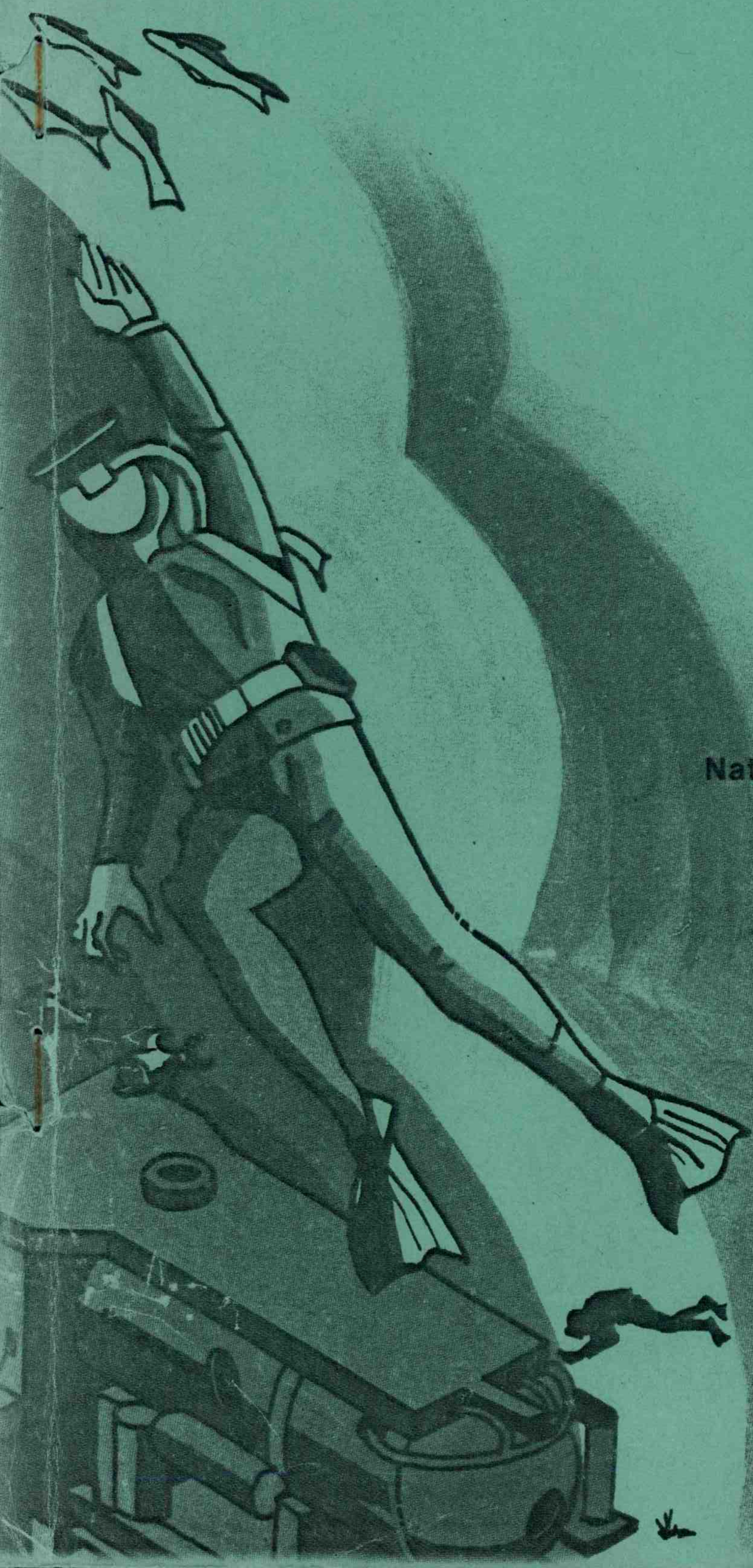
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NATIONAL UNDERSEA RESEARCH PROGRAM Program Summary

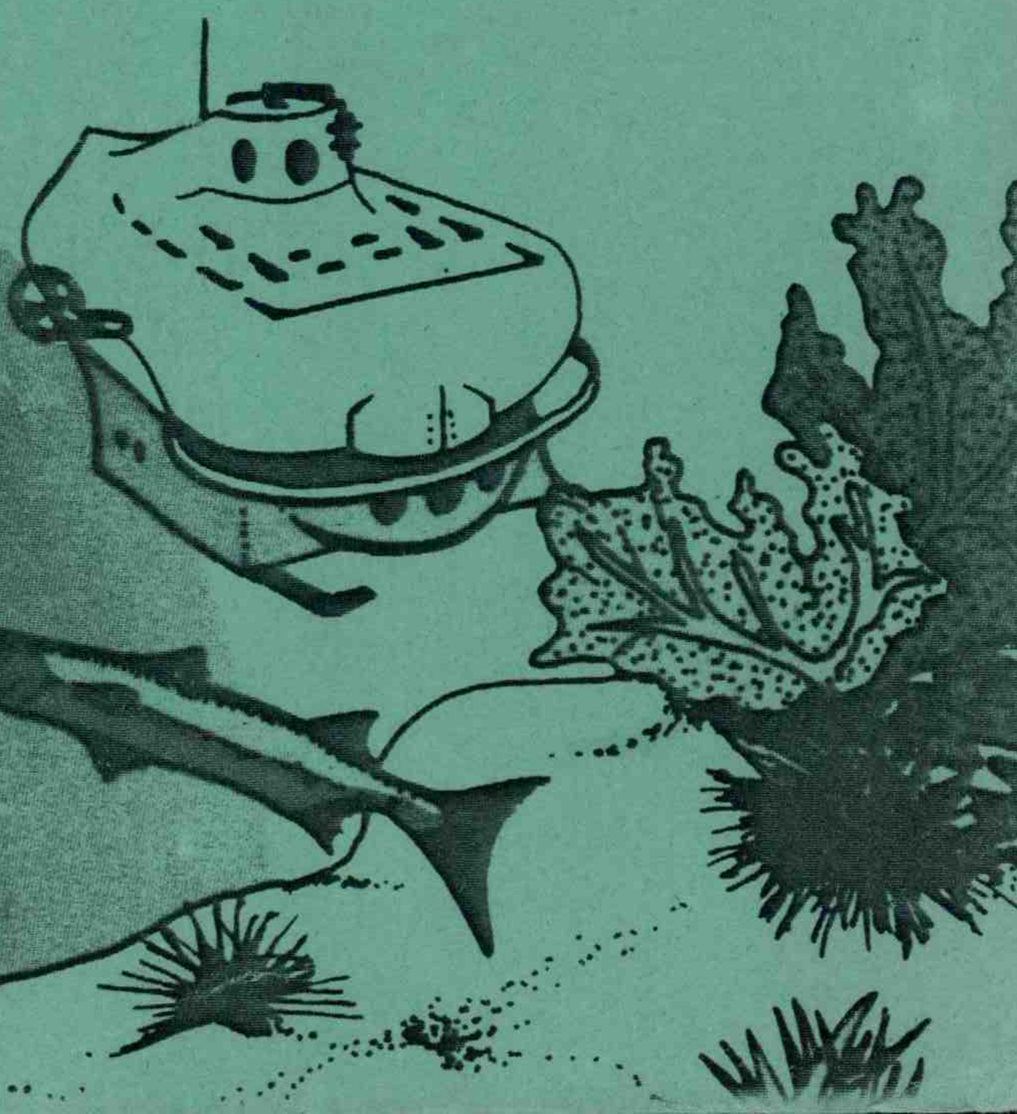
A Summary of Research Activities 1985–1986

May 1988





U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Oceanic and Atmospheric Research
Office of Undersea Research



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NATIONAL UNDERSEA RESEARCH PROGRAM Program Summary

A Summary of Research Activities 1985–1986

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NOAA'S OFFICE OF UNDERSEA RESEARCH

SCIENCE REPORT FOR 1985-1986

SCIENCE REPORT 1985-1986

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PREFACE

NOAA's Office of Undersea Research provides scientific support for a broad range of research activities that meet the mission requirements of the agency or deal with overriding national science concerns. During 1985, the Office conducted three major programs in support of undersea research. These are the Submersible Science Program, the National Undersea Research Program (a network of university-based undersea science programs), and the Diving Research and Development Program. This report describes science activities for the first two programs.

Office-sponsored research is grouped into six broad scientific areas. A separate chapter is devoted to each category of research: global oceanic and climatic processes; pathways and fate of material in the ocean; coastal oceanic and estuarine processes; ocean lithosphere and mineral resources; biological productivity and living resources; and ocean services. Another chapter describes the international science activities conducted by the Office.

The research activities described in this report and publications resulting from these investigations cover the 1985-1986 calendar years. Each of the investigations supported during 1985 and 1986 was designed to reduce the size of the knowledge gap pertaining to the processes governing the balance of ecosystems. Research will continue in each of the research categories outlined above so that ultimately, armed with an understanding of how physical, chemical, biological, and geological processes control marine environments important to the United States, informed decisions can be made with respect to the management and wise use of our nation's ocean resources.

Michael P. De Luca
Program Scientist

ACKNOWLEDGMENTS

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I. INTRODUCTION

I.A. BACKGROUND

In the last 20 years, scientists have made major advances in understanding the marine environment and its resources. The development of new technologies, such as satellites, advanced seismic techniques, and ocean drilling, has contributed significantly to this research. These and other tools, such as supercomputers, are expected to play an even larger role in future oceanic research. The National Oceanic and Atmospheric Administration (NOAA) and several other Federal agencies have been involved in performing the Nation's civilian undersea research in this period. The National Science Foundation (NSF), the U.S. Geological Survey (USGS), the Environmental Protection Agency (EPA), the Department of Energy (DOE), the Department of the Interior (DOI), the U.S. Navy, and the U.S. Army Corps of Engineers (COE) have supported marine research in various scientific areas.

Since its establishment in 1970, NOAA has had an ocean science research program that has achieved several notable successes in areas such as biological productivity, seafloor processes, and undersea technology development. NOAA's Office of Undersea Research (OUR) has provided vigorous support to the undersea research community since 1977, primarily by making available a broad range of undersea research vehicles and platforms--from habitats to submersibles and remotely operated vehicles--to be used in scientific investigations of coastal marine environments. OUR currently operates a national network of research programs at six locations: Fairleigh Dickinson University's West Indies Laboratory at St. Croix in the U.S. Virgin Islands; University of Hawaii at Manoa; the University of North Carolina at Wilmington; the University of Southern California at Catalina Island; the University of Connecticut at Avery Point; and the Caribbean Marine Research Center at Lee Stocking Island, Bahamas.

Research proposals received by OUR from scientists affiliated with academic, scientific, and private-sector institutions are carefully reviewed by NOAA and outside reviewers, and are evaluated in accordance with the relevance of the proposed research to the following criteria:

- Scientific merit
- NOAA's undersea mission responsibilities or the National interest
- Importance of the vehicle or facility (habitat, submersible, etc.) to the successful performance of the research.

This science report is the first in a series of reports designed to reflect the Office of Undersea Research's efforts on behalf of NOAA's historic ocean research charter, embodied in Presidential Order No. 4 (1970). OUR is vigorously supporting NOAA's comprehensive marine research program, which ranges from

fundamental research in global oceanic and lithospheric sciences to investigations of a broad variety of ocean resources. Accordingly, the sections that follow report on the results of calendar years 1985-1986 research activities sponsored by OUR and conducted by government, academic, and private-sector scientists from a host of technical disciplines. Research results and future plans are grouped into six broad subject categories; within each category, individual project summaries are arranged in sections devoted to the research carried out by each National Undersea Research Program.

I.B. NATIONAL UNDERSEA RESEARCH PROGRAM FACILITIES

Since 1980, the National Oceanic and Atmospheric Administration (NOAA) has developed and utilized a national network of undersea research laboratories to meet its Congressionally mandated responsibilities in U.S. coastal marine environments. The National Undersea Research Program (NURP) network consists of oceanic facilities in six locations: Fairleigh Dickinson University's West Indies Laboratory at St. Croix; University of Hawaii; University of North Carolina at Wilmington; University of Southern California; Caribbean Marine Research Center at Lee Stocking Island; and University of Connecticut at Avery Point. Through formal cooperative agreements with these institutions, NOAA is able to conduct studies of underwater biological, geological, and ecological processes throughout the nation's exclusive economic zone in an efficient and cost-effective manner.

Research carried out through the network of undersea programs has been multi-disciplinary in character and has focused on six areas of scientific inquiry designated by NOAA as policy priorities. Highlights of the activities and projects undertaken by each of the NURP programs during calendar years 1985-1986 are described below, followed in Section II by a discussion of the objectives and results of specific scientific efforts.

Fairleigh Dickinson University (St. Croix, U.S. Virgin Islands)

NOAA's initial undersea program was established in 1977 in St. Croix, U.S. Virgin Islands, and is operated by the West Indies Laboratory of Fairleigh Dickinson University. The focal point of the Caribbean program has been the saturation habitat Hydrolab, which supported seven missions addressing eight separate scientific projects from January through July 1985. Twenty-eight aquanauts participated in dives involving a total of 818 excursion hours and 4,704 saturation hours; these scientific missions included studies of nitrogen cycling in the water column and sediments of a reef environment, chemical interactions between sponges and corals, and the role of sheltering fishes as nutrient sources for tropical reef communities.

Preliminary results from these missions were reported in 24 presentations made at various scientific conferences in 1985. A list of publications of Hydrolab research that appeared or were submitted in 1985 is presented in Appendix C of this report.

During 1986, NOAA initiated a process to replace Hydrolab with a new, more advanced, mobile saturation habitat system. Consequently no science activities were conducted during 1986.

University of Hawaii - Manoa

NOAA's Hawaiian Undersea Research Program, conducted under the aegis of the University of Hawaii, is based at the Makai Research Pier at Makapuu Point on the island of Oahu. In 1985, the Hawaiian component of the NURP network conducted a series of dives using the two-person research submersible Makali'i to conduct 11 scientific missions in the waters of the lower Hawaiian Islands. Project leaders included researchers from the University of Hawaii, Lamont-Doherty Geological Observatory (Columbia University), University of Florida, NOAA/National Marine Fisheries Service, and the U.S. Department of the Interior/U.S. Geological Survey.

Key areas of research for the period 1985-1986 covered by this report included ecology of seamounts and shallow-water banks, potential fishery development, and the environmental effects of waste disposal in deep ocean waters.

University of Southern California - Catalina Island

The headquarters of the third element in NOAA's cooperative undersea research program is located at the University of Southern California's (USC) facility on Santa Catalina Island, 25 miles offshore from the coast of Los Angeles. The USC facility has developed an extensive tether-diving program that employs an open bell and underwater way stations.

Research activities sponsored through USC focused especially on the ecology of kelp beds and assessment of faunal distribution and abundance.

This program was discontinued in 1986. NOAA plans to establish a new program on the west coast in 1989 to meet the undersea research requirements of this region.

University of North Carolina - Wilmington

Through a cooperative agreement between NOAA, the University of North Carolina at Wilmington, and the Southeastern Consortium for Undersea Research Efforts (comprised of academic institutions, research organizations, and government agencies from Virginia, North Carolina, South Carolina, and Georgia), the fourth component

in NOAA's national undersea laboratory program was established in 1980. The southeastern program relies on the research vessel (R/V) Seahawk, a converted 70-foot-long shrimp trawler, to support its scientific investigations in the waters along the eastern seaboard.

Research activities in 1985-1986 focused on the productivity of marine communities, pollution in marine sanctuaries, growth rates of the ocean quahog, and the search for potentially effective new marine biomedicinals.

University of Connecticut - Avery Point

The research requirements of marine scientists in the northeastern region of the United States are served by the recently developed facility in NOAA's National Undersea Research Program, located at the University of Connecticut at Avery Point (UCAP). After its establishment in 1983, an Advisory Board was created with special subcommittees to determine policy in three areas: Priorities/Planning; Technology Evaluation/Development; and Proposal Review.

In 1985, UCAP support for undersea research involved grants for 36 proposals received from scientists in the New England and Great Lakes areas. A total of 90 days of vessel/submersible/ remotely operated vehicle time was used to address a wide range of research tasks. In addition, presentations emphasizing the scope and nature of science activities were delivered by UCAP personnel to members of Congress, educational institutions, and industry associations.

The UCAP program focuses on research directed at increasing our understanding of estuarine and coastal processes. Particular areas of emphasis include studies of benthic productivity, assessments of the fate and transport of toxicants, and evaluations of the destruction and restoration of habitats.

Caribbean Marine Research Center (CMRC), Lee Stocking Island

The most recent addition to the National Undersea Research Program is the Carribean Marine Research Center (CMRC) in the Bahamas. The primary investigation at CMRC involves technology development for low-cost seawater culture of a Florida red tilapia hybrid. Tilapia have been extensively studied and cultured in freshwater systems, but the potential for mariculture promises maximum production with minimal use of scarce freshwater resources. CMRC investigations on the physiology, genetics, and population dynamics of tilapia have led to the successful development of techniques for quickly raising these fish to harvestable size in seawater.

Another study in progress at the CMRC involves research in the recruitment processes and the early life history of the queen

conch, Strombus gigas, a major source of food and income for many people of the Caribbean. Location of a dense bed of juvenile conch near Lee Stocking Island (Bahamas) has greatly facilitated investigations of the physical and ecological factors affecting the population dynamics of this organism.

II. RESULTS OF THE SCIENCE PROGRAM, 1985-1986

II.A. GLOBAL OCEANIC AND CLIMATIC PROCESSES

Research conducted in this multidisciplinary area is designed to increase man's understanding of the ocean as an integrated global system. The interactions and reciprocal impacts among world weather and climate, environmental quality, and biological productivity are investigated in global oceanic studies. The technologies involved in this research include supercomputers, satellites, and undersea sampling and experimentation techniques.

NOAA works closely with the National Aeronautics and Space Administration (NASA), Department of Defense (DOD) agencies, and the National Science Foundation (NSF) in research projects in this topical area. NASA has primary responsibility for the space technology and satellite aspects of this research; DOD oversees defense satellite operations; and the NSF provides analytical support. NOAA's responsibilities in research of this type include environmental data handling, research design, instrumentation, and provision of undersea research vehicles and facilities.

The benefits of an increased understanding of global oceanic processes will be better and more accurate weather predictions, greater advance warning of natural climatic disasters, and better management and use of the earth's biological resources. In 1985, NOAA sponsored a series of deep-water submersible dives designed to further our understanding of the role of hydrothermal processes in oceanic chemical and thermal exchange mechanisms.

1985 PROJECTS

Characterization of the Galapagos Sulfide Deposits

The deep-water submersible Alvin, supported by the R/V Atlantis II, was used to conduct 15 dives in the vicinity of the Galapagos sulfide deposits, which were first discovered during a similar NOAA-sponsored dive in 1981. The goals of these dives included mapping the deposit in detail, sampling material beneath the sulfide chimneys, comparing the original site to sites in the vicinity recently discovered by German undersea scientists, measuring the effects of hydrothermal alteration on the local magnetic and electromagnetic fields, and using the Atlantis's new SeaBeam system to map the area.

NOAA scientists participating in these dives discovered a unique hydrothermal alteration zone on the north side of a 50-80 meter horst block separating the northern portion of the rift valley, which apparently contains the youngest volcanic pillow flows. The massive sulfide deposits occur primarily at the base of the southern face of the horst, but some deposits are also found on the horst above the alteration zone. The rocks most severely affected by the hydrothermal activity occur in a narrow zone about 30 meters wide around the hydrothermal vents. Results of these observations will provide scientists with evidence derived from recent seafloor processes that can be used to confirm

prior hypotheses about chemical and thermal alterations of ocean basalts.

1986 PROJECTS

Pisces Submersible Exploration of the Hydrothermal Vent Fields in the Caldera of Axial Volcano

A joint U.S.-Canadian scientific effort obtained quantitative time series data on the effects of hydrothermal heat and mass emissions on the chemistry of the oceans. Increasingly compelling evidence supports hypotheses that hydrothermal venting plays a major and direct role in the chemical evolution of the global ocean and that hydrothermal fluxes of dissolved gases directly and indirectly affect atmospheric chemistry as well.

The principal high-temperature hydrothermal vent field on Axial Volcano was discovered but only briefly observed during a NURP-sponsored dive program in 1984. In 1986, this site was revisited and found to be an ideal location for initial deployment and testing of a suite of instruments and experiments designed to obtain quantitative information for long periods of time at near and mid-field distances to active vents.

The principal high-temperature vent field is about 100 m in diameter and the core consists of three major sulfide edifices with multiple black smoker spouts emanating water with temperatures of at least 330^{o} C. Another vent built and rebuilt an anhydrite spire at the rate of decimeters per day. Hot water up to 225^{o} C emanated directly out of basalt cracks throughout the general area. Plumes of smoker particulates emanating from the larger high-temperature vents rose to about 15-25 m above the seafloor and were primarily composed of anhydrite, sphalerite, chalcopyrite, and pyrite. The grain sizes of the individual particulates ranged from 1 to 100 microns in diameter. One of the larger phases consisted of as yet unidentified titanium-rich iron oxides. This is the first time that such material has been observed in a particulate phase on the Juan de Fuca Ridge.

Vent fauna extensively carpeted the hydrothermal field and formed dense assemblages around each vent. Five new species of organisms were recognized at sea, including a vent fish about 25 cm long.

The eastern vent site was characterized by low temperature venting in a 1,000 m by 100 m band, probably associated with the eastern limb of an overlapping rift zone first observed on sidescan sonar records. A 1 m high pyritic chimney was recovered in this field, although active high temperature venting was not found.

Future submersible investigation at Axial will focus on developing quantitative near-field measurments of dynamic venting

phenomena, determining the relationship between hydrothermal life cycles and geological and geophysical settings, and continuing of studies on sulfide ore formation and vent fauna ecology.

II.B. PATHWAYS AND FATE OF MATERIALS IN THE OCEAN

Research classified under the Pathways and Fate heading focuses on our understanding of how materials injected into the oceans by man are transformed and transported vertically within the water column and horizontally from the coasts across the continental shelf and into the deep oceans. Studies of the fate of pollutants have recently gained in importance as traditional land-based methods of waste disposal are being phased-out because they result in the leaching of hazardous waste constituents into the Nation's groundwater supply.

Earlier NOAA-sponsored research has shown that recirculation and sediment disturbances can keep pollutants active and biologically available for much longer periods than were previously recognized. Additional research is needed to understand how processes such as advection, sedimentation, and diffusion work at the pycnocline and near or at the seabed throughout the coastal zone. An understanding of the role of living organisms in determining the chemical composition of sediments and in assimilating and transporting pollutants is also essential to the development of predictive models of contaminant behavior in the coastal ecosystem.

In 1985 and 1986, NURP programs at the universities of Hawaii, North Carolina-Wilmington, and Connecticut-Avery Point conducted research projects involving the study of the pathway and fate of materials in the ocean. Synopses of individual missions are presented below.

1985 PROJECTS

Characterization of Ocean Disposal Sites by In-Situ Inspection With the Manned Submersible Johnson Sea-Link (UCAP)

In response to the mandate of the Marine Protection Research and Sanctuaries Act, research was conducted in 1985 to assess the sites and potential impacts of waste disposal (dredge material) at selected dump locations in the Gulf of Maine. Discrete sampling techniques and intensive in-situ photodocumentation were employed to obtain data on elusive benthic fauna and to characterize specific seafloor areas. The findings will be used to make decisions on permitting, site designation, monitoring, and management of dredged material in ocean disposal sites. In addition, the research will advance understanding of marine pollution control to contain contaminants and reduce seafood and fishery impacts at several offshore sites.

This 3-day cruise afforded an opportunity for the NURP/UCAP program to integrate interagency research and coordinate specific marine management responsibilities through the submersible surveys, as well as to test new equipment and techniques.

Sources, Composition, and Cycling of Organic Contaminants in the Benthic Nepheloid Layer of Lake Superior (UCAP)

As part of NURP's Great Lakes program, a study was implemented in 1985 to determine the sources and composition of particles in the benthic nepheloid layer of Lake Superior and the role of these factors in the cycling of organic pollutants (e.g., PCB's, DDT, PAH's). Samples of particles and water collected at or near the sediment-water interface were analyzed for organic contaminants, organic carbon, and geochemical tracers. Preliminary data suggest that the fine layer of silt covering the lake bottom is enriched in certain organic pollutants and may be the result of rapid settling of freshly produced particles. Although further analysis is ongoing, scientists believe that this layer may be a direct link between atmospheric deposition and sediment accumulation of organic pollutants.

Equipment developed and evaluated for use with the Johnson Sea-Link submersible--sediment corers and a quantitative filtration sampling system--will be made operational during the 1986 NURP cruise on Lakes Huron and Superior. Collaborative efforts with other geochemists involved in the Great Lakes program will further elucidate relationships between pollutant transport and the geochemistry of large lakes and provide a better understanding of the aquatic behavior of organic contaminants, including refined estimates of their net residence times.

Geochemical Processes and Rates of Chemical Exchange at the Water Sediment Interface in Profundal Lake Sediments (UCAP)

The sediment-water interface in profundal lake environments is in part responsible for recycling nutrients and determining the fate of pollutants in the Great Lakes. Because accurate sampling of this interface from the surface is difficult, understanding of the physical and chemical nature of this important zone is limited. To help close this knowledge gap, research to determine the geochemical processes and rates of reaction working at the sediment-water interface was carried out using a manned submersible.

Five chemical zones were defined for study: the pre-nepheloid layer, the nepheloid layer, the sediment boundary layer, the sediment-water interface, and the sediment column. The chemistry and mineralogy of sediments taken in core samples and the chemistry of associated filtrated water samples were measured so that thermal dynamics/kinetic models could be developed.

Preliminary results suggest that submersibles will be important in Great Lakes' geochemical research.

Response of the Benthic Ecosystem to Deep Ocean Sewage Outfalls in Hawaii (U-HI)

To test the hypothesis that the fate of sewage-derived organic material can be determined and measured quantitatively, researchers set out to investigate the fraction and spatial distribution of sewage effluent that reaches the sediment-water interface and to measure the rates and spatial distributions of metabolic processes occurring in the benthic boundary layer. Four sets of dives were completed involving the submersible Makali'i, which deployed benthic incubation chambers at several stations in the vicinity of two deep-water sewage outfalls off Oahu and at a control site. Using this methodology, diver-scientists were able to measure the particulate and dissolved fluxes into and out of the benthic boundary layer.

Results of the research indicate that domestic sewage that has been pre-treated has little or no detrimental impact when it is discharged into the open ocean below the depth of the thermocline. This lack of effect is due to the rapid dilution and dispersal of pollutants in the ocean environment. In the case of the very small fraction of effluent material that does reach the sediment surface, metabolic processes quickly recycle nutrients back to dissolved species that are then dispersed in the water column; consequently, very little of the effluent material is retained in the sediment column in any form.

Bacterial mats, which act as a natural trickling filter system to strip organic material from effluent streams, appear to be caused by periodic pulses of high biological oxygen demand effluent originating during the seasonal activity of the Hawaiian pineapple canneries. Sloughed bacterial mats on the sediment surface serve as a substrate for surface benthic metabolism; when the mats are not active, benthic metabolism at the outfall is not significantly different from that at control sites.

Microbiology and Biochemistry of Ocean Density Discontinuities (U-HI)

Recent evidence suggests that slowly sinking organic detritus accumulates at density discontinuity horizons that are caused by the layering of water masses with distinct temperatures and salinities. To test the hypothesis that the microbiology and biochemistry associated with particles in these horizons are distinct from those of suspended particles above and below the horizon, a group of scientists used the Makali'i to: 1) demonstrate that the submersible could be used to perform detailed profiles of physical and biological properties of the water column; 2) examine spatial variability of the distribution and

morphology of suspended particles in relation to depth; 3) correlate microbial distribution and activity with particle and dissolved nutrient abundances; and 4) examine the vertical distribution of macroplankton.

During a 13-day dive series at a site north of Kaneohe Bay, Oahu, physical, video, photographic, and voice data were amassed. Their analysis revealed the following: 1) the physical structure of the water column varied subtly over the dive series; 2) despite low biological standing stocks and dissolved nutrient concentration at this site, particles were abundant throughout the water column; 3) distinct layering of particles and macroplankton was observed on the first dive and became more diffuse as the series continued; 4) large aggregated marine snow particles, not apparent in shallower water, were commonly seen below approximately 120 m, and bubbles were associated with many of these particles; and 5) undescribed species of ctenophore and a flashing luminescent crustacean were sighted. Water samples taken during these dives are being analyzed for particulate and dissolved carbon and nitrogen, microbial abundance and metabolic activity, dissolved inorganic nutrients, volatile fatty acids, and methane.

Detection and Measurement of Submarine Ground Water Discharge Quality (U-NC)

The first phase of a study to investigate stromatolite (blue-green algae) formations in Key Largo Sanctuary and pore water seepage carrying pollutants into the sanctuary was conducted during the period from March 9 through October 2, 1985. Ground water discharge was collected and measured at various depths using seepage meters. In control experiments, the volume collected exceeded passive flow into seepage meter bags in open water, and outflow was always greater than inflow. The quality of water collected was different from that of ambient seawater.

Other pertinent data resulting from this study include the following: 1) there was a positive hydraulic head across the seepage meters and from shallow wells, in most instances; 2) the hydraulic head varied with depth in the sediment; 3) depth had no effect on flow; 4) water temperature was always lower in the sediments than in overlying ambient water; 5) discharge seemed to be independent of tides and "seepage holes"; and 6) greater flows appeared to be associated with the presence of current.

The role of benthic algal mats as biological indicators of ground-water discharge will be investigated in 1986 during the final phase of this study.

Animal-Sediment Relations in Profundal Lake Superior Sediments (UCAP)

Researchers examined a west-to-east depth gradient in a north-south trough located north of Crisp Point in Lake Superior, using a variety of innovative techniques:

- o shipboard 35 mm and submersible-operated CCD video sediment profile cameras for rapid reconnaissance of the lake floor
- o sediment coring (both tube and box corers) modified for submersible use, for geological, geochemical, radionuclide dating, and x-radiographic analysis
- o particle spreading experiments to measure in situ deposit feeder ingestion rates and bioturbation
- o fecal pellet production and decomposition experiments, where sediments are marked with tracers in two unequal cohorts.

This research is expected to continue for 3 to 5 years to compare specific benthic processes within and between the lakes and the marine environment. An understanding of animal-sediment-fluid interactions at the sediment-water interface and their control of boundary layer transport and mixing processes is critical to model lacustrine sedimentary environments accurately.

Sources and Dynamics of Particles, Organic Carbon, and Organic Contaminants in the Benthic Nepheloid Layer of Large Lakes (UCAP)

In 1986, detailed vertical profiles of particles were collected at four dive sites in Lake Superior with the Johnson Sea-Link II from the R/V Seward Johnson. Particles were collected via submersible from the benthic nepheloid layer (BNL) -- a zone enriched in particles extending above the sediment-water interface, from the sediment boundary layer, and from sediment cores. Air and surface water were sampled from the surface ship at each dive site.

The overall objective of this study is to investigate the role played by the cycling of particles and organic carbon in the transport of hydrophobic organic contaminants (e.g., PCBs, DDT, PAHs) in large lakes. In addition, researchers hope to identify sources and estimate fluxes of particles and organic carbon through the water column, to identify and quantify selected organic contaminants, to estimate vertical fluxes of organic contaminants throughout the water column, and to construct a mass balance model of particles, organic carbon, and organic contaminants in the sediment-water environment.

Initial results of the study include confirmation of the presence of a BNL and establishment of the existence of the

sediment boundary layer. In addition, the high amount of biological activity suggests rapid processing of organic-rich particles in the benthic region. Researchers hypothesize that (1) the BNL originated from resuspension of sediments and/or from downslope transport during non-stratified conditions, and (2) the sediment boundary layer (fluff) consists of particles that have settled from the water column during stratified conditions. Preliminary findings from dives at Whitefish Bay demonstrate that BNL and fluff particles have different contaminant geochemistries, suggesting that they derive from different sources.

Analysis (for organic contaminants and organic geochemicals) of samples collected at four sites is ongoing; the data will be incorporated with data collected by other geochemists participating in the NURP Great Lakes cruises.

Biogeochemical Processes at the Benthic Boundary Layer (UCAP)

High quality sediment cores taken from the Johnson Sea-Link/Seward Johnson in eastern Lake Superior have revealed a remarkable variability in benthic environments in this region. Cores from a shallow coastal bay (> 100 feet), an intermediate depth (400 feet) depositional basin, and several deep (> 100 feet) basins indicate order-of-magnitude changes in sediment accumulation rates, benthic metabolism, and microbial activity associated with biogeochemical cycling processes in the upper 30 cm of sediment. Observations and samples from the deepest basins of the lake showed marked differences: at water depths of ~1200 feet, sediments were organically richer and more rapidly accumulating than sediments at 1330 feet, where only a thin veneer of flocculant sediments over highly compacted clay and sand was observed. The biological community was abundant in both basins, despite seemingly significant differences in the fluxes of labile organic materials to support the benthic food chain. Ripple marks at ~1200 feet in the southern portion of the deepest basin provide tentative evidence of high-energy events (benthic storms) that may prevent the net accumulation of material on a permanent basis.

Samples were also collected for determination of the amino acid composition of recently deposited material. Flocculant surface sediments are being compared with sediments from other Great Lakes environments to qualitatively assess the extent to which surface sediments in the deepest basins of the Great Lakes resemble "fresh" or "aged" detrital material and provide information on the speed with which such material reaches the bottom and the length of time it remains there.

Rare Earth Element Tracer Studies of Biogenic and Physical Sediment Transport in the Great Lakes (UCAP)

A study was conducted during the 1985 and 1986 NOAA/NURP Great Lakes research cruises (1) to accurately measure in-situ rates of physical and biogenic sediment reworking and redistribution in fine-grained Great Lakes sediments; (2) to determine the

importance of in-place pollutants in profundal Great Lakes sediments and to understand their role as sources of contaminants to water and biota; (3) to determine whether in-situ (submersible-collected) geochemical sampling techniques provide superior sample quality compared to conventional shipboard sampling techniques; and (4) to determine whether observed differences in the techniques can account for the inability to construct accurate mass balance models for certain contaminants, such as PCBs, in Great Lakes sediments.

The methodology employed calls for researchers to place (and mark with underwater beacons) tracer pellets of rare earth element-enriched fine grained muds in quiescent, profundal depositional basins; after periods of months to years, the tracer pellets are relocated and sampled. Analysis of the collected sediments by instrumental neutron activation (in addition to standard sedimentological methods) is followed by calculation of the rates of lateral and vertical sediment transport. These rates, combined with measured sediment pollutant concentration and adsorption-desorption equilibria, yield estimated rates of contaminant release to overlying water. Sediment cores collected in statistically significant numbers from shipboard and submersible are analyzed geochemically and compared to determine if significant differences appear.

Thirty punch, gravity, and box cores have been collected from dives conducted during this period. All of the cores have been extruded, sectioned, and preserved, but their analysis is not yet complete.

Aerobic Methane Oxidation in Lake Superior (UCAP)

Scientists generated profiles of methane concentrations in the sediments from several sites in Lake Superior by analyzing punch cores taken from the Johnson Sea-Link II. Methane-oxidizing bacteria have been isolated from these samples, and researchers have begun to characterize these strains. A kinetic approach has been used to determine Km and Vmax values for methane oxidation, and methane profiles have been used to estimate in situ methane consumption rates.

Presentation and publication of these data are anticipated in the near future.

Geochemical Processes at the Sediment Water Interface in Profundal Lake Environments (UCAP)

A study begun in 1985 continued during a 1986 Great Lakes cruise; the study has the following objectives:

- to determine the chemistry/mineralogy and origin of the nepheloid layer and the fluff layer

- to identify mechanisms and rates of chemical transfer across the water-sediment interface

- to define the nature of chemical diagenesis with depth in sediment.

Researchers vertically sampled the water column and sediments in defined areas of Lake Superior that are characterized by relatively high sedimentation rates and thick post-glacial sediment. Precisely located and undisturbed box cores, benthic sediment fluff, and water samples were collected with the submersible, followed by shipboard work that included taking longer gravity cores to supplement the box coring, extruding the cores (under both N_2 and air), making preliminary measurements on the sediment and water samples, and preparing the samples for shipment to the land-based lab. Because of its diffuse nature, large volumes of the nepheloid material could not be obtained during the 1986 cruise, but better fluff samples were collected than during the preceding year. All samples are currently being analyzed.

The Biogeochemistry and Cycling of Iron and Manganese in the Sediment Boundary Layer of Lake Superior and Lake Huron (UCAP)

Scientists examined pore water profiles for the presence of metals to assess the distribution of soluble and particulate phases in various sediments in Lake Huron and Lake Superior. Sediment cores were processed on the ship immediately after collection using the coring apparatus on the submersible Johnson Sea-Link II. Further characterization of the cores included: oxygen microprofiles that were determined using microelectrodes; distribution of Mn oxidizing and reducing bacteria using culture techniques and enumeration methods; distribution of particulate and soluble iron; and profiles of total carbon, hydrogen, and nitrogen. A second approach involved the employment of environmental chambers at specified sites for long-term incubation experiments. These chambers, which communicated with the lake environment via semi-permeable membranes, were sterilized, loaded with a variety of different chemical and biological materials (pure cultures of Mn oxidizing and reducing bacteria, Mn oxides, Mn nodule material), and placed in contact with the water and sediments.

A large part of the data gathering for the sediment core analyses has been completed. Oxygen profiles, particulate and soluble Mn, and Mn-oxidizing bacteria have all been finished. The remaining data are being worked up. The chambers will remain in place until researchers can retrieve them. Also planned is a comparison of an offshore core sample with the deep Lake Superior core data.

Comparison of Sediment Function and Structure Above and Below the Euphotic Zone of Lake Superior (UCAP)

Studies on the metabolic activity of microbial communities in surficial aquatic sediments of Lake Superior were conducted in 1985 and 1986. Pore waters from cores collected using the Johnson Sea-Link II have been analyzed for nitrate, nitrite, sulfate, and oxygen. The process rates of aerobic respiration, dentrification, and sulfate reduction were also measured. These data, coupled with the organic matter content and estimates of microbial biomass of the respective sediments, are expected to provide a better understanding of early diagenetic processes in Lake Superior sediments.

Ground-Water Discharge in a Deep Coral Reef Habitat (U-NC)

In 1986, the second phase of a continuing study to measure the quantity and quality of submarine ground-water discharge into a deep coral reef habitat using seepage meters and submarine piezometers was conducted. Four sites were investigated in the vicinity of Key Largo, Florida.

The data from both types of sampling units showed that the ground water had a different chemical composition than did ambient seawater. Rates of discharge were independent of tidal action and depth. Use of a manometer demonstrated the presence of a positive hydraulic head on both sampling units. Although salinity varied in the sampling units with respect to ambient seawater, the data suggest that a mechanism exists for moving nutrients and trace minerals across the sediment/water interface, which may be global in its nature and may transcend regional or localized effects of ground-water influx through confined aquifers.

II.C. COASTAL OCEANIC AND ESTUARINE PROCESSES

Many of the estuaries of the United States have been seriously degraded by activities such as the application of pesticides to agricultural lands, which results in the run-off of hazardous wastes into adjoining waterways, or the direct dumping of wastes into rivers or the estuary or coastal area itself. Estuaries, which are the most complex and variable portion of the ocean, can thus serve as "natural" laboratories for the study of the impacts of human activities on the ocean environment.

A long-term research program designed to characterize the variations in coastal oceanic conditions and to relate these variations to external factors is desperately needed at the present time. Several NOAA-sponsored projects conducted in 1985 and 1986 explored important oceanic and estuarine features, such as sedimentary processes in the Gulf of Maine, the cycling of contaminants in the Great Lakes, and the decomposition of algae in the sediments of Salt River Canyon. Two of NOAA's Undersea Research programs, those at the universities of Connecticut and Fairleigh Dickinson, placed particular scientific emphasis on coastal oceanic and estuarine processes. The sections below describe these projects individually.

1985 PROJECTS

Sedimentological Investigations by Submersibles in the Gulf of Maine (UCAP)

In a series of dives to investigate sedimentary processes in the Gulf of Maine, scientists using the Johnson Sea-Link submersible system obtained samples and observed distribution patterns of various sediment types. Video and photographic transects were run at historic sampling sites, at depths of 30-70 m, for visual verification of features previously recorded in seismic profiles. Box cores and cylinder cores also were taken for later geochemical analysis. Between dives the R/V Link engaged in seismic profiling to correlate with the submersible's track.

As a result of this mission, the paleoshoreline in Machias Bay was discovered and the following marine phenomena were identified: viable herring spawning grounds, the rubble transition zone, scallop drag marks, mud drapes and turbid plumes, and a carbonate halo around bedrock pinnacles.

Although this project was intended, originally, to last a single year, a longer term investigation is now envisioned that would involve in-situ experimentation with sediment traps and repetitive occupation of sites.

Optical Patterns and Characteristics of the Benthic Particulates in the Gulf of Maine (UCAP)

As a means of quantifying and defining the nature of the benthic nepheloid layer in the Gulf of Maine, a study was undertaken in 1985 of the structure of light transmission, or turbidity, within the bottom 5 meters of the water column in several areas. However, only two dives in a shallow estuarine environment actually were performed because of problems with ship scheduling and weather. These two dives were sufficient to permit the project's marine scientists to test proposed techniques: in-situ measurement of environmental parameters (conductivity, temperature, light transmission) and water sampling for on-deck laboratory analyses of particulates, including Coulter Counter and chromatographic studies.

The proposed techniques proved successful and, as a consequence, a larger scale program is being planned. This new program should provide a broader understanding of the network of particle dynamics in at least one marine environment and of the supply of nutritionally rich particles in benthic biota.

In-Situ Study of the Sediment-Water Interface and Benthic Boundary Layer Dynamics (UCAP)

In 1985, year one of a projected 3- to 5-year effort, testing and refinement of the methodology proposed to implement a study of the benthic boundary layer dynamics in deep depositional basins of Lake Superior was inaugurated. The techniques evaluated include:

(1) utilization of the newly developed video sediment profile camera (VSPC) for rapid aerial reconnaissance;
(2) employment of the rare-earth-element (REE) tracer to measure vertical and lateral sediment transport; and
(3) conventional geological and geochemical analysis (e.g., radionuclide dating, roentgenography) using sediment coring, with box and cylinder cores especially designed for submersible use.

Initial results showed that the VSPC worked well with the submersible, and an improved version for 1986 should provide capability for more detailed and rapid data acquisition. In addition, diver-scientists made several significant observations: video transects revealed high densities of sculpin (unexpected in such a hyperoligotrophic environment), and unusual sedimentary features, which may result from past sculpin activity, were discovered by x-raying box cores.

Submersible Studies of Sedimentary Furrows in Lake Superior (UCAP)

Marine scientists in the Great Lakes area conducted a series of dives in Lake Superior during 1985 to study the relationship between fine-grained sediment transport and bottom currents in deep lakes, with particular emphasis on gaining an understanding of furrows so they can be used by scientists as indirect indicators of currents and sediment transport. To achieve their objectives, these scientists made detailed visual and photographic observations of furrows, and, with respect to bed forms, collected oriented sediment samples and deployed current meters.

Preliminary analyses of sediment samples were subsequently performed to quantify the cross-furrow changes in texture and structure observed at the time of collection, to determine the stratigraphy of the site, and to measure magnetic fabric. Several samples showed significant amounts of disturbance (in magnetic properties and under x-ray analysis). In addition, an extensive bathymetric and side-scan sonar mapping around the furrow study site was conducted to establish the relationship between the moorings and the furrows.

Based on the results of the 1985 dive series, a study has been proposed for 1986 that would examine other features, including lineations and modified rings, that are common on side-scan sonar records from deeper portions of the lake and suggest that bottom currents often rework lake sediments as deep as 250 m.

Sediment Composition of the Distribution of Terminal Electron Acceptors in Sediments of Lake Superior (UCAP)

A fourth study of the waters in Lake Superior was implemented in 1985, with the following objectives:

(1) To examine visually and photo-document large areas of sediment to evaluate the heterogeneity of the lake bottom and take appropriate samples for shipboard analysis;
(2) To characterize the microbial activity of the sediments;
(3) To determine the concentrations of various water solutes, particularly the inorganic terminal electron acceptors--oxygen, nitrate, nitrite, and sulfate;
(4) To determine the organic content of the sediments; and
(5) To determine the depth distribution of benthic algal productivity.

The data collected during the mission revealed much about the general characteristics of Lake Superior's sediments and will provide a basis for a further study being proposed for 1986. Two particular findings warrant mention: (1) the depth of penetration of oxygen into sediments of Lake Superior is much less

than previously supposed (5 to 10 mm, as opposed to 5 to 10 cm), and (2) microbial activity below the upper centimeter is very low.

Boundary Layer Structure in a Region of Sedimentary Furrows (UCAP)

To determine the forms of organized flow structures associated with furrows in the floor of Lake Superior, scientists emplaced autonomous current profilers (cyclesondes) at 100 m on either side of a furrow in the known furrow field off Copper Harbor, Michigan, with the intention of obtaining current velocity and temperature profiles from areas near the bottom to within 20 m of the surface.

During the August 1985 cruise, lake bottom currents were very low (< 2 cm/sec) so that the cyclesonde rotors did not even turn. This was the result of an extended period of very calm weather that allowed spin-down of surface circulation and strengthening of stratification. In late October, scientists returned to the site to position the moorings and reinstall the cyclesondes, which were set to obtain profiles over the succeeding 6 weeks. However, because of rough weather conditions and the absence of vessels on the lake in December, it was not possible to recover the instruments at the end of the recording period. Recovery is planned for spring 1986.

Scientists hypothesize that there are furrow-related organized vortex-pair structures in the lake bottom boundary layer flow. Such structures have been observed in the atmospheric boundary layer, but although there is indirect evidence (e.g., furrows) of their existence in ocean and lake bottom flows, no direct observations have yet been made. Analysis of data from the recovered instruments may confirm this hypothesis. Establishing that these structures exist at the lake bottom would change conventional thinking about these boundary layers, from the current hypothesis about the importance of random turbulence toward a more structured model.

1986 PROJECTS

Particulate Matter Fluxes in the Gulf of Maine (UCAP)

Scientists have hypothesized that large, fast-sinking fecal pellets from zooplankton constitute a major source of biogenic particulate material exported from the photic zone to the benthos. A single species of zooplankton, the euphausiid Meganyctiphanes norvegica, was selected for intensive study in the first year of a 5-year program to confirm this hypothesis. The objectives of the long-term project are as follows:

1. Study in-situ the diel migratory and epibenthic feeding behavior of euphausiids with a submersible to correlate

their distribution and abundance with mixed layer production, physical/chemical gradients, and sediment organic loads.

2. Conduct in situ and laboratory studies of fecal pellets produced by euphausiids (distribution, abundance, sinking rates, chemical composition, and taxonomic components) to define the extent to which fecal pellet biomass from this source represents an energy flow link between primary producers and benthic consumers.

3. Deploy a free-drifting sediment trap and a moored sediment trap to quantify daily flux rates of fecal pellets and other particulate matter below the mixed layer and near the sea floor.

Submersible-based observations of Meganyctiphanes norvegica have indicated that large quantities of fecal pellets are released daily in the mixed layer by migratory, nocturnally feeding populations. An abundance of these euphausiids resides near the bottom and is likely to consume flocculent biogenic sediments near or on the sea floor, thus acting as bioturbators. The coupling of benthic and pelagic environments, via the downward transport of particulate material, is of major interest to the entire oceanographic community. The production of particulate organic material in the water column represents the primary food source for the benthos, and, therefore, the processes that affect delivery and modification of these organic resources ultimately regulate benthic productivity.

Benthic Productivity and Resources of the Gulf of Maine (UCAP)

The approach to this study, which was designed to describe the nature of particulate maxima that occur just above the bottom and within narrow depth strata in the Gulf of Maine (sites believed to represent areas of enhanced biological activity), was modified 10 days before the cruise to allow the collection of samples from a surface ship because mechanical problems forced the cancellation of all submersible dive operations.

Scientists designed, constructed, and collected samples with a 3 X 30 L rosette water sampler from various elevations above the bottom at both a shallow and deep site in the Gulf of Maine. These samples were analyzed for chlorophyll, particulate carbon and nitrogen concentrations, "total" and biologically available protein, ATP (as a measure of living biomass), electron transport system activity (as a measure of respiratory activity), abundances of heterotrophic bacteria, abundances of autotrophic and heterotrophic nanoplankton, and particle concentrations and physical and optical characteristics of particles.

Preliminary results of this study indicate that the benthic nepheloid layer can sometimes be a zone of enhanced nutritive

value and biological activity. Investigators found considerable temporal and spatial variability that may be related to events in the surface waters but is affected by horizontal advection at depth. By comparing the composition of the particulate organic matter, the accompanying organisms, and the ensuing biological activity in a variety of areas, it should be possible to determine the role of the bottom nepheloid layer in the benthic productivity of the Gulf.

II.D. OCEAN LITHOSPHERE AND MINERAL RESOURCES

Scientific projects in the ocean lithosphere and mineral resources area emphasize the mechanisms and processes associated with the tectonic evolution of the ocean basins and the materials comprising the seafloor. An understanding of the ocean lithosphere and its mineral resources is essential both to the prediction of events such as earthquakes and tectonic movement and to the mining of seafloor minerals. Among minerals to be found in the deep seabed are: cobalt, manganese, nickel, copper, and platinum. Other offshore deposits that have significant economic potential are oil and gas resources.

The Office of Undersea Research has sponsored an important series of research dives to explore the manganese-cobalt crusts that form on seamounts and the ore-grade deposits of sulfide ores rich in zinc, copper, and silver formed by hydrothermal activity. These dives have utilized the deep-water submersible Alvin, which has a depth capability of 4,000 meters. A long-term OUR-sponsored project, called Project Sea Sub, has investigated the impact of oil and gas well drilling on the level of tissue-bound toxicants in several indicator species of fish and invertebrates.

The University of Hawaii NURP program conducted two ocean lithosphere studies in 1985. In 1986 three such studies were conducted by the Connecticut NURP program. These projects are summarized below.

1985 PROJECTS

Detailed Sampling and Mapping of the Submarine Extensions of Several Historic Hawaiian Lava Flows Using Makali'i (U-HI)

In a series of 10 dives during 1985, scientists employed the research submersible Makali'i to map in detail the submarine extensions of several historic lava flows on the island of Hawaii, collect in-situ samples of the lava from depths between 50 m and 350 m, and characterize the morphology and structure of each lava flow to assess the first-order processes involved in lava movement across a shoreline and into shallow water.

Over 50 rock samples were collected, cataloged, split, and thin-sectioned using an epoxy and paint technique so that fragile palagonite rinds were undisturbed during preparation. Chemical

analyses of these samples--expected to be completed by Fall 1986--should reveal chemical affinities with subaerially collected samples from the same flows and help researchers to determine whether lava composition was influenced by processes associated with flow differentiation. In addition, submarine continuations of selected lava flows were successfully mapped and their flow margins and flow fronts delimited.

It is anticipated that analysis results will contribute to an understanding of how oceanic islands grow through expansions of coastlines caused by lava flows that cross the shoreline and of the physical factors involved in palagonite growth from volcanic glass (e.g., temperature, depth, salinity, surface area) and the rate at which this clay mineral forms rinds on glassy basaltic lavas.

Investigation of Submerged Reefs off Kona, Hawaii (U-HI)

A systematic study of two ancient drowned coral reefs off Kona, Hawaii, was undertaken in 1985 to map their extent and depth, determine their age, and observe their relationships with volcanic and structural features such as lava flows, faults, landslides, and differential subsidence. Samples of coralline algae from the upper face of the deeper reef (-360 m) have yielded tentative Uranium - series ages of 99 to 120 Ka. Previous dating of corals from the shallower reef (-150m) revealed that it drowned 13 Ka ago. Together, these figures have confirmed scientific estimates that the northwestern coast of Hawaii is subsiding at an absolute rate of 1.7 to 2.0 mm/year.

Detailed investigation of the 150-m reef indicated that the reef wall has undergone extensive erosion and solution since formation and cover by lava and that the unprotected reef face between lava flows has receded shoreward as much as 100 m. The entire face, including lava flows, may have receded considerably more. Analyses are underway on associated lava flows of the two reefs to determine their source (whether from Kilauea or Mauna Loa volcano) and to estimate their age and water depth at the time of cooling.

Several publications describing this research are in progress. Results of the study will contribute to an understanding of the rapid submergence of the island of Hawaii--caused by the absolute subsidence of the volcano, which is caused in turn by the rapid loading of the lithosphere by volcanic material, and by the current eustatic rise of the sea level. This information is of interest to scientists studying the volcano- tectonic history of the Hawaiian Ridge, and, in addition, is of practical importance to coastal communities that must deal with the inevitability of a rising sea level.

1986 PROJECTS

Sediment Dynamics Along the Inner Shelf of the Gulf of Maine: Comparison of Geophysical Remote Sensing and Submersible Observations (UCAP)

In a series of nine dives lasting 1 to 3 hours each, scientists examined the nearshore Gulf of Maine and its adjacent estuaries using seismic profiling, coring, and grab sampling equipment and techniques in order to evaluate sedimentary processes and sediment distribution. These direct observations permitted on-site confirmation of remotely sensed sedimentologic processes and materials, such as rippled scour depressions, carbonate-rich haloes around rock pinnacles, and till.

These efforts have contributed to the building of a data base of seismic profiles and side-scan sonar information that can be applied in the future to develop nearshore maps of sediment types that would benefit fishermen. The results of this research have been described in two publications, and three additional papers are in preparation.

Investigation of the Reworking of Glacial Sediments on the Southeastern New England Shelf (UCAP)

As part of a project to further general knowledge of the mechanisms and products of marine and biological reworking of relict and palimpsest sediments of the inner and outer shelf environments, investigators studied the large bedform field located in eastern Long Island Sound and observed and collected sediment samples in the vicinity of Long Sand Shoal. Plans to make a reconnaissance of Block Delta and Block Canyon were abandoned for the time being because of inclement weather.

Initial ship transects across the bedform field using a Raytheon fathometer identified specific dive sites and overall characteristics of the sand waves. Submersible dives were made perpendicular to the flow because of strong tidal currents. Diver observations revealed a hierarchy of bedforms, with the larger forms frequently being composed of several smaller ones. The troughs of the sand waves had been stabilized by a biological covering of hydroids. The crestal portion of the sand waves was composed of medium-sized sand and exhibited steep active slipfaces.

Studies of Current-Created and Modified Topography in Lake Superior (UCAP)

Sedimentary furrows and ring segments found in earlier investigations of the floor of Lake Superior were studied by diver-scientists, utilizing a submersible, to determine whether strong, deep-flowing currents could have been important agents in

eroding, transporting, and redepositing lake bed sediments and associated pollutants.

Analysis of precisely located cores in the sedimentary furrows found in water near Copper Harbor, Michigan, revealed that these bed forms have been active during the last few hundred years and have also been active also within the last 10 years. Direct current meter measurements have shown that deep currents are minimal during the summer months, but they can become quite strong during fall and winter storms. The presence of furrows here suggests that periodic bottom currents exist deep in the lake; a long-term current meter will be recovered during the summer of 1987 to determine yearly current variations at this site.

A ring segment was studied at a depth of 240 meters. This large crescent-shaped depression (5 m deep, 100 m long, and 20 m wide) was apparently formed by erosion, because laminated, glacial-lacustrine clays exist just below the depression floor. These sediments usually were buried by 1.5 to 2 meters of post-glacial sediments. A field of current ripples found on the steep wall of the depression appears to have been formed recently by bottom currents, leading scientists to conclude that such currents are active agents even in the deep central lake and that they must play a role in transporting sediments throughout the lake.

II.E. BIOLOGICAL PRODUCTIVITY AND LIVING RESOURCES

The research included under the heading of Biological Productivity and Living Marine Resources is related to the management and conservation of marine resources and to the development of oceanic technology that will enable scientists to make better use of our natural resources. NOAA's Undersea Research Program has been heavily involved in scientific research in this topical area for several years. Major advances made as a result of NOAA-sponsored research include the development of a circle hook to replace the traditional J-hook used to catch halibut, which has increased catch efficiency by 60 percent.

All six of NURP's program elements--at Fairleigh Dickinson in St. Croix, North Carolina at Wilmington, Southern California at Catalina Island, Hawaii at Manoa, Connecticut at Avery Point, and the Caribbean Marine Research Center--conducted active research programs related to biological productivity and living resources in 1985. In 1986, the Connecticut, Hawaii, and North Carolina programs were active in this research area. Individual research projects are summarized below.

1985 PROJECTS

In-Situ Studies of the Efficiency of Sink Gill Nets and an Assessment of the Ghost Gill Net Problem (UCAP)

As part of an ongoing study to determine the magnitude of the ghost net problem on fishing grounds frequented by gill netters in the vicinity of Jeffrey's Ledge in the Gulf of Maine, a team of marine scientists aboard the R/V Seward Johnson used the Johnson Sea-Link submersible to measure the number and areal extent of the ghost nets in these waters and to assess their impact on local resources. In addition, ghost nets discovered in 1984 were revisited in 1985 in an effort to discern any changes in net condition and configuration or in the type and condition of ghost net catch.

Researchers have preliminarily concluded that ghost gill nets do not represent a significant hazard to other resource users (principally, party boats and trawlers) in the areas surveyed, but the study will not be completed until 1986. At that time, the Stellwagen Bank vicinity of the Gulf of Maine--an area of continued gear conflict involving gill nets--will be studied extensively. One of the benefits of this study has been the sharing of survey results with the New England Fisheries Management Council, which is using these findings to help in resolving a space conflict between gill netters and other resource users.

The Feeding Biology of Brittle Stars (Echinodermata: Ophiuroidea) in the Gulf of Maine and Their Role as Prey for American Plaice (UCAP)

Because of poor weather conditions, a project designed to take place in Cashes Basin in the Gulf of Maine in 1985 will be conducted in 1986. The study's objectives are to determine the species diversity and density of brittle stars, their diets and feeding behavior, their ecological impact on the substrate, and their importance as prey for American plaice (Hippoglossoides platessoides) in Cashes Basin.

The methodology envisioned includes the obtaining of brittle star specimens for taxonomic and ecological studies and several kinds of photographic data for both qualitative and quantitative assessment of the macrobenthos. Surface sediment samples will be collected by grab and coring devices and analyzed by various methods; baited trays will be employed and observed over time to determine the behavioral responses of various brittle star species; and specially designed baited rigs will be used to capture American plaice at the same dive locations at which brittle stars are collected. The contents of the plaice stomachs will then be analyzed and compared.

Ecology of the Sea Scallop, Placopecten magellanicus, in the Gulf of Maine (UCAP)

A comparative study of two offshore beds of the commercially valuable species Placopecten magellanicus was conducted in 1985 to provide baseline data on the general structure of the beds; scallop distribution and behavior; predation, competition, and natural mortality; and substrate. In addition, manipulative experiments were initiated to study the epizootic community associated with these beds and in particular the scallop shells. The 1985 dives were the first in a proposed 3-5 year program. Revisitation of the study site in 1986 should provide sufficient data to determine the actual length of time needed to complete this research.

Distribution and Abundance of Pennatulids in the Gulf of Maine (UCAP)

Another multiyear project being conducted in the Gulf of Maine has as its objective the documentation of deep-water pennatulid (sea pen) occurrence in Gulf basins and the assessment of their importance in the ecosystem. In 1985, photographs and video footage along transects were used to record the distribution and abundance of pennatulids in relation to abiotic and biotic factors, and efforts were made to collect pennatulids for morphological study and experimentation. However, few pennatulids were captured for laboratory studies, and this aspect of the study will be a critical objective for future years. Scientists were

particularly interested in the absence of sea pens in the Wilkinson Basin, which contrasts with their presence in all of the other deep basins. Investigations to determine whether there are basic ecological differences among the Gulf basins will be examined later in this ongoing study.

Community Structure and Predation Intensity in Deep Offshore Habitats in the Gulf of Maine (UCAP)

In the second year of a 3-year investigation of subtidal community dynamics in the Gulf of Maine, progress was made toward achieving the following objectives: 1) describing benthic faunal zonation on deep rocky substrates, 2) conducting experiments on the effects of predators and larval recruitment on the composition of these communities, and 3) establishing long-term monitoring sites to examine growth rates and other trends.

Divers using the Johnson Sea-Link I discovered new information on the distribution of benthic invertebrates in deep offshore communities, observed a previously undescribed crinoid zone in the Gulf of Maine, and gathered preliminary evidence of trophic linkage between benthic invertebrates and commercially important species, e.g., the anemone Bolocera feeds on shrimp, and the cod Gadus morhua consumes anemones. Several publications based on these findings are expected in 1986.

The Impact of Macroalgal Detritus on Benthic Productivity: Patterns of Distribution and Abundance (UCAP)

To test the hypothesis that macroalgae are important to benthic productivity as a source of organic matter, marine scientists sought to quantify photometrically the detrital macroalgae in coastal and offshore habitats below the photic zone and to collect detrital macroalgae for species and biomass determinations. The Johnson Sea-Link submersible was used to survey the bottom and collect macroalgae whenever possible. This project was a collaborative effort involving several scientists, all of whom reported macroalgae whenever they were seen in the course of their investigations.

Herring Egg Bed Studies (UCAP)

Field work performed during September 1985 initiated a 4-year project to 1) identify physical and biological features characteristic of herring spawning sites, 2) determine the size of individual egg beds and habitat characteristics associated with variations in the distribution and abundance of eggs, 3) assess the factors affecting egg mortality and larval hatching rates, and 4) discover the conditions that impact the survival and downstream transport of recently hatched larvae.

The initial investigation was conducted in shallow coastal waters in eastern Maine with a remotely operated vehicle (ROV) deployed from a small vessel. Two spawning sites were surveyed; data were collected on video tape and by sampling eggs, larvae, and substrate with plankton nets and benthic grabs deployed from a second surface vessel. Analysis of these findings is underway. Future work will include mapping of individual egg beds and in-situ sampling of eggs and larvae with an ROV.

Patterns of Zonation in Deep Water Benthic Algae in the Gulf of Maine (UCAP)

A team of marine scientists conducted studies in the Gulf of Maine to quantify and map the occurrence of a centrally located deep water macroalgal community, to examine factors affecting patterns of zonation, and to measure primary productivity along a depth gradient (at depths of 30, 45, 60, and 75 meters). Using experimental Depth-specific Research Stations (DRS) emplaced at each of the study depths, investigators affixed algae, collected by scuba, to the DRS's submersible-deployed panels. Each DRS holds four panels; in total, the panels contain 298 transplanted chips, which will be re-examined during the summer of 1986 to determine survivorship and growth along the depth gradient.

The 1986 follow-up project will determine the viability of the experimental design in addition to measuring the growth and vigor of the transplanted algae.

Factors Affecting Distribution and Abundance of Flatfish Prey on Jeffreys Bank, Central Gulf of Maine (UCAP)

Inclement weather, poor visibility, and other adverse conditions severely limited the efforts of diver-scientists engaged in a study to:

(1) determine the homogeneity of mega- and macro-faunal distributions over a selected flatfish fishing ground;
(2) discover the effects of selected megafaunal species, such as large ceriantharians, on the localized distributions of infaunal species;
(3) examine the stomach contents of flatfishes in areas of dense megafauna; and
(4) determine the biomass of infauna in the absence of fish predation.

Only three samples were obtained during this limited project; these samples are being analyzed to identify the component taxa.

Diel Vertical Migration of the Opossum Shrimp Mysis relicta in Lake Superior (UCAP)

Samples taken and visual observations made during two dives in the summer of 1985 were carried out to segregate and define two populations of Mysis relicta believed to exist during the day and night in Lake Superior. The sampling approach was timed to the diel vertical migration pattern of the opossum shrimp.

Four objectives were achieved during the investigation: 1) observation of the mating position, photo period time, and depth location of Mysis during mating; 2) determination of the existence of nonmigratory portions of Mysis and Limnocalarus macrurus, a euryhaline calanoid copepod; 3) observation of high densities of Mysis at the surface (0-3 m) during the night dive (surface populations are usually observed only during isothermal periods); and 4) observation of higher than expected total zooplankton densities in the nepheloid layer just above the sediments.

The project is part of an ongoing program, Leg II of which is scheduled for July-August 1986.

Spawning Habitat Requirements of Lake Trout in the Great Lakes (UCAP)

A project to develop visual records of the surficial substrates and measure the interstitial water quality of representative offshore reefs used historically and currently as spawning grounds by lake trout was undertaken in 1985 in support of an ongoing international effort to re-establish lake trout throughout their former range in the Great Lakes. During the five-dive research sequence, a video documentary of typical substrates present in lake trout spawning grounds was made and samples were collected of interstitial water at Stannard Rock, Gull Island Shoal, and Superior Shoal.

Interstitial dissolved oxygen concentrations were found to be at or above saturation at the spawning grounds at all locations sampled; interstitial pH values were within the normal range expected for Lake Superior waters. Incubation of interstitial water samples showed that only Stannard Rock and Gull Island Reef supported populations of bacteria that are capable of producing hydrogen sulfide, a substance that is toxic to fish and fish eggs.

Information gathered in this project in Lake Superior, where water and substrate quality are unimpaired and where native lake trout stocks are reproducing successfully, provides a baseline against which lake trout spawning habitat quality in the other four Great Lakes can be evaluated. These data will be used to increase the potential for success of future stocking efforts.

Underwater Detection and Observation of Lost Gill Net Gear: A Survey and Experimental Assessment of the Problem (UCAP)

In 1985, a study was undertaken to assess the extent to which ghost gill nets present a hazard to the commercially and historically important fish stocks in Whitefish Bay, Lake Superior. Transect surveys were conducted along dropoffs in areas of the bay where net losses reportedly were most frequent. Visibility in Whitefish Bay was very poor, seldom exceeding 4 meters, and the second scheduled day of transect survey activities was cancelled. Future work on this project is planned to test the hypothesis--suggested by observations made directly from the Johnson Sea-Link submersible--that shelters are a limiting factor of sculpin populations.

Biogeochemical Processes at the Benthic Boundary Layer (UCAP)

Four objectives to further the understanding of how deep Great Lakes benthic communities function and what role detritus processing plays in the ecosystem as a whole formed the basis of submersible research begun in the summer of 1985. These objectives are:

1) to determine the extent and rates of organic matter diagenesis in Great Lakes sediments, with particular emphasis on organic carbon and nitrogen cycling and the role of amino acids as intermediate metabolites in the decomposition of detritus;
2) to characterize the proteinaceous components of the detrital material found in and above the benthic boundary layer via measurements of the total hydrolyzable amino acid content of surface sediments and suspended material;
3) to estimate the residence times and recycling rates for those fractions of the material deposited in deep Great Lakes sediments that can be metabolized and mineralized; and
4) to compare sediment deposition rates and rates of diagenesis in a spectrum of Great Lakes sediments from coastal bays to deep basins.

The findings of this study were remarkable in terms of the number and apparent activity of zooplankton and other organisms associated with zones of highly flocculent sediments near the sediment-water interface. Although decomposition processes within the water column remineralize organic matter fixed within the photic zone, a considerable fraction of this material may reach the sediments, primarily through vertical transport on large particles and fecal pellets. This detrital "fallout" appears to support high densities of benthic organisms.

Deep Water Assessment of Larval Lamprey Distribution and Abundance in Lake Superior, With Special Reference to Batchawana Bay (UCAP)

A second-year effort in a 3- to 5-year research project to unravel the determinants of lentic ammocoete distribution and abundance was conducted in the summer of 1985 to identify and explain the major physical and biological factors affecting both sea lamprey and native lamprey lentic ammocoete distribution and abundance and to determine the effectiveness of, and reaction to, current and past sampling/control techniques on the part of lentic larval sea lamprey and native lamprey.

Analysis of information to date suggests that substrate particle size distribution, thermal regime, and aspects of intra- and inter-specific competition are probably the major determinants of past and present lentic ammocoete distribution and abundance. At present, bed slopes and suspended food particle distribution appear to be of secondary importance.

Benthic Invertebrate Research With a Submersible (UCAP)

Scientists conducted research in Whitefish Bay and the Caribou Basin at Lake Superior to examine microdistributions of the major invertebrate groups and determine if distributions are related to bacterial abundances. A second objective was to determine the efficiency of the Ponar grab sampler in deep water.

Four box cores in each location were taken with the submersible. Each of the box cores was divided into quadrants, and the number of invertebrates and bacteria in each quadrant was determined. Standard statistical procedures will be used to compare variability both between and within cores and to define any relationships between invertebrates and bacteria. Ten samples were also taken in Whitefish Bay with a Ponar grab. Numbers found in these samples will be compared to numbers found in the box core samples taken from the same site.

Most previous studies of the benthos in the Great Lakes have been descriptive in nature, yielding only relative estimates of abundance. However, more process-oriented research, such as the study described here, requires absolute estimates of abundance. In addition, this research examines potential causes of patchiness in the dominant invertebrate groups. A better understanding of aggregation would enable major improvements in sampling design for field studies of all benthic organisms.

Patterns of Spore Dispersal and Survivorship of Juvenile Sporophytes on Various Substrates in the Elk Kelp (USC)

A long-term project designed to investigate the population dynamics of the elk kelp (Pelagophycus porra) was initiated in 1985 with a series of scuba dives made over an 8-month period.

The elk kelp is a giant annual brown alga endemic to the coastal waters of southern California. The elk kelp population is characterized by irregular periods of loss and renewal and by wide variation in the size of individual plants.

Elk kelp are an important resource because their holdfasts provide stability to the substrate and kelp forests attract other species of algae, invertebrates, and fish. These kelp apparently use masses of Chaetopterus worm tubes to anchor their holdfasts. Scientists from the University of Southern California assessed the density of Chaetopterus worm tubes in several regions and placed artificial worm tube masses at a number of sites in the hope that the kelp would use them as anchors. In other experiments, aquanauts conducted transplant experiments to evaluate changes in the kelp's growth rate, pigment concentration, and photosynthetic ability. Results of these research projects will help scientists to determine why elk kelp, which are vital to the recovery of Big Fisherman's Cove from the effects of El Nino in 1983, have not renewed themselves in the cove.

A Mechanistic Study of Apparent Competition (USC)

Divers using a tethered diving system set up six study sites at Pumpernickel Cove to investigate mortality among snails and bivalves in the area. During set-up, empty snail shells were removed from the sites and live snails were marked and counted. The size structure of the snail population was analyzed by measuring more than a thousand randomly selected live snails. Approximately 3,000 live bivalves were added to the study sites to act as a secondary indicator of mortality. Researchers will return to these sites at regular intervals to monitor mortality rates, causes of death, and other factors.

Importation of Nutrients by Fishes, Macroinvertebrates, and Microorganisms into Deep Rocky Reefs (USC)

In experiments designed to measure the differential in ammonium excretion of marine animals during the day and night, scientists captured members of several macroinvertebrate, fish, and microbial species and measured their ammonium output. Results show that blackeye gobies excrete the most ammonium, followed by the sea cucumber. In general, excretion in all species was lower at night.

Enhancement of Florida's Outer Continental Shelf Fisheries in the Gulf of Mexico

Diver/scientists, using the Johnson Sea-Link I and the R/V Edwin Link and accompanied by the Oregon II, conducted a series of 11 dives in September 1985 to identify tilefish and grouper concentrations and their habitats along the outer continental

shelf off the west coast of Florida and to provide base information for sidescan and longline fishing operations by the Oregon II in the same area. The first six dives took place approximately 130 nautical miles southwest of St. Petersburg, Florida, in depths of 517-1,104 feet. Data were obtained from audio records, video and 35-mm film, and sediment samples.

The dominant species, both from submersible observations and from fishing activities, were blueline tilefish (Caulatilus microps), yellowedge grouper (Epinephalus flavolimbatus), speckled hind (Epinephalus drummondhayi), and grouper (Epinephalus niveatus). They occupied a unique habitat of patchily distributed calcareous limestone outcrops that occurred randomly in sandy-mud surface sediments. When approached by the submersible, the outcrops ranged from large (2-3 m) boulders with pronounced scour basins to heavily eroded outcrops. In addition, one dive encountered large "pavement" areas where the entire bottom appeared to be covered by smooth limestone deposits.

The second five dives took place approximately 120 nautical miles northwest of St. Petersburg in depths of 534-970 feet. The dominant species of commercial interest were golden tilefish (Lopholatilus chamacleonticeps), but these were small and sparse. Both physical (temperature, depth, substrate composition) and biological (other fish and invertebrates) characteristics were similar to those observed for golden tilefish on the east coast.

One additional dive, not part of the original research plan, was conducted when it became apparent to investigators that limestone-based habitats were important fish habitats at the edge of the continental shelf. The objective of this dive was to identify a large Karst sinkhole that occurred in bottom depths of approximately 550 feet due east of Cape Roamain, Florida. The sinkhole consisted of a rapidly sloping upper cone (to about 600 feet), which dropped abruptly to 753 feet at the bottom. The circumference of the bottom of the shaft was estimated to be 300-400 yards; the upper portion of the cone and the vertical shaft appeared to be the most productive portion for invertebrates and fish. Species of commercial importance were large and frequently abundant, including Warsaw grouper (Epinephalus nigritus), snowy grouper, blueline tilefish, and red porgy (Pagrus sedecim). Clouds of anthine serranids were often abundant. Researchers concluded that this location, and perhaps others like it, may serve as important habitats for many species by functioning as refugia for economically important species in areas where rough topography makes fishing difficult.

Gulf of Maine Lobster Habitat Ecology Program

The R/V Seward Johnson, chartered by NOAA along with the research submersible Johnson Sea-Link II, departed Boothbay Harbor, Maine, in June 1985 to conduct biological and geological studies in the central Gulf of Maine (Jordan Basin) in the U.S.

Exclusive Economic Zone (EEZ) and at the Grand Manan Banks and transition zone into Grand Manan Basin in the Bay of Fundy. Adverse weather conditions forced diver scientists to abandon their plans for dives in Canadian EEZ sites, although five dives were completed in St. Mary's Bay, Nova Scotia. Three of these dives provided useful information and gave Canadian scientists the opportunity to participate in the dives.

A major result of the cruise was verification of a working hypothesis that hagfish (Mykaine glutinosa) are a primary competitor for bait in newly set lobster pots in the deep mud basin regions of the Gulf of Maine. An experimental pot array enabled researchers to establish the timing, magnitude, and duration of hagfish feeding activity on trap baits. The activity and behavior of the primitive, eel-like fishes were observed during a series of four dives extending over 26 hours. Excellent video and photographic documentation was obtained. The findings raise important questions about the efficiency and cost-effectiveness of baited lobster traps in the context of currently practiced fishing strategy.

Florida Straits Transport Measurements Via Submerged Cable

In a single dive conducted in 600 feet of water approximately 9 miles east of Jupiter, Florida, divers located a section of submerged cable known to have a fault; their task was to section the cable at a suitable distance east of the fault.

The cable was easily located from the surface ship Edwin Link using a sensitive electric field sensing device -- the MARGUS probe -- and the Johnson Sea-Link I was launched, with the MARGUS probe strapped to its side, at a position south of the cable near the assumed fault location. Within minutes the cable was located, visually detected, and recorded on video. Poor visibility and the absence of bottom current made the search difficult and time consuming, but the submersible was able to track the cable for several hundred feet and scientists were able to find the entanglement of cable and cable armor. The cable was then cut at an appropriate site east of the entanglement.

Nitrogen Cycling in the Water Column and Sediments of a Reef Environment (FDU)

To characterize and contrast the interactions between the water column and sediments of an inshore lagoon and the carbonate sands of a reef flat area, particularly with regard to nitrogen and phosphorous fluxes, marine scientists conducted (1) sedimentological and water column surveys of Salt River from the head of the mangroves to beyond Hydrolab on the canyon floor; (2) measured the rate of sedimentation at Hydrolab and in Triton Bay of the Salt River; (3) calculated the rate of exchange of oxygen, ammonium, nitrite, nitrate, and phosphate between the

sediments and water column of Triton Bay and the Hydrolab site; (4) analyzed concentrations of inorganic N and P in sediment interstitial waters and nitrogen transformations in interstitial waters; and (5) estimated ^{14}C primary productivity, ammonium uptake, and ammonium production (using ^{15}N) in the water column.

This was the first study to utilize the stable isotope ^{15}N, the state-of-the-art technology for measuring rates of nitrogen recycling on reefs. Research results showed reef sand productivity to be unexpectedly high. Despite the fact that sand areas support large populations of commercially valuable mollusks, they have received a low conservation priority. Findings from this study and its planned continuation should help to reverse this trend.

Decomposition of Drift Algae in the Sediments of Salt River Canyon (FDU)

Another West Indies study conducted in 1985 had as its objective the examination of the relationship between production of macroalgae on hard substratum and the eventual fate of these macroalgae in the sediments. The work involved determining patterns in the distribution and abundance of attached macroalgae on the canyon walls and detrital macroalgae on the canyon floor. The decomposition, breakdown, and microbial responses to detrital algae on and in the sediment were also examined. A census of organisms feeding on detritus was taken. Methodologies employed included microelectrode analysis, CHN analysis, tracking of sediment movement using dyed particles, and bromine:carbon ratio analysis.

This research will provide an assessment of the importance of decomposing macroalgae to coral reef environments in terms of nutrient recycling and infauna prey organism distributions. Nutrients recycled from buried detritus may fuel the newly discovered and unexpectedly high rates of productivity of reef sand macroalgae, which are a major food source of conch. The project also represents the successful first field test of microelectrodes below wading depth. The investigators are comparing their results to those obtained in parallel studies in Maine, which will provide a unique assessment of the differences in temperate versus tropical ecological processes.

Productivity, Nocturnal Growth, Chemical Defenses, and Susceptibility to Herbivory (FDU)

In a study to determine the potential interaction between herbivory, diel patterns of growth, and production of secondary metabolites in the common seaweed Halimeda incrassata, marine scientists tested four major hypotheses:

(1) growth of Halimeda occurs primarily at night;
(2) nocturnal growth of Halimeda is correlated with a predictable decrease in herbivore activity that occurs at night;
(3) newly produced segments of Halimeda have low concentrations of these chemicals that deter herbivores; however, concentrations of these chemicals increase rapidly within a few hours after segment production; and
(4) individuals that produce low concentrations of defensive compounds will grow more rapidly--but be at greater risk of herbivore damage--than individuals that produce high concentrations of these compounds.

The investigative approaches used included plant tagging and transplantation, bioassays of various chemicals from Halimeda against herbivores, identification and quantification of secondary metabolites using thin layer and high performance liquid chromatography and nuclear magnetic resonance analysis, and CHN analyses of the alga.

Two compounds isolated from Halimeda, halimedatrial and tetracetate, are potently bioactive. Final results from this research will provide the first data on between-plant variation and diurnal patterns in compound production--information that will prove useful for planning harvest strategies. The cost to Halimeda in terms of growth caused by production of these special compounds will be determined. Halimeda growth is secondary to coralline algae in its contribution to the vertical accretion of coral reefs.

Chemical Interactions Between Sponges and Corals (FDU)

A study to document the presence of an allelochemical interaction between the sponge Plakortis zygompha and the coral Agaracia lamarki was completed in 1985 as part of the NURP-FDU program. Using the previously developed techniques of in-situ chemical sampling, the effects of water soluble and nonwater soluble Plakortis extracts on coral physiology were examined to determine which was responsible for the necrotic effects. Quantitative respirometry studies were also undertaken with A. lamarki, which had a history of contact with the sponge Ectyoplasia ferox. Long-term experimental transplants as well as permanent photographic transects were set up to monitor the success of corals living near or in contact with sponges. These experiments will determine whether the growth and reproductive rates of corals growing near the sponges are lower--and the death rate higher--than for corals growing free of association with sponges.

Production, Decomposition, and Heterotrophic Utilization of the Deep Seagrass Halophila decipiens (FDU)

Halophila decipiens, the only deep-water seagrass in the Caribbean, was the focus of a research project designed to describe and quantify the contribution of seagrass-derived matter to primary and secondary benthic production in Salt River Canyon. Determinations were made of the distribution and production of Halophila in the study area and of the rates of biomass turnover and decomposition using plant marking and litter bag techniques. Decomposing plant material was analyzed for bacterial production using a tritium isotope, bacterial abundances, and CHN content. Using the acetylene reduction method, the nitrogen fixation activity was estimated for living and dead Halophila, various other seagrass detritus, and algae.

The estimate of Halophila production in Salt River Canyon that will result from these data will be used in conjunction with ongoing conch research to provide an estimate of carrying capacity for conch in the canyon, the basis for management of this resource.

Growth and Metamorphosis of Coral Reef Fish Larval Stages in the Salt River Canyon, St. Croix, U.S. Virgin Islands (FDU)

The collection, identification, and determination of larval fish distribution in Salt River Canyon was undertaken by aquanauts in order to prepare illustrations, a taxonomic key, and information on the biology of coral reef larval fish recruitment. To carry out this task, two types of traps were designed that would replicate the natural shelter sites of the larvae and facilitate the attraction of greater numbers of larvae to lights at locations away from the powerful lights of the habitat Hydrolab. Distributional studies throughout the canyon were also included, and large samples were collected around the habitat for statistical analysis and expansion of a preliminary illustrated key.

Development of the anticipated taxonomic key to Caribbean coral reef fish larvae is fundamental to the determination of recruitment processes involved in the multispecific coral reef fisheries of the area. Management of these fisheries is problematic because of their multispecies composition and a lack of basic biological information, such as recruitment. At present the fisheries are severely overexploited.

Role of Sheltering Fishes as Nutrient Sources for a Tropical Reef Community (FDU)

Paradoxically, coral reefs support one of the highest productivities on earth, ranking with agricultural crops, despite the nutrient-poor environment in which they grow. An

understanding of the mechanisms responsible for this productivity is important when considering the management of resources in the Caribbean. To this end, research has been initiated on the amount and impact of nutrients nocturnally released by the abundant planktivorous and herbivorous fishes into the coral reef community of Salt River Canyon.

The excretion rates of ammonium and phosphorus and defecation rates of 51 fishes were measured. The amount of nutrients leaching from fecal pellets over the short-term was determined by standard ammonium, phosphorus, and CHN analyses. Distribution of these fishes was determined in order to calculate the nutrient input on an areal basis. The growth of algae was compared from sites with and without concentrations of these fishes.

Efficient nutrient recycling is a mechanism hypothesized to account for high productivity, and, when completed, this study will provide the first estimate of the role of the most abundant fish communities involved. Other beneficial results expected from the study include information relevant to fisheries management and increased knowledge of the distribution of pollutants.

Effects of Water Flow on Coral Energetics (FDU)

The inability of scientists to assess potential disturbances to coral reefs is caused in part by the lack of basic data on coral metabolism. To help fill this information gap, marine scientists completed a study in 1985 that had as its objective the investigation of the effect of water flow on the energetics of the coral Montastrea annularis. A system of three recirculating respirometers with undirectional flow was used to measure coral respiration and productivity. A Li-Cor irradiance meter was used to record light, and three Nestor oxygen meters with permanent-membrane probes were used to record oxygen changes in the chambers. Thermistor flow meters were used to measure flow in each chamber. Mainstream flow (50 cm above the substratum) was measured using a portable microthermistor flow meter. All data were transmitted from the chambers on the reef to instruments within the habitat Hydrolab via cables. Outputs from the instruments were linked to an Apple IIe microcomputer using an A/D-D/A converter and signal processing hardware.

Results of this study will provide a data base for a dominant reef-building coral that will enable prediction of respiration and productivity as a function of flow regimes. Flow regime is expected to determine, to some extent, a coral's ability to sustain pollution events.

Calibration of Population Assessment Techniques for Three Types of Reef Fish Communities in the South Atlantic Bight

A cooperative research effort sponsored by the Harbor Branch Foundation, NOAA's National Marine Fisheries Service (Southeast Fisheries Center), and the South Carolina Marine Resources Research Institute was undertaken in the summer of 1985 to achieve the following objectives:

1) to compare assessments of fish stocks made via submersible observations with those made by capturing fish using removal gear and by surveying fish by means of remotely operated TV
2) to continue an intensive study of life history parameters (age, growth, reproduction) of all priority fish species of commercial/recreational interest.

This mission was originally planned to be carried out in three separate phases or "legs." However, bad weather interfered with the performance of the first two planned segments of this project. During Leg 3 of the mission, the submersible Johnson Sea-Link I, supported by the R/V Edwin Link, was used to conduct visual stock assessments that were later compared with catches of fish made using standard capture techniques. Transects for visual counts and point counts were made in the deep rocky outcrop (snowy grouper/tilefish) habitats, the shelf-edge rocky outcrop (snapper/grouper) habitats, and the mid-shelf sponge coral (sea bass/porgy) habitats. The number of replicates of visual transect counts and visual point counts was dependent on the amount of dive time and the difficulty in conducting transects within a given habitat type. Video tapes and photographs from the Johnson Sea-Link I then were used to describe details of habitat types, confirm species identification, and record species associations. The remotely aimed dual laser beams greatly facilitated the estimation of fish lengths and habitat dimensions.

Water Column Ecology: Properties and Processes in the Gulf of Maine and Georges Bank

Marine scientists from the Harbor Branch Foundation and NOAA's National Marine Fisheries Service collaborated on a study of the water column within the Gulf of Maine and the canyons (Oceanographer, Hydrographer, Veatch, and Atlantis) south of Georges Bank. Observations, photographs, videotapes, and collections of siphonophores, euphausiids, and fecal pellets were made at several locations throughout the water column to depths of 825 m. Environmental data (depth, temperature, conductivity, and transmittance) were recorded on magnetic tape during every dive.

This research, a continuation of studies initiated in 1983 and 1984, was undertaken with the R/V Seward Johnson and the Johnson Sea-Link II submersible and consisted of 13 dives completed in early July 1985. Despite the occurrence of heavy

seas and dense fog, several of the major objectives planned for the mission were accomplished. Specifically, the abundance of euphausiids and their fecal pellets was estimated by means of novel photographic gear, the Fresnel-Benthos system. Fecal pellets were collected successfully at depth intervals just above the thermocline using a modified detritus sampler. Continuous measurements of environmental data were recorded and processed at sea. Data on the vertical distribution, relative abundance, and predatory feeding of physonect siphonophores were also obtained.

Prodigious numbers of euphausiids (Meganyctiphanes norvegica) occurred within 30 m of the seafloor in the Gulf and the canyons at night. These observations are consistent with those made in previous years and suggest strong support for the hypothesis that the abundance of this species, which constitutes a major food resource for demersal fishes and marine mammals, has been grossly underestimated as a result of the use of conventional plankton net sampling. From the samples collected, researchers expect to estimate the nutritional value of euphausiids and to determine if they are feeding on benthic sediments or planktonic organisms.

Dense concentrations of fecal rods were observed at the base of the mixed water region. These rods may constitute a significant input to the vertical flux of organic matter in the Gulf of Maine and probably represent a major pathway that provides continuity between pelagic and benthic food chains. Proximate chemical analyses, as well as estimates of microbial densities and growth rates on collected samples, should provide sufficient data to support this thesis.

Finally, in-situ observations and collections of the physonect siphonophore Nanomia cara, previously identified as a potential predator of larval fish in the northeast Atlantic, produced distributional information in relation to vertical bioluminescence, data on community structure, and samples of gastrozooid contents from a total of 48 siphonophores. Major prey items were copepods, but other crustaceans (euphausiids and amphipods) were also consumed. Nanomia cara were offered larval fish in shipboard experiments, but none were ingested. However, Artemia nauplii were consumed and digested in approximately 2 hours.

Deep-Water Habitat and Fisheries Evaluation Around Puerto Rico and the U.S. Virgin Islands

A joint deepwater research cruise was conducted by NOAA, the University of Puerto Rico's Department of Marine Sciences, CODREMAR of the Commonwealth of Puerto Rico, and the Department of Conservation and Cultural Affairs of the Government of the Virgin Islands. The cruise was conducted using the R/V Seward Johnson and the research submersible Johnson Sea-Link II, in coordination with the NOAA ship Chapman (the Chapman's participation was supported additionally by the Mississippi Laboratories of NMFS and

the Caribbean Fishery Management Council).

Thirty-one dives were made at 16 sites around Puerto Rico and the U.S. Virgin Islands to meet the following specific objectives: 1) categorize deep-water benthic habitats around Puerto Rico and the U.S. Virgin Islands in terms of bottom type, configuration, and cover; 2) determine species complexes associated with each habitat; 3) provide catch-per-unit-effort data from trap and longline fishing for correlation with faunal indices within habitats and for historical comparison; 4) determine effective fishing ranges of traps for deepwater fishes and invertebrates of commercial potential; 5) evaluate the physical and biological factors that impact the effectiveness of fish traps in deepwater rocky and smooth habitats; 6) compare stock densities, faunal components, and biological characteristics for the deepwater benthic habitats of the U.S. Caribbean, the U.S. South Atlantic coast, and the northwestern Gulf of Mexico; 7) evaluate fishing configurations and the effectiveness of deepwater fish attraction devices deployed in 1984 off the U.S. Virgin Islands; 8) provide an assessment of the abundance and distribution of deepwater black and bamboo corals and benthic macroalgae around Puerto Rico and the U.S. Virgin Islands; and 9) add to the biological knowledge of the deepwater fishes and invertebrates in the Caribbean area.

Results of this mission led participating scientists to conclude that the potential for a deepwater shrimp fishery has not been fully defined, and continued work is necessary to determine the extent of deepwater shrimp distributions and their density. Trap efficiency and bait attraction studies were inconclusive, and additional effort is needed to determine appropriate trap design and bait preference to optimize catchability. Additional effort also will be required to provide quantitative fish density estimates of outer shelf areas to relate diver estimates on the inner shelf to upper and lower continental slope submersible-derived estimates of faunal density.

Coral and algae studies were hampered by heavy sedimentation at the sites selected. Additional sites in sediment-free areas should be surveyed to provide a better summary of species distribution and abundance around Puerto Rico and the U.S. Virgin Islands. A majority of the habitats in these areas were barren sand, followed by deep sand-rubble, a 300- to 400-foot steep wall at the upper edge of the continental slope, and limited areas of rugged rock. The barren sand, rock-rubble, and wall area below 450 feet were extremely unproductive, with few attached invertebrates and a depauperate fish fauna. Above 450 feet, productivity increased sharply with sponges, corals, and associated fishes becoming more abundant and diverse as the upper edge of the continental slope was approached at 200 to 300 feet.

A number of commercial species were associated with the upper slope and shelf edge and were not found below the 450-foot depth where substantial ambient light was first noted. Dominant deepwater species were silk, blackfin, wenchman, and queen

snappers, but none of these fish were found in abundance. Grouper abundance was very low, even along the upper shelf edge and reef top, where the greatest number and variety were seen.

Both submersible and bottom longlines proved effective tools for estimating the abundance of deepwater snappers and groupers, with projected catch rates based on submersible-derived density estimates being similar to actual bottom longline catch rates made at the same locations surveyed by the submersible. The upper shelf edge and reef top were highly productive, but the complexity of vertebrate and invertebrate fauna will require assessment and analytical techniques of a higher degree of sophistication than those employed for the deepwater studies conducted in the past by NMFS. Longlines will be ineffective in assessing stocks on the flat tropical reef top and shelf edge because of excessive fouling of longline gear and rapid bait loss caused by the feeding of large numbers of small, tropical reef fishes.

Deep-Sea Artificial Reef Research in Hawaii (U-HI)

The Southwest Fisheries Center Honolulu Laboratory, National Marine Fisheries Service, is engaged in long-term research to evaluate artificial reefs as a tool to enhance the production of spiny lobsters and deepwater snappers and groupers in Hawaii. Populations of these resources are typically found in areas with considerable bottom relief, particularly in the case of bottom fishes on the steep slopes of islands and banks. However, the tops of many banks are flat, sandy, and support a very low density of lobsters and fish. To test the hypothesis that lobster and bottom fish populations are limited by the availability of high relief habitats and that artificial reefs can turn habitats that currently do not support populations of these resources into productive ones, scientists placed an artificial bottom fish reef at a depth of 130 m and two groups of artificial lobster reefs at depths of 80 m and 40 m in the Penguin Bank area, about 25 miles from Oahu.

The submersible Makali'i was first used to evaluate bottom conditions before reef emplacement, and, one day after placement of the reefs, it re-visited these sites to document their condition and to note the species that were immediately attracted to them. Two months later a second visit was made to record any changes. This program of regular monitoring will continue throughout 1986. All reefs appeared to be structurally stable after 2 months. At that time, the bottom reef had been very successful in attracting schools of bottom fishes, but the lobster reefs had attracted no lobsters. Recruitment from the larval stage for both these resources is thought to occur in early summer, and scientists will have to wait until that season in 1986 to observe whether juveniles recruit to the artificial reefs.

Since juvenile bottom fishes and lobsters cannot be captured with fishing gear, visual censusing with the Makali'i is the only

way to document the entire marine community that develops around these deep artificial reefs. If it appears that bottom fish or lobster stocks are benefiting from the reef, a larger scale reef project will be developed to estimate the increase in yield that can be achieved for lobsters and bottom fishes by the use of artificial reefs in Hawaiian waters. This second stage of research will answer the question, "Do artificial reefs simply attract fish from nearby habitats, or can artificial reefs actually increase fish production?" It will be possible also to determine the biological pathways, such as increased growth, reduced mortality, increased larval setting, etc., that account for any increased production.

Estimating Bottom Fish Catchability at Penguin Bank in Hawaii (U-HI)

The submersible Makali'i was used to study the relationship between catch rate and the local abundance of commercial species of bottom fish at the well-known "First Finger" of Penguin Bank. The submersible made several dives at fishing sites on three separate occasions in 1985.

Results indicated that there was very low bottom fish catchability at First Finger. Well over 40 line-hours of fishing effort produced a catch of only four bottom fish, for an overall catch rate of approximately 0.10 fish/line-hour. In contrast, at Johnston Atoll, a National Wildlife Refuge, an identical fishing operation conducted earlier by the same vessel resulted in an average catch rate of 3.00 bottom fish/line-hour. These results would suggest a much higher (30 times greater) abundance of bottom fish at the Wildlife Refuge; however, observations made from the submersible revealed a high abundance of bottom fish at First Finger. Semi-quantitative counts also suggested a similar level of in-situ abundance of commercially significant species when these two localities, each characterized by divergent fishing histories, were compared.

These findings suggest that the catchability of bottom fish may vary with level of exploitation. Biologically it is quite plausible that these species "learn" to avoid capture by hooks. If this hypothesis is accurate, standard methods of evaluating stock abundance and the effects of fishing may result in a highly inaccurate assessment of stock condition, e.g., what may appear superficially to be a severely stressed fishing location may in fact represent a population no longer vulnerable to the gear. (This hypothesis would be applicable only to passive types of fishing gear, such as hook and line.) Further laboratory studies are planned to evaluate the generality of these findings.

Deep Water Benthic Communities: Temporal Variations, Colonization, and Community Structure (U-HI)

The major findings of this investigation to date suggest that:

1) Recruitment of benthic algae and invertebrates onto artificial substrata is slow and perhaps seasonal. Brown and red filamentous algae were the first colonizers of the blocks. They persisted for at least 3 months after the deployment of 22 settling block arrays. Calcareous algae, bryozoans, sponges, and oysters were observed on the settling blocks 7 months after deployment.
2) Deep water carbonate production is approximately an order of magnitude lower than shallow water carbonate production. Preliminary estimates of carbonate production by coralline algae from the settling blocks average 200 grams $m^{-2}y^{-1}$. This rate is typical of some temperate water benthic communities. Average percent cover of the bottom by coralline algae, bryozoans, and the calcareous green alga, Halimeda, determined from 35-mm slides taken on phototransects, was significant (i.e., 20-30%), and in many areas the calcareous community cover was 100 percent. Rates of deep water carbonate production and average percent cover on Penguin Bank, coupled with the vast deep water bank area in the Hawaiian Archipelago, suggest that the annual production of calcium carbonate on deep water banks is comparable to shallow water production.
3) Increased physical heterogeneity of the substratum enhances survival of fishes and motile invertebrates by providing protection from predators. Each settling block array has its own complement of small fishes -- primarily tilefish, gobies, and butterfly fish. One lobster was observed living in an array. Fishes, hermit crabs, and gastropods were observed grazing the surfaces of the blocks. The grazing activities of these organisms may be an important factor influencing the community composition of benthic organisms on the blocks and on Penguin Bank.

Repeated observations of the study site over the last year suggest that carbonate sedimentation on Penguin Bank occurs autochthonously. Deep water benthic carbonate production is transformed into highly reactive, fine-grained particles by biological, physical, and chemical degradation processes, aided by bioturbation. Penguin Bank represents an active site of bioturbation. Large bat rays create depressions in the sediment surface; loose calcareous organisms fall into the depressions. These organisms may be buried and subsequently broken down by chemical degradation. Callianassid shrimps and sea cucumbers rework the sediment by their burrowing activities and expel fine-grained carbonate particles into the water column.

Deep water banks around the Hawaiian Archipelago may represent potentially significant sites of production of highly reactive carbonate particles. The horizontal transport of these particles from banks to open ocean waters and their subsequent dissolution may contribute, in part, to the alkalinity excess observed at waters of intermediate depth in the western Pacific Ocean. Future work on Penguin Bank will focus on quantifying some of the carbonate fluxes using chemical estimation techniques with Plexiglas domes and analysis of remaining settling block arrays.

Recovery and Recruitment of Deep Sea Precious Corals (U-HI)

A three-dive reassessment of the Makapuu precious coral bed at 366 m was undertaken in December 1985 to determine the extent of recovery in the last 6 years (in the absence of harvesting) of Corallium and Gerardia (pink and gold coral) and to measure rates of recruitment of each species so that a management model developed in 1978 might be validated. One dive at the north end of the bed has been scheduled for 1986.

Diver-scientists conducted photo transects of the major portion of the Makapuu bed, measured the size frequency of pink and gold coral colonies, collected colonies exhibiting regenerative growth, and documented the results photographically. The data base generated by this study will serve as a measure of the accuracy of a predictive model developed in 1978 by the Western Pacific Regional Fisheries Management Council to manage precious coral resources in the State of Hawaii. The data will also be useful for calculating new estimates of natural recruitment and growth rates for species found on deep hard bottom substrates, since very little is known of the population dynamics of deep benthic assemblages found on such grounds. Interest in this subject has increased recently because of the potential manganese-cobalt crust mining operations on Hawaiian seamounts.

Benthic Productivity in North Carolina Continental Shelf Waters (U-NC)

As part of a project begun in 1982 to determine the importance to the continental shelf ecosystem of sediment-water column interactions, particularly those centered around production by benthic microalgae, 20 dive days were devoted in 1985 to measuring such things as benthic primary production and respiration, water column primary production, light flux, benthic chlorophyll, water column chlorophyll, benthic and water column ATP, demersal zooplankton abundance (by taxon), sediment carbon, water column particulate organic carbon, water column inorganic carbon, sediment nitrogen, sediment phosphorus, ammonium, nitrate, nitrite, phosphate, and temperature. In addition, scientists collected 42 taxa using three different trapping techniques at 10 or more locations at different times of the year. Although some

of these data have yet to be analyzed, sufficient information is available to present preliminary findings.

Benthic microalgal production appears to be very important in North Carolina continental shelf waters. Gross production by benthic microalgae can equal or exceed integrated water column primary production. If study results are truly representative of conditions in shelf waters, then the shelf could be as much as twice as productive as had been estimated previously. Moreover, benthic microalgae represent a concentrated highly productive food source at the bottom, where many kinds of organisms have access to it. Since sandy bottoms were thought to be barren and unproductive, scientific thinking about the food sources supporting demersal fish larvae and fish populations associated with natural and man-made reef structures may need to change.

The demersal zooplankton appear to be an important link between benthic microalgae and small fish. These organisms can be extremely abundant and are concentrated at the sediment-water column interface. Many of these are known to be herbivorous or deposit-feeders that should be capable of eating benthic microalgae. This assemblage includes many species that are known to be eaten by juvenile fish. Their nocturnal migrations probably act to carry them into reef areas, where resident fish can exploit them as food.

The sediments are a source of regenerated nutrients that can be exploited by benthic microalgae and phytoplankton. Ammonium regeneration data suggest that nitrogen is limiting, but, more importantly, that benthic microalgae can play an important role in intercepting nutrients regenerated from the bottom before phytoplankton can gain access to them. Light levels at the bottom apparently regulate this interception process. Higher ammonium regeneration rates were observed in dark chambers and on cloudy days than in light chambers and on sunny days. These observations, if supported by analyses of nitrate and nitrite data, suggest a possible mechanism in the regulation of continental shelf production. In the absence of mixing events, phytoplankton settle to the bottom, cleaning the water column and allowing higher light levels. Higher light levels, in turn, permit higher benthic microalgal production, which increasingly limits nutrient flux into the water column, thus limiting water column production and driving more benthic production.

Other factors, such as storm activity and seasonality, appear also to affect benthic production. Further studies should substantiate these preliminary findings. In addition, 1985 study results make it clear that the lower depth limits for benthic microalgal production have not yet been determined. It may be that benthic microalgae are important primary producers across the entire continental shelf and down the continental slope. Further measurements at lower depth limits are necessary to confirm this hypothesis. More realistic in-situ measurements of nitrogen fixation by shelf sediment organisms may also establish that

actual rates are much higher than indicated by the crude sampling techniques employed in these 1985 experiments.

Study of Productivity Measurements of Continental Shelf Seaweeds off Cape Fear, North Carolina (U-NC)

A 2-year project to measure the primary productivity and assess the nutrient environment of hard substrate macrophytes of the North Carolina continental shelf was completed in 1985. Results from the 1984 and 1985 cruises aboard the R/V Seahawk provided researchers with the deepest in-situ diurnal photosynthetic measurements made of benthic seaweeds.

The North Carolina continental shelf seaweeds are capable of net photosynthesis at very low ambient light. Increases in photosynthetic performance are related to increasing ambient irradiance: there is no evidence of an "afternoon depression" on sunny days. Algal abundance patterns reflect photosynthetic performance. Those species with high SA: V ratios are generally dominant in this habitat. Nutrient data from the 1984 cruise suggest that these algae may have the ability to take up N-nutrients from low ambient concentrations or to sequester nitrogen reserves. Analysis of bottom water samples taken during the 1985 cruises should help to characterize temporal fluctuation in the N-nutrient environment of this habitat. This information, in addition to analysis of algal tissue for pigment and elemental (carbon, nitrogen) concentrations, will contribute enormously to an understanding of the growth strategy of seaweeds under a low light/low nutrient regime.

In-Situ Studies of Ocean Quahog Growth in Natural Populations (U-NC)

During 1985, the second year of a 3- to 4-year project consisting of in-situ field tests of laboratory growth rate studies for the ocean quahog (Arctica islandica), much faster growth rates were observed for the species (an important fisheries resource) than the literature suggests. Annual revisitations to the site where known age (juvenile) clams were placed in their natural habitat to measure clam growth are expected to verify these accelerated growth rates. Should this prove to be the case, the size of the allowable harvest of ocean quahogs may have to be significantly altered.

Population Dynamics of Queen Conch, Strombus gigas (CMRC)

The queen conch is one of the most important marine species in the Carribean region. It has been the target of a major fishery for the past century. Its popularity as a source of food, however, has resulted in the depletion of this species in southern Florida, the Bahamas, and most of the Carribean and Bermuda.

During 1985, the CMRC initiated a study to investigate the early life history of the queen conch. Discovery and survey of a major nursery ground numbering in excess of 570,000 individuals led to focused studies on the growth, population dynamics, seasonal distribution, and mortality of this conch population.

Mark and recapture techniques are being utilized to develop estimates of year class strength, growth rates, and rates of natural mortality.

Experimental Saltwater Tilapia Culture (CMRC)

In 1984-85, the CMRC initiated research aimed at developing technology for seawater production of tilapias (a euryhaline finfish group) as an inexpensive food source for the Caribbean and similar regions where freshwater resources are limited.

A Florida red tilapia hybrid (*Oreochromis urolepis hornorum x O. mossambiscus*) was chosen for cage rearing in seawater ponds because of its rapid growth, hardiness, and herbivorous feeding behavior. Studies were initiated to develop hatchery, nursery, and growout techniques for this species.

1986 PROJECTS

The Biology of Gelatinous Zooplankton: Comparative Studies of Oceanic and Neritic Salps and Further Investigation of Mesopelagic Organisms (UCAP)

Using a combination of direct observation and collection, a team of eight research scientists and two technicians made eight dives over a 4-day period with the *Johnson Sea-Link* submersible. Their objectives were to characterize the midwater gelatinous fauna of the continental slope margins off southern New England and to understand how these fauna interact with other parts of the midwater, continental slope, and shelf communities in the region. The following specimens were collected:

No. of specimens	Specimen
11	*Bolinopsis infundibulum*
26	Ctenophores (belonging to 3 species)
6	*Bathocyroe fosteri*
4	Undescribed red ctenophore
1	*Thalassocalyce inconstans*
19	Siphonophores (belonging to 11 species)
8	Medusae
2	Salp

In addition, several sexually mature Solmissus spp. were collected. The team also studied a number of fishes that orient vertically in the water and compared these observations with some made previously in the Bahamas.

A 2-week summer follow-up cruise is planned. Preliminary study results indicate that these previously unknown components of the gelatinous fauna may have a substantial impact on fish recruitment in the Georges Bank region.

Characteristics of the Food Available to the Sea Scallop Placopecten magellanicus, at Depths Below 100 Meters (UCAP)

Differences in the allometric relationships of deeper water sea scallops from those of their shallow water counterparts is attributed to the source and quality of food available to each. In order to determine the food source and quality of that source for both types of sea scallop in the Gulf of Maine, investigators proposed research that would (1) develop submersible-based and ROV-based sampling techniques capable of quantitative sampling of the sediment surface fluff layer and of the nepheloid layer; (2) determine the nutritional value of the sediment surface fluff layer and of the nepheloid layer over a sea scallop bed at depths over 100 meters; (3) determine the nature of the material consumed by the sea scallops in these beds; and (4) compare the ingested material with the material found in the food source samples.

The project was postponed because of cutbacks in funding for vessel time. However, much of the project work has progressed more or less on schedule. Development of the sampling head for collecting the fluff layer was accomplished, as well as development of the material for handling large volumes of seawater. Although researchers were unable to collect fluff layers and nepheloid layer samples during the 1986 cruise, they were able to collect some scallops from two areas and to perform stomach content species analysis for same.

Primary Productivity and Zonation of Deep Water Benthic Algae in the Gulf of Maine (UCAP)

A study to examine patterns in the distribution, abundance, and processes affecting zonation patterns of unique deepwater flora centrally located in the Gulf of Maine was conducted, using extensive submersible and scuba diving observations and an array of manipulative experiments to meet the following objectives:

- to quantify the structure and zonation of this deepwater flora

- to monitor the manipulative experiments (initiated in 1985) with respect to survivorship, growth, and reproduction

- to isolate processes such as recruitment, herbivory, and rates of primary production that may influence the upper and lower distributional limits of three algal zones.

Zonation patterns were quantified using the Johnson Sea-Link submersible laser-scaled video system and by recording the maximum depth of occurrence of algal species as seen from submarines. Collections were made when possible by scuba diving or from the submersible. Genetic studies on kelp were used to determine if they are new species.

Numerous manipulative experiments were deployed, including epoxy embedded algal transplants affixed to PVC rocks that were placed and retrieved by submersibles. In 1985, each abundant algal species had been transplanted to regions below its natural depth maxima (extinction depth). Several biological factors were examined, such as growth and competition for both recruiting juvenile and adult plants for each assemblage. Licor integrating light meters were deployed at various depths to determine light profiles.

Initial findings from these investigations suggest that extinction depths may not indicate a simple physiological balance between photosynthesis and respiration among adult plants; a more likely explanation is that some other stage (spores or germlings) is depth-limited and results in the observed distribution of the plants.

Ecology of the Sea Scallop, Placopecten Magellanicus (Gmelin), in the Gulf of Maine (UCAP)

The final research activity of a 3-year study to investigate scallop bed structure and faunal associations, analyze food resources, and examine the shell fouling community took place in 1986, with scientists using manned submersibles in the Gulf of Maine. The research team visited selected scallop grounds, photographically documented the scallop beds, and established specific experimental sites to collect animals for food and shell fouling studies. Data from 1984 through 1986 are currently being analyzed and prepared for presentation.

To date, qualitative comparisons have shown that the macrobenthic scallop bed communities are very similar throughout the Gulf of Maine. Three invertebrates -- the scallop, myxicolid worms, and cerianthid anemones -- dominate all the sites. The bottom substrata is also similar (sandy to silty sand), and the distribution of the three dominant animals is patchy.

Herring Egg Bed Studies (UCAP)

Herring egg bed surveys were conducted aboard a 40-ft. vessel in eastern Maine coastal waters using an ROV (Mini-Rover) in conjunction with traditional survey and sampling procedures. A total of 43 ROV dives, 197 grab samples, and approximately 20 SCUBA samples were made at two egg bed locations and three additional spawning sites where eggs were deposited on previous occasions.

The purpose of these surveys was (1) to identify the physical characteristics of spawning sites; (2) to determine the size of individual egg beds and habitat characteristics associated with egg distribution and abundance; (3) to determine factors affecting egg mortality and larval hatching success; and (4) to determine factors affecting the survival and downstream transport of recently hatched larvae.

Preliminary findings indicate that egg deposition at one spawning site is fairly heavy and egg mortality is very low. The eastern Maine coast appears to provide optimum conditions for herring egg deposition and survival.

Community Structure and Secondary Production in Rocky Subtidal Habitats of the Gulf of Maine (UCAP)

A project begun in 1985 to describe the structure of benthic invertebrate communities at Ammen Rock was continued in the summer of 1986. The results of this study will be used to provide the first estimates of benthic (secondary) production for subtidal rock surfaces in the Gulf of Maine and to determine the amount of secondary production utilized by predatory fish and invertebrates. Because the invertebrate communities in deep subtidal habitats are still poorly known, it is important to continue to quantify patterns of species abundance and distribution.

Substantial progress toward these research goals has been made in three areas: patterns of community structure, secondary production, and utilization of macrofaunal production. Initial findings suggest that:

- Three major faunal zones exist along the 30 to 85m depth gradient. The shallowest is a sparse kelp forest characterized by an abundance of sea anemones. A marked increase in the abundance of suspension-feeding invertebrates at 38m depth indicates the beginning of zone 2. The substratum changes from sloping rock ledge to a cobble-gravel bottom at 65m; the dominant fauna are the polychaete Myxicola infundibulum and the anemone Cerianthus borealis.

- Granite substrata at 30m were colonized by kelp, upright and encrusting red algae, and bryozoans. The dominant

species at 45, 60, and 75m were bryozoans, indicating that they are an opportunistic species. There was a clear trend of decreasing recruitment with depth below 45m.

- Investigation of the stomach contents of fish caught on site, observations from SCUBA and submersible and predator-prey interactions, experimental manipulations of sea star and their invertebrate prey, and time-lapse movies of predatory activity patterns combine to suggest that fish play an important role in affecting the distribution and behavior of benthic invertebrates.

The Diel Vertical Migration of the Oppossum Shrimp, Mysis Relicta, in Lake Superior (UCAP)

A submersible study to observe and sample the behavior of the oppossum shrimp during its migratory cycle at offshore stations in Lake Superior was conducted in 1985-1986. Sampling protocols employed to achieve this goal included visual observations (videotape), net samples from the Johnson Sea-Link II, and net tows from the R/V Seward Johnson.

The submersible dives indicated several new and previously unknown behaviors by the shrimp and a sense of heightened complexity of the classical migration pattern exhibited by the species in the Great Lakes.

Ecology and Bioenergetics of Deepwater Sculpins (UCAP)

Based on 1985 diver observations, a study focusing on the behavior, feeding, bioenergetics, and growth of deepwater sculpins was conducted in 1986. Sculpins are the largest resident fish biomass at depths exceeding 200m in the Great Lakes, and they are crucial to aphotic zone ecologic studies because they are the most abundant predators in deep waters and represent the least understood major biotic element in the lake ecosystem.

Over 900 linear meters were quantitatively surveyed to yield preliminary density and distribution data at various depths. Using the submersible mounted electrosampler, nine sculpins were collected and divided up for otolith aging, stomach analysis, and toxicant load analysis. In addition, four growth study cages were released; one cage has been recovered to date, and analysis is pending. Over three hours of behavioral data were recorded on videotape.

Analysis of survey data indicates an average density of 0.6 sculpins/m2 with highly clumped distributions. Results on toxicant, stomach behavior, and growth analysis are pending. Future work will revolve around analysis of habitat selection

parameters and initial characterization of stock structure along with feeding ecology.

Spawning Habitat Requirements of Lake Trout in the Great Lakes (UCAP)

A study to develop substance and water quality criteria needed to evaluate historical lake trout spawning grounds and to guide the development of fishery management plans designed to accelerate the reestablishment of self-sustaining stocks of the fish throughout the Great Lakes was conducted in 1986 by scientists employing side scan sonar and the Johnson Sea-Link II submersible. Detailed documentation of the composition and distribution of the substrates and determination of water quality in the substrate interstices were the study's objectives. Reefs selected for study include those that presently support reproduction by self-sustaining stocks of lake trout and others that are perceived to have potential for supporting such stocks.

Water samples and water quality data collected from substrate interstices on Six Fathom Bank in central Lake Huron have been analyzed. Video tapes of the lake bed have been reviewed and used to assist in the interpretation of side scan sonar mosaic maps and the production of computer-generated color substrate maps. Results of this work have been disseminated in several abstracts and manuscripts for publication.

Assessment of Lentic Larval Lamprey Habitat Preferences in Lake Superior with Special Reference to Batchawana Bay (UCAP)

In order to provide baseline data on lamprey that drift or selectively move out of the nursery streams and into the Great Lakes immediately or soon after hatching, research was begun in 1985 and continued in 1986 to facilitate understanding of the ecology of lentic ammocoetes (both native and introduced species) in relation to their specific physical and biological environment.

Based on 1985 dive results, the relative importance of substrate particle size versus thermal acclimatization below the thermocline was tested using a cross-factor design in order to explain gross distributional patterns. Four 3m square patches were lined out on the bottom with PVC pipe. Two patches were modified to a sand/silt/clay composition. In one modified and one unmodified patch, marked ammocoetes were acclimatized in situ prior to release; unacclimatized ammocoetes were released in the other two patches. Results obtained by sampling with a quantified submersible mounted electrosampler indicate that neither particle size distribution nor thermal acclimatization alone are major determinants of lentic habitat selection.

Interdiction of the thermocline with steep slopes in the bay along with cross slope currents appears to be the remaining major

correlate with lentic ammocoete distribution patterns. Experiments to test concordant hypotheses are currently being developed.

Behavior and Distribution of Deepwater Sculpin (UCAP)

An ongoing study of deepwater sculpin behavior and distribution was launched in 1986. Sculpins collected from each of the upper Great Lakes (where extant populations of these fish reside) are currently being examined to compare the concentrations of mercury (total and methyl), PAHs, DDT, and PCBs found in each group to determine the effect trophic status has on accumulation rate in these fish. Data on similar toxic substances in other parts of the food chain and in various components of the sediments are also being assembled.

A paper is planned that discusses the contaminant relationships for five toxic chemicals found in deepwater sculpin and how these toxicity-concentration versus length-of-sculpin data differ among the three lakes.

The Role of Nepheloid Feeding Benthic Cnidarians in the Gulf of Maine (UCAP)

Using manned submersibles, scientists made a series of dives to locate a high density patch of sea pens and to observe their behavior. Two additional dives were conducted to collect animals for potential laboratory observation. Sea pens are known to periodically retract completely into the sediment, and in-situ observations confirmed that the Gulf of Maine species are no exception. No obvious environmental cause elicits a contraction; 21 sea pens were observed in the survey area, but only two of those observed to be fully extended on one dive were retracted on the subsequent dives. In some instances, animals not previously observed were noted as present. Observations of these probable contractions and extensions are being compared with video recordings and 35 mm pictures to clarify events and then revise abundance estimates.

Specimens collected for laboratory observation were seen to extend and contract completely into the mud on an irregular basis. The sea pens were observed to be extruding eggs, and after this their condition deteriorated. Morphological observations are currently in progress on preserved specimens.

Deep-Sea Artificial Reef Research in Hawaii (U-HI)

Six dives were conducted in 1986 using the research submersible Makali'i to support a continuing project to monitor the effect of artificial reefs on the enhancement of spiny lobster and bottom fish populations in barren habitats, such as those

found on Penguin Bank. Submersible dives were made at three sites on Penguin Bank (where artificial reefs had been placed in October 1985) to record changes in the condition of the reefs and to census the marine community around them. Still and video cameras aboard the Makali'i were used for documentation. This program of censusing will continue through 1987.

The number of fishes and species diversity observed at all the reef sites continues to increase, and densities greatly exceed those observed at sand bottom control sites. Fish communities at the two deep (95 m concrete and 120 m fiberglass) reefs were similar; commercially important species, including unicorn tangs, jacks, and snappers, were approximately the same. Two spiny lobsters were observed on the fiberglass reef, but they did not remain; several slipper lobsters were later observed. At the 60m concrete reefs, shallow commercial species such as taape (snapper), big eye, and surgeon fish were observed. Fish diversity was greater on the shallow reefs.

Growth of encrusting organisms progressed with time. By February 1986 it was obvious that growth was better on the fiberglass cylinders of the 120 m reef than on the concrete reef structures; by October oysters, barnacles, sponges, and bryozoans had covered most of the fiberglass frame of the 120 m reef. Additional dives have been scheduled to monitor the changes in the biological communities associated with the reefs.

The Effects of Nutrient Cycling and Fluxes on Fisheries Production in the Penguin Bank Ecosystem (U-HI)

Ten dives were conducted in 1986 to support an ongoing project to quantify temporal variations in abundance and diversity of deepwater benthic organisms at a permanent site located on Penguin Bank. The study is determining rates of colonization, community metabolism, and carbonate production by benthic organisms on artificial substrate emplaced at the site--thus providing the first systematic benthic community characterization of an important fishing ground.

Net community carbonate production determined from chemical estimation techniques was 380 grams/m2 per year. The calcareous benthic community at the study site is composed of an unattached assemblage of coralline algae, bryozoans, calcareous green algae, and foraminifera; this assemblage differs from typical shallow water reef communities in which corals are dominant and bryozoans are rare.

The mineralogical composition of sediments on Penguin Bank suggests that the production of carbonate sediments occurs in situ rather than from shallow benthic or pelagic organisms. A comparison between Penguin Bank and typical shallow water reefs indicates that the mid-depth bank ecosystem may operate as a functionally separate entity. The production and fate of calcium

carbonate particles from mid-depth banks may be significant (and as yet unaccounted for) components in the global biogeochemical cycles of carbon and calcium.

The Role of Benthic Microalgae in the Continental Shelf Ecosystem (U-NC)

In 1986, work was completed on a 4-year project to test the hypothesis that light and nutrient availability on the bottom are sufficient to support growth by benthic microalgae on the continental shelf of North Carolina. Thirteen cruises were run in the period from 1982 to 1984 in support of this project and its ancillary study examining the ecology of demersal zooplankton.

The findings from this project suggest that benthic microalgae live at depths greater than previously thought to allow plant growth. Chlorophyll a and ATP were found in sediment samples collected at 285 m on the North Carolina continental slope, indicating that benthic microalgae would be growing there.

Another hypothesis resulting from research on this project has to do with the physiological adaptations that permit benthic microalgae to photosynthesize at depths of up to at least 41 m. Shade adaptation has classically been thought to be a matter of increased production of chlorophyll a by cells that find themselves in poorly lit water. However, chlorophyll a is primarily responsible for absorption of red light, which is attenuated rapidly in the water column, so increased production of chlorophyll a by deep dwelling cells would make little sense. Rather, increased cellular production of carotenoids would appear to be a more reasonable adaptation to low light levels at depth.

Nitrogen appears to be the limiting element in continental shelf waters. Interception of nitrogen compounds by benthic macroalgae and the low nitrogen/phosphorus flux ratios found in this study also indicate that benthic macroalgae might be nitrogen-limited, at least occasionally. The presence of excess phosphate and light sufficient to support photosynthesis leads to the possibility that blue-green algae in the sediment might, at times, be fixing nitrogen. Some nitrogen fixation measurements have already been made. The values obtained were low but might reflect improper technique or improper timing. In any event, the values were comparable to those few data obtained elsewhere in shelf waters.

The trophic link between benthic microalgae and demersal zooplankton suggests that benthic microalgae might be important in supporting populations of fish that congregate around live bottoms and structure, indicating that artificial reefs might enable humans to harness and utilize the productivity of the benthic microalgae.

Finally, the role of storms in regulating the productivity of the water column and benthic microalgae merits further study. Calm conditions increasingly favor benthic microalgae production, nutrient interception, and decreases in water column production. Stormy conditions resuspend at least some of the benthic microalgae and reverse these processes, thus favoring phytoplankton growth at the expense of benthic microalgae. Therefore, storms are likely to play a critical role in determining the levels and distribution of microalgae primary production in continental shelf waters.

Further investigations to test these hypotheses resulting from evidence uncovered during this 4-year project is either already scheduled or is being proposed.

North Carolina Artificial Reef Research: R/V Seahawk Mission of 16-23 June 1986 (U-NC)

General objectives of this mission were to (1) describe trophic relationships of benthic reef fishes and the food resources available at the R.R. STONE reef site; (2) conduct quantitative visual surveys of reef fishes over a 24-hour cycle at the site; and (3) survey three anticipated artificial reef development sites before deployment of railroad boxcars. The ultimate goal of the research program is to define the necessary parameters to best design, locate, build, and maintain artificial reefs for the specific fishery in the southeastern United States being enhanced.

Preliminary results of the mission include verification of the research team's expectations about the diurnal and nocturnal activities of reef fishes on the inner shelf temperate and subtropical reefs of the Carolinas. In addition, seven different collections of reef fishes were made, yielding eight different species for trophic analyses; six separate collections of sessile organisms were scraped from various surfaces of the tug wreck; and pre-deployment surveys of the three sites designated for railroad boxcars were conducted. (During these surveys, 82 fish were tagged at a rock ledge nearby the 5-mile area of the sites. It is expected that some of these fish will migrate to the railroad cars after they are deployed.)

More in-depth findings from this initial mission will be published after analyses are completed.

Population Dynamics of Queen Conch, Strombus gigas (CMRC)

Although recent development of hatchery techniques has provided a better understanding of the early life stages of queen conch, relatively little is known about the factors governing recruitment, habitat selection, density dependency, and survival of this species during the first months of settlement. During

1986, preliminary biological information was gathered on the queen conch to begin filling in these knowledge gaps.

Standard scuba techniques were used to observe and measure juvenile conch. Plastic spaghetti tags were cut and tied around the spires of the conch shell. Conch distribution in one area was attributed to the higher temperature and possibly higher nutrient content of effluent from a salt pond.

From the 1986 study, it is evident that the area around Lee Stocking Island is a major nursery ground for juvenile conch. This area will remain the focus of investigations on recruitment of young into nursery areas, determination of factors governing survival of the youngest conch, predation, and food availability.

Experimental Saltwater Tilapia Culture (CMRC)

Experimental studies on the culture of a Florida red hybrid tilapia continued in 1986. Studies focused on 4 research areas:

- Determination of the effects of salinity on growth and reproduction.
- Development of seawater acclimation methods to mitigate the requirement for freshwater.
- Determination of the utility of organic fertilizers in lieu of prepared feeds for fingerling production in seawater tanks.
- Determination of the rates of survival and growth of Florida red tilapia reared in floating cages.

Efforts also were begun to assess the feasibility of transferring the mariculture technology to Haiti.

II.F. OCEAN SERVICES

Research conducted in support of ocean services has a variety of objectives, ranging from diving research and development to the identification of marine compounds potentially useful as biomedicinal substances. Other scientific areas that fall within the ocean services category include assessment of the effect on potential undersea mine sites of current or planned deep ocean mining exploration and recovery activities and the identification of potential marine sanctuary sites within the U. S. exclusive economic zone.

Major achievements of recent ocean services research projects sponsored by OUR have included: the development of shallow water saturation diving tables to be used by scientific divers breathing a mixture of nitrogen-oxygen (nitrox); an evaluation of the impact on the environment of ocean thermal energy systems; and the development of procedures and equipment to be used to protect divers from the chemical, microbial, and thermal hazards associated with diving in polluted waters.

All National Undersea Research Program facilities conduct research in the ocean services area. In 1985, the University of North Carolina at Wilmington (UNC-W) supported two ocean services science missions. In 1986, both the Hawaii and the Connecticut programs conducted such research. Individual missions are described below.

1985 PROJECTS

Biomedical Investigations of the Deeper Water Marine Plants and Invertebrates of Bermuda (UNC-W)

In May 1985, diver scientists investigated Bermuda reef habitats to collect diverse specimens of deep water organisms to assess their chemical content for potential usefulness as new marine biomedicinals. Fifty-nine samples were collected, and these algae, tunicates, and gorgonians were then analyzed by thin-layer chromatography onboard the research vessel Seahawk.

Among the specimens collected were several types of algae--Stypopodium zonale, Laurencia obtusa, Avrainvillea sp., and an unknown foliaceous red alga. Tunicate samples were limited to several colonial species found in shallow waters near Castle Harbor, but the gorgonians collected consisted of numerous representatives of the genera Pseudopterogorgia, Eunicea, Plexaura, Pseudoplexaura, and Muricea, as well as several interesting voucher specimens of uncommon gorgonians. Both the unknown red alga and the rare gorgonians were submitted to the Smithsonian Institution for taxonomic identification.

All other specimens were sent to the Scripps Institution of Oceanography for comprehensive chemical evaluation, expected to take a year or more. A more thorough investigation off Bermuda's

banks will be necessary before the area's potential as a resource for pharmaceuticals can be properly assessed.

Bathymetric Distribution of Seaweeds in Offshore Bermudian Habitats (UNC-W)

Another UNC project conducted in the offshore habitats of Bermuda consisted of a series of more than 50 dives to determine the spatial distribution of seaweeds in Bermuda, to compare the trophic structures of North Carolina and Bermuda marine systems, and to search for new algal extracts and new species. This exploration of 10 sites surrounding the Bermuda islands took place in June 1985 and served as a complement to a similar project conducted in August 1983.

A survey of the waters along the western and northern coasts of the Bermuda islands revealed little variation in the macroalgal community. The entire area was dominated by Stypopodium zonale (Dictyotales, Phaeophyta), a large, leafy seaweed producing an almost total canopy cover over dead coral and exposed rock. Although quantities of living hermatypic and gorgonian corals varied from site to site, no trends were obvious either vertically or horizontally, nor were any impressive colonies of living corals found. Fish diversity and density, however, were great at most of the sites both in and outside of the Stypopodium meadows. Three species of Dictyota, Cryptonemia, Schizothix, Ceramium, Cladophora, Lobophora, Polystrata, crustose corallines, and an unidentifiable brown crust also were found to be present, although clearly subservient to the larger, prolific Stypopodium. In addition, epiphyte specimens of Antithamnion, Apoglossum, Nitophyllum, Herposiphonia, Heterosiphonia, Stylonema, and Griffithsia were discovered, although these were barely visible to the unaided eyes of the divers. Of particular importance among all these plants is the presence of Polystrata, an anatomically complex genus found, until recently, only in the South Pacific.

The southern shore of the islands presented a striking contrast: Stypopodium was not collected at any depth of any site, and, with the exception of Lobophora variegata and two or three species of Dictyota, algae were much sparser than those at all depths along the western and northern coasts. Most of the other species (perhaps 12 macroalgae) were small in stature in comparison to plants of the same taxa from the Carolinas, probably reduced by continuous grazing of herviborous fish. Clearly dominant over the other macroalgae collected were two species, grown to full size and unmolested by herbivores: Trichogloea herveyi and Liagora pectinata. These two species were found in abundance at one site only in the Stypopodium-free zone, which was characterized by an irregular bottom of eroded dead coral with deep channels and holes. Fauna included a variety of living hermatypic and gorgonian corals, a slate pencil urchin, and a diverse population of fish. Evidence of grazing was obvious on the corals and rocks between the soft, bushy red plants of

Trichogloea and Liagora, the latter of which has been found fertile. Further information will be required, however, before the factor or factors responsible for the narrow distribution of these two large red algae can be determined.

Data resulting from surveys of these two algal zones are being analyzed and were sufficient to allow biogeographic and floristic comparisons with the islands' North American latitudinal counterpart, North Carolina. Due to poor weather conditions and high seas, investigators were unable to work at depths greater than 130 feet, for the most part. Thus, documentation of the lower limit of the Stypopodium meadow community was not possible.

1986 PROJECTS

In-Situ Confirmation of the Acoustic Size of Forage Fish at Mid-Depths (UCAP)

A study to determine (in situ) the species composition and relative size of individual fish, to follow the diel vertical migration patterns of forage species, and to relate these observations to hydro-acoustic estimates of target strength was completed in 1986 in the Great Lakes. Visibility during the dive was very poor, and only a few fish were observed. Acoustic records showed large concentrations of fish at mid-depths, but these were impossible to see either from the submersible or during viewing of the video footage. The hydro-acoustic data and midwater trawl catch data collected prior to and immediately after the dive are providing some target strength information.

Two Research Projects in the Area of Ocean Technology and Services (U-HI)

Two Makali'i dives were completed for the City and County of Honolulu, Board of Water Supply, in support of an ongoing environmental monitoring project at the Sand Island and Barber's Point Sewer Outfalls off the island of Oahu. In addition, Makali'i dives were conducted for the R.M. Towill Corporation, who used the submersible to map the site for a potential sewer outfall off the Kona coast of the island of Hawaii.

III. INTERNATIONAL ACTIVITIES

III. INTERNATIONAL ACTIVITIES

A. United States-Japan

The United States-Japan Cooperative Program in Natural Resources (UJNR), a collaborative effort established in 1964 to share information and technical data and exchange scientific personnel and research equipment, maintained its ties to NOAA's Office of Undersea Research (OUR) during 1985 and 1986 through a number of activities coordinated by the UJNR Panel on Diving Physiology and Technology. In June 1985, OUR hosted the 8th biennial joint meeting of this body, divided into two sessions: the first was held June 6-8 at the Undersea Medical Society in Washington, D.C.; the second session convened at the University of Hawaii on June 15-17. Thirty-one American and 13 Japanese panel members and advisors participated in these sessions, and a total of 35 papers and presentations were given. In addition, five study tours were conducted.

A number of other cooperative activities were initiated during this time period. Two Japanese scientists, Dr. Tetsuro Urabe from the University of Tokyo and Dr. Makoto Yuasa from the Geological Survey of Japan, participated as members of the research team on NOAA's Alvin submersible cruise to the Galapagos Ridge during September to October 1985. The objective of the cruise was to examine the extent, distribution, mineralogy, and geological setting of the seafloor sulfide bodies.

Under the auspices of UJNR, the Office of Undersea Research sponsored the participation of four U.S. scientists in the New-Seatopia saturation dives (at 1,000 feet on mixed gas), a continuation of the former Sea Dragon series of deep experimental dives. The New-Seatopia dives were conducted in Japanese waters at the Japan Marine Science and Technology Center (JAMSTEC) during November and December of 1985; their purpose was to monitor and assess the effects of a hyperbaric environment on human physiological functioning.

As part of a joint long-range undersea submersible science program that is being developed by NOAA and Japan's Science and Technology Agency, Dr. Marjorie Reaka (University of Maryland) and Dr. Alex Malahoff (University of Hawaii) participated in a Shinkai 2000 cruise off the coast of Japan in the Bonnin Islands area. They made two dives during November 1986 to investigate both geological and biological events. A possible follow-up mission may be scheduled in 1987.

Japanese participation in two American initiatives was also planned: a 2-year series of experimental deep dives conducted by the U.S. Naval Medical Research Institute in Bethesda, Maryland and scheduled for 1986-87 will include Japanese observers during the first segment of the series and Japanese visiting scientists during the second; in addition, JAMSTEC has inquired about the possibility of having two of its diving medical officers attend NOAA's "Physician Training Course for Hyperbaric Chamber

Operations" and the U.S. Navy's "Medical Diving Officer Course." NOAA has taken action to comply with this request.

B. United States-France

Beginning in August 1985, a series of planning sessions was held between NOAA's Office of Undersea Research (OUR) and the Institut Francais de Recherche pour l'Exploitation de la Mer (IFREMER) with the aim of encouraging cooperative multidisciplinary undersea investigations. This program will involve all types of undersea vehicles, including the new habitat being built by OUR in the Caribbean.

A joint submersible cruise in the South Pacific region is planned for 1988 or 1989. This multidisciplinary research effort will emphasize increased understanding of the region's geological and biological resources and their associated processes.

C. United States-Canada

Representatives of OUR, NOAA's VENTS Program, and the Canadian Institute of Ocean Sciences met in November 1985 to develop a cooperative undersea program that would provide time series information on the environmental processes occurring at active hydrothermal vent sites. An exploration of the Axial Volcano site on the Gorda-Juan de Fuca ridge system in the eastern Pacific Ocean is scheduled to begin in the summer of 1986. This investigation will be conducted using the Canadian research submersible Pisces and its designated support vessel Pandora and will focus on obtaining long-term measurements of vent parameters.

D. United States-Caribbean Basin Undersea Research Program

OUR program staff met with the chairman of IOCARIBE during Sea Grant week at Newport, Rhode Island, to discuss future participation in the evolving undersea research program for the Caribbean Basin. Results of this meeting include the decision to have IOCARIBE develop, with input from the regional scientific community, a document outlining research priorities for the Basin, followed by an OUR-sponsored workshop, to be held in late Spring 1986, where discussion of the draft document will lead to a fully developed future research plan.

IV. FUTURE PLANS

IV. FUTURE PLANS

Among all of the Federal agencies, NOAA has the mandate and the resources necessary to assume a unique and essential role in helping the United States to achieve its national, economic, political, and environmental ocean resource goals. By taking a leadership role in ocean research, particularly in undersea scientific research and technology development, the OUR is working actively to help NOAA implement its historic charter.

The OUR program focuses on six broad research areas:

1) Global oceanic and climatic processes
2) Pathways and fate of materials in the ocean
3) Coastal oceanic and estuarine processes
4) Ocean lithosphere and mineral resources
5) Biological productivity and living resources
6) Ocean services.

In the future, the majority of undersea investigations conducted or sponsored by NOAA's Office of Undersea Research will support one or more of these general research themes. Each of the six NURP facilities places special emphasis on one or more of these areas. Most OUR-sponsored research activities are truly multidisciplinary and thus reflect the evolution of marine science from a descriptive to an empirical science. A brief summary of future research plans follows.

A. Global Oceanic and Climatic Processes

Through its National Undersea Research Program at the University of Hawaii (NURP-UH) and its Submersible Science Program, and in conjunction with the Atlantic Oceanographic and Meteorological Laboratory and the Pacific Marine Environmental Laboratory, NOAA meets its mandated responsibilities to determine the environmental effects of adding material to the ocean. Studying the effluents from hydrothermal vents that are suspected of altering the overall chemistry of the ocean to a significant degree is an example of the type of marine research included in this research category, which NOAA considers a priority in its future program plans.

During 1986, investigations of the vent fields existing at Axial Volcano on the Juan de Fuca Ridge were initiated. Using submersibles and remotely operated vehicles, scientists established long-term monitoring stations to assess the chemistry, temperature, and flow rate of vent fluids in this area and the effects of these fluids on the marine environment. In the future, the hydrogen-spreading centers on the continental margin systems, thought to be methane-driven, will be explored.

B. Pathways and Fate of Materials in the Ocean

Ongoing studies of contaminant behavior in the Great Lakes, dredged material disposal sites in the Gulf of Maine, the effects of deep ocean disposal of municipal sewage, and the preservation of coral reefs ravaged by pollutants will continue to be supported by the Office of Undersea Research. Findings from these research efforts contribute fundamentally to the information essential to make sound judgments regarding the management and uses of marine coastal environments.

C. Coastal Oceanic and Estuarine Processes

Processes occurring at the sediment-water interface or benthic boundary layer are directly affected by operations such as offshore sewage disposal, dredge spoil dumping, oil drilling, and the recovery of minerals. Investigations of the effects of these human activities will continue to be supported by the Office of Undersea Research in diverse marine habitats -- the Great Lakes, Gulf of Maine, Chesapeake Bay, Caribbean Sea, and the Hawaiian Archipelago -- to aid in decisionmaking regarding resource development and waste disposal.

D. Ocean Lithosphere and Mineral Resources

Seafloor sedimentological studies and research on tectonic evolution are the keystones of the ocean lithosphere and mineral resources aspect of OUR's programmatic focus. In the future, OUR will continue to emphasize three types of investigation falling within this category: research on the surficial geology of a variety of regions to provide detailed information fundamental to an understanding of recent geological history and the ecology of ocean floor fauna; identification of processes governing sulfide metallogenesis along deepsea ridge axes and the occurrence of cobalt-enriched manganese crusts associated with seamounts; and studies to determine the origin and sedimentology of submarine canyons.

E. Biological Productivity and Living Resources

Primary productivity and nutrient cycling research together comprise an area of study that all NURP facilities as well as OUR's Submersible Science Program engage in. In 1986, studies begun earlier in the Gulf of Maine continued to address problems related to community dominance, diversity, and abundance patterns; experimental manipulations and time-series monitoring of the physical and biological processes important to observed patterns; energy transfer through the food web; and organic transport mechanisms.

F. Ocean Services

OUR intends to continue to emphasize support for diving safety and technology development research projects. In the safety area, the Office's major project is the development of the third edition of the NOAA Diving Manual, which will involve the addition of several new chapters and the revision and updating of more than half of all the material in the second edition. In addition, several dive-safety-related workshops will be conducted on decompression table validation, diving fitness, and the narcotic effects of nitrogen.

Technology development will focus on advances in the capabilities of remotely operated vehicles, including autonomous and tethered ROV's. OUR's function as a clearinghouse for information on undersea science research will also be enhanced by the development of a computerized data base of all ongoing research projects.

Other points of focus in the future will include: investigations of the use of marine secondary compounds as potential pharmaceuticals or antifouling agents; fishery development; and gear assessment.

G. Shallow-water Submersible Science Program

In 1986, NOAA's shallow-water submersible program supported activities of the National Marine Fisheries Service, including:

- larval recruitment in the Gulf of Maine
- mortality of shellfish due to culling practices
- biological and geological processes on eastern Georges Bank
- growth of ocean quahog in natural populations
- benthic productivity in North Carolina shelf waters
- population dynamics of deepsea golden crab
- effects of trawl activities on benthic resources of the Bering Sea.

Activities in the future will be directed toward the Pacific Northwest, with the expectation that a west coast submersible research program will then be in place. Program emphases will include coastal fishery resources and shallow-water vents located off the Oregon shoreline. Other planned activities include the deployment of a remotely operated vehicle to gather data on the dynamics of deepsea fish stocks and the validation of biomass estimates used to regulate annual fish harvests.

H. Deep-water Submersible Science Program

Investigation of hydrothermal processes at the TAG hydrothermal field on the mid-Atlantic Ridge and a determination of the dynamic processes of Wilmington Canyon on the Mid-Atlantic coast together form the thrust of the projected deepsea program that will involve the Alvin in the future. The Alvin will be employed to gather time-series data on active processes at hydrothermal vent sites on the Juan de Fuca Ridge.

APPENDIXES

APPENDIX A

UNDERSEA RESEARCH PLATFORMS

The National Oceanic and Atmospheric Administration's (NOAA) Office of Undersea Research provides the national and international marine science community with facilities, platforms, and equipment for conducting in-situ undersea research activities. Using this technology, scientists can routinely make direct observations, record with real-time video systems and still cameras, collect samples, deploy instruments, and monitor long-term experiments to depths of 4,000 m (13,120 ft.) seawater. Major facilities include manned submersibles, remotely operated vehicles (ROV's), and undersea research habitats. Some of these systems are owned by NOAA, while others are available through leasing arrangements. The following section provides information on the performance characteristics and capabilities of the research platforms that were used or were under development in 1985-1986.

MANNED SUBMERSIBLES

Manned submersibles are the ideal platform for coordinating in-situ marine research because these systems bring the scientist to the research site for conducting observational and manipulative experiments. Submersibles utilized by NURP carry from 1 to 2 observers and have depth capabilities ranging from 366 m (1,200 ft.) to 4,000 m (13,120 ft.). These submersibles provide excellent viewing capability and can carry a variety of tools and instrumentation including: color and low-light video cameras and monitors; 35mm still cameras and probes; sample storage baskets; water samplers, sediment grab samplers; suction devices for gathering biological samples; tracking systems; and other devices and sensors.

Alvin is a 3-person submersible operated by the Woods Hole Oceanographic Institution (WHOI) and is partially supported by OUR. Alvin has a depth capability of 4,000 m (13,120 ft.) and carries 2 observers in a 2.13 m (7.0 ft.) sphere. The submersible has two manipulators and a payload of 453 kg (996 lbs).

The Makali'i is a 2-person, battery-powered, 1-atmosphere submersible. It is 4.8 m (15-ft.) long and 1.54 m (5-ft.) in diameter and carries a pilot, an observer, and a payload of 95 kg (210 lbs). The submersible is equipped with a hydraulic manipulator arm. Dive duration is 4 to 5 hours, with emergency life support for 72 hours; the depth capability is 366 m (1,200 ft.). This system is operated by the National Undersea Research Program (NURP)-University of Hawaii.

The Pisces V submersible was acquired by NURP at the University of Hawaii and is presently being refurbished and modified for operations to 2,000 m (6,600 ft.). Test dives and science operations are planned for 1987. The 10,900 kg (12 t) submersible is capable of carrying three people (one pilot and two observers) and has a maximum mission time of from 6 to 8 hours.

Pisces V is equipped with two hydraulic manipulators and a sonar ranging system. Also under construction is a launch, recovery, and transport (LRT) vessel that is used to deploy the submersible in up to 3.7 meter (12 ft.) seas. A similar LRT is used to deploy the Makali'i submersible.

The Delta is a 2-man submersible owned and operated by MARFAB, Inc. It has a depth capability of 366 m (1,200 ft.), numerous viewing ports, and a mechanical sampling arm. The submersible has an overall length of 4.7 m (15.5 ft.) and weighs 2,270 kg (2.5t). The Delta has made numerous dives from various surface support ships.

The Pisces IV submersible is owned and operated by Canada's Department of Environment, Fisheries, and Oceans. It has a depth capability of 2,012 m (6,600 ft.) and weighs 10,362 kg (11.4 t). The submersible is 6.1 m (20 ft.) long and has a beam of 3 m (10 ft.). The Pisces IV can carry three persons (one pilot and two observers) and has a 590 kg (1,300 lb.) payload.

The Pisces VI manned submersible is owned and operated by International Underwater Contractors. It has physical characteristics and performance capabilities similar to those of the Pisces IV.

The Johnson Sea-Link (JSL) I and II submersibles are owned by the Harbor Branch Oceanographic Institution (HBOI) and have a depth capability of 805 m (2,640 ft.). These submersibles are leased on a cost-share basis with HBOI. These research platforms are typically deployed from the R/V Seward Johnson, a surface support vessel, using an A-frame. The dimensions of both Sea-Links are 7.2 m (23.6 ft.) long, with a 2.5 m (8.2 ft.) beam; each weighs approximately 10,000 kg (11 t). Both submersibles can carry two observers and a payload of 554 kg (1200 lbs).

REMOTELY OPERATED VEHICLES

Remotely operated vehicles (ROV's) provide underwater observation and, in some cases, manipulator capability. These platforms are controlled from the surface by a tether that also provides power to drive the thrusters and transmit the video images.

Snoopy is a small ROV that was developed primarily for underwater observation. Real time viewing is provided by a video system. A 35mm still camera is used for photographic documentation. The vehicle is designed for operations to a depth of 366 m (1,200 ft.). The ROV is operated by NURP-University of Hawaii and can be used from a ship-of-opportunity.

The Minirover MK II is a low-cost ROV having a 305 m (1,000 ft.) tether. Realistic maximum operational depths are 230 m (750 ft.). The ROV has a single-function manipulator claw, a low-light color video, and a depth and heading display. The ROV will be undergoing performance testing in 1987, and major improvements to

the design are planned (increased thrust, laser scaling, still camera). OUR acquired the system for program-wide use; it is operated by NURP-University of Connecticut and can be deployed from small boats.

UNDERSEA RESEARCH HABITATS

Manned saturation habitats allow scientist-aquanauts virtually unlimited bottom time for conducting experiments and making observations. The Hydrolab habitat has been the centerpiece of an active program (nearly 100 missions) in St. Croix operated by NURP-Fairleigh Dickinson University. Hydrolab was decommissioned in 1985 and is presently on display at the National Museum of Natural History, where it is part of a marine exhibit.

A replacement habitat for Hydrolab that is larger (6-man versus 4-man), more mobile, and has a deeper design depth capability [30 m (120 ft.) vs. 15 m (50 ft.)] has been under development. This habitat, the Aquarius, was shipped in April 1986 to St. Croix, where it is undergoing modifications for Caribbean operations. A contract was awarded for the design and development of a launch, recovery, and transport (LRT) vessel and baseplate to facilitate system mobility. Initial deployment of the Aquarius habitat is planned for mid-1987.

ADDITIONAL CAPABILITIES

In addition to submersibles, ROV's, and research habitats, NOAA's National Undersea Research Program offers diving capabilities for scientists. These include diving support for scuba, surface-supplied air, or mixed gas and allow research to depths of up to 300 fsw. The mixed gas system will be modified in 1987 to be modular, thus allowing surface support from ships-of-opportunity. NURP-University of North Carolina, Wilmington is responsible for operating this system.

APPENDIX B

MISSION SUMMARIES FOR 1986

I. Biological Productivity and Living Resources
A. University of Connecticut-Avery Point
1. New England

Title: ECOLOGY OF THE SEA SCALLOP, PLACOPECTEN MAGELLANICUS IN THE GULF OF MAINE

Principal Investigator: Richard Langton
Maine Dept. of Marine Resources
W. Boothbay Harbor, ME 04575
(207) 633-5572

Objectives:

Little is known of the ecology of this heavily fished, valuable commercial species, especially the offshore populations. This project compared two offshore scallop beds including: 1) size, etc.); 2) scallop behavior; 3) scallop distribution; 4) substrate; and 5) predation, competition, and natural mortality. In addition, manipulative experiments were initiated to study the epizootic community associated with these beds (particularly the scallop shells).

Approach/Methods:

Video and still photographs were used to determine scallop behavior and density; cages were deployed at two sites and scallops were transplanted from site to site, in order to study comparative feeding of the two populations and effects of environmental influence on shell epizootics; and scallops were collected for gut contents analysis.

Current Status:

This was year one of a proposed 3 to 5 year program: we successfully developed our cages, and revisitation in 1986 will determine the actual length of time needed.

Expected Benefits:

A presentation of the preliminary results was given at the Gulf of Maine workshop held in August 1985, Portland, ME, entitled "Ecology of the sea scallop, Placopecten magellanicus, in the Gulf of Maine," by P. Berkman, W. Robinson, and R. Langton. We also had the opportunity to witness first hand the impact of scallop dragging on the habitat; the video tape is being analyzed.

Title: ECOLOGY OF THE SEA SCALLOP, PLACOPECTEN MAGELLANICUS (GMELIN), IN THE GULF OF MAINE

Principal Investigators:

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Objectives:

The objectives of this project were to (a) investigate scallop bed structure and faunal associations, (b) analyze food resources, and (c) study the shell fouling community.

Approach/Methods:

Using manned submersibles, project tasks included visiting selected scallop grounds in the gulf of Maine, photographically documenting scallop beds, and establishing specific experimental sites to collect animals for food and shell fouling studies.

Current Status:

Data from 1984 through 1986, particularly photographic data, are being analyzed and prepared for presentation at the 6th Pectinid Workshop in Menai Bridge, U.K., in April 1987. In 1984, a single transect was run across Platts Bank using the MERMAID II. In 1985, the Johnson Sea-Link submersible system was utilized to run two transects on Jeffreys Ledge, an area actively being dragged for scallops. During the summer of 1986, the same two transects were revisited using the DELTA submersible, and new evidence of dragging activity was noted. In addition, three other transects were run on Fippennies Ledge through a very high-density scallop bed. For the workshop presentation, these three scallop beds will be compared and contrasted both qualitatively and quantitatively. Special attention will be given to the Jeffreys Ledge data base, where quantitative temporal comparisons are possible. To date, qualitative comparisons have shown that the macrobenthic scallop bed communities are very similar throughout the Gulf of Maine. Three invertebrates, the scallop, myxicolid worms, and cerianthid anemones, dominate all the sites. The bottom substrate is also similar, being sandy to silty sand, and the distribution of the three dominant animals is patchy. Quantitative analysis is now in process to evaluate patchiness and, where possible, the impact of scallop dragging.

Expected Benefits:

Data presented at the scallop workshop will be summarized in at least one peer-reviewed publication immediately following the April meeting. This work will give resource managers a better understanding of scallop ecology based on the detailed analysis of selected scallop beds.

Title: THE ROLE OF NEPHELOID-FEEDING BENTHIC CNIDARIANS IN THE GULF OF MAINE

Principal Investigators:

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Objectives:

The objectives of this study were to: (A) document abundance and distribution of sea pens (e.g., Pennatula aculeata) in the Gulf of Maine, (B) make in-situ observations on behavior to document extension and contraction behavior, (C) collect animals for laboratory and morphological studies, and (D) characterize a specific site with a high density of sea pens in a biological, physical, and chemical sense.

Approach/Methods:

Using manned submersibles, a series of dives was made to locate a high-density patch of sea pens. At this location (Jeffreys Bank, Loran C 12915.1; 44364.4) four 1-meter square quadrats were deployed and observed over 24 hours, on 5 separate dives, to note sea pen behavior. Two additional dives were conducted to collect animals for potential laboratory observation. Achieving objective (D) required specialized equipment that was not available on the submersible and so this initial objective was postponed until the required equipment is available.

Current Status:

Sea pens are known periodically to retract completely into the sediment. In-situ observations confirmed that the Gulf of Maine species, Pennatula sp., are no exception. However, there is no obvious environmental cue, such as day/night or tidal rhythms, that elicits a contraction. Twenty-one sea pens were observed within or near the quadrats and only two of those observed to be fully extended on one dive were retracted on the subsequent dive.

In some instances, animals that were not previously observed were noted as present. Unfortunately, visibility was not always good; therefore, although these are probably contractions and extensions, this observation may not be valid. These in-situ observations are being compared with video recordings and 35 mm pictures to resolve these questions. These data will then be utilized to correct abundance estimates. Twenty sea pens were collected for laboratory observation. In the wet lab they were maintained at 5 degrees Celsius in an oxygenated water supply that was partially replaced approximately three times per week. The sea pens established themselves and survived through October. During this period they were observed to extend and contract completely into the mud on an irregular basis. Zooplankton were introduced into the tank, but no feeding response was observed. In August and September the sea pens were observed to be extruding eggs and after this their condition deteriorated. This spawning behavior has not been noted previously. Morphological observations are currently in progress on preserved specimens. The relation between total size and pinna number is being assessed in an effort to allow size frequency data to be generated from photographs. To date, it is clear that there is some variability in the size and pinna number relationship and that pinna numbers are not easily counted in many photographs.

Expected Benefits:

Sea pens are one of the dominant sessile invertebrates on soft mud substrates. Their role in this community is not understood. These studies will assist in resolving their importance to soft bottom community structure. These data will be summarized in a peer-reviewed publication on sea pens in the Gulf of Maine. Data analysis for such a paper is now in progress.

Title: CHARACTERISTICS OF THE FOOD AVAILABLE TO THE SEA SCALLOP, PLACOPECTEN MAGELLANICUS, AT DEPTHS BELOW 100 METERS

Principal Investigator: Daniel F. Schick
Maine Department of Marine Resources
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(207) 633-5572

Objectives:

The sea scallop is a filter-feeding mollusc that lives in a wide depth range in the Gulf of Maine. The deeper water sea scallops have been shown to vary significantly from their shallow water counterparts in several of their allometric relationships. The source and quality of food are felt to play a major role in these differences. The objectives of this research are to determine the food source and the quality of that source. Specifically, the proposed research will 1) develop submersible-based and ROV-based sampling techniques capable of quantitative sampling of the sediment surface fluff layer and of the nepheloid layer; 2)

determine the nutritional value of the sediment surface fluff layer and of the nepheloid layer over a sea scallop bed at depths over 100 meters; 3) determine the nature of the material consumed by the sea scallops in these beds; and 4) compare the ingested material with the material found in the food source samples.

Approach/Methods:

The proposed research will determine the relationship between two possible food sources, the nepheloid layer and the fluff layer, and the gut contents of sea scallops in the vicinity. Samples of water from each source and scallop guts will be collected from at least two separate sites and analyzed for species content, protein, lipid, CHN, calorimetry, chlorophyll, and particle size distribution. A short video transect with parallel lasers will determine the size frequency and density of the scallops in the bed. The first year's research will include the development of a fluff layer sampling device and development of material and techniques for handling large volumes of seawater with a submersible and for processing these volumes on board. Subsequent years will involve continued sampling of the fluff layer, nepheloid layer, and sea scallop guts with modifications that will depend on the first year's results.

Current Status:

The project was postponed because of cutbacks in funding for vessel time. Nonetheless, other than the lack of some initial sample collection, the project has progressed more or less on schedule. The sampling head for collecting the fluff layer has been developed by Dr. Mayer and the material for handling large volumes of seawater has been developed by the Principal Investigator and Harbor Branch Foundation. Although we were unable to collect fluff layer and nepheloid layer samples during the 1986 cruise, we were able to collect some scallops from two areas, and gut content species analysis was performed by Dr. Selvin. This work was possible through the generous invitation of Chief Scientist Langton for the Principal Investigator to go on a leg of the 1986 cruise, become familiar with the gear, and collect specimens.

Expected Benefits:

The availability and quality of food limit growth and reproduction in an organism. This research expands the understanding of these limits by extending the study of the food-organism relationship in the sea scallop to a condition of depth-related stress.

Publications:

Shumway, S.E., R. Selvin and D.F. Schick. 1987. Food Resources Related to Habitat in the Scallop, Placopecten magellanicus (Gmelin, 1791): A Qualitative Study. (in prep.)

Title: COMMUNITY STRUCTURE AND PREDATION INTENSITY IN DEEP OFFSHORE HABITATS IN THE GULF OF MAINE

Principal Investigators: Kenneth P. Sebens
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Marine Science Maritime Studies Center
Northwestern University, East Point
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Objectives:

The project had three principal objectives: 1) to describe benthic faunal zonation on deep rocky substrata in the Gulf of Maine (30-95 m depth); 2) to conduct experiments on the effects of predators and larval recruitment on the makeup of these communities; and 3) to establish long-term monitoring sites to examine growth rates and other longer term trends in these communities.

Approach/Methods:

Benthic faunal zonation on an offshore rock pinnacle was quantified by photographic transects run at different depths. Four research stations were deployed at different depths (33-83 m): settlement panels and rock blocks were used to study epifaunal recruitment, and cages were set down to study effects of predators on benthic invertebrates. Finally, areas at different depths (39-66 m) were permanently marked and photographed; revisitation in subsequent years will provide valuable information on the population dynamics of the dominant species.

Current Status:

Ongoing 1985-1986. Preliminary survey begun in 1984, proposal submitted for 1986 studies.

Expected Benefits:

The dives in the Johnson Sea-Link I significantly advanced our understanding of subtidal community dynamics in the Gulf of Maine, which is one of our foremost research goals. The research also provided new information on the distribution of benthic invertebrates in deep offshore communities, discovered a previously undescribed crinoid zone in the Gulf of Maine, and provided preliminary evidence of trophic linkage between benthic invertebrates and commercially important species. Examples of these findings include the facts that the anemone Bolocera feeds on shrimp and the cod Gadus morhua consumes anemones (M. senile).

Publications:

Manuscript on benthic faunal zonation at Cashes Ledge, to be submitted to Marine Ecology Progress Series by 6/86.

Manuscript on a new species of Hymedesmia (Porifera: Demospongiae) in the Western North Atlantic (with W.D. Hartman), to be submitted to Proceedings of Biological Society of Washington by 6/86.

Paper on the spatial distribution of sponges at Cashes Ledge was presented at the Third International Sponge Conference in Woods Hole, MA, in 11/85.

Manuscript on recruitment and spatial competition of sessile invertebrates at Cashes Ledge, to be submitted to Journal of Experimental Marine Biology and Ecology by 12/86.

Manuscript on effect of predation on the depth zonation of Metridium and Modiolus at Cashes Ledge, to be submitted to Journal of Experimental Marine Biology and Ecology by 9/86.

Title: THE IMPACT OF MACROALGAL DETRITUS TO BENTHIC PRODUCTIVITY: PATTERNS OF DISTRIBUTION AND ABUNDANCE

Principal Investigator: Robert S. Steneck
University of Maine at Orono
Department of Zoology and
Oceanography Program
Orono, ME 04469
(207) 563-3146

Objectives:

The project had two goals: 1) to quantify photometrically detrital macroalgae in coastal and offshore habitats below the photic zone to test the hypothesis that macroalgae are important to the benthic productivity of the Gulf of Maine because they are a significant source of organic matter; and 2) to collect detrital macroalgae
for species and biomass determination as ground truth information to support objective 1.

Approach/Methods:

The submersible was used to survey the bottom and collect macroalgae whenever possible. This was accomplished by a collaborative effort involving most of the principal investigators. While few had time enough to make collections, most did report macroalgae in their transcript reports. Using the times of reported sightings in the transcripts, the appropriate segment of the video tapes was located and studied so that high-resolution measurements could be made.

Current Status:

Continued funding has been rejected, so the preliminary results reported in the published abstract will conclude this project.

Expected Benefits:

Same as above.

Title: PRIMARY PRODUCTIVITY AND ZONATION OF DEEP WATER BENTHIC ALGAE IN THE GULF OF MAINE

Principal Investigators: Robert S. Steneck and Robert L. Vadas
Dept. of Botany and Plant Pathology and
Marine Studies
University of Maine,
Orono ME, 04469
(207) 563-3146

Objectives:

This study examines the ecology of a unique deepwater flora centrally located in the Gulf of Maine at Ammen Rock Pinnacle. Our objectives were to examine patterns in their distribution and abundance and processes affecting those patterns at this site. Specifically, we used extensive submersible and scuba diving observations and an array of manipulative experiments to address the following objectives: 1) to quantify the structure and zonation of this deep water flora; 2) to monitor our manipulative experiments (initiated in 1985) with respect to survivorship, growth, and reproduction; and 3) to isolate processes such as recruitment, herbivory, and rates of primary production that may influence the upper and lower distributional limits of three algal zones.

Approach/Methods:

Zonation patterns were quantified using the Johnson Sea-Link submersible's laser-scaled video system and by recording the maximum depth of occurrence of algal species as seen from submarines. Collections were made when possible by scuba diving or from the submersible. Genetic studies on kelp were used to determine if they are new species. Numerous manipulative experiments were deployed; these include epoxy-embedded algal transplants affixed to PVC racks that were placed and retrieved by submersibles. In 1985 we transplanted each abundant algal species to regions below their natural depth maxima (extinction depth). We examined several biological factors such as growth and competition for both recruiting juveniles and adult plants for each assemblage. Licor integrating light meters were deployed at various depths to determine light profiles.

Current Status:

Algae transplanted in 1985 were revisited in 1986. Zonal assemblages are dominated by kelp, foliose red algae, and crustose algae, respectively, toward deeper water. The transplants

demonstrated that adults of each species (except kelp) can be successfully transplanted to depths greater than their natural depth maxima. At these "sub-extinction depths" they survive, grow, and reproduce, suggesting that extinction depths may not be a simple physiological balance between photosynthesis and respiration among adult plants (which is assumed in most laboratory studies). Instead it is more likely that some other stage (spores or germlings) are depth limited and result in the observed distribution of the plants. In-situ growth studies on the kelp indicate that young plants grow at rates comparable to coastal populations but growth decreases with age (size). Ultimately the extinction depth of kelp at this site may be limited by the maximum depth to which plants of reproductive size can grow. The entire region is devoid of conspicuous grazers and decapods. Gut analyses of fishes in the region and in-situ experiments indicate that this may be due to the intensive fish predation that exists in the region. The Ammen Rock Pinnacle may thus represent an analog to the coast of Maine as it was prior to the invasion of intense coastal fishing pressure.

Expected Benefits:

The kelp community at Ammen Rock Pinnacle is one of the deepest in the world (to depths of 40 m). Initial studies of the genetics of this kelp indicate that it is unlike the coastal species and may be a new species. An unusual race of the coastal limpet, Acmaea testudinalis, was also discovered. These two species may be examples of rapid genetic change occurring in a small, isolated, relatively young (ca. 7000 year old) submarine island.

Title: THE IMPACT OF MACROALGAL DETRITUS TO BENTHIC PRODUCTIVITY: RATES OF UTILIZATION AND DECOMPOSITION

Principal Investigators: Robert S. Steneck
Les Watling
University of Maine at Orono
Department of Zoology and
Oceanography Program
Orono, ME 04469
(207) 563-3146

Objectives:

This study had two major objectives: 1) to determine the rate of utilization and decomposition of detrital macroalgae at an offshore site in the Gulf of Maine (this, with survey data obtained from the companion study on patterns of the distribution and abundance of macroalgal detritus, will allow an estimation of deposition rates to be made); and 2) to quantify the response of microbes, sediment chemistry, and invertebrate biota (species and abundances) to both intact and pelletized detrital macroalgae over a period of one year.

Approach/Methods:

Measured quantities of macroalgal detritus were placed in three submersible-deployed cages. Within some of the cages, urchins were released to pelletize the algae. Control quadrats with algal strips were placed outside the cages as well. A five year pinger was placed to mark the site for our return in 1986.

Current Status:

Results are pending dive time for site revisitation.

Expected Benefits:

As described above.

Title: HERRING EGG BED STUDIES

Principal Invesigator: David Stevenson
Maine Dept. of Marine Resources
W. Boothbay Harbor, ME 04575
(207)633-5572

Objectives:

This project had several objectives: 1) to identify physical and biological features characteristic of herring spawning sites; 2) to determine the size of individual egg beds and habitat characteristics associated with variations in the distribution of abundance of eggs; 3) to determine factors affecting egg mortality and larval hatching rates; and 4) to determine factors affecting the survival and downstream transport of recently hatched larvae.
Approach/Methods:

This project is being conducted in shallow (50-150 ft.) coastal waters in eastern Maine with a remotely operated underwater vehicle deployed from a small vessel. The work is divided into two phases: 1) egg bed surveys and habitat description; and 2) factors affecting egg and larval survival. Field work in September 1985 was directed at testing the operation of the ROV and surveying egg bed habitat in two spawning sites. Data were collected on video tape and by sampling eggs, larvae, and substrate with plankton nets and benthic grabs deployed from a second surface vessel (support for supplementary sampling operations was provided by the University of Maine Sea Grant Program). Future work will include mapping of individual egg beds and in-situ sampling of eggs and larvae with a ROV.

Current Status:

The field work performed during September 4-17, 1985, represented the beginning of a 4-year project. Documentation and analysis of approximately 20 hours of material on 30 video-tape-recorded dives

are currently underway. Benthic grab samples must still be analyzed. Estimates of larval densities and the densities of a predatory copepod at various heights over the egg bed will be obtained from moored plankton nets that were deployed at one spawning site; these samples have been processed.
Expected Benefits:

A descriptive account of 1985 egg bed research will be presented in a Maine Department of Marine Resources Reference Document to be completed in the winter of 1986. More detailed findings of egg bed habitat and egg/substrate associations will be submitted to a suitable scientific journal at a later date. Results obtained to date have delineated some of the physical characteristics associated with herring spawning in a high-energy environment; it is anticipated that 1986 field work will produce additional data for a more complete analysis of egg bed habitat characteristics in eastern Maine. Future work will also contribute to a better understanding of the factors that affect recruitment variability in this important fishery resource.

Title: PATTERNS OF ZONATION IN DEEP WATER BENTHIC ALGAE IN THE GULF OF MAINE

Principal Investigators: Robert Vadas
Robert S. Steneck
University of Maine at Orono
Department of Botany and Plant Pathology, and Marine Science and Oceanography Program
Orono, ME 04469
(207) 581-2978

Objectives:

This study had two primary goals: 1) to quantify and map the occurrence of a deep water macroalgal community centrally located in the Gulf of Maine; and 2) to establish experiments to examine factors affecting patterns of zonation and to measure primary productivity along a depth gradient (at depths of 30, 45, 60, and 75 meters).

Approach/Methods:

The experimental Depth-specific Research Stations (DRS) involve affixing algae, collected by researchers, to submersible-deployed panels. A DRS is located at the depths listed above and each can hold four panels. In total, the panels contain 298 transplanted chips, which will be re-examined during the summer of 1986 to determine survivorship and growth along the depth gradient.

Current Status:

The followup project in 1986 will determine the viability of the

experimental design as well as measure the growth and vigor of the transplanted algae. The major benefit to date is a manuscript, that we hope will be the first of many on this flora.

Expected Benefits:

Same as above.

Title: COMMUNITY STRUCTURE AND SECONDARY PRODUCTION IN ROCKY SUBTIDAL HABITATS OF THE GULF OF MAINE

Principal Investigator: Jon D. Witman and Kenneth P. Sebens
Marine Science and Maritime Studies Center
Northeastern University
Nahant, MA 01908
(617) 581-7370

Objectives:

We have continued our efforts to describe the structure of benthic invertebrate communities at Ammen Rock. We can use these results to provide the first estimates of benthic (secondary) production for subtidal rock surfaces in the Gulf of Maine and determine the amount of secondary production utilized by predatory fish and invertebrates. Because the invertebrate commmunities in deep subtidal habitats are still poorly known, it is important to continue to quantify patterns of species abundance and distribution.

Approach/Methods:

1) Quantify depth zonation of benthic invertebrates (to~100 m) at two sites on Cashes Ledge (photography, benthic sampling). 2) Compute the standing stock biomass of benthic macrofauna (biomass estimates from 1). 3) Continue experiments on recolonization of epifauna to artificial and natural substrata (settling panels). 4) Investigate population dynamics of sessile invertebrates on monitored rock walls and permanent quadrats. 5) Survey food habits of fish and invertebrate predators (field studies, time lapse camera studies, gut contents). 6) Characterize the flow environment along the depth transect by emplacing recording current meters.

Current Status:

We have made substantial progress, during the summer 1986 cruise, toward realizing our research goals in the following three major categories:

Patterns of community structure. Quantitative photo transects conducted from the Johnson Sea-Link submersible enabled us to identify three major faunal zones along the 30-85 m depth gradient. The shallowest is a sparse kelp forest characterized

by high abundances of sea anemones, Metridium senile. A striking increase in the abundance of suspension-feeding invertebrates at ~ 38 m depth marks the beginning of zone 2, comprising the massive yellow sponges Mycale lingua, many species of encrusting sponges, and the anemone Tealia crassicornis. The substratum changes from sloping rock ledge to a cobble-gravel bottom at ~ 65 m; the fauna is dominated by the polychaete Myxicola infundibulum and the anemone Cerianthus borealis.

Secondary Production. We have examined growth rates, recruitment, mortality and abundance of sessile benthos to estimate secondary productivity using permanent quadrats on the bottom. We marked and photographed rock walls at 30, 45, and 60 m depth for long-term monitoring in 1985. In June 1986, we marked and photographed 20 permanent 0.25 m2 quadrats (10 on rock walls, 10 on horizontal-sloping rock surfaces) by Scuba diving at the 30 m site. We also assessed the results of our recruitment experiment, begun in 1985, to evaluate community development on artificial (plexiglass) and natural (granite) substrata at 30-75 m, which were overwhelmingly dominated by bryozoans, indicating that they are an opportunistic species. There was a clear trend of decreasing recruitment with depth below 45 m. We set up a new experiment in 1986 to examine the influence of predators on recolonization of granite surfaces from 30-75 m depth.

Utilization of Macrofaunal Production. We are assembling a benthic food web for Ammen Rock Pinnacle by investigating the stomach contents of fish caught on site, from Scuba and submersible-based observations of predator-prey interactions, from experimental manipulations of sea stars and their invertebrate prey, and from time-lapse movies of predator activity patterns. Such information suggests that fish play an important role in affecting the distribution and behavior of benthic invertebrates. For example, cod, cusk, pollock, and wolffish prey on cancer crabs, which were noticeably absent from rocky habitats during daytime surveys. The time-lapse movie camera record indicated that crabs were more active at night than during the day, which could be a response designed to avoid fish predators.

Expected Benefits:

Scientific results have been presented in the following formats:

Publications: Witman, J.D. and K.P. Sebens. 1985. Benthic faunal zonation at a subridal rock ledge in the central Gulf of Maine, American Zoologist 25(4): 10.

Witman, J.D. and K.P. Sebens. 1986. In press. Distribution and ecology of sponges at a subtidal rock ledge in the central Gulf of Maine. Proceedings of the Third International Conference on the Biology of Sponges, Woods Hole.

Papers in Preparation:

Witman, J.D. and K.P. Stebens. Rocky subtidal community organization at Ammen Rock, Gulf of Maine.

Witman, J.D. and W.D. Hartman. A new poecilosclerid sponge in the genus Hymedesmia from the Gulf of Maine.

Sebens, K.P., J.D. Witman and D. Low. Spatial interactions among bryozoans in deep rocky subtidal habitats.

Papers Presented at Scientific Meetings:

Third International Conference on the Biology of Sponges. 1986. Marine Biological Laboratories, Woods-hole, MA. "Spatial distribution of sponges at Cashes Ledge, Gulf of Maine, USA."

Am. Soc. of Zool. 1985. Baltimore, MD. "Benthic faunal zonation at subtidal rock ledge in the central Gulf of Maine."

East Coast Benthic Ecology Meetings. University of Massachusetts at Boston, Boston, MA. "Community organization of deep rocky habitats in the outer Gulf of Maine."

I. Biological Productivity and Living Resources
A. University of Connecticut-Avery Point
2. Southern New England

Title: IN-SITU STUDIES OF THE EFFICIENCY OF SINK GILL NETS AND AN ASSESSMENT OF THE GHOST GILL NET PROBLEM

Principal Investigator: Richard A. Cooper
NOAA National Undersea Research Program
Univ. of Connecticut-Avery Point
Groton, CT 06340
(203) 445-4714

Objectives:

In 1985, the objectives of this project were to determine the magnitude of the ghost net problem on fishing grounds frequented by gillnetters as determined by 1) number of ghost nets, 2) areal extent of ghost nets, and 3) their apparent impact on local resources. In addition, ghost nets discovered in 1984 were revisited in 1985 in an effort to discern any changes in 1) net condition (fouling) and configuration, and 2) type and condition of catch.

Approach/Methods:

Gillnet fishing grounds on Jeffreys Ledge and Stellwagen Bank were mapped out, and within these areas, 1 nmi transects were randomly chosen for photographic and video documentation of the extent of ghost gill nets. Two ghost nets of known age (still attached to a sunken vessel) were also photographed and videotaped to study net changes over time.

Current Status:

The ghost net survey should be completed in 1986: our conclusion to date is that ghost gill nets do not represent a significant hazard to other resource users (e.g., recreational fishermen) in the areas surveyed. Studies on ghost net parameters will likely be continued beyond 1986, but these will use other techniques (scuba, ROV).

Expected Benefits:

The most substantial benefit of the program is the information we are providing to the New England Fisheries Management Council to assist them in resolving a space conflict between gillnetters and other resource users (principally party boats and trawlers). Results have been presented at a NEFMC open hearing devoted to the issue.

Publications:

Carr, A., B. Amaral, A. Hulbert, and R. Cooper. 1985. Underwater survey of simulated lost demersal and lost commercial gillnets off New England. Proceedings of a Workshop on the Fate and Impact of Marine Debris. University of Hawaii.

Three informal discussion sessions were held with recreational and commercial fishermen for presentation of some results and exchange of ideas.

I. Biological Productivity and Living Resources
A. University of Connecticut-Avery Point
3. Great Lakes

Title: DIEL VERTICAL MIGRATION OF THE OPOSSUM SHRIMP, MYSIS RELICTA, IN LAKE SUPERIOR

Principal Investigator: James A. Bowers
University of Michigan
Great Lakes & Marine Waters Center
1070 NU
Ann Arbor, MI 48109

Objectives:

The purpose of this submersible study was to observe and sample the behavior of Mysis during its migratory cycle at offshore stations in Lake Superior.

Approach/Methods:

Sampling protocols included visual observations (videotape), net samples from the JSL-II, and net tows from the R/V Seward Johnson.

Current Status:

Two papers have been submitted and accepted for presentation at the Skidaway Institute of Oceanography and the annual meeting of the International Association for Great Lakes Research.

Expected Benefits:

The submersible dives in 1985-1986 in Lake Superior indicated several new and previously unknown behaviors by Mysis and a heightened complexity of the classical migration pattern exhibited by mysids in the Great Lakes.

Title: DIEL VERTICAL MIGRATION OF THE OPOSSUM SHRIMP, MYSIS RELICTA, IN LAKE SUPERIOR

Principal Investigators:

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Center for Great Lakes Studies
University of Wisconsin-Milwaukee
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Milwaukee, WI 53201
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Objectives:

The purpose of the first year's dive was to segregate and define two hypothesized Mysis relicta populations existing during the day and night in Lake Superior.

Approach/Methods:

The sampling approach was timed to the diel vertical migration pattern of the opossum shrimp Mysis relicta. Sampling and visual observations were performed during two dives (at 1200 h and 2400 h).

Current Status:

This is an ongoing program, with 2 days of diving planned for the Lake Superior-Lake Huron dives in 1986. Additional funding has also been requested through the University of Michigan Sea Grant Program.

Expected Benefits:

Four discoveries were made during the 1985 dives. During the first dive, the mating behavior of the Mysis was observed. Mating position, photoperiod time, and depth location have never been previously observed in the laboratory or field. There existed non-migratory portions of Mysis and Limnocalanus macrurus, a euryhaline calamoid copepod. Further, high densities of Mysis were observed at the surface (0-3 m) during the night dive. Surface populations are usually observed only during isothermal periods. Finally, total zooplankton densities in the nepheloid layer just above the sediments were much higher than expected.

Title: ECOLOGY AND BIOENERGETICS OF DEEPWATER SCULPINS

Principal Investigators:

W.E. Cooper
Department of Zoology
Michigan State University
East Lansing, MI 48824
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G.R. Smith
Museum of Zoology
University of Michigan
Ann Arbor, MI 48109
(313) 764-0491

Objectives:

Based on 1985 dive observations, deepwater sculpins constitute the largest resident fish biomass at depths exceeding 200 m. Sculpins are crucial to Great Lakes aphotic zone ecological studies because they are the most abundant predator in deep waters and represent the least understood major biotic element in the lake ecosystem. Initial research was designed to focus on behavior, feeding, bioenergetics, and growth in relation to habitat and density.

Approach/Methods:

Over 900 linear meters have been quantitatively surveyed to yield preliminary density and distribution data at various depths. In collaboration with associated investigators using the submersible-mounted electrosampler, nine sculpins were collected and divided up for otolith aging, stomach analysis, and toxicant load analysis. In addition, four growth study cages were released. One cage has been recovered thus far and analysis is pending. Finally, over 3 hours of behavioral data have been recorded on videotape.

Current Status:

Results on toxicant, stomach, behavior, and growth analyses are pending. Analysis of survey data indicates an average density of 0.6 sculpins/m^2, with highly clumped distributions. Future work will revolve around analysis of habitat selection parameters and initial characterization of stock structure, along with feeding ecology.

Expected Benefits:

Invited presentation on deepwater sculpin behavior and related fossil data are to be presented at the IAGLER Symposium in May 1987.

Publications:

Planned publications, pending future research:

Density and distribution of deepwater sculpins by size and habitat

Feeding ecology of deepwater sculpins below 150 m.

Title: SPAWNING HABITAT REQUIREMENTS OF LAKE TROUT IN THE GREAT LAKES

Principal Investigator: Thomas A. Edsall
Great Lakes Fishery Lab
1451 Green Rd.
Ann Arbor, MI 48105
(313) 994-3331

Objectives:

The goal of this project was to develop visual records of surficial substrates and to measure interstitial water quality on representative offshore reefs used historically and currently as spawning grounds by lake trout; these results are to be used in support of an ongoing international effort to rehabilitate lake trout throughout their former range in the Great Lakes.

Approach/Methods:

Tasks performed to meet the objective include: (1) visual (video and still photographic) and narrative (audio) survey of reefs to develop records of the surficial substrate types; (2) collection of interstitial water samples for comparison with known water quality requirements of lake trout eggs, embryos, and fry and with interstitial water quality measurements made on lake trout spawning grounds elsewhere; and (3) a side-scan sonar survey of each area surveyed by the submersible to demonstrate the efficacy of complementary in-situ and side-scan techniques for mapping surficial substrates.

Current Status:

Five dives were made in Lake Superior in 1985. A video documentary of typical substrates present on lake trout spawning grounds in Lake Superior is being prepared. Samples of interstitial water at Stannard Rock, Gull Island Shoal, and Superior Shoal are being evaluated. Interstitial dissolved oxygen concentrations were at or above saturation on the spawning grounds at all locations sampled. Interstitial pH values were within the normal expected range in Lake Superior waters (7.3-7.9). Incubation of interstitial water samples showed that only Stannard Rock and Gull Island Reef supported populations of bacteria that are capable of producing hydrogen sulfide, a substance that is toxic to fish and fish eggs. Results of the side-scan surveys are being evaluated.

Expected Benefits:

Information gathered during the dives in 1985 in Lake Superior, where water and substrate quality are unimpaired and where native lake trout stocks are reproducing successfully, provides a baseline against which lake trout spawning habitat quality in the other four Great Lakes can be evaluated for stocking efforts. The principal scientific product of this study will be a paper describing the water quality and substrate characteristics of the four spawning grounds surveyed.

Title: SPAWNING HABITAT REQUIREMENTS OF LAKE TROUT IN THE GREAT LAKES

Principal Investigators: Thomas A. Edsall and Bruce A. Manny
U.S. Fish and Wildlife Service
National Fisheries Center-Great Lakes
1451 Green Rd.
Ann Arbor, MI 48105
(313) 994-3331

Objectives:

The purpose of this study is to develop the substrate and water

quality criteria needed to evaluate historical lake trout spawning grounds and guide the development of fishery management plans designed to accelerate the re-establishment of self-sustaining stocks of lake trout throughout the Great Lakes.

Approach/Methods:

We used side-scan sonar and the Johnson Sea-Link II submersible to develop detailed documentation of the composition and distribution of the substrates and determine water quality in the substrate interstices on representative offshore reefs used historically as spawning grounds by native lake trout. Reefs selected for study include those that presently support reproduction by self-sustaining stocks of lake trout and others that are perceived as having the potential for supporting such stocks.

Current Status:

Water samples and water quality data collected from substrate interstices on Six Fathom Bank in central Lake Huron in 1986 have been analyzed. Video tapes of the lake bed have been reviewed and used to assist in the interpretation of side-scan sonar mosaic maps and the production of computer-generated color substrate maps of Six Fathom Bank. Results of this work have been disseminated in several addresses and manuscripts for publication.

Expected Benefits:

Manny, B.A., and T.A. Edsall. Interstitial water quality on Six Fathom Bank, an historically important lake trout spawning ground in Lake Huron. Draft in review.

Edsall, T.A., and B.A. Manny. Spawning habitat of lake trout in the Great Lakes: A habitat suitability model. U.S. Fish Wildl. Serv., FWS/OBS. Draft in review.

Edsall, T.A., and C.E. Brown. Mapping and evaluation of lake trout spawning habitat in the Great Lakes. In prep.

Edsall, T.A., C.E. Brown, and B.A. Manny. Substrate quality on Six Fathom Bank, an historically important lake trout spawning ground in Lake Huron. In prep.

Edsall, T.A. Substrate characteristics of offshore lake trout spawning grounds in eastern and central Lake Superior. In prep.

Assessment by submarine of lake trout spawning habitat on Six Fathom Bank in central Lake Huron. Michigan Chapter of the American Fisheries Society. Grayling, Michigan, October 3, 1986.

Midland Michigan Chapter of Trout Unlimited, December 9, 1986 [Edsall]; Sigma Xi Society, Eastern Michigan University, February 19, 1987 [Edsall]; Michigan Academy of Science, University of Michigan, February 27, 1987 [Manny].

Interstitial water quality on historically important lake trout spawning grounds in Lake Huron, International Association of Great Lakes Research, Annual Meeting May 15, 1987 [Manny].

NOAA submarine used to study lake trout spawning habitat in Lake Huron. Live telephone interview on CBC's Toronto-based Today Show. August 29, 1986 [Edsall].

Title: BEHAVIOR AND DISTRIBUTION OF DEEPWATER SCULPIN

Principal Investigator: David J. Jude, Research Scientist
Great Lakes Research Division
University of Michigan
Ann Arbor, MI 48109
(313) 763-3183

Objectives:

This study had the following goals: (1) to observe the behavior of deepwater sculpins during feeding and spawning, if occurring, and note the presence of nests or egg-guarding behavior and diel difference in feeding or movements; (2) to observe microdistribution of deepwater sculpins: patchiness or evenness of distribution, density, and substrate preference, and observe mobility and site constancy; (3) to observe distribution of larvae and juveniles and describe nursery habitat; and (4) to record size-frequency distribution of deepwater sculpins for comparison with concurrently collected net samples.

Approach/Methods:

We used the submersible in water deeper than 50 m, over both rocky and soft substrate, to ensure that adequate numbers of deepwater sculpins were observed. Diel differences in deepwater sculpin behavior were studied on dives at several different times of day during the cruise. Ideally, efforts should be distributed over several depths, substrate types, and times of day to achieve all objectives. We used video and still photographs to record deepwater sculpin behavior and habitat. Personal observations were logged to supplement the photographs. We recorded feeding behavior, spawning and parental behavior, diel patterns in the above behavior, microdistribution of adults, distribution of larvae and juveniles, size-frequency distribution of the population, and proportion of deepwater vs. slimy sculpins observed.

Current Status:

One dive was made during the day in Lake Huron on 21 July 1986. In conjunction with this dive and with the assistance of EPA, which funded the analyses, the USFWS, which collected deepwater sculpins in Lake Huron and Lake Superior, and Marlene Evans of the

University of Michigan, who collected fish in Lake Michigan, I am currently comparing the concentrations of mercury (total and methyl), PAHs, DDT, and PCBs in deepwater sculpins from each of the upper Great Lakes where extant populations of these fish reside. I will compare concentrations of these materials in the fish among lakes to determine the effect tropic status has on accumulation rate in these fish. Colleagues on the submarine cruises will provide data on similar toxic substances in other parts of the food chain and in various components of the sediments. I will be giving a paper on the results at the International Association for Great Lakes Research on May 11, 1987.

Expected Benefits:

I plan to publish a paper on the contaminant relationships for five toxic chemicals found in deepwater sculpins, and how these toxicity concentration vs. length of sculpin data differ among the three lakes from which I have deepwater sculpin data. An elaboration of the mechanism of uptake and bioconcentration of these important anthropogenic substances should help us understand toxic contaminant recycling in the Great Lakes.

Title: ASSESSMENT OF LENTIC LARVAL LAMPREY HABITAT PREFERENCES IN LAKE SUPERIOR, WITH SPECIAL REFERENCE TO BATCHAWANA BAY

Principal Investigator: Douglas S. Lee
Department of Zoology
Michigan State University
East Lansing, MI 48824
(517) 355-4640

Objectives:

Control of adult sea lamprey in the Great Lakes is largely stream based. Individuals that drift or selectively move out of the nursery streams and into the lake immediately or soon afterhatching effectively escape control. Such individuals represent a threat to a salmonid fishery currently valued at over $1.3 billion annually. To provide baseline data on such individuals, the overall goal of this research is to understand better the ecology of lentic ammocoetes (both native and introduced species) in relation to their specific physical and biological enviromnent and in relation to current control measures.

Approach/Methods:

Based on Summer 1985 dive results, the relative importance of substrate particle size versus thermal acclimatization below the thermocline was tested using a cross-factor design to explain gross distributional patterns. Four 3-m square patches were lined

out on the bottom with pvc pipe. Two patches were modified to a sand/silt/clay substrate composition, while the remaining patches were left in their natural silt/clay composition. In one modified and one unmodified patch, marked ammocoetes were acclimatized in situ prior to release, while unacclimatized ammocoetes were released in the other two patches. Results obtained by sampling with a quantified submersible-mounted electrosampler indicate that neither particle size distribution nor thermal acclimatization alone is the major determinant of lentic habitat selection.

Current Status:

Interdiction of the thermocline with steep slopes in the bay, along with cross slope currents, appears to be the remaining major correlate with lentic ammocoete distribution patterns. Experiments to test concordant hypotheses are currently beingdeveloped.

Expected Benefits:

Provision of baseline data on lentic ammocoete ecology of potential value to management personnel.

Publications:

Lee, D.S. and R.F. Tusting. 1987. Development and use of an electrosampling device for submersible operations. Proc. ROV'87 Conf. MTS Society, San Diego Section.

Lee, D.S and J.G. Weise. 1987. Distribution of lentic larvallamprey and preliminary analysis of habitat selection in Batchawana Bay, Lake Superior. To be presented at IAGLR Symposium in May 1987.

Title: DEEP WATER ASSESSMENT OF LARVAL LAMPREY DISTRIBUTION AND ABUNDANCE IN LAKE SUPERIOR, WITH SPECIAL REFERENCE TO BATCHAWANA BAY

Principal Investigator: Douglas S. Lee
Department of Zoology
Michigan State University
East Lansing, MI 48824
(517) 353-6467

Objectives:

This study had several goals: to identify and explain the major physical and biological factors affecting both sea lamprey and native lamprey ammocoete distribution and abundance and to determine the effectiveness of, and reaction to, current and past sampling/control techniques on the part of lentic larval sea lamprey and native lamprey.

Approach/Methods:

The methodology involved the use of photographic and physical assessment of lentic ammocoete distribution and abundance on a 1600 x 2400 m sample plot off the mouth of the Harmony (Chippewa) River. With a specially designed electrosampling device attached to the Johnson Sea-Link II submersible, four quantitative transects were made throughout the sample area; prior to the arrival of the submersible, sediment samples were taken with a sonar dredge throughout the sample area to assess the abiotic characteristics of the plot. In the lab, the sediment samples were analyzed for particle size distribution and organic/inorganic content. Thermal/depth regimes, oxygen concentrations, conductivity, and PH were also monitored, and the behavior of lentic ammocoetes at the substrate-water column interface during a standard Bayer-73 control treatment was documented using visual and photographic documentation.

Current Status:

Last year's research constituted the preliminary work required to support a 3- to 5-year comprehensive research effort to unravel the determinants of lentic ammocoete distribution and abundance. Analysis of information to date suggests that substrate particle size distribution, thermal regime, and aspects of intra- and inter-specific competition are probably the major determinants of past and present lentic ammocoete distribution and abundance. At present, bed slopes and suspended food particle distribution look to be secondary or derived elements of importance.

Expected Benefits:

The benefits of this research include provision of baseline data on the ecology of lentic ammocoetes, which are necessary for informed management decisions to be made. This research represents the first-known use of electrosampling technology with a manned submersible.

Publications:

Lee, D.S. 1985. Annual report to the M.S.U. Foundation. 25 pp.

Trusting, R.F. and L.D. Taylor. 1985. Submersible mounted electrosampler for use in freshwater--operating manual. Harbor Branch Tech. Rep. 56, 22 pp.

Publications on field use of electrosampling gear for lentic sampling, field habitat preferences, distribution and abundance of lentic lamprey, laboratory analysis of substrate preferences, and habitat specific growth rates as an index of habitat suitability will be written after completion of future work.

Presentations made to date include: the 1986 annual meeting of the Ontario Council of Commercial Fishermen, Toronto, Ontario; Sigma Xi/M.S.U. undergraduate/graduate recruitment seminar; WKAR call-in radio talk show; and various high school and civic groups.

I. Biological Productivity and Living Resources
B. University of North Carolina-Wilmington

Title: FISH COMMUNITY POPULATION ASSESSMENT ON A DEEP WATER ARTIFICIAL REEF

Principal Investigator: Melvin Bell
SC Marine Resources Division
P.O. Box 12559
Charleston, SC 29412
(803) 795-6350

Objectives:

This study will permit scientists to make seasonal comparisons of similar new and old artificial reefs using divers to perform precision trapping, censusing, and video documentation.

Approach/Methods:

Quantitative, simultaneous dual-diver radial transects were conducted to measure fish abundance and to perform precision trapping, censusing, and video documentation of baited fish traps.

Current Status:

Initial cruise to assess techniques conducted. Techniques are well worked out for future seasonal cruises.

Expected Benefits:

The results will provide a better understanding of how artificial reefs work in the South Atlantic Bight.

Title: CHARACTERIZATION OF BENTHIC HABITAT AT ARTIFICIAL REEF SITES

Principal Investigator: Dr. Lawrence Cahoon
University of North
Carolina-Wilmington
Biology Department
Wilmington, NC 28403
(919) 395-3706

Objectives:

This program development cruise was designed to gather baseline data on potential future artificial reef sites and develop methodology for obtaining permits and developing research proposals.

Approach/Methods:

Diver-collected precision samples, video documentation and habitat definitions.

Current Status:

Baseline data have been analyzed, artificial reefs have been permitted, reefs have been constructed of railroad cars, and research proposals are being developed.

Expected Benefits:

Ultimately this project will yield considerable data on developing optimal artificial reefs for the future management of resources.

Title: BENTHIC PRODUCTIVITY IN NORTH CAROLINA CONTINENTAL SHELF WATERS: RECRUITMENT AND SUBSTRATE PREFERENCES IN DEMERSAL ZOOPLANKTON AND INVERTEBRATE LARVAE

Principal Investigators:

Lawrence Cahoon
University of North Carolina-Wilmington
Biology Department
Wilmington, NC 28403
(919) 395-3706

Anne McCrary
University of North Carolina-Wilmington
Biology Department
Wilmington, NC 28403
(919) 395-3475

Objectives:

Scientists will take the first benthic primary productivity measurements of the soft substrate benthos of North Carolina waters. In conjunction with the concurrent project of Dr. McCrary (SU-1484), this project will provide linkages to the secondary producers.

Approach/Methods:

Light/dark chambers, CHN analyses, larval and zooplankton traps, day/night and seasonal sampling.

Current Status:

Multi-year project completed in March 1986.

Expected Benefits:

1) Results show much higher benthic productivity of soft substrates than expected. 2) Results provide important clues to high artificial reef productivity, which is perhaps sustained by nearby soft substrates. 3) Refereed publications and technical literature are expected in 1987.

Title: FUNCTION, EFFICACY, AND SITING OF ARTIFICIAL REEF MATERIALS ON THE NORTH CAROLINA SHELF

Principal Investigator: David Lindquist
University of North Carolina-Wilmington
Biology Department
Wilmington, NC 28403
(919) 395-3474

Objectives:

This project is designed to evaluate artificial reef building materials on the basis of configuration, current patterns, fish abundance, and diversity.

Approach/Methods:

Multi-technique approach involving current meter deployments, video documentation, diver censusing, and experiments.

Current Status:

First mission of an anticipated and much larger multi-investigator, multi-disciplinary project.

Expected Benefits:

The findings of this project will lead to a better understanding of how artificial reefs function in the southeast. Ultimately, the objective is to design optimal, targetted species reefs.

I. Biological Productivity and Living Resources
C. University of Hawaii-Manoa
Hawaiian Undersea Research Program

Title: THE EFFECTS OF NUTRIENT CYCLING AND FLUXES ON FISHERIES PRODUCTION IN THE PENGUIN BANK ECOSYSTEM

Principal Investigator: Catherine R. Agegian
University of Hawaii
Hawaii Institute of Geophysics
Honolulu, HI 96822
(808) 948-7777

Objectives:

Mid-depth banks (50-100 m) of islands and atolls provide significant substrata for the development of benthic communities. In the Hawaiian Archipelago, these banks are six times the size of adjacent shallow reefs and are sites of major bottom fisheries. Despite heavy commercial and recreational fishing use, benthic communities on the banks were too deep to be investigated without a submersible. The objectives of this study are to describe the composition of the benthic community on one of the most heavily fished banks and to quantify carbonate production occurring there.

Approach/Methods:

In 1985, a permanent site was established at 82 m depth on Penguin Bank, and 22 settling block arrays were deployed there. Each array consisted of four cement blocks and four plexiglass plates attached inside a wire mesh basket. Variations in the abundance and composition of benthic organisms in the area were recorded and both organisms and substrates were collected. Variations in the colonization of benthic organisms on the arrays were recorded on each dive. Arrays were periodically retrieved to quantify the percent cover of benthic organisms and rates of cementation by calcium carbonate producing animals and plants. The carbonate mineralogy of the sediments and the dominant benthic organisms were determined by x-ray diffraction. Carbonate production of the benthos was estimated by placing a portion of the community inside a plexiglass incubation chamber for 4 hours at depth.

Current Status:

During the past year, the carbonate mineralogy and composition of the benthic community and sediments of Penguin Bank were determined at the permanent study site and at additional sites on the bank from 45-100 m depth. Net community carbonate production was determined from chemical estimation techniques and was 380 grams per meter square per year. Carbonate production by coralline algae determined from settling block experiments was 190 grams per meter square per year. The calcareous benthic community at the study site is composed of an unattached assemblage of

coralline algae, bryozoans, calcareous green algae, and foraminifera. This assemblage is very different from typical shallow water reef communities, in which corals are a dominant component of the community and bryozoans are rare.
The mineralogical composition of sediments on Penguin Bank suggests that the production of carbonate sediments occurs in situ rather than from shallow benthic or pelagic organisms. Studies have shown that coralline bryozoans and benthic foraminifera on Penguin Bank deposit magnesian calcite at a considerably lower rate than their shallow water counterparts. The magnesian calcite values on Penguin Bank are consistent with these low rates and are not the higher values that would be expected if shallow reef counterparts had been carried down to form the bank sediments. Pelagic organisms that also produce low magnesian calcite are represented in the fine sediment fraction; however, their numbers are very few. At Penguin Bank, the green alga Halimeda has been found to be the dominant producer of the carbonate mineral aragonite, whereas in shallow Hawaiian reef environments corals produce most of the aragonite.

A comparison between Penguin Bank and typical shallow water reefs suggests that the mid-depth bank ecosystem may operate as a functionally separate entity and have processes distinct from those defined for shallow water reef ecosystems. Preliminary evidence obtained with the submersible suggests that cold, nutrient-rich water from about 150 m depth is pumped onto Penguin Bank by the tidal cycle. Preliminary observations and calculations suggest that the production and fate of calcium carbonate particles from mid-depth banks may be significant, and as yet unaccounted for, components in the global biogeochemical cycles of carbon and calcium.

Expected Benefits:

Future research efforts will describe the mid-depth bank ecosystem in terms of the major fluxes of dissolved and particulate matter entering and leaving the bank. Quantification of these fluxes will lead to an understanding of the trophodynamics of these ecosystems and their associated fisheries. A symposium on this subject was led by Dr. Agegian at the December 1986 meeting of the Western Society of Naturalists. The paper submitted at this meeting by Agegian and MacKenzie is in press.

II. Pathways and Fate of Materials in the Ocean/Lake
A. University of Connecticut-Avery Point
2. Southern New England

Title: THE BIOLOGY OF GELATINOUS ZOOPLANKTON: COMPARATIVE STUDIES ON OCEANIC AND NERITIC SALPS; AND FURTHER INVESTIGATIONS ON MESOPELAGIC ORGANISMS, USING A SUBMERSIBLE

Principal Investigator: G.R. Harbison
Woods Hole Oceanographic Institution
Woods Hole, MA 02543
(617) 548-1140

Objectives:

The goals of this study were to characterize the midwater gelatinous fauna of the continental slope margins off southern New England, and to understand how this fauna interacts with other parts of the midwater, continental slope, and shelf communities in the southern New England area.

Approach/Methods:

Using a combination of direct observations and collections and a team of eight research scientists and two technicians, we made eight dives over a four-day period (30 August to 2 September 1986) with the submersible, JOHNSON-SEA-LINK (JSL). The primary emphasis was on maximizing interactions between the research scientists so that a more complete picture could be gained of the nature of the species we observed and collected and the nature of the interactions between them and other species. Since this was the first time our group had carriedout a dive series in this area, and our time was so limited, our observations must be regarded as preliminary.

Current Status:

Twenty-six specimens of ctenophores were collected, belonging to three species. Eleven specimens of Bolinopsis infundibulum were collected, at depths ranging between 1820 and 2500 ft. Six specimens of Bathocyroe fosteri were collected, and four specimens of an undescribed red ctenophore. A specimen of Thalassocalyce inconstans was collected that was eating a midwater fish, Ceratoscopelus sp. Nineteen specimens of siphonophores were collected, belonging to eleven species. Nine of these were Nanomia cara. It appears that five of the ten remaining species are undescribed, but further material is needed. Eight specimens of medusae, all previously described, were collected. One specimen of a rare and extremely delicate near-bottom medusa, Poralia rufescens, was collected intact. Several sexually mature Sollmissus spp. were also collected. Two specimens of a salp,

apparently belonging to an undescribed species, were collected. Further material is necessary, since the solitary sample was badly damaged upon removal from the detritus sampler. We also studied field fishing postures of a variety of ctenophores, siphonophores and medusae, and videotaped the escape responses of several animals, particularly midwater fish. We also studied a number of fishes that orient vertically in the water (chiefly species of Serrivomer and Notolepis), and compared our observations with some we had previously made in the Bahamas (chiefly on Diplospinus).

Future Plans:

It is necessary to follow up this initial study with a longer (ca. two weeks) cruise with the JSL this summer.

Expected Benefits:

Some of the undescribed material is being worked up now. As of this date, no publications are completed. It does appear that these previously unknown components of the gelatinous fauna may have a substantial impact on fish recruitment in the Georges Bank region.

Title: CHARACTERISTICS OF OCEAN DISPOSAL SITES (FADS Boston, CADS Cape Arundel) By IN-SITU INSPECTION WITH THE MANNED SUBMERSIBLE (JSL)

Principal Investigator: Lance L. Stewart
NURP-UCAP
Marine Sciences Institute
Groton, CT 06340
(203) 445-4714

Objectives:

In response to mandates of the Marine Protection Research and Sanctuaries Act, research was conducted to assess the sites andpotential impacts of waste disposal (dredged material) at selected dump sites in the Gulf of Maine. Detailed site characterization of specific seafloor areas (approximately 1 n. mi. square) required intensive in-situ photodocumentation and discrete sampling. A significant influence on sediment fabric and bioturbation is attributed to the mobile epibenthic fauna; this fraction of the biological community is poorly quantified and its behavior was unknown. Manned submersible data included: quantified video and 35mm footage of elusive benthic fauna; precise sediment core sampling at predetermined stations; epibenthic net samples obtained in difficult-to-sample terrain; water column CTD/transmissometer data related to benthic substrates and habitats; nepheloid layer in-situ samples on pre-determined stations; and hard rock samples and attached fauna quantification of deep (> 30m) seafloor habitats.

Approach/Methods:

Data were compiled for a DAMOS report to the COE to be used in the regulatory process of site designation and management at FADS and CADS. This 'grey literature' represents powerful marine research information that can play a direct role in the decision-making involving multi-million dollar dredge/disposal projects throughout New England. Also, these reports advance our understanding of marine pollution control of contaminants and methods to reduce seafood and fishery impacts at several offshore sites. This 3-day cruise was responsible for many "firsts" within the formal NURP/UCAP program: a) interagency research with specific marine management responsibilities was coordinated and integrated through the DAMOS/UCAP submersible surveys; b) results obtained by applying a precision navigation/computer interface system to track accurately (± 2m) and plot real-time submersible position and direct course transects to exact survey paths were related to extensive previous station sampling; c) parallel laser beams were mounted and used to calibrate areas of photo imagery coverage and gauge real size scale of sediment features and benthic organisms; and d) the combination of newly engineered 'closed collection bins' used for nepheloid layer samples coincident with low-mounted transmissometer readings was a new sub configuration to measure benthic-pelagic mechanisms of turbidity.

Current Status:

Data will be used to make decisions on permitting, site designation, monitoring, and management of dredged material ocean disposal sites. For the Boston Site (CADS), the survey of suspected low-level radioactive canister sites was negative. The variation in sediment/habitat type was mapped thoroughly, integrating: REMOTS, Smith MacIntyre, precision bathymetry, side-scan and submersible data for the site characterization documentation required for permitting. A change in the site designation at the Cape Arundel Disposal Site (CADS) is greatly dependent on data from the 1984 and 1985 NURP/UCAP ROV and manned submersible survey.

Expected Benefits:

A paper presented at the MTS ROV '85 Conference summarized ROV applications to dredge material monitoring and management. Results obtained from this cruise have been reported to the COE-NED for permit decisions in 1986. An abstract has been submitted to the Sixth International Ocean Disposal Symposium, and the paper, if accepted, will detail techniques developed for JSL in-situ research on dredge disposal sites.

Title: ECOSYSTEMS ANALYSIS OF THE GREAT SOUTH CHANNEL: BEHAVIOR, DENSITIES, GROUND TRUTHING, AND RELATION TO ENVIRONMENTAL VARIABLES

Principal Investigators: Howard E. Winn
Karen Wishner
Graduate School of Oceanography
University of Rhode Island
Kingston, RI 02881
(401) 792-1000

Objectives:

The first goal of this study was to determine the feasibility of using the Delta submersible for water column studies of zooplankton, especially (a) quantitative studies of zooplankton layers and patches, (b) species identification of important large zooplankters, (c) behavior as a clue to patch formation mechanisms, and (d) zooplankton distributions in relation to various environmental variables. The project was also intended to determine the feasibility and constraints of the complex currents of the Great South Channel and to make opportunistic observations of the underwater behavior of whales, particularly of such endangered species as the right whale. A final objective was to study bioluminescence as a potential cue for food location by whales. This work is a component of a larger project to study the ecosystem of the Great South Channel (South Channel Ocean Productivity Experiment, SCOPEX), an area that is unusually productive and has unusually abundant populations of top predators, including several species of whales.

Approach/Methods:

Six submersible dives were made aboard the Delta from the catamaran Atlantic Twin during June 1986. They were made near the BC buoy in the GSC area and on Stellwagen Bank. Due to a lack of time, we could not get to the right whale hot spots, about 40 miles to the south of BC buoy. There were day dives and night dives and dives over both silt and sand bottoms. In general, visibility was 25 to 30 feet; temperature and depth were recorded every 10 feet. Continuous video observations were recorded, photographs were taken, and research notes were made. Near the BC buoy, there was a great deal of particulate matter and small zooplankton were observed in the water column (depth 480 feet.). A thin layer of euphausiids (Meganyctiphanes norvegica) existed from the bottom to 10 feet. off the bottom. With the lights out, the krill produced bioluminescent flashes. On Stellwagen Bank at a depth of 360 feet., large and small copepods were seen from the surface to about 180 feet. down. The large copepods disappeared and only chaetognaths were seen from 180 ft. to the bottom. White-sided dolphins swam around the submersible for an extended period. Sand lance were seen in areas where they were not formerly abundant. The humpback whales, which in most years are abundant in these areas (Stellwagen, northern GSC), had

completely abandoned them in early May of 1985 and did not return until about December. Based on photographic identification of known individuals, at least some of the Stellwagen humpbacks were feeding near the front of our GSC experimental area.

Current Status:

Insufficient data were obtained for publication but tapes are under study for design of quantitative measuring devices. Video tapes are being used to confirm species identifications and a teaching tape, "A trip through the water column," is being made. After ONR, MMS, and NMFS funding of a pilot SCOPEX project for 1986, a new NSF grant application is being considered.

Expected Benefits:

All of the objectives were met, at least to some degree. With more sophisticated density measuring devices, a variety of valuable information will be obtained and used in the development of a Great South Channel Ecosystem model. Zooplankton behavior studies should aid in understanding patch information. Our understanding of habitat use by endangered whales should be enhanced by this research.

II. Pathways and Fate of Materials in the Ocean/Lake
A. University of Connecticut-Avery Point
3. Great Lakes

Title: IN-SITU STUDY OF THE SEDIMENT-WATER INTERFACE AND BENTHIC BOUNDARY LAYER DYNAMICS

Principal Investigator: Dr. Larry F. Boyer
Dept. of Geol. and Geophys. Science
Center for Great Lakes Studies
Univ. of Wisconsin--Milwaukee
Milwaukee, WI 53201
(414) 649-3003

Objectives:

The purposes of this study were to use newly developed video sediment profile camera (VSPC) and rare-earth-element (REE) tracer techniques to obtain geochemical and biological data on sediment transport rates, sedimentary structure, redox depth, and infaunal and epifaunal mixing depths: in short, to begin to understand benthic boundary layer dynamics in deep depositional basins of Lake Superior.

Approach/Methods:

To meet the objectives, three primary techniques were used: a) the VSPC was used for rapid areal reconnaissance; b) the REE tracer was deployed for several weeks to measure vertical and lateral sediment transport, and c) sediment coring, with box and cylinder cores specially designed for submersible use, was done for more conventional geological and geochemical analysis (e.g., radionuclide dating, x radiography).

Current Status:

This was the first year of a proposed 3-5 year effort. Year one was devoted mostly to testing and refinement of the methodology. More detailed experiments will be performed in subsequent years.

Expected Benefits:

1) The VSPC worked well with the submersible; an improved version for 1986 will result in more detailed and rapid data acquisition.
2) One paper was presented subsequent to the 1985 cruise: Boyer, L. and J. Hedrick (1985). Concept design and initial deployment of a sub-deployed CCD-video sediment-profile camera system. Trans. of Amer. Geophys. Union 66 (51): 1263. One paper is in preparation: Boyer, L. Hierarchies of bioturbation in Lake Superior sediments.
3) Other significant observations included: video transects revealed high densities of sculpin (unexpected in such a hyperoligotrophic environment), and unusual sedimentary features

(dish structures which were discovered by x-rays of box cores that may have been caused by past sculpin activity.

Title: ANIMAL-SEDIMENT RELATIONS IN PROFUNDAL LAKE SUPERIOR SEDIMENTS: EXAMINATION OF A WEST TO EAST DEPTH GRADIENT IN A NORTH-SOUTH TROUGH LOCATED AT APPROXIMATELY 47°00'N and 85°00'W, CRISP POINT, LAKE SUPERIOR, USA

Principal Investigators:

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Objectives:

The general objectives of this proposed study were: 1) to design and test a high-resolution version of the successful CCD video sediment-profile camera system, 2) to compare the magnitudes of physical vs. biological controls on vertical and horizontal mixing at the sediment-water interface, 3) to determine the rates of reworking at the sediment-water interface and the rates of pelletization by invertebrates, 4) to compare these parameters at a depth of 1100 feet; and 5) to compare these findings to the results of studies in marine coastal shelf environments along similar depth and environmental gradients.

Approach/Methods:

We examined in detail a 1000 m^2 area of profundal sediments at 350 m in Lake Superior using a variety of innovative techniques: run down a) shipboard 35 mm and submersible operated CCD video sediment profile cameras for rapid reconnaissance of the lake floor; b) sediment coring, both tube and box corers, modified for submersible use, for geological, geochemical, radionuclide dating, and x-radiographic analysis; c) particle spreading experiments to measure in-situ deposit-feeder ingestion rates and bioturbation; and d) fecal pellet production and decomposition experiments, where sediments are marked with tracers in two unequal cohorts.

Current Status:

We are continuing to process samples and data; we hope to return to Lake Superior in 1988. We expect that the proposed research will require 3-5 years of effort to compare specific benthic processes within and between the lakes and the marine environment.

Expected Benefits:

An understanding of animal-sediment-fluid interactions at the sediment-water interface and their control of boundary layer transport and mixing processes is critical for accurately modelling lacustrine sedimentary environments.

Title: SOURCES, COMPOSITION, AND CYCLING OF ORGANIC CONTAMINANTS IN THE BENTHIC NEPHELOID LAYER OF LAKE SUPERIOR

Principal Investigator: Steven J. Eisenreich
Department of Civil and Mineral Eng.
University of Minnesota
Minneapolis, MN 55455
(612) 373-2507

Objectives:

The overall objective of this research is to determine the source(s) and composition of particles in the benthic nepheloid layer (BNL) of Lake Superior, and to determine the role of the BNL in the cycling of organic pollutants (e.g., PCBs, DDT, PAHs). This is to be accomplished through chemical and physical measurements of inorganic and organic geochemical tracers in particles in the BNL, in the overlying water, and in surficial sediments. Measurement of organic contaminants in the BNL are being made to assess the role the BNL plays in the water column dynamics of organic pollutants.

Approach/Methods:

The approach of this study is to collect particles and water at and near the sediment-water interface in the open waters of Lake Superior. Use of a manned submersible enabled us to collect such samples in deep water. We participated in the NURP-sponsored cruise of the R/V Seward Johnson on Lake Superior in 1985 with two goals. First, we sought to develop and evaluate geochemical sampling equipment that could be employed by a manned submersible; this sediment corers and a water filtration system. Second, we planned to use this equipment to collect sediment cores, fine surficial sediments, suspended particles, and bulk water in the BNL. These samples will provide preliminary data for our overall objectives and will validate the sampling protocol. We were successful in collecting qualitative geochemical samples during the cruise.

Current Status:

Samples collected during this cruise are currently being analyzed for organic contaminants, organic carbon, and geochemical tracers. Preliminary data suggest that the fine layer of silt covering the lake bottom is enriched in certain organic pollutants and may be

the result of rapid settling of freshly produced particles. This layer may be a direct link between atmospheric deposition and sediment accumulation of organic pollutants. Further analysis is ongoing. We are also working in conjunction with other participants in the Great Lakes NURP Dive Program (D. Long, Michigan State) and the Harbor Branch Foundation to design, construct, and test a quantitative filtration sampling system for the Johnson Sea-Link submersible. This system should be operational during the 1986 NURP cruise in Lakes Huron and Superior.

Expected Benefits:

Potential benefits include a better understanding of the aquatic behavior of organic contaminants, including refined estimates of their net residence times. Collaborative efforts with other geochemists involved in NURP's Great Lakes program will further elucidate relationships between pollutant transport and the geochemistry of large lakes.

Title: SOURCES AND DYNAMICS OF PARTICLES, ORGANIC CARBON, AND ORGANIC CONTAMINANTS IN THE BENTHIC NEPHELOID LAYER OF LARGE LAKES

Principal Investigators: Steven J. Eisenreich and Joel E. Baker
Environmental Engineering Sciences
University of Minnesota
Minneapolis, MN 55455

Objectives:

The overall objective of this study is to investigate the role that the cycling of particles and organic carbon plays in the transport of hydrophobic organic contaminants (e.g., PCBs, DDT, PAHs) in large lakes. Specific sub-objectives are to identify sources and estimate fluxes of particles and organic carbon through the water column, to identify and quantify selected organic contaminants, to estimate vertical fluxes of organic contaminants throughout the water column, and to construct a mass balance model of particles, organic carbon, and organic contaminants in the sediment-water environment.

Approach/Methods:

In 1986, detailed vertical profiles of particles were collected at four dive sites in Lake Superior with the Johnson Sea-Link II and from the R/V Seward Johnson. Particles were collected via submersible from the benthic nepheloid layer (BNL, a zone enriched in particles extending above the sediment-water interface), from the sediment boundary layer, and from sediment cores. Air and surface water were sampled from the surface ship at each dive site. Concentrations of organic contaminants on particles are determined by extracting samples with organic solvents,

concentrating the extract by solvent reduction, analysis by liquid-solid chromatography, and analysis by gas chromatography with electron-capture or mass spectrometric detection. Suspended solids and dissolved and particulate organic carbon are measured using standard oceanographic techniques.

Current Status:

Significant observations made during Lake Superior dives include confirming the presence of BNL and establishing the existence of the sediment boundary layer. In addition, the high amount of biological activity suggests rapid processing of organic-rich particles in the benthic region. We hypothesize the following: (1) the BNL originates from resuspension of sediments and/or from downslope transport during non-stratified conditions, and (2) the sediment boundary layer ("fluff") consists of particles that have settled from the water column during stratified conditions. Geochemical analysis of particles collected from these zones as well as those collected from surface waters and surficial sediments allows these hypotheses to be tested. Initial results from Whitefish Bay (Dives 1390/1391) demonstrate that BNL and "fluff" particles have different contaminant geochemistries, suggesting that they derive from different sources. "Fluff" particles at this site have a PAH pattern most similar to those of air vapors and surface water dissolved phases, which is consistent with the idea that rapid settling of large aggregates removes contaminants from surface waters and provides a direct link between the atmosphere and the benthic region of large lakes. The PAH pattern of BNL particles resembles that of surficial sediments, suggesting that the BNL results from resuspension.

Expected Benefits:

Analysis of samples collected at four sites for organic contaminants is ongoing. In addition, these particles will be examined for organic geochemicals (including n-alkanes, phytane/pristine, and steranes) to aid in source determination. Cores at each site are being dated with 210-Pb and 137-Cs to estimate long-term contaminant accumulations. Through cooperation with NOAA GLERL, sediment trap material from Lake Superior will also be analyzed to provide information on fluxes of organic carbon and contaminants during stratification. Finally, our data will be incorporated with those of other geochemists participating in the NURP Great Lakes cruises.

Title: SEDIMENT COMPOSITION AND DISTRIBUTION OF TERMINAL ELECTRON ACCEPTORS IN SEDIMENTS OF LAKE SUPERIOR

Principal Investigators: Michael J. Klug, Richard G. Carlton, and Gregory S. Walker
Michigan State University
W.K. Kellog Biological Station
Hickory Corners, MI 49060
(616) 671-2341

Objectives:

The goals of this project are to examine visually and photodocument large areas of sediment in order to evaluate the heterogeneity of the lake bottom and take appropriate samples for shipboard analysis, 2) to characterize the microbial activity of the sediments, 3) to determine the concentrations of various pore water solutes, particularly the inorganic terminal electron acceptors oxygen, nitrate, nitrite, and sulfate, 4) to determine the organic content of the sediments, and 5) to determine the depth distribution of benthic algal productivity.

Approach/Methods:

All sampling and observation activities were conducted from the Johnson Sea-Link II. Photodocumentation was accomplished with still and video cameras on the sub. Over 30 sediment cores were taken using the robot arm. Oxygen microprofiles were measured as soon as possible after retrieving the sub using the microelectrode method of Ravsbech and Ward (Appl. Environ. Microbiol. 45:755, 1983). Following these non-destructive measurements, the water was extracted from 1-cm-thick core sections by centrification. Ion analyses were conducted aboard ship using HPLC.

Current Status:

The data collected during the 1985 mission revealed much about the general characteristics of Lake Superior's sediments as well as some unexpected findings. Consequently, we have formulated several new hypotheses and designed experiments that are planned for, 1986. Mud samples are presently being analyzed for organic content.

Expected Benefits:

These data will be presented in two papers at the 30th Conference of the International Association for Great Lakes Research.

Publications:

Carlton, R.G. and R.G. Wetzel. Microelectrode Studies of the Distribution of Oxygen and Microbial Respiration in Lake Superior Sediments.

Walker, G.S. and M.J. Klug. Distribution of Terminal Electron Acceptors and Microbial Processes in Lake Superior Sediments.

Title: BIOGEOCHEMICAL PROCESSES AT THE BENTHIC BOUNDARY LAYER

Principal Investigators: J. Val Klump and Charles C. Remsen
Center for Great Lakes Studies
University of Wisconsin--Milwaukee
600 E. Greeenfield Ave.
Milwaukee, WI 53204
(414) 649-3000

Objectives:

High-quality sediment cores taken from the Johnson Sea-Link/Seward Johnson in Eastern Lake Superior have revealed a remarkable variability in benthic environments in this topographically complex region. Cores from a shallow coastal bay (~100 ft.), an intermediate depth (400 ft.) depositional basin, and several deep (>1000 ft.) basins indicate order of magnitude changes in sediment accumulation rates, benthic metabolism, and microbial activity associated with biogeochemical cycling processes in the upper 30 cm of sediment. Perhaps most remarkable were the extreme differences observed from the submersible and in the samples collected between the deepest basins of the lake. In the northern Caribou Basin, sediments at water depths of ~1200 feet were organically richer and more rapidly accumulating than sediments in the deepest basin of the lake. At 1330 feet, the deepest basin lies in a similar geomorphological province, yet samples collected from the Sea-Link showed only a thin veneer of flocculant sediments over highly compacted clay and sand. Also surprising was the fact that the biological community (the attached Hydra, the demersal fish--primarily sculpins, and the planktonic detritivores which feed on the rain of debris from the water column above) appeared to be very abundant in both basins, despite what would seem to be significant differences in the fluxes of labile organic materials that support the benthic food chain. One implication appears to be that the deepest basins of the lake may be far more energetic on an episodic basis than previously realized. Ripple marks at ~1200 feet in the southern portion of the deepest basin are tentative evidence of high energy events, the so-called "benthic storms," which may prevent the net accumulation of material on a permanent basis.

Approach/Methods:

As part of a related study, samples were also collected for determination of the amino acid composition of recently deposited material. Fresh detritus apparently supports an amazing abundance of benthic life. Flocculant surface sediments are being compared with sediments from other Great Lakes environments in order to qualitatively assess the extent to which surface sediments in the deepest basins of the Great Lakes resemble "fresh" or "aged" detrital material. This assessment may provide insights into how

quickly or slowly material makes its way to the bottom and how long it seems to remain.

Current Status:

We are continuing to analyze data to reinforce our Lake Superior conclusions and are awaiting further opportunities to continue this work in Lake Michigan and some of the other Great Lakes.

Expected Benefits:

Publications:

Nalepa, T.F., C.C. Remsen, and J.V. Klump. 1987. Observations of Hydra from a submersible at two deep water sites in Lake Superior. J. Great Lakes Res. (In press).

Paddock, R., J.V. Klump, C.C. Remsen, P.D. Anderson, and S. Fitzgerald. 1987. Sediment accumulation and organic carbon deposition in Eastern Lake Superior basins. Abstract Ann. Mtg. Int. Assoc. Great Lakes Res., Ann Arbor. Great Lakes Res., Ann Arbor. May, 1987.

Boraas, M.E., C.C. Remsen, and J.V. Klump. 1987. Sediment ripples in the deepest basin of Lake Superior: Evidence of bottom currents? Abstract Ann. Mtg. Int. Assoc. Great Lakes Res., Ann Arbor. May, 1987.

Title: BIOGEOCHEMICAL PROCESSES AT THE BENTHIC BOUNDARY LAYER

Principal Investigators: J.V. Klump and C.C. Remsen
University of Wisconsin-Milwaukee
Center for Great Lakes Studies
600 E. Greenfield Ave.
Milwaukee, WI 53204
(414) 649-3000

Objectives:

To determine the extent and rates of organic matter diagenesis in Great Lakes sediments with particular emphasis on organic carbon and nitrogen cycling and the role of amino acids as intermediate metabolites in the decompositions of detritus, 2) to characterize the proteinaceous components of the detrital material found in and above the benthic boundary layer via measurements of the total hydrolyzable amino acid content of surface sediments and suspended material, 3) to estimate the residence times and recycling rates for the metabolizable and remineralizable fractions of the material deposited in deep Great Lakes sediments, and 4) to compare sediment decomposition rates and rates of diagenesis in a spectrum of Great Lakes sediments from coastal bays to deep basins.

Approach/Methods:

Retrieval and undisturbed high-quality sediment cores of the upper 20-30 cm of surface sediments, 2) retrieval of flocculant, nepheloid layer material within the benthic boundary layer andwithin the water column, using the submersible-based underwater"vacuum cleaner" system devised by Dr. Dave Long, Michigan StateUniversity, and 3) video and 35 mm photographic documentation ofphysical characteristics of the benthic boundary layer (e.g., thickness, visual density, depth, benthic zooplankton abundances).

Current Status:

Ongoing. Beginning second year in summer 1986.

Expected Benefits:

The role of detritus in the nutrition of benthic organisms and the importance of the detrital food chain in deep lakes are largely unknown. Observations from dives in the deep basins of Lake Superior in the summer of 1985 were remarkable in regard to the number and apparent activity of zooplankton and other organisms associated with zones of highly flocculent sediments near the sediment-water interface. Although decomposition processes within the water column remineralize organic matter fixed within the photic zone, a considerable fraction of this material may reach the sediments, primarily through vertical transport on large particles and fecal pellets. This detrital "fallout" appears to support high densities of benthic organisms. Our submersible studies should provide a better understanding on how deep Great Lakes benthic communities function and what role detritus processing plays in the ecosystems as a whole. Results from our 1985 dives will be of interest to the Journal for Great Lakes Research.

Title: RARE EARTH ELEMENT TRACER STUDIES OF BIOGENIC AND PHYSICAL SEDIMENT TRANSPORT IN THE GREAT LAKES: IN-SITU SUBMERSIBLE STUDIES

Principal Investigator: John R. Krezoski
Center for Great Lake Studies
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(414) 649-3000

Objectives:

The goals of this project are: 1) to measure accurately in-situ rates of physical and biogenic sediment reworking and redistribution in fine-grained Great Lakes sediments using rare earth element methodology; 2) to determine the importance of in-

place pollutants in profundal Great Lakes sediments and to understand their role as sources of contaminants to Great Lakes waters and biota; 3) to determine whether in-situ (submersible collected) geochemical sampling techniques provide superior sample quality compared to conventional shipboard sampling techniques; and 4) to determine whether observed differences in the techniques can account for our inability to construct accurate mass balance models for certain contaminants, such as PCBs, in Great Lakes sediments.

Approach/Methods:

1) Tracer pellets of rare earth element-enriched fine-grained muds are placed (and marked with underwater beacons) in quiescent, profundal depositional basins and are then relocated and sampled after periods of months to years. The collected sediments are analyzed by instrumental neutron activation analysis (in addition to standard sedimentological methods), and rates of lateral and vertical sediment transport are calculated. 2) Sediment reworking and transport rates determined in (1) above are combined with measured sediment pollutant concentrations and absorption-desorption equilibria to estimate rates of contaminant release to overlying water. 3) Sediment cores collected in statistically significant numbers from shipboard and submersible are analyzed geochemically and compared to determine if significant differences are apparent.

Current Status:

Thirty punch, gravity, and box cores were collected from three Lake Superior dives and one Lake Huron dive during the 1985 and 1986 NOAA/NURP Great Lakes research cruises. All of the cores have been extruded, sectioned, and preserved, and the analysis of 25 percent of them is completed. The remaining cores are currently undergoing analysis.

Expected Benefits:

Boyer, L.F., J.V. Klump, and J.R. Krezoski, 1986. Biochemistry: Nutrient and mineral cycling and sediment dynamics in the benthic boundary layer: Submersible studies of in-situ processes. $20,000 research award, University of Wisconsin Sea Grant Program, NOAA, July, 1986.

Krezoski, J.R., D.N. Edgington, J.V. Klump, and C.C. Remsen, 1986. In-situ measurement of sediment core variability in determining PCB inventories in Lakes Huron and Superior: EPA-NOAA submersible studies. $20,000 research award, US Environmental Protection Agency, ERL-Duluth, July, 1986.

Krezoski, J.R., 1987. Rare earth element tracer studies of biogenic and physical sediment redistribution in profundal Great Lakes sediments. (in prep.).

Krezoski, J.R., 1987. In-situ tracer studies of biogenic and physical sediment transport in the Great Lakes: In-situ submersible studies. 30th Ann. Conf., Internat. Assoc. Great Lakes Res., May 10-14, 1987, Ann Arbor, MI. (Submitted Abstract).

Krezoski, J.R., J.V. Klump, D.N. Edgington, and C.C. Remsen, 1987. Estimates of PCB concentrations in surficial sediments of Lakes Huron and Superior: A comparison of shipboard gravity coring vs. research submersible punch coring techniques. (in prep.).

Title: AEROBIC METHANE OXIDATION IN LAKE SUPERIOR

Principal Investigator: Mary E. Lidstrom
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Objectives:

To study aerobic methane oxidation in Lake Superior.

Approach/Methods:

From punch cores taken from the Johnson Sea-Link II, we have generated profiles of methane concentrations in the sediments from several sites in Lake Superior. We have isolated methane-oxidizing bacteria from these samples, and have begun to characterize these strains. A kinetic approach has been used to determine K_m and V_{max} values for methane oxidation, and methane profiles have been used to estimate in-situ methane consumption rates.

Current Status:

These data were presented, along with data from other studies we have done in various environments, at the American Chemical Society Division of Geochemistry Symposium, April 5-10, 1987. We anticipate submitting a paper, "Aerobic Methane Oxidation in Lakes and Marine Basins," to Limnology and Oceanography.

Expected Benefits:

Described above.

Title: GEOCHEMICAL PROCESSES AT THE SEDIMENT WATER INTERFACE IN PROFUNDAL LAKE ENVIRONMENTS

Principal Investigators: David T. Long
Dept. of Geological Sciences
Michigan State University
East Lansing, Michigan 48824
(517) 882-9085

Objectives:

This study had three objectives: (1) to determine the chemistry/mineralogy and origin of the nepheloid layer and the "fluff" layer; (2) to identify mechanisms and rates of chemical transfer across the water--sediment interface; and (3) to define the nature of chemical diagenesis with depth in sediment.

Approach/Methods:

Lake Superior has been the initial target lake because it is the least studied and it will serve, due to its relatively pristine state, as a background system when we study other lakes. Vertical sampling of the water column through the sediment column is done in defined areas of a lake. Such areas are generally characterized by relatively high sedimentation rates and thick post-glacial sediment. The methodology comprises work on the submersible, ship, and in the laboratory. The key to the research is to use the submersible to collect precisely located, undisturbed box cores, benthic sediment "fluff," and water samples. Shipboard work includes taking longer gravity cores to supplement the box coring, extruding the core on ship (both under N2 and under air), making preliminary measurements on the sediment and water samples and preparing the samples, for shipment back to the land based-lab.

Current Status:

A modification to the "fluff/nepheloid" sampler was made for the 1986 Great Lakes cruise. Better fluff samples were collected than during the 1985 cruise. Because of its diffuse nature, large volume samples of the nepheloid material could not be obtained. All samples have been properly prepared for analyses and we are at this time proceeding with the chemical analyses.

Expected Benefits:

Our current level of understanding of the role of the nepheloid and fluff layers in controlling the cycling of the elements across the sediment-water interface is tenuous. This research focuses on this role.

Wilson, T.P., D.T. Long and R.M. Owen. 1986. The water/sediment interface via manned submersible. Abstracts with program, International Association of Great Lakes Research, 29th Conference. University of Toronto, Spring 1986, p. 30.

McKee, J., T.P. Wilson, D.T. Long, and R.M. Owen. 1987. Geochemical processes at the sediment-water interface in profundal lake sediments. Abstracts with program, International Association of Great Lakes Research, 30th Conference. University of Michigan, Spring 1987.

McKee, J.D., J.L. Cambell, T.P. Wilson, and D.T. Long. 1987. Geochemical processes at the sediment-water interface in profundal lake sediments. Abstracts with program, International Association of Great Lakes Research, 30th Conference. University of Michigan, Spring 1987.

Olivarez, A.M., R.M. Owen, and D.T. Long. 1987. Geochemistry of rare earth elements in Lake Superior benthic layers. Abstracts with program, International Association of Great Lakes Research 30th Conference. University of Michigan, Spring 1987.

Title: GEOCHEMICAL PROCESSES AND RATES OF CHEMICAL EXCHANGE AT THE WATER SEDIMENT INTERFACE IN PROFUNDAL LAKE SEDIMENTS

Principal Investigator: David T. Long
Department of Geological Science
Michigan State University
East Lansing, MI 48824
(517) 882-9085

Objectives:

The sediment water interface in profundal lake environments is in part responsible for recycling nutrients and determining the fate of pollutants in the Great Lakes. Because accurate sampling of this interface from the surface is difficult, our understanding of the physical and chemical nature of this important zone is limited. The use of a manned submersible afforded an opportunity to resolve this problem. The study objective was to determine the geochemical processes and rates of reaction working at the sediment water interface.

Approach/Methods:

The approach of this research was to determine the type and rates of chemical processes in profundal lake systems. Five chemical zones were defined for study. They were the prenepheloid layer, the nepheloid layer, and zones in the sediment column. The chemistry and minerology of sediments taken in core samples and the chemistry of associated filtrated water samples will be measured, and thermal dynamics/kinetic models of the system will be developed based on these measurements.

Current Status:

This was the first year of a 3-5 year program. An important first year goal was to determine the probability of using a manned submersible in geochemical research. Appropriate nepheloid samplers were designed and tested successfully. They will be modified for subsequent research. First year funding was from the Dreyfus Foundation and Michigan State University. For the second year's funding, proposals have been submitted to the EPA and Sea Grant. Samples from the first year program are still being analyzed, but the preliminary results suggest that submersibles will be important in Great Lakes geochemical research.

Expected Benefits:

More than 20 presentations will have been given by our research team to public and private organizations such as the Shriners of America, high school science classes, geological departments in colleges and universities, science centers such as the Cranbrook Institute, and science meetings such as those held by the Geological Society of America and the International Association of Great Lakes Research. A manuscript is being prepared for the Journal of Great Lakes Research, and after more data are synthesized, for the Journal of Environmental Geology.

III. Coastal Oceanic and Estuarine Processes
A. University of Connecticut-Avery Point
1. New England

Title: BENTHIC PRODUCTIVITY AND RESOURCES OF THE GULF OF MAINE: PARTICULATE MATTER FLUXES.

Principal Investigators: Richard W. Spinrad, Quay Dortch, and David W. Townsend
Bigelow Laboratory for Ocean Sciences
W. Boothbay Harbor, ME 04575
(207) 633-5765

Objectives:

The purpose of this study was to describe the nature of particulate maxima that occur just above the bottom and withinnarrow depth strata in the Gulf of Maine, which are believed to represent sites of enhanced biological activity.

Approach/Methods:

Our approach was greatly modified 10 days prior to our cruise to allow us to collect samples from a surface ship, the R/V Oceanus, after cancellation of all submersible dive operations due to mechanical problems. We designed, constructed, and collected samples with a 3 X 30 L rosette water sampler from various elevations above the bottom (2, 5, 10, and 20 m) at a shallow (100 m) and deep (240 m) site in the Gulf. These samples were analyzed for: 1) chlorophyll using both acetone and hexane extractions, 2) particulate carbon and nitrogen concentrations, 3) "total" and biologically available protein, 4) ATP, as a measure of living biomass, 5) electron transport system activity as a measure of respiratory activity, 6) abundances of heterotrophic bacteria, 7) abundances of autotrophic and heterotrophic nano-plankton, and 8) particle concentrations and physical and optical characteristics of particles.

Current Status:

We applied for, and were awarded, a small National Science Foundation grant to carry out the above measurements; this support was in addition to the logistical support granted by NURP/UCAP. These measurements have been completed and form the basis for a renewal application to NSF, submitted on January 27, 1987.

Expected Benefits:

Our preliminary study has indicated that the benthic nepheloid layer can sometimes be a zone of enhanced nutritive value and biological activity. We found considerable temporal and spatial variability that may be related to events in surface waters but that is affected by horizontal advection at depth. By comparing

the composition of the particulate organic matter, the accompanying organisms, and the ensuing biological activity in a variety of areas, it should be possible to reach the broad programmatic goal of determining the role of the bottom nepheloid layer in the benthic productivity of the Gulf. We expect to be submitting at least one paper to a general oceanographic journal.

Title: PARTICULATE MATTER FLUXES IN THE GULF OF MAINE

Principal Investigators: Marsh J. Youngbluth, Thomas G. Bailey, Peter J. Davoll
Harbor Branch Oceanographic Institution
5600 Old Dixie Highway
Fort Pierce, FL 33450
(305) 465-2400, ext. 319

Objectives:

The goals of this project were to study with a submersible in situ the diel migratory and epibenthic feeding behavior of euphausiids, to correlate their distribution and abundance with mixed layer production, physical/chemical gradients, and sediment organic loads; 2) conduct in-situ and laboratory studies of fecal pellets produced by euphausiids (distribution, abundance, sinking rates, chemical composition, and taxonomic components) to define the extent to which fecal pellet biomass from this source represents an energy flow link between primary producers and benthic consumers; 3) deploy a free-drifting sediment trap and moored sediment trap to quantify daily flux rates of fecal pellets and other particulate matter below the mixed layer and near the seafloor.

Approach/Methods:

We have hypothesized that large, fast sinking fecal pellets from zooplankton constitute a major source of biogenic particulate material exported from the photic zone to the benthos. A single species of zooplankton, the euphausiid Meganyctiphanes norvegica, has been selected for intensive study. This euphausiid occurs throughout the Gulf of Maine in massive swarms, both near the surface and within 10 m of the seafloor. Submersible-basedobservations have indicated that large quantities of fecal pellets are released daily in the mixed layer by migratory, nocturnally feeding populations. In addition, a substantial abundance of these euphausiids resides near the bottom and is likely to consume flocculent biogenic sediments near or on the seafloor, thus acting as bioturbators. Fecal pellets collected with a manned submersible and sediment traps (free-drifting and moored arrays) will provide data for estimating their daily and seasonal flux rates to the sea floor, and morphological (biomass, size, taxonomic constituents) and chemical (CHN, proximate, caloric, HPLC, energy dispersible x-ray spectroscopy) measurements

will be made on pellets to quantify their biomass and composition.

Current Status:

First year of a 5-year program. Research ongoing.

Expected Benefits:

Fecal pellet flux from massive swarms of euphausiids (submission to Nature expected). The coupling of benthic and pelagic environments, via thedownward transport of particulate material, is of major interest to the entire oceanographic community. In the Gulf of Maine, as elsewhere, the production of particulate organic material in the water column represents the primary food source for the benthos. Consequently, the processes that affect delivery and modification of these organic resources ultimately regulate benthic productivity.

Title: SEDIMENTOLOGICAL INVESTIGATIONS BY SUBMERSIBLE IN THE GULF OF MAINE

Principal Investigator: Daniel F. Belknap
University of Maine
Dept. of Geological Science
Orono, ME 04469

Objectives:

A series of dives in four major embayments in Maine was done to compare bottom type with previously collected bottom samples and seismic profiling and to calibrate remotely sensed data with "ground truth." In particular, the patchiness of distribution of sediment types was observed by submersible. Sediment types are an important component of a study of processes of redistribution, such as waves and tidal currents.

Approach/Methods:

Video and photographic transects were run at historic sampling sites along the Maine coast (depths 30-70 m) for visual verification of features previously recorded in seismic profiles. Box cores and cylinder cores were also taken for geochemical analysis. The ship R/V Link engaged in seismic profiling between dives, to correlate with the sub's track.

Current Status:

The project was a first-time use of the Johnson Sea-Link system, and was originally a single year project. We have subsequently used the data to submit a proposal entitled "A Proposal to Evaluate Sediment Dynamics Along the Inner Shelf of the Gulf of Maine: Comparison of Geophysical Remote Sensing and Submersible Observations," by Daniel F. Belknap and Joseph T. Kelley, for

1986 NURP funding. This is intended to be a longer term, more specific investigation of the sedimentary processes involved by in-situ experimentation with sediment traps and repetitive occupation of sites.

Expected Benefits:

The series of dives included the first direct observations in Machias and Saco Bays, and a considerable upgrade of the 1984 dives in Sheepscot Bay. The paleoshoreline in Machias, identification of viable herring spawning grounds, the concept of a carbonate halo around bedrock pinnacles, the rubble transition zone, identification of mud drapes and turbid plumes, and the identification of scallop drag marks are important new findings. A direct future application of the sedimentological data would be initiation of a series of nearshore sediment-type maps. Building on a data base of seismic profiles and a growing side-scan sonar base, maps of benefit to fishermen could be produced.

References:

Belknap, D.F., Kelley, J.T., and Tu, W. 1986. Tidal and wave-formed bedforms on the Kennebec paleodelta (coastal Maine). Geological Society of America. Abstract. March 14, 1986.

Belknap, D.F., Shipp, R.C., and Kelley, J.T. Depositional setting and quaternary stratigraphy of the Sheepscot estuary, Maine: Preliminary report. Geographic Physique et Quaternaire in press. Belknap, D.F. et al. in press. The Kennebec paledodelta, west-central Maine coast.

Title: SEDIMENT DYNAMICS ALONG THE INNER SHELF OF THE GULF OF MAINE: COMPARISON OF GEOPHYSICAL REMOTE SENSING AND SUBMERSIBLE OBSERVATIONS

Principal Investigators: Daniel F. Belknap
Joseph T. Kelley*
Dept. Geological Sciences and Center for Marine Studies, and *Maine Geological Survey
University of Maine
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Objectives:

For the past 4 years, we have been involved in a series of NSF and NOAA-Sea Grant funded research projects to examine the near shore Gulf of Maine and its adjacent estuaries using seismic profiling, coring, and grab sampling to examine sediment distribution and sedimentary processes. When the opportunity to use submersibles in our field area arose, there was a clear need to compare remotely sensed and sampled sediment types and bedforms with direct on-site observation. In 1986, the objective was to begin

experimentation with movement of bedforms and turbidity currents with stake arrays and sediment traps. Because of the Challenger disaster and rescheduling of the Johnson Sea-Link, we continued in a reconnaissance mode with the Delta.

Approach/Methods:

As outlined in the quick-look report, we accomplished nine 1-3 hour dives in the period June 21-23, 1986. All were reconnaissance geologic observation of areas with existing high-resolution seismic profiling, side-scan sonar, and sediment grab samples.

Expected Benefits:

The scientific significance of these data has been on-site confirmation of remotely sensed sedimentologic processes andmaterials. In particular, confirmation of rippled scourdepressions, carbonate-rich halos around rock pinnacles, and in-situ observation of till are new, significant findings. A direct future application of the sedimentological data would be initiation of a series of nearshore maps of sediment types. Building on a data base of seismic profiles and a growing side-scan sonar data base, maps of benefit to fishermen could be produced. The most useful tool for this effort would be a comprehensive side-scan sonar survey, but direct observation of the remote images is important as a calibration.

Publications:

The publications resulting from this work include two publishedpapers, three in preparation, five abstracts presented at national meetings, and one open file report to the Maine Geological Survey.

IV. Ocean Lithosphere and Mineral Resources
A. University of Connecticut-Avery Point
2. Southern New England

Title: INVESTIGATION OF THE REWORKING OF GLACIAL SEDIMENTS ON THE SOUTHEASTERN NEW ENGLAND SHELF

Principal Investigators:

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Groton, CT 06340

Objectives:

The objectives of our mission were to study the large bedform field located in eastern Long Island Sound, make observations and collect sediment samples in the vicinity of Long Sand Shoal, and make a reconnaissance of Block Delta and Block Canyon. In the bedform field, our goal was to investigate how the 5 to 17 m high sand waves form and are modified, under what hydrodynamic conditions they are stable rather than migratory, and what their stratigraphic signature is. Dives along the seaward flank of Long Sand Shoal were designed to provide information concerning bedform migrational trends and net sand transport directions. Unfortunately, inclement weather prevented us from reaching the Block Delta area.

Approach/Methods:

Initial ship transects across the bedform field utilizing a Raytheon fathometer identified specific dive sites and overall characteristics of the sand waves. Due to the strength of the tidal currents (at times > 1.3 knots), submersible dives were made perpendicular to the flow. Diver observations revealed a hierarchy of bedforms and that larger forms are often composed of several smaller ones. It was also learned that the troughs of the sand waves had been stabilized by a biological covering of hydroids. The crestal portion of the sand waves was composed of medium-sized sand and exhibited steep, active slipfaces.

Current Status:

We are in the second year of our investigation of Long Island Sound and will begin our study of Block Delta this spring.

Expected Benefits:

We reported some results of our study of Long Sand Shoal at the Gulf Coast Sectional Meeting of SEPM. A peer-reviewed publication concerning this work is presently being prepared as part of a proceedings of this conference.

IV. OCEAN LITHOSPHERE AND MINERAL RESOURCES
A. University of Connecticut-Avery Point
3. Great Lakes

Title: STUDIES OF CURRENT-CREATED AND MODIFIED TOPOGRAPHY IN LAKE SUPERIOR

Principal Investigator: Roger D. Flood
Lamont-Doherty Geological Observatory of Columbia University
Palisades, New York 10964
(914) 359-2900

Objectives:

We have been utilizing a submersible to study the form and structure of features previously found on the floor of Lake Superior through the use of side-scan sonar. Several of these features could have been created by currents flowing deep in the lake. If strong currents are common at depth in the lake (i.e., below 100 m), they would be important agents in eroding, transporting, and redepositing lake bed sediments, and thus any pollutants associated with those sediments. Two specific features have been investigated: sedimentary furrows and ring segments.

Approach/Methods:

Sedimentary furrows are found in 100 m of water directly off Copper Harbor, Michigan. Similar bed forms are common in the deep sea and estuaries, and we need to understand how these bed forms are maintained and if they are active today. Analysis of precisely located cores shows that these bed forms have been active during the last few hundred years and have been active often within the last 10 years. Direct current meter measurements have shown that deep currents are minimal during the summer months, but they can become quite strong during fall and winter storms. The presence of furrows here thus suggests that periodic bottom currents exist deep in the lake. A long-term current meter will be recovered during the summer, 1987, to determine yearly current variations at this site.

Current Status:

Ring segments are common on the floor of Lake Superior, and one was studied at a depth of 240 m. This large, crescent-shaped depression (5 m deep, 100 m long, and 20 m wide) was apparently formed by erosion because laminated, glacial-lacustrine clays are present just below the depression floor. These sediments are usually buried by 1.5 to 2 m of post-glacial sediments. A field of current ripples found on the steep wall of the depression appears to have been formed recently by bottom currents. Thus bottom currents are active agents even in the deep, central lake,

and these currents must play a role in transporting sediments throughout the lake.

Expected Benefits:

Presentations:

Flood, R.D. Recent studies of abyssal sediment dynamics. Earth Sciences Colloquium, September 19, 1986. Lamont-Doherty Geological Observatory, Palisades, New York.

Flood, R.D. Furrows as indicators of dynamic sedimentary environments. Society of Economic Mineralogists and Paleontologists (SEPM), 1986 Midyear Meeting, September 28, 1986. Raleigh, North Carolina.

Planned Publications:

Flood, R.D. Bottom currents and sedimentary bed forms in Lake Superior. Great Lakes Research Journal.

Flood, R.D. Furrows in the deep sea and in Lake Superior. Marine Geology.

Title: IN-SITU CONFIRMATION OF THE ACOUSTIC SIZE OF FORAGE FISH AT MID-DEPTHS

Principal Investigator: Ray L. Argyle
U.S. Fish and Wildlife Service
National Fisheries Center-Great Lakes
1451 Green Rd.
Ann Arbor, MI 48105
(313) 994-3331

Objectives:

Our goal was to determine, in situ, species composition and the relative size of individual fish, and to follow the diel vertical migration patterns of forage species and relate these observations to hydroacoustic estimates of target strength.

Approach/Methods:

Our approach involved making observations and obtaining photographic records of fish distribution throughout the water column at night, when the major prey species are at mid-depths. The submersible was used to obtain photographic records of fish distribution at various depth strata using a "stairstep" type of survey in which the submersible was slowly propelled horizontally in a stratum (10 meters was the nominal stratum depth) for 10 minutes and then moved up to the next stratum and again propelled horizontally. Hydroacoustic surveys were conducted prior to and after the dive was completed to determine abundance and target strength of fish located in various strata throughout the water

column. The intent was to relate target strength estimates determined acoustically to video records from species identification and length estimates using the laser point measuring system on the submersible.

Current Status:

Completed. Visibility during the dive was very poor and only a few fish were observed. Acoustic records showed large concentrations of fish at mid-depths; however, these concentrations were impossible to see either from the submersible or during viewing of the video footage. The hydroacoustic data and midwater trawl catch data collected prior to and immediately after the dive are providing some target strength information.

Expected Benefits:

Because of the poor visibility, the video footage is not of any value for identifying fish or determining their length. However,the hydroacoustic data collected in concert with the dive will provide some information on target strength. The overall approach to the objectives was/is valid; however, visibility must be the primary consideration when selecting locations for similar investigations using a submersible.

APPENDIX C

LIST OF 1985-1986 PUBLICATIONS, PAPERS,
AND PRESENTATIONS
RESULTING FROM SCIENCE PROJECTS SPONSORED BY THE
OFFICE OF UNDERSEA RESEARCH

1985

Able, K. W., C. B. Grimes, and R. S. Jones. Habitat variation in tilefishes (Lopholatilus and Caulolatilus) off the east coast of Florida. Paper presented at the Annual Meeting of the American Society of Ichthyologists and Herpetologists. 1985.

Able, K. W., C. B. Grimes, R. S. Jones, and D. C. Twichell. Variation in burrow construction and behavior of tilefishes (Lopholatilus and Caulolatilus) off the east coast of Florida. Paper presented at the American Society of Ichthyologists and Herpetologists, Knoxville, Tenn. 1985.

Able, K. W., D. C. Twichell, C. B. Grimes, and R. S. Jones. Side-scan sonars as a tool for detection of fisheries resources. Paper presented at the Annual Meeting, Northeast Division, American Fisheries Society. 1985.

Adey, W. H., and R. S. Steneck. Highly productive eastern Caribbean reefs: Synergistic effects of biological, chemical, physical, and geological factors. In: M. L. Reaka (ed.), The Ecology of Coral Reefs, NOAA Symp. Ser. Undersea Res. 3(1):163-187, 1985.

Agegian, C. R., and I. A. Abbott. Deepwater macroalgal communities, a comparison between Penguin Bank and Johnston Atoll. Proc. 5th Int. Coral Reef Congress 5:47-50. 1985.

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Auster, P. J. A CPUE indicator for crustacean trap fisheries unbiased by distribution of soak time. NAFO Scientific Council Res. Doc. 85/82, 7 pp., 1985.

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Carr, H. A., E. H. Amaral, A. W. Hulbert, and R. A. Cooper. Underwater survey of simulated lost demersal and lost commercial gill nets off New England. NOAA Technical Memorandum, 1985.

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Coulston, M. L., R. W. Berey, A. C. Dempsey, and P. Odum. Assessment of the queen conch (Strombus gigas) population and predation studies of hatchery-reared juveniles in Salt River Canyon, St. Croix, U.S.V.I. Presentation at the 38th Annual Gulf and Caribbean Fisheries Institute, Martinique, Nov. 11-15, 1985.

Coulston, M. L. NOAA's National Undersea Research Program, West Indies Laboratory--a habitat for saturation diving. Presentation at 8th CMAS International Scientific Diving Symposium, Miami, FL, Apr. 23, 1985.

Dennison, W. C. The effects of light on photosynthesis and distribution of seagrasses. Presentation at the 8th Biennial Estuarine Research Federation Meeting, Univ. of New Hampshire, Aug. 28-Sept. 2, 1985.

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