottom-dwelling organisms and bottom sediments. In addition, WRUL scientists could:

- develop and test new methods of sampling pollution-impacted areas
- observe and modify surface-oriented gear
- study the soft-bottom biological communities to identify indicators of the relative health of the bottom.

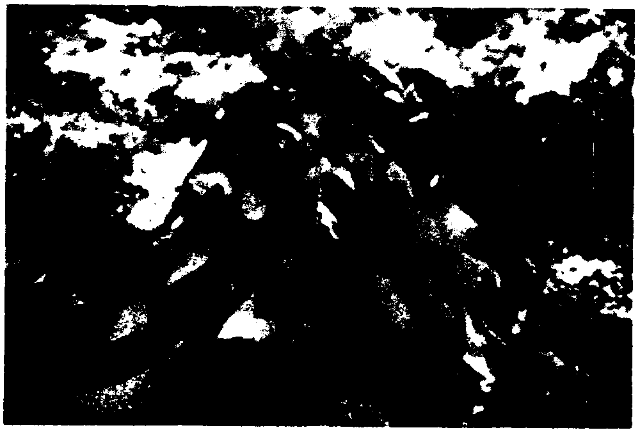


Figure III-22 C.—Shallow-water kelp

Seafloor Properties and Processes. The great majority of seafloor research has historically been conducted from surface ships, although deep-diving submersible vehicles have recently been used to make short-term sampling forays. The scientific advantages offered by the long-term, single-site, habitat-based saturation capabilities of the WRUL program will permit such nearshore seafloor processes as scouring, biogenic activity, bioturbation, soil accumulation on newly exposed surfaces, and the chemical properties of substrates and their effects on biological activities to be studied at first hand.

Other WRUL Research Plans

In addition to research within the broad categories defined by NOAA, the Santa Catalina location of the future WRUL habitat offers special advantages for studies in human physiology, the effects of the habitat itself on the surrounding natural environment, oceanography, nautical archaeology, and marine geology (Fig. III–22). An excellent example of the kind of site/facility/research technique compatibility that will be possible once the WRUL habitat becomes operational in 1984 is the graduate-level course in Methods in Underwater Archaeology taught in 1980 at the Catalina Marine Science Center. This course outlined the advantages of saturation diving techniques as an archaeological tool; such preexpedition training greatly reduces the amount of valuable excavation time scientists/aquanauts would have to spend in on-site training. The underwater landslide site of the WRUL habitat is known to be rich in Gabrielino Indian artifacts because it was once the dwelling area of these Indians, and aquanaut-archeologist teams are expected to use the WRUL habitat when it is operational.

A planned geological research project similarly designed to take specific advantage of the WRUL site and facility involves *in-situ* observation of the feeding and excretory behavior of the California sheepbend *(Semicossyphus pulcher)*, which feeds on echinoderms and is believed to play an important role in the formation of the shelly debris sediment found in the vicinity of Santa Catalina Island.

These brief descriptions of projected WRUL missions are intended to indicate the breadth and diversity of the types of research and the scientific disciplines that NOAA's regional programs encourage and support. Scientists interested in using the WRUL facilities, or those of NOAA's other regional programs, are requested to submit proposals describing their research plans. All proposals are first evaluated for technical and logistical feasibility by the Science Director of the regional program, and are then reviewed for scientific merit by the Peer Review Board. Proposals accepted by the Board are then scheduled by the regional program director. This quality control process ensures that NOAA's Regional Undersea Laboratories program continues to facilitate and make possible scientifically vital and valuable research in the underwater sciences.

Southeastern Undersea Research Facility Program

In July 1980, the Southeastern Undersea Research Facility (SURF) was initiated under the terms of a cooperative agreement signed by NOAA's Office of Undersea Research, the University of North Carolina at Wilmington (UNC-W), and the Southeastern Consortium for Undersea Research Efforts (SECURE). The SURF program thus forms the fourth part of OUR's regional underwater research program. The SECURE consortium, which is composed of academic organizations, research institutions, and government agencies from Virginia, North Carolina, South Carolina, and Georgia, was established to develop a versatile undersea research diving system capable of supporting a wide range of underwater research projects on the Continental Shelf. The principal areas of research that will be performed by SURF include marine fisheries, seafloor processes, petroleum pollution, ocean dumping, dredge spoil disposal, and diving medicine and safety.

Research Vessel Seahawk

To prepare for the initiation of research missions in the spring of 1982, the SURF program's major emphasis in 1981 was the conversion of the UNC-W's 79-foot long shrimp trawler *Lady Ellen* into the modern, well-equipped, and versatile *Research Vessel (R/V) Seahawk* (Fig. III-23). Renovation of the vessel involved making room for a research laboratory, scientists' berths, and a large galley. The pilot house was elevated 4 to 5 feet to allow better all-around visibility and to provide more space below deck. The trawler's former fish hold has been converted to a space large enough to house a deck decompression chamber and a hyperbaric room. Specifications for the *Seahawk* and a schematic of her deck arrangement are shown in Figures III-24 and 25.

The *Seahawk* will be able to support a total crew and research group of 12 on missions lasting from 3 to 5 days. Divers will be able to choose SCUBA, surface-supplied air, or mixed gas diving modes, as appropriate for the type of research being performed. The *Seahawk* will serve as the base for divers at depths as great as 300 fsw; the vessel is equipped with two Mako high-pressure air compressors for diving support and an additional low-pressure air system to supply the ship's needs. An open diving bell that permits divers to sit comfortably in the bell without their helmets while being raised or lowered in the water will contribute to diver safety and to the vessel's research capabilities (Fig. III-26). The bell is equipped with a surface-controlled underwater zoom television camera for monitoring the divers and their research activities. The *R/V Seahawk* is scheduled to undergo sea trials in March 1982.

Figure III-23 A.—*R/V Seahawk*

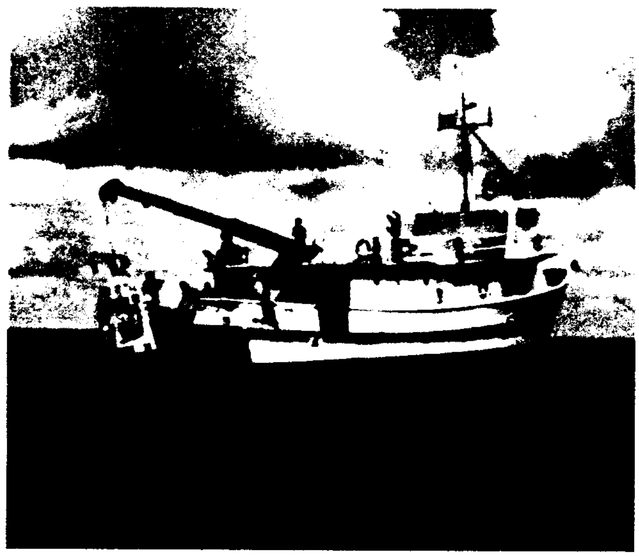


Figure III-23 B.—Bell being lowered

SURF Personnel Training and Staff Development

To ensure the success of future SURF program activities and the *R/V Seahawk*'s research missions, several staff members were hired during 1981. In addition, the University of North Carolina has initiated a pro-

SPECIFICATIONS -- R/V SEAHAWK

Built:	1977 Quality Marine Inc. Bayou La Batre, AL	Refitted:	1981 Southeastern Undersea Research Facility Wilmington, NC

Hull:	Steel	Cruising Speed:	9 knots
Length (overall):	79.1 ft.	Range:	3,000 NM
Breadth (maximum):	22.1 ft.	Power:	540 bhp
Draft (design):	8.25 ft.	Fuel #2 Diesel:	10,000 gals.
Displacement (DL):	174 tons		
Freshwater:	4,700 gal.	Fuel Consumption:	26 gal. /hr.
		Endurance:	14 days

ENGINEERING SYSTEMS

Propulsion:		Electrical:	
Type:	Geared diesel	Generators:	1 - 80 kW Diesel Caterpillar 3208 1 - 20 kW Diesel Gm 2-71
Engines:	2-Cummins Nt-855-M		
Horsepower:	270 bhp (each)		
Reduction:	6:1		
Gear:	Twin disc Mg-514	Service:	208 VAC Three-phase 208 VAC Single-phase 120 VAC Single-phase
Propeller:	2-4 blade, 4' dia.		

ELECTRONICS SYSTEM

Communications:	Navigation:
2 - VHF FM Transceivers	Radar:
1 - SSB Transceiver	2-Loran C-DECCA
1 - EPIRB	Recording fathometer
	Magnetic compass

ANCHORING/MOORING

Bow:		Stern:	
Anchor:	300 lb. LWT	Anchors:	2-200 lb. LWT
Winch:	Gearmatic hydraulic	Winches:	Gearmatic hydraulic
Capacity:	1,500 ft., 1/2-in. wire rope	Capacity:	790 ft., 1/2-in. wire rope

Figure III-24.—*Seahawk* specifications

DECK MACHINERY

Bell Handling:	Grove crane	Boom:	Small boat launch
Capacity:	1,800 lbs. 30'		
Drive:	Hydraulic	Type:	Fixed length
Stern Clearance:	14 ft.	Capacity:	1,000 lbs.
		Location:	Boat Deck

POLLUTION CONTROL

Marine Sanitation Device: Microphor
Type II
"Flow-through treatment"

SAFETY EQUIPMENT

Utility: Support boat	Liferafts: 2 - 15 man
Type: Zodiac - Mark II GR	Service: Ocean USCG
Length: 13 ft.	Approved with hydrostatic release
Capacity: 6 men/1,540 lbs.	
Propulsion/HP: 40 HP	

SCIENTIFIC LABORATORY AND EQUIPMENT

Wet laboratory with 2 sinks, fresh and seawater taps
Refrigerator and freezer
Instruments and equipment: STD, bathythermograph, current meters, plankton nets, fathometer, grab sampler, corers, small hand winches, side scan sonar

ACCOMMODATIONS

Berthing:	12, (8 crew, 4 researchers)
Double staterooms:	4
Four-man berthing space:	1
Heads with shower:	2

DIVING SYSTEM

HP Air Compressors:	2 - MAKO Model 4,500, low noise, 9.2 CFM compressor/purification systems
HP Air Storage Capacity:	13,800 SCF in 4 banks; 60 HP cylinders
HP O_2 Storage Capacity:	5,040 SCF in 1 bank; 21 HP cylinders

Figure III-24.—*Seahawk* specifications—Continued

UNISUIT in sizes L(1), M(2) and S(1)
(includes: suit inflation bottle, gloves and weights)

AGA DIVATOR Model 324 - 4 units
(includes: cylinder assembly, harness assembly,

regulator assembly, SPM-1 full face mask or breathing valve adaptable for SCUBA or surface-supplied gas).

Diving bell:
(includes acrylic dome, communications, self-contained breathing gas cylinders with masks for 2 divers, and ballast)

Diver Decompression Chamber:
Specifications: rated design 133 psig., (equiv. 300') includes CO_2 Scrubber, BIBS
Outside: Height 6'1", Length 4'8"
Inside: Entry Lock - Diameter 50", Length 4'8"
Main Lock - Diameter 60", Length 8'11"
Medical Lock - Diameter 12", Length 1'6"

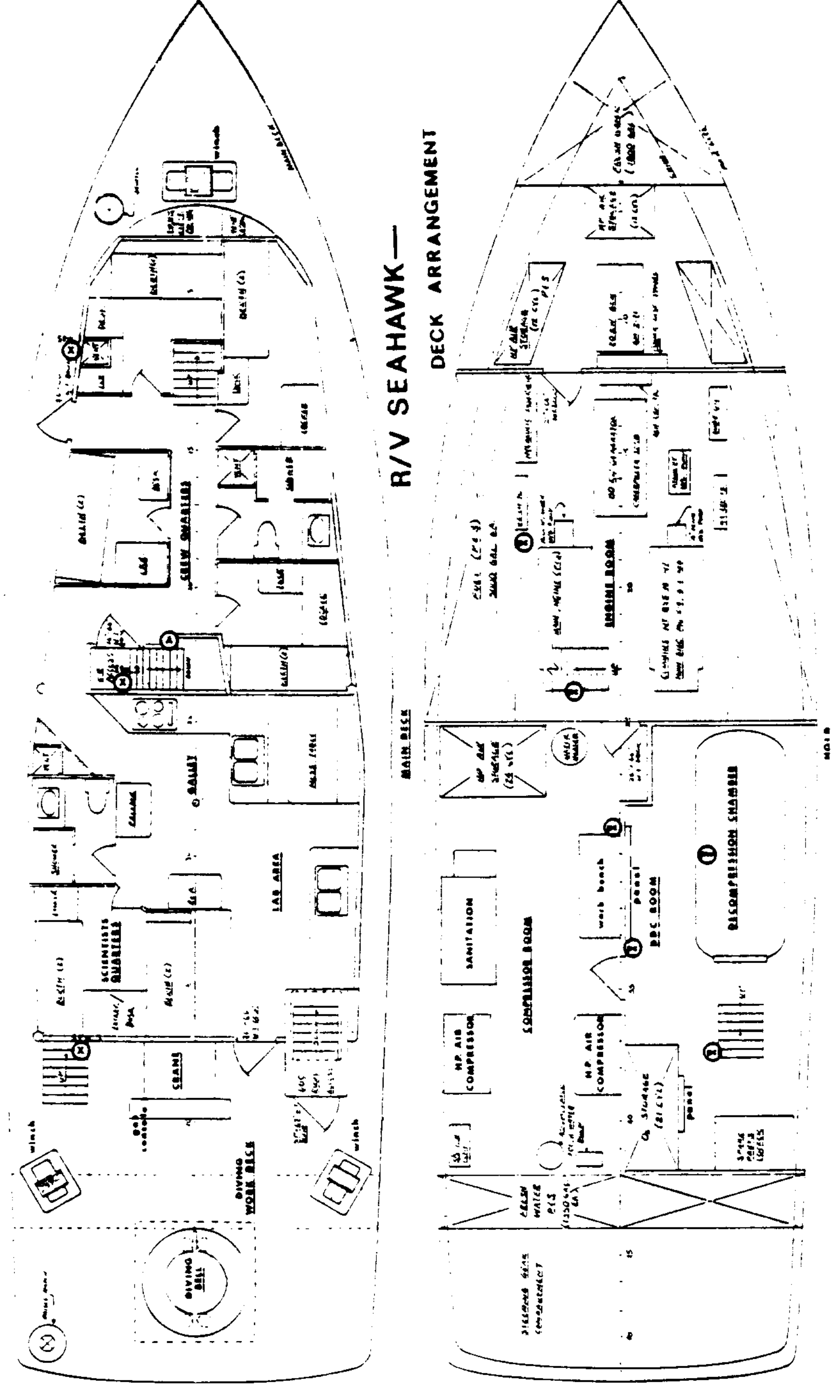
Figure III-24.—*Seahawk* specifications—Continued

gram in diver training at the Wilmington campus. The professional staff from the SURF program teaches the course, which enrolls selected UNC-W students who are experienced SCUBA divers. The training program has two objectives: providing teaching experience for the SURF staff and developing a group of qualified diving technicians to serve as alternate or back-up tenders on research missions.

SURF Research Missions and Proposals

The *R/V Seahawk*'s home port will be the Port of Wilmington, and the SURF program's operations center is located at the same port. The Port Authority has provided dockside space to be used for quarters for visiting scientists and their staffs. The program has actively solicited proposals for underwater research projects from investigators who are planning studies of applied research problems on the Continental Shelf, and seven research missions have been scheduled for 1982. Proposals are solicited on both the national and regional levels and will be evaluated by a scientific review panel made up of personnel from research, academic, government, and private organizations.

Dr. Gilbert Bane, Director of the SURF Project, has also prepared a slide and poster show explaining the program and acquainting scientists with its research possibilities. In addition, Dr. Bane presented information on SURF activities at scientific meetings in Boston, Miami, Tampa, Raleigh, Galveston, Charleston, and Columbia, South Carolina. The refitting of the *R/V Seahawk*, the selection and training of staff and crew members, and the rigorous proposal review process instituted by the SECURE Board will all encourage research of high quality that is both compatible with NOAA's research priorities and responsive to national needs.



EMERGENCY FIRE EQUIPMENT & STATIONS

Ⓐ-AUTOMATIC FIRE PROTECTION SYSTEM CO_2 FOR ENGINE ROOM (HOLD)

Ⓧ-FIRE FIGHTING EQUIPMENT STATIONS WITH HOSE AND FIRE AXE

Ⓟ-PORTABLE CO_2 EXTINGUISHER

Ⓣ-PORTABLE H_2O EXTINGUISHER

Figure III-25.—*Seahawk's* deck arrangement

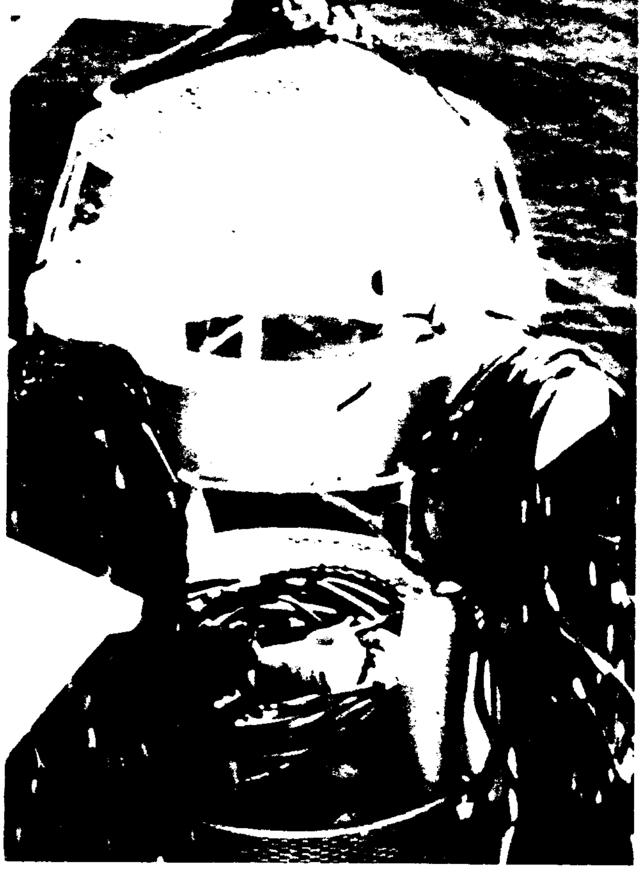


Figure III-26 A.—Open diving bell

Figure III-26 B.—Submerged view of bell

SECTION IV
Research and Activities Related to Diver Safety

BACKGROUND

In the years since NOAA's establishment, the Agency has consistently emphasized diver safety and effectiveness. Until 1979, the Manned Undersea Science and Technology (MUS&T) Office (see Section I) was concerned both with maintaining, supplying, and encouraging the use of underwater habitats and submersibles and with developing and managing NOAA's diving program. These responsibilities included the training, safety, and certification of NOAA Corps divers and both the technological and medical aspects of diving research and development. When the MUS&T office was administratively reorganized in 1979 into the NOAA Diving Office and the Office of Undersea Research (OUR), the latter retained the responsibility for diving research and development.

The OUR office has been active on many fronts on behalf of diving research and development, and it has been assisted in its efforts to fulfill these responsibilities by such organizations and agencies as the Undersea Medical Society, the National Institute for Occupational Safety and Health, the Department of the Navy, the Department of Energy, several universities, the Association of Diving Contractors, and many other institutions in the United States and other countries. NOAA has also supported a wide range of research efforts in response to the Agency's mandate, under the Outer Continental Shelf Act, to ensure the safety and health both of its own divers and of commercial divers operating on the U.S. Outer Continental Shelf. Individual projects conducted in connection with OUR's research and development obligations are briefly described below.

National Diving Accident Network

In response to the rapid increase in the number of diving enthusiasts in the United States and the acknowledged scarcity of physicians trained in diving medicine, OUR, with support from the Department of Energy and the National Institute for Occupational Safety and Health, established in 1981 a national Diving Accident Network. Duke University houses the Network's headquarters, and the Undersea Medical Society furnishes administrative support for this undertaking.

The Network is designed to provide 24-hour medical consultation on the recognition, immediate care, transportation, and recompression chamber treatment of diving accident patients anywhere in the United States. To perform this function, the Network has established a 24-hour collect telephone number to the central hospital at Duke University; this number is continuously connected via beeper to an on-call physician experienced in the treatment of diving-related injuries and illnesses. The emergency number is (919) 684-8111, and collect callers may ask for DAN (Diving Accident Network).

In addition, the Network has divided the United States into seven administrative regions: Southeast; Northeast; Mid-West; Gulf; Northwest; Southwest; and Pacific; each of these regions has a medical director. The regional directors are responsible for:

1. Coordinating efforts by local and regional rescue and treatment systems;
2. Providing diving medical education at the community level for physicians, divers, and emergency medical service personnel;
3. Advising local physicians on recompression treatment techniques, if asked to do so by the Network Center at Duke University; and
4. Providing educational and technical assistance to regional recompression chambers when needed.

The Network also maintains a complete listing of all U.S. recompression chambers and their current status, including location, availability, emergency telephone contacts, and medical support services. This listing is kept up to date by contacting each chamber facility at least once every 6 months to determine any changes in status. These precautions will prevent the recurrence of a situation that occurred before the establishment of the Network when an injured diver was transported to a treatment chamber but no physician was available to provide treatment. Information on air ambulance capabilities to transport injured divers to treatment facilities is also available from the Network.

To publicize the Network and to improve the treatment of diving casualties, a poster briefly summarizing the signs and symptoms of diving accidents has been distributed to the emergency rooms of the more than 7,000 hospitals in the United States. A smaller poster designed to be displayed on dive boats and in ambulances, and a brochure describing the Network, have also been widely disseminated. All publicity materials have space for the telephone numbers of the Network's headquarters and the appropriate regional center. The smaller posters and brochures are available without cost from any regional Network office.

A secondary but important purpose of the national Diving Accident Network is to collect and forward to NOAA and the National Institute for Occupational Safety and Health complete records of all diving decompression accidents, whether fatal or non-fatal. These records will form the basis for epidemiological studies of diving accidents, the results of which will be used, in turn, to improve the safety and health of both sports and commercial divers in the future.

EMERGENCY MANAGEMENT OF DIVING ACCIDENTS

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

24 HOURS • 7 DAYS A WEEK

(919) 684-8111

Collect Calls Will Be Accepted For Real Emergencies only. Ask for DIVING ACCIDENT NETWORK at F. G. HALL LAB., DUKE UNIV. MED. CENTER.

FLORIDA UNDERWATER COUNCIL
CONSERVATION SAFETY

WITHIN MINUTES TO HOURS AFTER COMPRESSED GAS (e.g. scuba) DIVING, THE FOLLOWING MANIFESTATIONS MAY REQUIRE IMMEDIATE TRANSFER TO A RECOMPRESSION CHAMBER:

ARTERIAL GAS EMBOLISM

Unconsciousness, paralysis, weakness, confusion, headache, or any other neurological deficit. Can be associated with pneumothorax or air under the skin of the neck. Can result from as shallow as 4 feet of water depth.

DECOMPRESSION SICKNESS ("BENDS")

Joint pain, back or abdominal pain, paralysis, numbness, tingling, inability to control bowels or urine, headache, dizziness, partial blindness, confusion, shortness of breath, chest pain, cough, shock.

PHOTO BY Y. HARPER

Figure IV-1.—Diving Accident Network poster

U.S. Underwater Diving Fatality Statistics

Since 1972, NOAA and the U.S. Coast Guard have supported the University of Rhode Island's National Underwater Accident Data Center, located at Kingston, R.I. The National Institute for Occupational Safety and Health has also provided support for this project since 1979. The purpose of the program is to collect and analyze information on all underwater diving fatalities in the United States; this information is then distributed as widely as possible to national sport diving training agencies, diving equipment manufacturers, commercial divers, recreational divers, and members of the general public. Accident records are categorized on the basis of the victim's occupational status in relation to diving, e.g., professional diver or nonprofessional. These categories are further subdivided for statistical analyis, and data derived from individual cases are then entered into a computerized data bank.

Accident information is obtained from media clipping services, autopsy reports, the Diving Accident Network, verified telephone and letter reports from private citizens, Federal and State government agencies, diver training agencies, police departments, and various other sources. The circumstances surrounding each accident are analyzed to determine, to the extent possible, the cause of the victim's death; factors such as age and experience of the victim, activity at time of death, diving equipment in use, medical aspects, and environmental conditions are analyzed.

Information obtained from the thorough analysis of these case reports of underwater fatalities has been useful to NOAA in its efforts to improve diving safety in general and that of the NOAA Diving Corps in particular, to the Coast Guard in fulfilling its mandate to improve the safety and health of commercial divers operating on the Outer Continental Shelf, and to the National Institute for Occupational Safety and Health in carrying out its responsibilities to commercial divers working anywhere in the United States. In addition, several of the recommendations for improving diver safety that have been made by the National Underwater Accident Data Center have been adopted by diving equipment manufacturers and diver training organizations. The Center's efforts have contributed to the decline in the number of underwater fatalities observed in the United States since 1976; in recognition of the importance of the Center's work, NOAA's Office of Underwater Research intends to continue to support this program in the future.

Publication: McAniff, John J., editor. 1981. *U.S. Underwater Diving Fatality Statistics, 1970-1979.* Report NOAA Grant No. 4-3-158-31. Kingston, Rhode Island: University of Rhode Island.

International Symposia on Underwater Physiology

Since 1955, leading scientists working in both the laboratory and clinical aspects of underwater medicine and physiology have met at approximately 3-year intervals to present papers and exchange views on topics of significance in this rapidly advancing field. After these meetings, the papers presented at the symposia have been edited and published as Proceedings. The early symposia were co-sponsored by the University of Pennsylvania and the Office of Naval Research and, since 1972, NOAA has joined with these sponsors to plan and support this important series.

The seventh symposium was held in Athens, Greece, in 1980; a total of 96 papers on a variety of research, applied, and clinical topics was presented and later published in the *Proceedings.* The Eighth Symposium on Underwater Physiology will be held in St. Jovite, Quebec, Canada, in 1983.

Publication: Bachrach, A.J., and M.M. Matzen, editors. 1981. *Underwater Physiology VII. Proceedings of the Seventh Symposium on Underwater Physiology.* Bethesda, Md.: Undersea Medical Society.

Bibliography of Underwater Medicine and Related Sciences

Since 1972, the Undersea Medical Society has published an on-going series of volumes entitled: *Underwater Medicine and Related Sciences, A Guide to the Literature.* Each volume contains approximately 2,000 informative abstracts, with complete bibliographic data, of papers and books published in the fields of diving and underwater medicine and physiology in the 2-year period preceding publication of the bibliography. NOAA has supported the preparation and publication of this valuable series, in conjunction with the Office of Naval Research, since 1977. These abstracts are also available to subscribers on a monthly basis or may be obtained for individual topics by calling or writing the Undersea Medical Society. (There is a small fee for this search service.) The Office of Undersea Research plans to continue its support of this project in the future.

Publication: Teven, Lynn, and C.W. Shilling, editors. *Underwater Medicine and Related Sciences, A Guide to the Literature.* Vol. V. Bethesda, Md.: Undersea Medical Society, 1981.

Biomedical Advisory Service

For the past several years, NOAA has had a general contract with the Undersea Medical Society (UMS) to provide current information on developments in the fields of diver training, medicine, treatment procedures, and equipment. The Undersea Medical Society is uniquely qualified to provide this type of support because the Society has more than 1,400 diving physicians, physiologists, and other professionals among its members. In addition, the Society publishes the leading professional journal in diving research and medicine, *Undersea Biomedical Research*, a newsletter, *Pressure*, that is widely distributed and highly respected in the diving community, and an authoritative series of workshop reports on topics of interest to the diving community.

Under the terms of this contract, the Undersea Medical Society provides the Office of Undersea Research with information on the latest developments in diving-related research, in the form of special reports, literature retrieval services, workshop proceedings, and expert opinion. The Society also organizes workshops and seminars on topics of special interest to NOAA, recommends peer reviewers to evaluate research proposals, and provides expert assistance in performing critical review of documents if necessary.

Microbial Hazards Associated with Diving in Polluted Waters

In the course of their work, NOAA Corps divers are occasionally required to dive in harbor and coastal waters that are or may be contaminated with hazardous biological material, such as pathogenic bacteria. To assess the risks associated with diving in polluted water, NOAA initiated a long-term research project in 1977; the University of Maryland, the Naval Medical Research Institute (NMRI), the U.S. Coast Guard, and the Veterans Administration have participated in this effort at various stages. In FY 1981, the University of Maryland, represented by Dr. Rita R. Colwell, and NMRI, represented by Dr. James C. Coolbaugh, were the principal participants. The objectives of the study completed in 1981 were as follows:

- Investigate operational diving areas to assess biological risks
- Evaluate the degree of bacterial contamination of divers in selected operational areas characteristic of various geographic and pollutant conditions
- Evaluate the effectiveness of the protection against contamination offered by various types of diving equipment
- Evaluate methods of disinfecting contaminated diving equipment.

During FY 1981, the protective qualities of various types of diving gear were investigated in aquatic environments while NOAA divers participated in NOAA operations in Norfolk, Virginia, and White Oak, Maryland. Bacteria of the Aeromonas species were the most frequently isolated pathogen identified on the skin and suits of divers during these dives, but staphylococci, streptococci, Gram-negative enteric bacteria, actinomycetes, and salmonella were among the other organisms isolated. Treating divers prophylactically with acetic-acid eardrops reduced the number of individuals with increased ear canal bacterial counts. On the other hand, wearing rubber diving hoods increased the number of bacteria in divers' ear canals.

Equipment used to assess the effectiveness of bacterial decontamination procedures included three types of variable-volume dry suits, a wet suit, and three types of masks. The relationship between the demand and free-flow modes of diver air supply and potential microbial contamination was also studied.

The neoprene wet suit provided no barrier between the diver and the contaminated water environment, but thorough rinsing and spraying with disinfectant after use effectively reduced the potential for infection. All three dry suits studied protected divers from polluted waters, but suits with smooth exteriors were easier to disinfect than the rough-textured suit. The masks all provided good diver protection when properly sealed, and all were easily disinfected after diving. The free-flow air supply mode permitted an aerosol spray of water to reach the diver's face, a potentially hazardous situation in polluted aquatic environments.

Results of these ongoing studies clearly point to the need for careful bacterial analysis of dive sites, when possible, before diving operations commence. Water clarity is generally not a good indicator of microbiological hazard. The prophylactic use of ear drops is also recommended as a routine measure.

Publications: Brook, I., J. C. Coolbaugh, and R. G. Williscroft, 1982. Effect of diving hoods on the bacterial flora of the external ear canal and skin. *J. Clin. Microbiol.* 15: 855-859.

Coolbaugh, J. C., O. P. Daily, S. W. Joseph, R. I. Walker, R. W. Attwell, and R. R. Colwell. 1982. Protection of divers from microbiological hazards in polluted waters. In: *Proceedings of the Seventh Congress of the European Undersea Biomedical Society*, edited by J. S. Dick.

Daily, O. P., S. W. Joseph, J. D. Gillmore, R. J. Seidler, D. A. Allen, and R. R. Colwell. 1981. Water-borne microbial pathogens: Potential human health hazards in marine environments. In: *Underwater Physiology VII. Proceedings of the Seventh Symposium on Underwater Physiology*, edited by A. J. Bachrach and M. M. Matzen. Bethesda, Md.: Undersea Medical Society.

Cavari, B. Z., D. A. Allen, and R. R. Colwell. 1981. Effect of temperature on growth and activity of *Aeromonas* spp. and mixed bacterial populations in the Anacostia River. *Appl. Environ. Microbiol.* 41: 1052-1054.

Attwell, R. W., R. R. Colwell, and J. C. Coolbaugh. 1981. Actinomycetes, a possible hazard encountered in diving operations. *Mar. Technol. Soc. J.* 15: 36-40.

Daily, O. P., S. W. Joseph, J. C. Coolbaugh, R. I. Walker, B. R. Merrell, D. M. Rollins, R. J. Seidler, R. R.

Colwell, and C. R. Lissner. 1981. Association of *Aeromonas sobia* with human infection. *J. Clin. Microbiol.* 13: 769-777.

Kaper, J., D. Lockman, R. R. Colwell, and S. W. Joseph. 1981. *Aeromonas hydrophilia:* Ecology and toxigenicity of isolates from an estuary. *J. Appl. Bacteriol.* 50: 359-377.

Coolbaugh, J. C., O. P. Daily, S. W. Joseph, and R. R. Colwell. 1981. Bacterial contamination of divers during training exercises in coastal waters. *Mar. Technol. Soc. J.* 15: 15-21.

Field Evaluation of NITROX Saturation Diving

In FY 1981, OUR supported a planning meeting to develop a protocol for the field evaluation of commercial divers using nitrogen-oxygen (NITROX) saturation diving procedures. The meeting was managed by the Undersea Medical Society and was attended by physicians and scientists from the Society and the supporting agency. The planning group's purpose was to develop field trial methods of evaluating commercial divers at work on underwater tasks. Topics of particular significance for NITROX saturation diving include: acute and chronic oxygen toxicity; impaired performance caused by nitrogen narcosis; and the development of safe decompression tables to be used in NITROX dives.

Development of a Baseline Physical Examination for Deep-Sea Divers

In conjunction with NIOSH and the United Brotherhood of Carpenters and Joiners of America, the OUR sponsored an Undersea Medical Society workshop to develop a protocol for physical examinations of deep-sea divers. The workshop was attended by scientists from NIOSH and NOAA, physicians from the Undersea Medical Society and the Navy, officials of the sponsoring union, and participants from the National Institutes of Health and the Association of Diving Contractors.

The group outlined the essential elements of a standard diving physical, including the physical, neuromuscular, neurological, biochemical, and psychometric dimensions to be considered.

Man in the Cold Environment

The Undersea Medical Society has been involved in studying the problem of hypothermia in the underwater environment for several years. In 1980, the Society produced a bibliography on the biomedical aspects of hypothermia under contract to the Navy Medical Research Laboratory in New London, Connecticut. In 1981, NOAA's OUR program supported the Society's continuing efforts to develop a comprehensive annotated bibliography of the world literature on this topic of increasing importance in underwater research.

Publication: *Man in the Cold Environment: An Annotated Bibliography.* Bethesda, Md.: Undersea Medical Society, 1981.

SECTION V
Future Plans

The Office of Undersea Research plans to continue its support of several of the programs described in the preceding sections and to develop new initiatives and strengthen other program areas in the future. Particular emphasis will be given to strengthening national and international cooperative undertakings, enhancing the usefulness of NOAA's regional programs, and developing NOAA's underwater research capabilities.

Intergovernmental Oceanographic Commission

The Intergovernmental Oceanographic Commission (IOC) is an autonomous body within the United Nations Educational, Scientific and Cultural Organization (UNESCO); the IOC was established in 1960. The Commission's purpose is to "promote scientific investigation with a view to learning more about the nature and resources of the oceans through the concerted action of its members." In addition, the IOC is the body within the United Nations that is charged with the responsibility of coordinating marine scientific and related activities on an international basis. At present, more than 100 countries participate in the work of the Commission.

The Office of Undersea Research is expected to become increasingly involved in the affairs of the IOC, particularly in the Caribbean region. The *Hydrolab* habitat has the capability to become the focus for regional projects sponsored by UNESCO on behalf of the IOC.

United States–Japan Cooperative Research in Saturation Diving

In 1964, the United States–Japan Natural Resources Program (UJNR) was established when the U.S.-Japan Cabinet-level Committee on Trade and Economic Affairs agreed that exchanges of information, specialists, technical data, and research equipment in the field of natural resources would be beneficial to both countries. The program's goals are to increase the efficiency of natural resources development and planning and to strengthen bonds between the participating countries.

The UJNR performs its activities by means of 17 panels, 7 of which deal with marine science and 10 of which are concerned with non-marine affairs. A coordinator from the Science and Technology Agency of Japan and a coordinator from NOAA jointly oversee the work of the marine panels. The UJNR holds a conference once every 2 years; this conference meets alternately in Washington, D.C. and in Japan. The following marine panels are currently active:

- the Aquaculture Panel
- the Diving Physiology and Technology Panel
- the Marine Electronics and Communications Panel
- the Marine Facilities Panel
- the Marine Geology Panel
- the Marine Mining Panel
- the Seabottom Surveys Panel

Most panel members are scientists from the national governments, although technical personnel from academia and the private sector also contribute to the work of the panels. Members meet regularly to review progress and to plan future activities. In FY 1981, the Panel on Diving Physiology and Technology met in California for the Sixth Meeting of the UJNR.

Papers presented at the meeting addressed such topics as decompression sickness in divers and compressed air workers, the hyperbaric facilities and research program at the National Naval Medical Research Institute, the undersea research programs of the U.S. National Sea Grant Office and NOAA's OUR program, radiological evidence of dysbaric osteonecrosis in divers, and studies of the onset of air embolism, the effects of cold on diving performance, body heat balance during saturation diving, and psychomotor effects during nitrogen-oxygen shallow water saturation dives. NOAA's Office of Undersea Research plans to continue the Agency's support of this important international program.

Expansion of the Regional Program

The success of the Office of Undersea Research's regional laboratory program has encouraged NOAA to consider adding a fifth regional research facility to the existing Caribbean, North Carolina, Hawaii, and Santa Catalina laboratories.

The principal site under consideration is off the coast of the northeastern United States. Locating an additional regional facility in the northern Atlantic region would permit NOAA to draw on personnel and research capabilities available in the Atlantic seaboard states and to exploit the unique submarine resources characteristic of this area. Expanding OUR's regional program would help NOAA to implement the suggestions of the Ocean Sciences Board of the National Research Council, National Academy of Sciences, which recommended nationally coordinated regional programs as the best way of meeting the Nation's underwater research needs.

Remotely Operated Vehicles

Snoopy

The Office of Undersea Research has received numerous requests from marine scientists interested in using remotely operated vehicles (ROV's) in their underwater research. OUR believes that these vehicles can be used to make scientific missions more productive by targeting those underwater sites that will yield the best information.

As a first step toward providing ROV systems, *Snoopy*, a small remotely manned vehicle (Fig. V-1) developed specifically to perform underwater observational tasks, has been made available to the Hawaiian Undersea Research Laboratory (HURL) program. *Snoopy* weighs approximately 150 pounds and can operate at depths of 1500 fsw. The vehicle provides real-time viewing via a black and white TV camera and a quartz-iodine light source. *Snoopy* is propelled by three pressure-compensated electric motors controlled from the surface. The vehicle can be operated from any suitable platform, and has minimum support requirements. In the HURL Program, *Snoopy* is used to perform pre-site surveys to screen available underwater sites to locate those most suitable for subsequent manned submersible research missions.

Figure V-1.—The ROV *Snoopy* being lowered to perform pre-site surveys

Cord

In addition to the ROV *Snoopy*, OUR is participating with the Harbor Branch Foundation (HBF) in cruises designed to compare the functional capabilities of manned submersibles and remotely operated vehicles (ROV's). To perform these experiments, the Foundation provides both the vehicles and their respective surface ships and crews: the submersible *Johnson Sea Link 1* and its support ship *R/V Johnson*, and the ROV *Cord* (Fig. V-2) and its support ship *R/V Sea Diver*. When this series of dives is completed, it will be possible to compare the amount and accuracy of the data obtained by the videotape cameras of the submersible and the ROV.

The OUR program intends to continue its support of this ongoing research project, as well as research involving other ROV's, in order to provide the marine science community with a comprehensive and integrated ensemble of research tools and facilities.

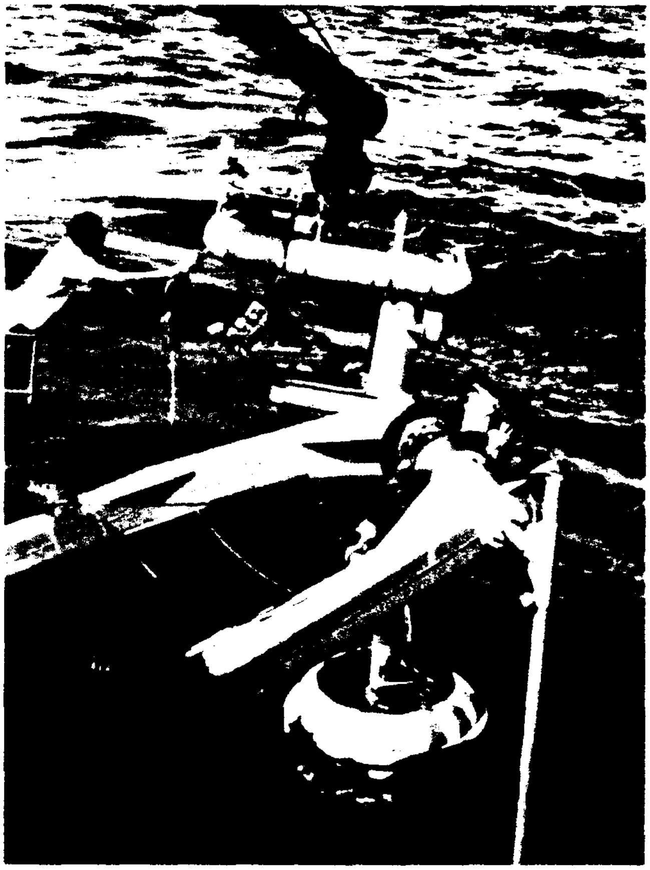


Figure V-2.—The ROV *Cord*

Annual Office of Undersea Research Symposium

In its role of coordinator of NOAA's regional undersea research program, the Office of Undersea Research is planning to sponsor an annual symposium. The symposium will provide the marine science community with an opportunity to exchange ideas and to become familiar with other NOAA-supported underwater research projects and personnel.

The principal investigators and other personnel who have participated in research missions using OUR's regional facilities will present papers reporting their research results, and symposium participants will have the opportunity to comment on the presentations. The first of these symposia will be held in 1983, in conjunction with the annual meeting of the American Society of Zoologists. The symposium will take the form of a Workshop on Coral Reefs, and NOAA plans to publish the papers in a separate volume. In addition, OUR plans to establish a data-bank which will permit scientists to conduct literature searches and to retrieve relevant scientific data.

These annual symposia will also serve as a means of determining the marine science community's requirements for research support facilities, such as remotely operated vehicles, atmospheric diving suits, submersibles, and deep diving systems. OUR's centralized planning approach to the needs of the underwater research community will ensure cost-effectiveness while simultaneously enhancing the quality of NOAA's undersea research efforts.