



# VIMS

THIRTY-THIRD  
THIRTY-FOURTH  
THIRTY-FIFTH

# ANNUAL REPORTS

FOR THE PERIOD ENDING 30 JUNE, 1976

# 1974/1975/1976

VIRGINIA INSTITUTE OF MARINE SCIENCE  
Gloucester Point, Virginia 23062

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Gloucester Point, Virginia 23062

COMMONWEALTH OF VIRGINIA  
RICHMOND

MAR 1977



# COMMONWEALTH of VIRGINIA

*Virginia Institute of Marine Science*

*Gloucester Point, Virginia 23062*

WILLIAM J. HARGIS, JR.  
DIRECTOR

Phone: (804) 642-2111

Honorable Mills E. Godwin, Jr.  
Governor of Virginia  
Richmond, Virginia 23219

Dear Governor Godwin:

The Thirty-Third, Thirty-Fourth and Thirty-Fifth Annual Reports of the Virginia Institute of Marine Science, covering the periods ending June 30 of 1974, 1975 and 1976, are respectfully submitted on the accompanying pages.

On the whole, these three years have been devoted to the enormous tasks associated with growth in projects and programs and in efforts to assist in the solutions to environmental and resource allocation and use problems which affect the Commonwealth.

It is worth noting that the programs, projects and services reported upon in these documents are directly in line with those responsibilities assigned us by the General Assembly and by Executive intervention. Also noteworthy is the fact that seventy percent (70%) of the money required to finance these programs, projects and services were raised from non-state sources by the officers and staff of this Institute, all of whom deserve our thanks.

With appreciation for your continued interest and support of Virginia's marine research, service and training program, I am

Respectfully yours,

A handwritten signature in black ink, appearing to read "William J. Hargis, Jr.", with a long horizontal flourish extending to the right.

William J. Hargis, Jr.  
Director

## Board of Administration

1974

1975

1976

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Burton's Seafood  
East Side  
Chincoteague, Virginia 23336

Mr. Carl P. Croasdale  
C. P. Croasdale Seafood Co.  
Palmer, Virginia 22533

Honorable James E. Douglas, Jr.  
Commissioner of Marine Resources  
P. O. Box 756  
Newport News, Virginia 23607  
(ex-officio)

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Lawyer Law Building  
Norfolk, Virginia 23510

Mr. John E. Flipse (Vice Chairman)  
Deepsea Ventures, Inc.  
Gloucester Point, Virginia 23062

Mr. Roger G. Hopper  
Attorney at Law  
Saluda, Virginia 23149

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Vice President for Academic Affairs  
The College of William and Mary  
Williamsburg, Virginia 23185

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Tracor Jitco, Inc.  
1776 East Jefferson Street  
Rockville, Maryland 20852

Dr. W. D. Whitehead  
Dean of Graduate School of Arts and Sciences  
University of Virginia  
Charlottesville, Virginia 22901

# Organizational Structure

## General Administration

Director  
Executive Assistant  
Executive Secretary and Special-Assistant  
Information and Publications Director  
Scientific Illustrator  
Photographic Supervisor  
Information Director

## Administrative Groups

Associate Director  
Finance, Budget and Audit, Department of Personnel,  
Section of  
Administrative Services, Department of  
Computer and Statistics, Department of  
Oceanographic Library

## Scientific Groups

Division of Science Service and Special Programs  
Director and Division Head  
Office of Special Programs  
Advisory Services, Department of  
Wachapreague Laboratory

Division of Biological Oceanography  
Assistant Director and Division Head  
Invertebrate Ecology, Department of  
Marine Culture, Department of  
Microbiology—Pathology, Department of  
Parasitology, Section of  
Planktology, Department of

Division of Environmental Science and Services  
Assistant Director and Division Head  
Ecology Pollution, Department of  
Environmental Physiology, Department of  
Wetlands, Section of

Division of Fishery Science and Services  
Assistant Director and Division Head  
Applied Biology, Department of  
Crustaceology, Department of  
Ichthyology, Department of  
Malacology, Department of

Division of Physical Science and Ocean Engineering  
Assistant Director and Division Head  
Physical Oceanography and Hydraulics, Department of  
Chemical and Geological Oceanography, Department of

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# Introduction

The three-year period from 1 July 1973 to 30 June 1976 was one of phenomenal growth and increased productivity in the research and engineering programs of the Institute. Advisory service programs and educational activities also grew markedly.

Peak employment grew from 325 in 1973 to 480 in June of 1976. The funding of maintenance and operations grew from \$3,466,877 in 1973-74 to \$5,631,127 for the 1975-76 period, an increase of 62%. This capped the 5-year period between 1970-71 and 1975-76 when the operating capital increased by 116%. Most of the gain was in Special Funds derived from contracts and grants, which sum nearly tripled during the 5-year period. Special Funds were raised by the scientific staff and administration which submitted research proposals (mostly to Federal agencies), each competing with similar proposals from other research institutions. The increasing success in contract awards was owing to the competence of the Institute's staff to produce as well as its diverse capabilities in the overall marine research and engineering field.

These accomplishments, introduced here, are explained in greater detail on the pages to follow.

## Functions

In keeping with the provisions of Title 28.1, Chapter 9 of the Code of Virginia, and with the instructions of the Governor, General Assembly and VIMS Board of Administration, the Institute continued to develop and conduct research activities and investigations of the seafood and fishing industries and other segments of the maritime economy; to conduct hydrographic and biological studies of tidal waters; and to engage in research in the marine sciences and provide education therein.

Through affiliation with Virginia institutions of higher education, VIMS continued to serve as the School of Marine Science of the College of William and Mary and the Department of Marine Science of the University of Virginia. The VIMS professional staff served on the faculty of each

institution, training graduate students at the M.A. and Ph.D. levels for careers as professional marine scientists. In addition, a VIMS non-degree marine science educational program continued growth in cooperation with the Virginia Department of Education, community colleges, colleges and universities and other educational institutions throughout the Commonwealth.

Student enrollment in the graduate programs was 70 in 1973-74 and 75 in 1975-76. During the three report periods of this document, 42 students were graduated, 26 M.A. and 17 Ph.D.

The Council of Higher Education decided to phase out the affiliate program with the University of Virginia during academic year 1975-76. No new enrollments have been made in that program since, and those already enrolled will continue until graduation.

VIMS began cooperative programs with Rappahannock Community College and Thomas Nelson Community College in the 1972-73 fiscal year. These received further development during the 1973-76 periods.

The role, position and contributions of the Institute were strengthened as professional advisor and consultant to the Governor and the General Assembly, to other Commonwealth agencies, and to various other planning and decision-making groups and individuals having interests in the Old Dominion's valuable marine environment and its rich store of material and esthetic treasures.

## The R/V VIRGINIAN SEA

VIMS acquired the 144 ft. minesweeper U.S.S. THRUSH from the Office of the Navy during 1975 and completed most conversion work during the 1975-76 fiscal year to transform it into an ocean research vessel. Re-named the R/V VIRGINIAN SEA, her maiden research cruise occurred in June 1976 during which she performed satisfactorily in studies over the continental shelf that were financed by the Bureau of Land Management. The vessel provided VIMS with competent offshore ship capabilities that were former-

ly acquired through expensive chartering procedures.

### **OFFSHORE BENCHMARK STUDY**

The one-year contract with the Bureau of Land Management (BLM), originally established in 1975 at a fee of \$1.2 million, was increased to \$2.0 million. A one-year renewal contract proposal was being prepared, calling for funding of approximately \$3 million by BLM. Environmental baseline data (biological and chemical) was being acquired from the Baltimore Canyon Trough area of the middle Atlantic Bight, considered a high-interest area for oil and gas exploration and exploitation. Designed to provide background information against which the impacts of these and other potential outer continental shelf developments may be measured, the studies were expected to endure for at least a three-year period.

### **KEPONE**

VIMS participated with other members of the Commonwealth's Kepone Task Force, beginning in December 1975, in an emergency research program to determine the distribution of this substance in the marine environment. A VIMS fishery economist also assisted in studies of the economic impact of the problem to the Tidewater area.

# Research Activities and Programs

## Finfish

### *Anadromous Fishes*

Financial support from the Bureau of Sport Fisheries and Wildlife, National Marine Fisheries Service, and Commonwealth of Virginia allowed continuation of research programs dealing with striped bass, river herring and American shad under the provisions of the Anadromous Fish Act (PL 89-304). These species continue to be important commercial and recreational fishery resources in Virginia and the Chesapeake Bay as a whole.

The striped bass research program under PL 89-304 was directed jointly by Dr. Merriner and Dr. Hoagman and completed in the summer of 1973. Data from the commercial and recreational fishery indicated that the bulk of the harvest in Virginia is age II. Only in cases of strong yearclasses do age I fishes represent a significant fraction of the catch. Larger fishes, 10 lbs. and up, are taken in the fishery but their overall incidence was rather low. Jumbo striped bass have become very scarce in our samples from the commercial fishery and are less frequent in the recreational fishery as well. Monitoring of relative yearclass strength revealed 1970 as the last strong yearclass. The 1971 through 1974 yearclasses were below average. These events have resulted in a declining commercial catch and a relative scarcity of striped bass in the recreational fishery. Recently, the 1975 yearclass of striped bass was above average in abundance. Early indications are that striped bass have perhaps yielded the largest yearclass since 1970 in the bicentennial celebration year. The high success of the 1976 yearclass has also been noted by researchers in Maryland and North Carolina. We attribute the observed fluctuations in yearclass strength to natural variation in environmental factors and its effects upon survival from egg to juvenile stages. We look forward to increased abundance of striped bass in Chesapeake Bay and along the ocean beaches over the next several years as these yearclasses pass through the fishery.

Tag returns from striped bass released in Virginia tributaries indicate harvest of age groups I through III by the

commercial fishery to be greater than that by the sport fishery. Individual river differences in catch statistics are somewhat confounded by interestuary exchanges: appreciable movement by tagged fish between rivers (30-50%) and movement of I+ fish out of Chesapeake Bay (over 5%). We anticipate continued research on the striped bass in Chesapeake Bay to focus on monitoring yearclass strength, documentation of commercial and recreational harvest, population dynamics of the estuarine and Atlantic coastal stocks, as well as field and laboratory definition of factors affecting fluctuations in yearclass strength.

Population dynamics of adult and juvenile American shad, blueback herring, and alewife in Virginia are key study elements in an anadromous fish project formerly directed by Drs. Hoagman and Merriner and in 1976 by Drs. Merriner and Loesch. This research is of paramount importance to formulation of an effective management program for these resources under the guidelines of extended fishery jurisdiction. At present the estimated size of the spawning population of alosids in Virginia is less than one-third of its size prior to 1969. Expansion of the offshore fishery by foreign nationals coincided with the decline in the inshore landings. The foreign fleets took 20% of the reported river herring catch in 1974 from ICNAF sub area 6. Departmental personnel have provided input to ASMFC, NMFS, ICNAF and other fishery management agencies at the State, national and international level; and assisted in the negotiation of international fishery agreements relative to river herring and shad as well as other fishes.

The number of pound nets and the catch of alosine fishes per net in 1975 continued to decline from 1973 levels. Although effort by stake gill nets increased, estimated catch declined. The James River yielded an estimated 853,847 pounds of American shad (down 47% from 1974) with the peak of the run at the end of March. Stake gill nets landed 246,036 pounds of American shad in the York River, a decrease from 1974. Official estimates of hickory shad landings declined 83% in the York River. Pound nets in the Rappahannock River had a 75% reduction in Ameri-

can shad catch and stake gill net catch was down 13% from 1974. River herring catch estimates were down 13% in the Rappahannock River. Estimated catch of American shad in pound nets declined 47%, while landings from stake gill nets increased by 44% from 1974 in the Potomac River. River herring landings increased 34% in the Potomac River.

Seven thousand specimens of alosine fishes from the Virginia commercial fishery were obtained during the spawning season. Age four dominated the river herring run, with percentages ranging from 68 to 83%, up considerably over the last few years and nearly double the age four contribution of ten years ago. Age four American shad made up from 24 to 39% of the shad run. Weights of river herring remained below the long term average while shad have not changed.

Estimates of the juvenile populations in early fall (i.e., yearclass strength) have been made for 1970 through 1975 in the form of annual indices of abundance for each species and river. We have conducted gear type, tow time, and intervessel comparison tests to ascertain reliability of the derived estimates of yearclass strength. The juvenile abundance survey has become reasonably standardized and is now virtually specific for river herring and shad.

Blueback herring had a strong yearclass in every Virginia nursery zone sampled in 1975. Alewife and American shad on the other hand had small yearclasses, continuing a long-term decline. Our 1970 and 1971 estimates of yearclass strength forecasted the 1975 run of American shad quite well, whereas river herring landings and age composition in 1975 did not follow changes in measured yearclass strength between 1970 and 1971.

Juvenile alewife feeding energetics were the topic of James Weaver's Ph.D. dissertation and were supported by the anadromous fish project.

In early 1975 project and departmental personnel sponsored a one day workshop on river herring and shad for fishermen and representatives of industry in conjunction with the Sea Grant Advisory Services staff to provide a basic understanding of the resource, its attributes, problems, and the ongoing studies at VIMS.

A joint research program on river herring and shad will be proposed by Virginia and North Carolina researchers for the 1976-1979 study period as provided for under the provisions of PL 89-304. This approach will bring together biologists from the two states to address mutual problems of resource management, population dynamics, and production of juveniles.

### *Estuarine Fisheries*

Trawl surveys of the demersal fish populations in the Chesapeake Bay, James, York, Rappahannock and Potomac rivers as well as their tributaries has been conducted during the winter and summer periods. These programs have been alternately directed by Drs. Merriner, Hoagman and Musick. These surveys provide yearclass assessment and habitat utilization data for estuarine species of commercial and recreational importance as well as fish community data for application in EIS evaluation and other advisory functions of the department.

Winter trawl survey data exist for the James, York, Rap-

pahannock and Potomac rivers from 1972-76. Densities of white perch, channel catfish, spottail shiner, and several other river residents have been found to differ substantially among rivers, as do their relative abundance ranks.

A three year long trawl program in a stratified random sampling design was completed in 1975 for the York River. Spatial and temporal distribution patterns of fish species are difficult to establish due to sampling variations. However, dominant species are readily identified and several have shown large changes in abundance from year to year due to differences in the strength of successive yearclasses. Recognition of this natural variation, which can only be defined by several years of sampling, is necessary if the impact of a given environmental alteration upon the fauna is to be detected.

Fish survey data (specifically length frequencies, species distribution patterns, and accompanying measurements of hydrographic parameters) contain a vast number of potentially useful interrelationships between the organisms and their environment as well as their interactions with one another. It is hoped that an opportunity to pursue some of these possibilities will arise in the future.

These data sets have already proven their long term worth by having served as important input for several Institute programs (Tropical Storm Agnes assessment, the 3-C report to State Planning, the 208 planning program for the Tidewater region, CZM critical habitat assessments, and VIMS wetlands section assessments) as well as a number of other habitat quality and resource status assessments. The utility of historic data sets is expected to increase in the future, as more environmental choices have to be made by resource managers.

We shall continue a general census and survey of the commercial and recreational finfish resources of the Commonwealth as funds allow and will endeavor to provide both predictive and descriptive information for resource users, managers, and scientists in a timely manner.

Drs. Merriner and Davis and Mr. C. E. Richards have been engaged in the planning and implementation phases of a Virginia artificial fishing reef program since 1972. Assistance and consultation services have been given to the Virginia Office of State Planning, Virginia Marine Resources Commission, National Marine Fisheries Service, Tidewater Artificial Reef Association of Virginia, Seaside Sport Fishing Improvement Association, North Carolina Department of Natural and Economic Resources, Menhaden industry representatives, and several sport fishing clubs or associations.

Merriner, Richards, and Davis of VIMS and several NASA Langley Research Center Scientists collectively developed and demonstrated an electronic tracking system to automatically monitor the movements of fishes. Telemetry methodology, miniaturization of tag and remote automated monitoring of the "target fish" are advances attained over manual fish tracking systems. The system is mobile and cost effective compared to manual methods.

Research programs, especially relevant to the recreational fisheries, have included life history and ecological studies on cobia, red drum, black seabass (supported by the Sport Fishing Institute and VIMS), grey tilefish, several sciaenid species, dusky shark, sandbar shark, striped bass, cownose

ray, etc. Many fish species of recreational interest are included in the census programs. Staff scientists also serve as advisory and/or active members of several sport fishing groups (angling clubs, associations, conservation groups, etc.) and have often presented talks, programs, or papers at local, regional, and national meetings pertaining to recreational fisheries.

Public interest spawned by Virginia's first documented unprovoked shark attack in 1973 and the motion picture "Jaws", resulted in intensified studies under the direction of Dr. Musick on the seasonal distribution and abundance of sharks in lower Chesapeake Bay and adjacent ocean waters. Cruises are conducted from April through November on R.V. *Pathfinder*, weather permitting, to document the occurrence and abundance of sharks. The reproductive biology and food habits of common species are also under study. Despite the widespread public interest and concern about sharks, as a group, they are the least well known of the major predator components of Virginia's ichthyofauna. They also represent underutilized "tackle busting" recreational species in Virginia, although the number of shark fishing enthusiasts is increasing steadily. Recent trends from the Gulf of Mexico and Florida suggest a greater public acceptance of shark meat as a food resource. Some sharks have long been harvested for market on the seaside of the Eastern Shore of Virginia. Since they are noted as being very longlived and having low reproduction rates, we should know their biology before we pursue them for food in Virginia.

#### *Community Ecology of Offshore Fishes*

Community relationships among fishes of the continental shelf, based upon trawl catches of the R/V *Sea Breeze* and *Albatross IV*, as well as data from the continental slope and Norfolk Canyon area are being studied by Dr. Musick. Analysis of distribution by season, temperature and depth as well as community biology statistics provide insights into biology of the ecologically dominant species as well as the commercial and recreational fishes of the Middle Atlantic Coastal region.

The National Science Foundation has supported a study of the community ecology of fishes in Norfolk Canyon and the adjacent continental slope and rise since 1973. Seasonal sampling by otter trawl and other gear is included to describe species assemblages, provide estimates of abundance and biomass of fishes, and describe their relationships with depth and temperature. Related research on fish communities in the vicinity of a deep-water dumpsite off New Jersey was conducted by department personnel on the continental rise (under contract to N.O.A.A.). Concurrent studies related to the fish community description and distributional work include research on reproduction, food habits, parasites and age and growth of numerous ecologically dominant deep-sea fishes.

Dr. Musick has summarized the program and its ecological importance as follows: Otter trawl cruises conducted off the middle Atlantic coast by VIMS scientists from 1971 to 1975 yielded more than 50,000 specimens of demersal fishes at depths of 75 m to 3000 m. Species assemblages were distributed along a coenocline with bathymetric areas

of rapid faunal change (anantoclines) and of more gradual faunal change (aganoclines). Between 75 and 3000 m anantoclines were found at 150 to 200 m, 400 to 600m, 900 to 1000 m, 1350 to 1500 m, and 1900 to 2100 m. Species diversity ( $H'$ ) increased between the continental shelf and slope, remained constant to about 1800 m, then declined rapidly at greater depths (primarily related to species richness, not evenness).

Numerical abundance increased between the shelf and slope but then declined exponentially. Biomass increased between the continental shelf and slope and then remained fairly constant out to a depth of about 1800 m beyond which there was an exponential decline (but not as rapid as that for numerical abundance).

The average size of fishes was about the same on the shelf and upper-slope out to a depth of about 1800 m, beyond which size increased by threefold. This size increase is contrary to that found for the benthic meiofauna and macrofauna. The basis of this difference lies in the mobility of fishes, which allows them to maintain viable, sexually-reproducing populations at relatively small population size.

Biomass of fishes was of the same order of magnitude as that reported for the infauna at similar depths. This apparent contradiction of the classic trophic pyramid structure is resolved because the mobility of fishes allows them to utilize pelagic as well as benthic food sources. The declines in diversity and biomass and the increase in average size of fishes, all occurred at around 1800 m near the slope-rise border beyond which regular food sources of continental origin are absent.

The applicability and significance of these studies to scientific, governmental and industrial personnel, and environmental groups are only beginning to be realized by administrators. Their importance will increase in the future with the development of potential oil resources on the outer continental shelf (OCS) in the Baltimore Canyon Trough and fishery resource management plans under the "Fishery Conservation and Management Act of 1976". Our research experience and continuing efforts on fishes of the continental shelf, slope, and submarine canyons have established VIMS as a leader in the field of shelf and deep water fisheries research.

#### *Ichthyoplankton Research*

Fish eggs and larvae entrainment studies funded by VEPCO were begun in April of 1975 at the Surry Nuclear Power Station. Sampling is most intense during periods of high river temperatures (August and September) and the spawning season of anadromous species (April - June). This project is designed to describe the species and quantities of ichthyoplankton entrained by the power station and its thermal plume. The field sampling is to continue through December 1976.

Naked goby, *Gobiosoma bosci*, and bay anchovy, *Anchoa mitchille*, comprised over 90% of the catch during the spring and summer months near VEPCO Surry. Ichthyoplankton is not abundant in June and is lowest in late winter. Atlantic croaker (*Micropogon undulatus*), spot (*Leiostomus xanthurus*) and blueback herring (*Alosa aestivalis*) postlarvae and juveniles were seasonally abundant.

dant; their densities occasionally exceed  $1/m^3$ . The data set provides a measure of the natural variability in ichthyoplankton abundance in the vicinity of Hog Island and the variability inherent in any sampling program.

### *Oil Spills*

Development of the OCS for oil as well as increased utilization of Chesapeake Bay Ports by shipping tend to increase the likelihood of a major oil spill affecting the continental shelf waters in the vicinity of the mouth of Chesapeake Bay. Baseline environmental data are being collected which will provide a description of ichthyoplankton and ichthyoneuston occurrence and abundance in the area between  $37^{\circ} 10' N$  and  $36^{\circ} 50' N$  from the Bay Bridge Tunnel to 45 miles offshore. The study area is reported as a spawning area for menhaden, weakfish, spot, croaker, channel bass, black drum, black seabass, etc. Using the R/V *Pathfinder*, monthly samples beginning in January 1976 are being collected at 13 stations.

Results will provide the Commonwealth with a data base for assessment and forecasting of environmental damages from oil spills or other catastrophic events which might affect the viability of fish eggs and larvae. These data will also extend and strengthen the neuston and ichthyoplankton segments of the BLM OCS project since the projected track of an offshore oil spill or contamination is inshore and southward at both surface and bottom.

### *Cownose Ray*

Cownose rays, *Rhinoptera bonasus*, are destructive of shellfish resources (e.g. oyster and soft clam beds) in Chesapeake Bay. Several Virginia oyster growers reported recurrent losses to seed and harvestable oyster beds as a result of cownose ray predation. One Virginia oyster grower reported a total loss of over \$33,000 from four plantings. In the spring of 1975, eight major Virginia oyster growers solicited aid in the form of research on potential control measures to reduce cownose ray predation upon their oysters. Loss of eelgrass habitat due to ray predation on infauna is often considerable and results in reduced biological productivity of shoal areas within Chesapeake Bay as well as reduced sediment stability which may result in localized erosion.

In 1976 the Sea Grant program joined VIMS in supporting this research on the cownose ray problem. Life history, ecology, and feeding behavior of cownose ray are being investigated, as well as short term and long term mechanisms to protect desirable resources from decimation by cownose rays. Potential utilization of cownose rays as an edible seafood product will be explored on a small scale. Project results will provide useful information for oyster growers, commercial fishermen and state management agencies in their encounters with cownose rays.

### *Kepone Research*

Collections of fish for Kepone analysis were obtained during the 1976 winter trawl survey (January – February) and summer trawl survey (June – July). Upper, lower and middle zones were established in each of the major

Virginia rivers. For each of these zones samples of each fish species were retained for laboratory analysis. These data will allow description of the distribution of Kepone in the fish communities of the James River. Monthly collections of young of the year spot, croaker, and grey trout are being retained for Kepone analysis so we can determine the rate of Kepone uptake of this pesticide in the young fish. A pictorial guide to some common marine and estuarine fishes of commercial and sport importance has also been prepared by Dr. J. W. Merriner and Mr. R. T. Doyle for use by Virginia Department of Agriculture Food Inspectors.

Special studies were conducted at the request of the Marine Subcommittee: Distribution of fishing effort and catch composition of catfishes in the James River fishery; Special sampling program for American shad; Summarization of information on the distribution and biology of the major recreational and commercial species in Chesapeake Bay which might be affected by Kepone, preparatory key for identification of catfishes known to occur in the tidal James River; conduct of an identification workshop for employees of the Virginia Department of Agriculture, and; other advisory tasks as requested by the full task force or the marine subcommittee.

### *Academic Program*

Staff members have directed the graduate programs of numerous graduate students (maximum of 21 in one semester) at the College of William and Mary and University of Virginia. The department has a strong commitment to the education of fishery and ichthyology research scientists. Courses offered by the staff include Marine Fishery Science, Ichthyology, Advanced Biological Oceanography, Population Dynamics, as well as Problems and Special Topics courses as required. Student research topics include studies of : a) ecology and/or systematics of alepocephalids, sharks, black sea bass, macrourids, killifish, sciaenids, rays tilefish; b) fishes in the ocean surf zone; c) biology of deep-sea eels, d) community ecology of estuarine demersal fishes; and e) energetics of juvenile alewife, f) ecology of larval fishes; and, g) sciaenid habitat preference.

The department maintains reference, teaching and marking collections of freshwater, Chesapeake Bay and offshore fishes. All fish collections from Chesapeake Biological Laboratory are being transferred to VIMS.

VIMS was the host institution for the annual meeting of an international scientific society. Ichthyology Department personnel formed the nucleus of the local committee which organized the meeting for the American Society of Ichthyologists and Herpetologists in June of 1975. More than 500 registrants from around the world attended the meetings which were held on the campus of the College of William and Mary.

### *Crustaceans*

The major objectives of research on crustaceans were: 1) To obtain data for effective harvesting and future management of hard blue crabs (*Callinectes sapidus*); 2) To identify the physical, chemical and biological conditions necessary for increasing the commercial production of soft

blue crabs; 3) to obtain data on the harvesting of the American lobster (*Homarus americanus*), and to describe biological characteristics of the lobster stocks on the continental shelf and in canyons at the edge of the shelf off Virginia, for use in guiding management of the resource; 4) To obtain biological data from other large crustaceans of the continental shelf, slope and canyons that are of commercial importance and currently underutilized.

#### *Hard blue crabs*

Commercial landings of hard blue crabs from Virginia and Maryland for 1973 through 1975 were substantially less than the recent 16-year average of 70 million pounds. During the last four years there has been an 18% decline in landings, from 72 million pounds in 1972 to 59 million pounds in 1975. The decline continued and steepened in 1976. In the first nine months (through September), landings were about 38% smaller than the quantity caught in the first nine months of 1975. The 1976 catch is expected to be about 45% smaller than the catch of 1972.

Plummeting of the commercial catch coincided with the near complete loss of eelgrass, a submerged aquatic plant, from Chesapeake Bay beginning in mid-summer 1973. Eelgrass beds harbor an abundant and varied fauna of invertebrates and fishes, thus providing food and protection for small, juvenile crabs. Decimation of eelgrass beds is believed caused by a climatic factor, abnormally warm water temperatures in winter since 1970. The recent decimation of eelgrass beds and severe decline of the commercial catch of hard blue crabs are reminiscent of an earlier, parallel situation. Eelgrass disappeared almost entirely from Chesapeake Bay between 1930 and 1931; recovery was slow. The blue crab catch subsequently declined from 60 million pounds (1930) to 50 million pounds (1933), a 17% loss. There was a further decline of 29% to 36 million pounds in 1934. The four-year loss was 40%. At present, theories of the cause of the 1930-31 loss of eelgrass are being re-examined.

If crabs were totally dependent on eelgrass beds, we would expect a greater than 40% loss in abundance in four years since 1972. Marshes may be as important as eelgrass beds as nursery grounds for small blue crabs. Their role needs investigation.

This marked decline of the commercial catch was not anticipated: predictions of the catch were made a year in advance to assist industry in planning its operations.

The catch for the biological year (for blue crabs) of September 1976 through August 1977 is expected to be low, less than 45 million pounds.

#### *Soft blue crabs*

Occasional large losses of individuals occur when peeler crabs are held for shedding. Because of the wide variety of fishing gear and seawater systems used in the peeler and soft crab industry, there are no simple answers to the causes of crab losses. Members of the crabbing industry have frequently requested guidelines for securing high yields of soft crabs. To obtain data necessary for formulating guidelines, commercial methods of handling and shedding blue crabs in the Chesapeake Bay were reviewed in 1973.

"Methods of handling and shedding blue crabs, *Callinectes sapidus*" was published in 1974 (Marine Resources Advisory Series No. 8) and may be obtained from the Institute. The manual considers fishing methods, the construction and use of floats and tanks, temperature, salinity, and dissolved oxygen of the water, and diseases of the blue crab.

In 1974, research on soft crabs centered on improving a recirculated seawater tank system for shedding crabs. Earlier models were successful in obtaining a high percentage yield of soft crabs only when small quantities of crabs were confined. These models employed a variety of water conditioners, none of which were able to remove large concentrations of toxic nitrogenous wastes that gradually accumulated.

In the new design, waste water was circulated through vinyl-core filters and a tank containing a green plant, *Ulva* sp. However, this system also failed to remove the nitrogenous wastes. In the future, we propose to experiment with an anaerobic filter, believed to have promise.

#### *American lobster*

A study of the lobster fishery and lobster stocks on the continental shelf off Virginia was initiated in June 1974. Catch and effort data from the fishery were obtained and some of the biological characteristics of the lobster stocks were described. Since June 1974, twelve cruises on commercial fishing vessels were made, over 2000 traps were examined for catch rate, 4586 lobsters were examined for the quality of the catch, and over 2250 lobsters measured. Examination of logbook data furnished by a Virginia offshore lobster operation shows that peaks in catch per trap-haul were obtained in July to August and October 1974 and May to July and October to November 1975.

Catches of lobsters per trap-haul (TH) ranged from 3.94 to 0.64 per trap-haul. Only seven percent of the catch examined was smaller than the legal minimum of 81 mm CL (3-3/16 inches) from June 1974 to June 1975 and 12.3 percent from July 1975 to June 1976.

Variations in the size frequency distribution were not apparent seasonally nor among the four principal fishing sites (Washington, Baltimore, and Norfolk canyons and the continental slope from Norfolk Canyon to Oregon Inlet, N.C.).

Evidence was obtained to suggest that sexual maturity in nearly all females occurs when they reach about 75-80 mm CL. All or almost all females smaller than 70 mm CL are juvenile.

Intestines of 177 lobsters, caught on commercial and research vessels, were examined for parasites from July 1975 through June 1976. Thirty-one lobsters (17.5%) contained the offshore lobster stock discriminator, *Ascarophis* sp., and one lobster contained the coastal discriminator, *Corynosoma* sp.

#### *Continental Shelf Studies*

From 1973 to 1976, personnel from Crustaceology participated in several cruises to Norfolk Canyon and the adjacent shelf and slope region. Collections of crustaceans were

obtained during demersal trawling operations in cooperation with VIMS Ichthyology Department utilizing University of Miami research vessels *C. O. Iselin* and *J. M. Gilliss*. The specimens from the trawl collections are being processed by departmental staff and students. For each of these species, information was obtained on the size range and relative numbers of juveniles, and adult males and females at various depths; their reproductive stage; and the presence of certain kinds of external fouling organisms on peeler, paper-shell and hard crabs. Data analysis has resulted in publication of papers on various aspects of the biology of potentially commercial species: rock crab, *Cancer irroratus*; jonah crab, *C. borealis*; deep-sea red crab, *Geryon quinquedens*; and other decapods (i.e. *Bathynectes superbus*, *Munida forceps* and *Munidopsis bermudezi*).

The offshore crustacean collections have formed the basis for three theses and one doctoral dissertation research problems. These included studies on a deep-sea portunid crab (*Bathynectes superbus*), the jonah and rock crabs (*Cancer borealis* and *C. irroratus*), the galatheid (*Munida iris*), and the autecology of natantians and reptantians.

### Other Activities

Dissertation research on pheromone-mediated behavior in the blue crab was nearing completion. The presence of a sex pheromone in the urine of maturing female blue crabs has been demonstrated to elicit courtship behavior in male crabs. The study was supported by grants from Sigma Xi and the National Science Foundation.

Courses offered by Crustaceology from 1973 to 1976 included Introduction to Marine Science, Survey of Marine and Freshwater Invertebrates, and Biology of Selected Marine Invertebrates.

With the cooperation of the Graphic Arts Department, an exhibit of edible crabs of the United States was prepared and displayed at the spring and fall 1976 meetings of the Virginia Seafood Council and the Blue Crab Industry Association in Virginia Beach and Newport News.

Field work in Crustaceology was also geared to collection of crustaceans and finfish for Kepone analysis.

Fifteen scientific articles written by staff and students of the Department have been published since June 1973. Three graduate students completed all requirements for the M.A. degree. Two graduate students were working on the requirements for the Ph.D. degree and three students were working on the requirements for the M.A. degree at the close of the report period.

### Mollusks

#### *Production of Superior Oysters for Mariculture*

The superior oyster breeding and selection program was continued with the objectives of obtaining genetic races that would grow to market size in two years on natural bottoms. VIMS planned to provide broodstocks for commercial hatcheries with fast growth and disease resistance when needed. In March 1974, the National Sea Grant Program sponsored a national meeting at VIMS of geneticists active in shellfisheries genetic research. They reviewed the VIMS

program and advised continued intensive selection combined with mass outbreeding of varied genetic stocks from the Middle Atlantic Coastal Region.

Following these recommendations, several lines were outcrossed with each other and with four selected lots from Delaware Bay. These were bred in the summer of 1975 and 1976 using mass crosses in a circular or rotational pattern to increase vigor and limit inbreeding regression. The spat were taken to a pond to avoid predation, fouling and wild spatfall. An unexplained sickness called "Pond Disease" killed many spat in August 1975 before they could be removed to the York River. The survivors grew well in late 1975 and early 1976.

Selection of oysters was done in open waters on natural beds with lots in legged trays. The high rainfall and excessive runoff that began in 1971, continued through 1972 with its unwelcome visitor, Hurricane Agnes, as well as, the years 1973 and 1974. Salinities were low and the disease caused by MSX (*Minchinia nelsoni*) was essentially absent in our testing areas at Gloucester Point in 1972 and 1973. It was back to full destructiveness in 1974 and 1975, but our selected oyster lines retained their genetic resistance despite their lack of previous exposure to the disease as spat.

Thirty laboratory-bred lots were available in 1973 and twenty in 1974 from which the best were selected for monitoring in the York River in trays. Many of these were inbred lots which exhibited considerable "runtiness", and after May 1, 1974 a shift was made to outbreeding. Inbreeding has been carried five generations with considerable reduction in genetic variability. Some larval failures may have been genetic in origin, although only one lot has exhibited failure to produce eggs and sperm. This happens to be a lot with superior growth characteristic and with a distinctive cupped shell-shape. The shells in the fast-growing lots are only about half as thick and heavy as control lots of the same marketable size. The cupped oysters reached market size in 15 months.

Some 22 lots of progeny were produced in 1975 of which 17 were being monitored in trays on a natural oyster ground at Gloucester Point. Most of these were outcrosses although a few were inbreds for line maintenance. All of these progeny lots except the control groups (progeny from Horsehead Bar parents) were resistant to MSX. Both 1975 and 1976 exhibited strong activity by the Delaware Bay disease caused by *Minchinia nelsoni* in the lower Chesapeake Bay. Growth was only fair in 1975 due to stoppages of about 6 weeks in early spring and mid-summer caused by dinoflagellate blooms. Control stocks of wild James River seed oysters grew quite poorly in 1975 at stations in each of the three major rivers in Virginia.

Hatcheries have come and gone in the early 1970's without establishing economic viability. Millions of spat have been reared to  $\frac{1}{2}$  to  $\frac{3}{4}$  inch, but the failure of plantings of this size spat on natural bottoms — the nursery period — has limited success. In 1975 Sea Grant assigned this program the task of finding effective methods of utilizing hatchery seed. Plans for semi-commercial trials were prepared, but limited funding restricted tests to square-feet rather than acres. Due to probable smothering by mud on marginal private bottoms, it seemed necessary to use natu-

ral public beds for plantings and hence to augment public seed supplies. Blue crab predation of free cultchless spat reared in hatcheries was another problem to be met.

An experiment with current-year spat on hard, shelly, natural oyster beds in the James River was conducted during 1975-1976 by SCUBA. Spat of three sizes, above (30-40 mm), below (25 mm) and near 25 mm, were placed on cleaned 100 sq. ft. plots in a thickly-populated oyster bed on 27 September 1975. Predation by crabs was not severe but many of the spat had been moved by storms in 15-17 feet of water into surrounding oyster beds. Almost no growth had occurred by June 1976 in these spat near Mile's Watchhouse in the lower seed area.

The handling of hatchery seed through the nursery period, in which they are vulnerable to drill and crab predation and smothering, remains unsolved at this time. It is probable that most spat over one inch would survive if planted on hard seed beds containing many wild oysters. The job of finding and extricating spat where a host of oysters are releasing metabolic products may inhibit crab predation.

After the genetics conference in 1974, isozyme tests of inbred VIMS oyster lots were begun by Dr. Wyatt Anderson of the University of Georgia. Two large groups of 200 oysters were processed for 30 enzymes and smaller lots of 30 to 60 were done for 8 enzymes. One of the large lots was a control group of wild James River seed oysters. These tests will indicate the effects of inbreeding in reducing variability in one set of genetic traits. The application of isozyme tests remains to be evaluated.

At a meeting with geneticists Wyatt Anderson and Robert Wall on 3 May 1976, the breeding program was reviewed for objectives, methods, and results. To avoid further inbreeding, they recommended rotational breeding using as many parents as feasible — at least 10 individuals of each sex. Also the use of selected strains from other Mid-Atlantic areas as well as in Chesapeake Bay was proposed. Four strains from Rutgers breeding in Delaware Bay were imported and transplanted to the Rappahannock River for fattening.

Results of the isozyme tests on VIMS strains of oysters were explained by Wyatt Anderson of the University of Georgia, who did the work. Compared to a control lot of 200 James River seed oysters, Anderson found only 25% of heterozygosity of alleles for isozymes remaining. Some enzyme systems had become fixed (homozygous) in our strains. Mendelian segregation ratios of 3 to 1 and 1 to 1 were observed throughout the enzyme systems. However, application of the results seems limited to the conclusion that inbreeding has followed Mendelian inheritance patterns, and to the reduction of variation and fixing of alleles in four of eight enzyme systems. No evidence of linkage to growth and disease resistance traits was found. Even "runts" of one lot exhibited the same gene distribution as larger oysters of the lot.

Numerous lots of disease-resistant fast-growing oysters of various ages and yearclasses are being held as potential broodstock for hatcheries to use. It is expected that outcrossing will increase vigor of stocks. Economically successful use of broodstocks commercially seems to lie somewhere in the future because problems of pollution, pro-

duction, markets and level prices are limiting oyster farming. There are also large acreages of unused public beds that could be made productive by planting natural seed or hatchery seed. However, hatchery seed at about 1¢ each ¼ inch spat is scarcely competitive with two-inch wild seed which sells 2 or 3 for a penny.

## Marine Culture

For the last six years the Marine Culture Department has been developing an efficient method to grow and set oyster larvae on a year-round basis. The Marine Culture Department has achieved and completed its designed goals for a complete system.

The following objectives have been achieved:

1. The ability to spawn oysters on a year-round basis.
2. The development of a new algal diet which, when fed sequentially, yields growth and setting in 7 to 10 days.
3. The testing of optimal larval culture densities for the algal diet used, in order to obtain optimal setting yields and metamorphosis.
4. The development and implementation of an efficient setting system to obtain cultch-free spat.
5. The design and use of new tank systems to optimize the conditioning and spawning of broodstock oysters and the growth of their offspring to 17 mm in size.
6. The design and use of a mass algal culture system.

## 1973--75 Periods

At the close of the 1973--75 periods, some work remained to be done to optimize most of the achievements in relation to their utilization by commercial hatchery systems.

In contrast, there remained much to be done to achieve the utilization of a completely artificial-formulated diet when considering the "state of the art" vis-a-vis the nutrition of oyster larvae. Even though VIMS had cultured food which yielded excellent growth and setting of oyster larvae, the cost, and sometimes the reliability, left much to be desired. The successful formulation of an artificially-produced diet would result in the removal of about 30 percent of the total cost to a hatchery system in terms of energy, efficiency, reliability, space and labor. As a consequence the development of artificial foods for larvae was deemed a necessary major research thrust to complete the system.

## Methods

The methods utilized by the VIMS Marine Culture Department to obtain oyster larvae and produce cultch-free oyster spat demonstrated a continued reliability. However, they were modified in order to obtain, at a lower cost both to the research unit and a commercial hatchery, the setting of oyster larvae in 8 — 12 days. The first major change was

the isolation bioassay and testing of a new species of algae to replace *Pyramimonas virginica*, which had been difficult to culture. The second major change was a new method to set oyster larvae on vertical surfaces which allowed the setting of large numbers of oyster larvae on multiple sheets instead of the more laborious method of setting on one plastic sheet per unit effort time. These methods were described in the following publications: [1) *A New Type of Oyster Hatchery*, 1974. 2) *Some physical and nutritional factors which affect the growth and setting of larvae of the oyster, Crassostrea virginica in the laboratory*, 1975. 4) *A new mass setting method obtain cultch-free spat of Crassostrea virginica*, 1975. 5) *The Translation of Mariculture Research to Viable Commercial Culture Systems, Proceedings*, October 1974.]

### Service

The Marine Culture Department sent oyster spat to several institutions for testing, and trained two groups in the methodology utilized by this department. In addition, we delivered approximately 50,000 oyster spat (10 mm size) of the newly-developed strains to the Woods Hole Sea Grant Polyculture Project.

A total of 10 groups of both mass and sibling crosses comprising a minimum of 2,000 spat for each group were set for the Superior Oysters subproject as of May 1, 1975. In addition, oyster larvae were supplied to the chlorine bioassay subproject and other departments.

Much of the planning, equipment lists and architectural drawings are being assembled for a hatchery manual to be completed by January 1, 1977.

A reasonable amount of time was expended in a cooperative effort with representatives of the French Oyster Industry. Two groups, one representing about 80% of the French Oyster Industry cooperatives, spent three days each observing both the VIMS system at Gloucester Point and a hatchery using the same system. Continuing advice and algal cultures were supplied to these people.

### Experimental Results

1. The inbreeding and mass out-breeding work was fairly successful in terms of setting and growth of the two new lines of cupped, fast-growing, and disease-resistant oysters. The P-86 line (the first line to show fast growth marked cupping of the left valve, and a flat right valve) continued to exhibit these characteristics for two successive generations of both out-breeding (sibling cross) and inbreeding (sibling and mass cross within the group). As previously reported, the outbreeding (sibling P-86 female x wild male) returned the larval vigor which the larvae of the (P-86 x P-86 male) did not exhibit. The resulting P-122 (P-86 female x wild male) continued to exhibit the cupping and the fast growth of the parents. It is interesting to note, however, that the offspring of the P-122, (P-122 female x P-122 male sibling and P-122 female x P-122 male mass) not only showed the same cupped characteristics, but also greater growth when subjected to the same conditions. Also, their general shape was much like that of the European oyster, *Ostrea edulis*.

In addition to the P-86 line another cupped line was obtained. The P-127 group, the result of three generations of inbred sibling crosses, exhibited the characteristic cupped shape and fast growth. These oysters were utilized in an attempt to obtain a second generation of inbred sibling and mass lots and a cross with the P-122X. Six groups were cultured (P-127 female x P-127 male and P-127 female x P-122 male) but no set was obtained. The larvae grew to the "eyed" stage normally in 10 days but the foot of the "eyed" larvae was abnormal and non-motile. All crosses, utilizing a P-127 female or several P-127 female oysters within and without the group, did not produce set. In contrast, the P-127 male, when used within P-141 female and P-122 female, did produce normal eyed larvae with a good set. The question remained as to what the possible problems were with the female P-127S. This problem remained constant for two years, utilizing different oysters of the same group.

2. As previously reported, the Marine Culture Department utilized trays to set oysters on single sheets. For breeding purposes this was quite adequate and was still being used. However, it became evident that this method would be too time-consuming and laborious for use in a commercial hatchery. From previous observations it was noted that turbulence along a surface increased setting rate at that point on the surface where the turbulence was applied. From these observations, a new setting tank similar in size (length and width) to the spat tanks, but 8" deeper, was designed and tested. Ten frames, each holding 2 sheets of Mylar, were hung vertically in the tank. Three air stones were placed between each frame and hung from a manifold so that the whole surface of the sheet was bathed in gentle turbulence, caused by the streams of air rising to the surface. Under these conditions setting was relatively uniform and allowed the hatchery to set a minimum of 100,000 oysters at one time in one tank. The system employed earlier allowed only 5,000 set oysters per tray per unit time.

In addition, it was found that relatively high losses of newly-set oysters occurred because they were being put directly in raw ambient sea water. Further experimental work demonstrated that newly-set oysters should be kept in one-micron filtered water and artificially fed for a least 72 hours after completion of metamorphosis. This kept losses at a minimum (ca 3-5%).

3. The modification of the feeding protocol with six individual experimental larval broods showed that by replacing *Pyramimonas virginica* with Va-52 as food, "eyed" larvae were developed in 10 - 12 days. A mixture (by volume) of  $\frac{1}{2}$  *Pyramimonas* (Va-17) and  $\frac{3}{4}$  Va-52, rather than all Va-17, resulted in "eyed" larvae within 8 - 12 days. The use of Va-52 as a complete substitute for *Pyramimonas virginica* promoted oyster sets in 11 days.

Two *Crassostrea gigas* cultures were also used to test the new algae, and "eyed" larvae were seen after 13 days in culture.

### 1975-1976 Period

The methods utilized to obtain, grow, and set oyster larvae and to produce cultch-free spat by the VIMS Marine Culture Department, previously reported, were modified in

order to obtain reliability as well as greater yields in a shorter period of time. The first major change in methodology has been a reduction in the number of larvae to 3-5 per unit volume of culture medium. This yielded 85% of the fertilized eggs to setting and successful metamorphoses in 7-8 days.

Experimental results showed that in concentrations of greater than five larvae per milliliter of culture, the larvae exhibited normal growth rates, but displayed irritation resulting in a large percentage of abnormal pediveligers as well as larvae which had a sticky coat of mucus on the larval shell. These pediveliger larvae exhibited "eyes" that were abnormal in shape and small in size. A large proportion (80%) of these "eyed" larvae did not set. In addition, a large number, which appeared to have "set", were actually only stuck to the substrate. As a result, 50 to 60% of the total number of larvae that had "set" failed to go through metamorphosis.

The second major change was in the feeding protocol. The same three species of algae -- *Pyraminonas virginica*, *Pseudoisochrysis paradoxa* and *Chlorella* sp. -- were used, but in different proportions and at higher volumes during the latter part of the larval cycle. Testing of a modification of the feeding protocol using only three species, *Pyraminonas virginica* (Va-17), *Chlorella* sp. (Va-52), and *Pseudoisochrysis paradoxa* (Va-12), was completed. This change in the feeding rate increased the growth rate, decreased the size range of the population, increased the yield of eyed larvae and decreased the time of culture to seven days.

The third major change in the system was the method of setting larvae using aeration and vertically-hung plastic sheets. This method was reported above.

These major changes increased the efficiency of the hatchery system and the total production per unit time effort, while decreasing the cost per unit production.

The data generated at VIMS on the design and operation of a hatchery system received increasing interest from the oyster industry and state and federal agencies over the past three years. A significant amount of time was spent in supplying information and advice to various commercial hatcheries both in the United States and in Europe. Both algal cultures and the results from our experimental work were being supplied to these hatcheries and other institutions on a continuing basis. It became necessary to visit the other hatcheries and view the problems being encountered in order to adequately advise on corrective procedure. In addition, the Marine Culture Department, with its culture facilities at VIMS, supplied 500,000 oyster spat for distribution to various high schools for educational purposes during 1975-76.

It also supplied small quantities of oyster spat to other institutions requesting them, including the Philadelphia Academy of Science and East Carolina University.

A total of 15 groups (both mass and sibling crosses) containing 75,000 spat were delivered to the Institute's Superior Oyster Project. Oyster larvae were supplied for chlorine bioassay and to other internal departments which requested this service. During 1975-76 approximately 11,158 liters of unialgal food were produced from 5 to 10 gallon mass cultures for consumption by various species of bivalves and

their larvae. A large-scale effort was expended to produce *Tetraselmis succica* for use in feeding experiments and in conditioning of Kepone-contaminated oysters.

The continuing inbreeding and mass out-breeding was successful in terms of setting and growth of the P-86 line. It was determined that, even though the P86X wild male cross had retained the highly cupped and fast growth characteristics, the offspring had lost their resistance to the MSX disease. Because of this, a sibling cross between a known resistant P99 and a P86 was accomplished. This group exhibited the cupped shape and fast growth characteristics of the P86 line. It is hoped that subsequent testing for MSX would indicate in a renewed MSX-resistant characteristic the next year.

Two sets of Kepone-contaminated adult oysters were conditioned and spawned to test for any effects of the pesticide on the quality of gametes as it pertained to oyster larval growth, successful setting and metamorphosis. In both experiments no obvious effects were seen to indicate that Kepone was detrimental to the successful reproduction of the oysters obtained from the James River.

## Applied Biology

### *Investigation of the Seed Oyster Reserves in Virginia - 1 July 1973 through 30 June 1976*

Because of the decline in productivity of the seed oyster areas in the James River after 1960, a study was initiated in 1973 to document the densities of seed oysters and spat on representative areas of various rocks and to show annual changes. Also included in the study were representative areas in the Piankatank River and the Great Wicomico River.

These areas were sampled using a hydraulically operated patent tong and statistical methods. Each representative area was included in a grid system and approximately fifty percent of the stations in each representative area were sampled. Locations were determined by the use of a Hastings-Radydist precision electronic navigational system.

Samples obtained with patent tongs were used to estimate total volume of oysters, shell, cinder, the total number of oysters in the various age and size categories; percentage of exposed shell; numbers of old and new boxes, and; the count of spat.

The estimated number of oysters per acre significantly declined in all three rivers between 1 July 1973 and 30 June 1975. In 1976, however, there was an increase in numbers of seed per acre in the lower James due to an unusually heavy set in 1974. Numbers of seed oysters continued to decline in the Great Wicomico and Piankatank rivers.

This project received support from the National Marine Fisheries Service through the Virginia Marine Resources Commission.

### *Development of a Mechanical Oyster Harvester*

During the 1973-1976 period, a mechanical oyster harvester was developed. This gear utilizes the escalator system from the conventional Maryland-type soft clam harvester. To this has been added a completely new harvester head,

designed to rake oysters from the bottom.

The harvester head consists of a rectangular steel box with an inside width of 36", and an overall length of 36". The box narrows to a width of 18" where it attaches to the escalator. Inside this box are rows of flexible steel tines affixed to two steel cylinders which are rotated by an underwater hydraulic motor. As the box slides on steel runners over the bottom, the tines rake oysters and shells from the bottom. A horizontal jet of water washes them onto the escalator, which carries them to the surface.

Since the mechanical harvester can be operated by two persons, it represents a savings in manpower over the conventional harvester which usually requires three workers. Also, unwanted shell falls directly back to the bottom, which eliminates the need to pick it out or shovel it overboard. The dredge causes no apparent damage to the bottom since it harvests only the top two or three inches.

Harvest rates of oysters range up to 27 bushels per hour on planted bottoms; shells may be raised up to 774 bushels per hour.

The harvester was demonstrated to oyster growers and to the news media. A bulletin was prepared describing the gear.

#### *Oyster Spatfall and Meat Quality Monitoring*

In this study departmental scientists monitored the public rocks in Virginia to evaluate quantities of shell, oysters, and spat. Data were recorded in terms of spat, shells, or oysters per bushel. Data were also collected on predators such as *Urosalpinx cinerea* and mortalities were based on box counts.

A second aspect of this program was the monitoring of oyster spatfall in the rivers and tributary creeks. Data were collected weekly at over 80 locations beginning in June and ending in October by placing strings of shells in representative locations. After being in the water a week, the shells were removed and taken to the laboratory where attached spat were counted. Results of this study were published weekly and mailed to over 1500 persons. Survival of set was also monitored by placing bags of shells in representative locations in the spring and counting surviving set in the fall.

A third aspect of this work was to monitor oyster meat quality on public rocks in the James, York and Rappahannock rivers. This information was also published and distributed to the industry.

#### *Controlled Depuration of Oysters*

A joint project was begun on June 15, 1973 and involved the Department of Applied Biology and the Bacteriology Section of the Department of Microbiology-Pathology. Its purpose was to determine if the Eastern Oyster may be depurated under commercial conditions in this regions and the factors involved. Oysters with high coliform and fecal coliform levels were held in flowing water under varying conditions of turbidity, O<sub>2</sub>, temperature and salinity. Bacterial levels were monitored. A pilot sized depuration plant was constructed and operated. Techniques used in evaluating bacterial levels were investigated. This project, which received support from the U. S. Food and Drug Administra-

tion, demonstrated that oysters may be freed of undesirable levels of fecal coliform bacteria in 48 hours in a depuration plant.

#### *Studies for the Virginia Department of Highways*

Two studies were conducted in cooperation with the Virginia Department of Highways, which also shared project support expenses.

One involved examination of the area adjacent to the construction site of the second James River Bridge. The purpose of the study was to survey the distribution of oysters on leased bottoms adjacent to the bridge and to determine possible effects the construction may have on this population.

A second project involved estimates of the possible damage to oyster populations associated with constructions of a new bridge (Granby Street) in the Elizabeth River.

#### *Survey of the Oyster Industry of Virginia*

Work continued during the report year on an in-depth study of the Virginia oyster industry from 1931 to 1971. All phases were to be covered with emphasis on economic aspects as well as biology.

#### *A Study on the Growth and Survival of Cultchless Spat in the Potomac River, and Two of Its Virginia Tributaries*

The growth of hatchery raised cultchless oyster spat was studied in three locations. One study started in 1972 investigated growth and survival in the Potomac River off Morgantown, Maryland. This study was done in cooperation with the Potomac River Fisheries Commission and the Maryland Department of Natural Resources. After 2 years 50% of the seed originally planted had survived and oysters had reached a size of about 2 inches.

The second study followed growth and survival of 6.2 million hatchery raised seed (¾ inch long) in Nomini and lower Machodoc Creek. This study was made in cooperation with the Virginia Marine Resources Commission which initiated the program. After two years about 35% of the spat had survived and had grown to slightly over two inches long.

#### *Kepone Studies*

In 1975 a study was made in cooperation with the Department of Ecology and Pollution on rates at which Kepone could be depurated from oysters.

#### *Studies for the Potomac River Fisheries Commission*

The commission was assisted during the period in formulating management plans and in surveys of the oyster resources in the Potomac River.

#### *Survey for Hampton Roads Sanitation Department*

A survey was made of the oyster resources at the mouth

of the Warwick River prior to and after construction of a new sewerage outfall pipeline in that area. This study was made in 1974.

#### *Study for NUS Corp.*

A study of oysters, hard clams, and soft clams was made in 1974 along the route of a proposed petroleum pipeline in the lower James River.

#### *Study for Consulting Company (McGaughy, Marshall and MacMillan – Hazen and Sawyer)*

A study was made in 1974 of oyster, hard clam and soft clam densities in the lower James River in the vicinity of a proposed sewerage outfall.

### Eastern Shore Programs

Clam and scallop culture experiments continued at the VIMS Eastern Shore Laboratory throughout the report period. Clams and scallops were spawned and grown in a hatchery till setting. The Glancy method was used to separate and grow usable mixed cultures of algae. After setting, the larvae were moved to a new grow-out facility in a converted oyster shucking house. Clams were grown in this facility until they reached 2 mm width at which time they were moved to a field nursery plot. In the fall of 1974, 657,000 small clams were planted in a nursery plot prepared with current baffles and aggregate for protection. This was a pilot experiment of a commercial method for growing clams. This method also tested the market acceptance of clams grown.

Scallops were moved from the grow-out facility when they were 13 mm wide and placed in large pens constructed of plastic mesh screen. Scallops could be grown to marketable size in 5 to 7 months in pens, but it was found that the adductor muscle greatly increased in size if the scallops were left in the pens for 9 months. Scallop pens with sewn-in bottoms were tested. This type of pen was considerably easier to harvest than the old type, but survival did not appear as good. Further tests are in progress.

Cost accounting was carried out on all mariculture projects to assess the economic feasibility of each project. The best size and season for planting was studied at the close of the 1975-76 period. This will continue.

The cost per clam planted and maintained during 1974 was 1.8 cents per clam. The cost per clam in 1975 was about 1.1 cents. This significant reduction was due mainly to more efficient use of the post-larval grow-out facility.

The system used for field grow-out of clams is made up of various components. Even though the system works and is apparently economically feasible, an analysis of variance experiment to test each component of the system is being conducted. The ANOVA experiment will ascertain the importance of each component in relation to every other component, in every combination and might suggest further simplification of the system to further reduce costs.

Samples of the 1974 clam plantings indicated that the ring baffles were superior to the square panels and that baffle arrays with greater areas appeared to have less survival.

Field tests of several designs of baffles were included as part of the analysis of variance experiment. The difference in survival of different sized baffle arrays will be tested in the future.

Two papers were given, one at the NSA -- SINA meeting in Charleston, South Carolina, and one at the European Marine Biology Symposium in Ostend, Belgium.

In addition to numerous calls and letters requesting information and many visitors to see the method, we have trained 24 individuals in 10 groups on growing clams using the VIMS system.

Thirty-five thousand sexually mature scallops were given to the Eastern Shore Watermen's Association to try to re-establish a scallop population in the eelgrass beds in Chincoteague Bay.

The following publications were produced during the report periods:

Castagna, M. and P. Chanley. 1973. Salinity tolerance of some marine bivalves from inshore and estuarine environments in Virginia waters on the western mid-Atlantic coast. *Malacologia* 12(1): 47-96.

Castagna, Michael. 1973. Shipworms and other marine borers. *Marine Fisheries Review* 35(8): 7-12. Revised version of Fishery Leaflet 505.

Kennedy, V.S., W. H. Roosenburg, H. H. Zion, and M. Castagna. 1974. Temperature-time relationships for survival of embryos and larvae of *Mulinia lateralis* (Mollusca: Bivalvia). *Marine Biology* 24(2): 137-145.

Kennedy, V. S., W. H. Roosenburg, M. Castagna, and J. A. Mihursky. 1974. *Mercenaria mercenaria* (Mollusca: Bivalvia): Temperature-time relationships for survival of embryos and larvae. *Fishery Bulletin* 72(4): 1160-1166.

Castagna, M. 1975. Culture of the bay scallop, *Argopecten irradians*, in Virginia. *Marine Fisheries Review* 37(1): 19-24.

Able, K. W. and M. Castagna. 1975. Aspects of an undescribed reproductive behavior in *Fundulus heteroclitus* (Pisces: Cyprinodontidae) from Virginia. *Chesapeake Science* 16(4): 282-284.

Sunderlin, J. B., M. Brenner, M. Castagna, J. Hirota, R. W. Menzel, and O. A. Roels. 1975. Comparative growth of hardshell clams (*Mercenaria mercenaria* Linne and *Mercenaria campechiensis* Gmelin) and their F<sub>1</sub> cross in temperate, subtropical and tropical natural waters and in a tropical "artificial upwelling" mariculture system. *Proceedings of the World Mariculture Society*, pp. 171-183.

Duggan, William P. 1975. Reactions of the bay scallop, *Argopecten irradians*, to gradual reductions in salinity. *Chesapeake Science* 16(4): 284-286.

### Microbiology-Pathology-Bacteriology

#### *1973-1975 Period*

Research on estuarine fungi and protozoa centered around studies of structure, taxonomic identity, life cycles, and roles of selected species in the estuaries. Those microorganisms, which are involved in degradation of biological materials or which cause diseases in commercially-significant invertebrates, were given special attention, resulting in

the publication of 10 scientific papers.

The oyster disease organisms, *Minchinia nelsoni* (MSX) and *Dermocystidium marinum* and the crab pathogen, *Minchinia louisiana* were further described at the fine structure level. As a result of these studies, it was recognized that species of *Minchinia* have a nuclear division apparatus which resembles that of the malarial disease organisms (*Plasmodium* spp.). Since some antimalarial drugs are believed to inhibit nuclear division of *Plasmodium* spp., use of such drugs on MSX-infected oysters was initiated. The results were promising but conclusions as to the potential for disease control have not yet been derived.

Fine structure studies of *Minchinia louisiana* confirmed its close relationship to *Minchinia nelsoni*, the MSX organism. However, spores from this crab pathogen did not establish MSX-like infections in oysters; thus, *M. louisiana* in crabs is likely not to be the reservoir of MSX infective elements.

A study to determine the species of fungi associated with marsh grass (*Spartina* spp.) and their role in marsh grass degradation was completed. Typical "soil" fungi were prevalent on decaying *Spartina*. Materials in higher salinities contained a higher proportion of fungi capable of clearing acid-swollen cellulose, while those in the lower salinities yielded more fungi (numbers of isolates and diversity) able to decompose cellulose.

Cell biology studies of lower fungi and protozoa resulted in basic information concerning the taxonomic position of a large group of ubiquitous estuarine and marine organisms (the labyrinthulids and thraustochytrids). Formerly considered to be lower fungi, they were shown to be unique protozoa, thus requiring establishment of a new subphylum. The organisms were found to have a diverse nutritional mode of existence being able to (1) utilize dissolved nutrients in seawater, 2) enrobe and digest microorganisms by utilizing ectoplasmic extensions, and, (3) penetrate and digest plant or animal cells.

Investigations into the conditions required for elimination of total and fecal coliform bacteria from oysters were initiated. It was determined that oysters would eliminate coliform bacteria to acceptable levels (50 fecal coliforms/100 or 230 total coliforms/100 g of oyster meats) within 72 hours in all conditions tested except at temperatures below about 13°–10° C. The tests were conducted in small trays on small numbers of oysters in anticipation of expansion to a commercial-size operation after June 30, 1975.

The Department's service facility for preparation of histological slides has provided 17,400 slides for use by researchers at the Virginia Institute of Marine Science. Projects which were supported by this service included investigations of MSX distribution in Chesapeake Bay, various diseases of other commercially important Bay animals, crab and fish reproduction, and parasites in fish.

#### 1975–1976 Period

Studies of pathogenic organisms were centered around three haplosporidan species related to the oyster disease organism, *Minchinia nelsoni* (MSX), in an effort to better understand the life cycle and general biology of the Chesapeake Bay oyster blight. Three scientific papers were published.

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Fine structure studies of *Marteilia refringens*, a major disease organism of the European flat oyster, revealed its affinities with *M. nelsoni*. As with the Chesapeake Bay pathogen and other haplosporidan pathogens, direct transmission of infections from host-to-host of the same species could not be accomplished in the laboratory despite our best efforts. Investigations of a pathogen of Australian oysters resulted in a description of a new species, *Marteilia sudneyi*, which closely resembles the disease organism in European flat oysters. Investigations being conducted by Australian, English, French, and Dutch oyster biologists may yield information which could be used in formulating solutions to the *M. nelsoni* problem, since it was shown that the three species of pathogens were related.

Another haplosporidan disease found in nematodes of Virginia coastal zone surf clams was studied and described as a new species, *Urosporidium spisuli*. It was determined that the nematodes in the clam tissues become black and died when *U. spisuli* formed spores. It was noted that no species of haplosporidan was parasitic on humans, and it was found that temperatures used in commercial preparation of surf clam meats killed both the nematode and *U. spisuli*.

Fine structure studies of the oyster pathogen, *Dermocystidium marinum*, showed that the organism is related to the *Coccidia*, well-known pathogens of poultry and livestock. Since there was a wide range of anticoccidial drugs available on the market, research was planned to see if one of the drugs could be used to protect oyster populations against *D. marinum*.

#### Histology Laboratory

The Histology Laboratory was involved in the baseline studies of benthic organisms from the Atlantic continental shelf waters. These studies are being conducted to detect dominant, existing pathological conditions in those organisms. Protozoan parasites and virus-like inclusions were found in molluscs and crustaceans but no neoplasms. During this period, 8,676 slides were prepared in support of the baseline studies as well as for studies conducted by other VIMS scientists.

#### Bacteriology Section

Activities of the Bacteriology Section of the department were divided into research dealing with public health microbiology, marine bacteriology, and the microbiology of petroleum pollution in tidal salt-marsh ecosystems. Approximately 3500 water samples were processed for total and fecal coliforms for research projects dealing with the depuration of polluted oysters, non-point source runoff, wastewater effluents and process water from a kraft pulp-paper factory, pollution of watersheds and estuaries, and drinking-water quality evaluations. Routinely, water samples were analyzed for fecal streptococci, *Salmonella*, gram-negative enterics, total heterotrophic bacteria and petroleum degrading bacteria.

A significant number of coliform analyses were devoted

to understand the depuration of contaminated oysters under various temperature, salinity, and oxygen regimes. This research was supported by the Food and Drug Administration program designed to develop guidelines for depuration of polluted Chesapeake Bay oysters.

Another aspect of public health microbiology concerning VIMS bacteriologists was examination of the effects of effluents from a kraft pulp-paper mill on the bacteriological quality of the York estuary relative to water quality standards for shellfish harvesting.

Much VIMS bacteriological research was directed towards accumulation of basic data describing the distribution and activities of heterotrophic marine bacteria on the mid-Atlantic continental shelf capable of degrading petroleum hydrocarbons. Samples for determination of levels of petroleum degrading bacteria, their metabolic activities, and taxonomy have been obtained from the surface microlayer, surface waters (1 m), and the shelf sediments. This was a subproject of the VIMS contract study supported by the Bureau of Land Management.

Additionally, VIMS bacteriologists participated in a program supported by the American Petroleum Institute designed to evaluate the biological and chemical effects of petroleum spillage in a tidal salt marsh. Specifically, the levels of heterotrophic and petroleum degrading bacteria, fungi, and bacteria capable of degrading the biopolymers chitin and cellulose were monitored. The latter compounds are required for preservation of detrital food webs which include many organisms of aesthetic and economic significance.

### *Marine Parasites*

Studies to determine the important parasites and diseases of Chesapeake Bay fauna and their effects continued throughout the three report periods. A major study, developed earlier with Dr. I. Paperna (NSF senior Foreign Scientists Fellow), to examine the impact of parasites as pathogens and potential pathogens on populations of striped bass, received high priority. A paper describing an interesting protozoan parasite, *Kudoa cerebralis*, in the brains of Striped Bass was published. The fact that this parasite was associated with the brain and spinal cord was significant since other parasites of this genus had been previously reported only from the muscles and kidneys of fishes.

Other species of fishes were also examined to determine if they harbored parasites in common with those of Striped Bass. Another paper published during the report periods described a massive leech infestation found on a York River White Catfish. The response of the fish's skin to the attachment of the parasites appeared similar to changes noted in some types of tumor development.

Other projects in our Striped Bass parasite survey included work on a parasitic copepod, *Ergasilus labracis*, which was found to infest the gills of over 90% of the individuals studied. The distribution, life cycle, and seasonal abundance of the parasite were examined as well as the tissue response of the fish. This work was completed during the 1975-1976 period and a report was published. Another paper on *E. labracis* infestations being prepared for publication examined the pathological aspects. Work on the overall parasite survey of local populations of Striped Bass

was being concluded in mid-1976. Forty-five species of parasitic organisms were found, and the seasonal abundance and pathology of the most prevalent forms are being described.

Studies attempting to elucidate the life cycle and pathology of a parasitic nematode, *Philometra rubra*, found in the body cavity of Striped Bass were also begun. Extensive damage to body organs was associated with the birth of the larval worms during May and June and their migration through the flesh of the fish to the outside.

The Parasitology Section continued to furnish advisory services on parasite and disease problems involving local fauna to Institute staff members and to persons outside VIMS. Assistance was rendered to Dr. F. O. Perkins (Head, Department of Microbiology-Pathology) in studies of a blackened parasite noted in surf clams. A paper describing the protozoan as a new species and describing its effect on the surf clam industry was published with Dr. F. O. Perkins, senior author, and Mr. R. K. Dias. A paper on the immature nematode published in collaboration with Dr. J. R. Lichtenfels, Animal Parasitology Institute, USDA, and others was presented at the Annual American Microscopical Society meeting in November.

Lobster intestines were examined for parasites in conjunction with a contract funded by the National Marine Fisheries Service, to finance the study of the biology of Virginia lobsters. Parasites were previously used with success to tag populations of marine, generally migratory fauna. The presence or absence of one or more parasites associated with an animal serves as a clue to habitats occupied sometime during its life. Lobsters can harbor two immature worms, an acanthocephalan and a nematode, which discriminate coastal or offshore stocks. With one exception, intestines removed from lobsters sampled by Crustaceology personnel were found to harbor only a few nematodes.

The discovery of the insecticide Kepone in local fauna caused initiation of many studies throughout the Institute. The Parasitology Section was assigned the task of determining whether or not finfishes were affected by the poison, and if so, what was the nature and extent of the effect. A histological approach was adopted.

Selected tissues were taken from fishes collected in the field and subsequently analyzed for Kepone. Collections were made in the James, York, Rappahannock, and Potomac rivers and in lower Chesapeake Bay. Comparisons between those fishes with non-detectable quantities of Kepone (the controls) and those fishes with high levels of Kepone (the test animals) were being made. It was hoped that gross tissue changes, if present, would be evident with this technique. Relating Kepone load to lesions or a series of tissue alterations with any certainty requires not only an abundance of data to satisfy statistical rules of evidence, but also the ability to recognize the normal condition with its variances due to differences in sex, age, season, etc. Work towards a total understanding of the processes continued.

remained to be analyzed for Kepone and prepared for histological examination. In addition to the histological examination, all fishes were being checked for gut parasites. It is hoped that qualitative and quantitative changes in parasite fauna as related to Kepone load might tell something about

the effects the susceptibility of the fishes to parasites.

Systematic and ecological studies and bibliographic activities concerning monogenetic trematode parasites of fishes from the world ocean continued. Important literature was accessioned and data was extracted for inclusion in host-specificity and systematic catalogs. These data aided our own studies on Monogenea and were available to colleagues around the world. Additional specimens were cataloged into our collection of Monogenea, and several lots of type material were loaned to investigators. Several systematic papers on Monogenea collected from Australian and Antarctic fishes were in various stages of preparation. Two translations from Russian were received and one has been made ready for publication. The next supplement to our continuing Bibliography on monogenetic trematodes literature was also readied for publication.

## Planktology

Work by the Department of Planktology during the report periods included studies describing distribution of zooplankton abundance and specific composition in estuarine waters of the James River and lower Chesapeake Bay, continental shelf waters off Virginia, New Jersey and Delaware, and oceanic waters of the Norfolk Canyon region. A project to determine the effects of nuclear power plant entrainment on zooplankton within a brackish water (James River) environment was initiated. New research efforts relative to oil and gas development off the Middle Atlantic States spurred an increase in the departmental staff.

### *Zooplankton of the lower Chesapeake Bay*

The final monthly cruise of a two-year monthly survey of lower Chesapeake Bay zooplankton was conducted in July 1973. Analyses of the masses of data accumulated was a major task of the department for the next two years, continuing past June 30, 1976. These data were examined to determine spatial and temporal variations of parameters under study within the sampling area. Several theses at both the Masters and Ph.D. levels have been based on them. These include studies of the fish eggs and larvae, the cladocerans, the decapod larvae and a general treatment of the biomass, seasonal composition and abundance of collected species.

Other portions of the data have been treated in a more general sense or for particular purposes, such as an examination of the effects of Tropical Storm Agnes on zooplankton populations. These were initiated on fish eggs and larvae, cladocerans, decapod larvae and mysids. Other dominant groups such as copepods and chaetognaths were also enumerated. Physical, chemical and biomass data were compiled into a report.

A manuscript on the Chaetognatha was submitted for publication during the 1975-76 fiscal year. Another on a redescription of early larvae of a flounder was accepted for publication, and a paper on the seasonal distribution of biomass was delivered at the annual meeting of the American Society of Limnology and Oceanography.

Four cruises were conducted between August 1973 and August 1974 to monitor seasonal changes in the parameters

studied during the earlier surveys. A 24-hour station at the mouth of the York River was initiated and limited data on diurnal variations in plankton abundance composition were obtained.

In October of 1973 and June of 1975, zooplankton studies were conducted with stations along a transect from the Bay mouth to the continental slope. It was hoped that the degree of change from an estuarine to an oceanic zooplankton population could be measured and evaluated.

Two additional 3-day cruises of the lower Bay area were undertaken in August 1975 and March 1976 to examine the neuston and subsurface plankton at randomly-selected, night and daytime stations.

Four theses and dissertations based on the Chesapeake Bay data were expected to be completed by 1977. Other publications and reports will continue to be issued.

### *Norfolk Canyon Zooplankton*

Waters of the continental shelf edge and slope in the vicinity of Norfolk Canyon were sampled in April 1974 by VIMS scientists stationed aboard the R/V *EASTWARD* (Duke University vessel), and again in November 1974 by a VIMS contingent aboard the R/V *GILLIS* (Miami University vessel). Collections for a seasonal, depth-stratified study of the zooplankton in this area (including depths from 75-3000 meters) were completed by three similar cruises in the 1975-76 period: (1) July 1975, aboard the R/V *EASTWARD*; September 1975, (2) aboard the R/V *GILLIS* and (3) January 1976, aboard the R/V *GILLIS*.

A primary objective of these cruises was to facilitate the characterization of zooplankton fauna in waters overlying a submarine canyon, and to compare that community structure with a nearby population on the open slope.

In addition to depth-stratified random sampling of surface waters, the use of an opening-closing 1/2-meter bongo system allowed the serial collection of zooplankton samples at various depth zones down to 1000 meters. Sampling was conducted during the daylight and at night in order to explore effects of diurnal vertical migrations on zooplankton abundance and species composition. Simultaneous towing of an 8" and the 1/2-meter bongo system provided data on another source of variation in the catches.

Support from the National Science Foundation was limited to providing ship time and for collection and analysis of benthic fishes. The MARMAP program of the National Marine Fisheries Service provided some zooplankton collection equipment. This limited support has been inadequate. Analysis of the plethora of accumulated data placed heavy demands upon available Planktology Department manpower. Additional support for this phase was being sought as the 1975-1976 report period ended.

The value of these collections has become more apparent as interests in offshore oil development shifted southward from the offshore New Jersey sites already leased.

### *Nuclear Power Plant Entrainment of Zooplankton*

In April 1975 monthly sampling of intake and discharge waters of the VEPCO Surry nuclear power plant on James River was begun, funded by VEPCO, to determine mortal-

ity rates of those zooplankton organisms entrained in the cooling waters of the plant. Intake and discharge stations were occupied for 24-hour periods each month and samples were used for a seasonal and diurnal assessment of entrainment magnitude and effect. An established method of staining live vs. dead organisms was evaluated and appropriate alternate methodology was developed.

This project was completed in March 1975, and a final report was being drafted at the close of 1975-76 report period. Several methods for estimating mortality of entrained organisms were employed in the study.

Faunal studies showed that the plant was located at a transition and overlap zone between fresh water and oligohaline conditions, so that entrained organisms can be from either, depending on the season and the amount of freshwater runoff. Measurements of mortality revealed a high survival rate for entrained zooplankton throughout most of the year.

#### *Assessment of Middle Atlantic Outer Continental Shelf Waters*

Quarterly sampling of a six-station transect extending from Atlantic City, New Jersey, to the edge of the continental shelf was carried out in October 1975, and in February and June 1976. Each station was occupied for a 24-hour period with collections of neuston taken every 3 hours, and a pair of oblique tows through the water column using 24-inch bong samplers with two different mesh sizes. Samples were frozen for analysis of hydrocarbons and trace metals from each of the bongo tows, while individual species were selected from neuston tows for chemical analysis. Tarballs were removed from neuston samples and frozen separately for analysis.

Taxonomic studies of collected zooplankton included quantitative splitting and sorting of samples into major groups, species identification, transfer of results onto data processing cards, cluster analysis of the data (both sample clusters and the inverse species clusters), and calculation of diversity for each collection.

Two theses (one Masters and one Ph.D.) were initiated on this material. One is concerned with the decapod larvae, poorly described for this region, the other with hyperiid amphipods. A preliminary report on the fall 1975 neustonic copepods was presented to the spring 1976 meeting of the Atlantic Estuarine Research Society.

#### *Preparation of Guideline for Sampling Phytoplankton and Zooplankton in Baseline and Monitoring Surveys*

A contract with the Environmental Protection Agency, established in November 1975, will produce two sets of guidelines for use by EPA officials in specifying details of sampling and analysis. One is being prepared for phytoplankton, the other for zooplankton.

### **Invertebrate Ecology**

#### *1973-1975 Period*

With support from the Council of Environmental Quali-

ty (CEQ) and the Bureau of Land Management (BLM), members of the Department reviewed available literature regarding marine chemistry and marine biology for the coastal and offshore area extending from Sandy Hook, New Jersey to Cape Canaveral, Florida. The review covered both flora and fauna of the region, including birds and mammals. These data were synthesized to develop a summary description of the region. The entire region was described in a report to CEQ. A more detailed summary for the southern half of the region (Cape Hatteras south) was prepared for BLM, including habitat descriptions and life history summaries for an extensive list of species. These reports were a part of the federal effort to evaluate the ecological effects of developing oil and gas reserves on the outer continental shelf.

Under a contract with the National Commission of Water Quality (NCWQ), a synthesis of ecological conditions in the Chesapeake Bay (both Maryland and Virginia waters) was carried out. Based on projections of water quality conditions made by the Department of Physical Oceanography and Hydraulics at VIMS, predictions were made of the ecological effects of reductions in point source discharges of pollutants (esp. sewage treatment plants). This endeavor was a part of the overall effort of NCWQ to evaluate the effectiveness of the Federal Water Pollution Control Act Amendment of 1972 (PL 92-500).

A program was initiated to evaluate the acute toxicity to estuarine organisms of oxidative chlorine, which is used as a disinfectant or an antifouling agent. Chlorine had been implicated in fish kills observed in the lower James River in June 1973-74. These studies demonstrated that oxidative chlorine is a toxic to a variety of marine life ranging from phytoplankton to fishes. Among the most sensitive species are oyster larvae and copepods, both of economic importance in the Chesapeake Bay system. The results were provided to the Virginia Chlorine Task Force to assist in resolving the environmental problems associated with chlorine usage.

A cooperative study on water quality criteria and the biota of Chesapeake Bay was completed by members of the department in conjunction with the Smithsonian Institution and the University of Maryland. This was part of the U. S. Army Corps of Engineers Chesapeake Bay study. Topics covered were ecological concepts and environmental factors affecting Chesapeake Bay, the biology of significant Bay organisms (24 species), general ecological descriptions of several Chesapeake Bay communities and selection of several communities for more detailed study, water quality standards and criteria pertinent to the Chesapeake Bay, and applicability of the Chesapeake Bay hydraulic model to biological problems.

Doctoral dissertations were produced on the growth and condition of the marsh clam, *Rangia cuneata*, and on hermit crabs of the western Indian Ocean. One doctoral study was initiated on saccoglossans and nudibranchs of Chesapeake Bay and the seaside of the Eastern Shore. Another doctoral study was undertaken to assess the effects of crab and fish predation on the community structure of benthic organisms. Yet another was completed on hydroids associated with pelagic Sargassum.

Effects of Tropical Storm Agnes on estuarine inverte-

brates continued under investigation, particularly for evidences of recovery. Studies continued on the long-term dynamics of communities of benthic invertebrates in the Chesapeake Bay. Assessments of the impacts of various dredging and dredged material disposal activities on benthic organisms were undertaken in several regions of the Bay.

The distribution of eelgrass, *Zostera marina*, along the western shore of the Chesapeake Bay, was analyzed with aerial photography and ground surveys. Historical changes in eelgrass distribution were also examined from the existing data base files and related to the present-day distribution of eelgrass. Causes for the disappearance of eelgrass in many sections of the lower Bay, and the effects of this disappearance, were investigated.

#### 1975-1976 Period

Determining the distribution of eelgrass along both the western and eastern shores was continued. Work was initiated on several projects, including the effects of the Chesapeake Bay Oil Spill on submerged aquatic vegetation and associated benthos, nutrient enrichment of eelgrass beds and biology of eelgrass as related to its growth cycle in the Bay.

Review of manuscripts of the "Agnes" volume and Chesapeake Science, as well as of environmental impact statements, continued. A shipworm study began in 1938 correlated rainfall with salinity and borer setting. Other involvement was with avifauna, the effect of wave energy-producing devices on the environment and revised taxonomic keys to several invertebrate groups, particularly amphipods.

An extensive study of the benthic communities of the middle Atlantic continental shelf from northern New Jersey to Virginia was begun as part of the U. S. Bureau of Land Management (BLM) outer continental shelf benchmark studies. This research was designed to describe the broad, intermediate and small scale patterns of distribution and community structure of macrobenthos. The sampling produced scores of species which were previously unknown from this region or new to science.

Studies of benthic communities in the Chesapeake Bay included: 1) continued assessment of long-term dynamics of benthic communities; 2) the effects of predaceous crabs and fishes on infaunal community structure; 3) the impact of marsh habitat development from dredged material; 4) the colonization of tidal freshwater marshes by benthic invertebrates; 5) the long-term effects of subaqueous borrow pits; 6) the effects of chronic pollution in the vicinity of an oil refinery; and, 7) the acute effects of a major oil spill.

Under a grant from the Environmental Protection Agency, research and synthesis were conducted on the application of multivariate statistical analyses in the ecological assessments of water pollution. The first phase, involving a review and application of numerical classification, was completed; similar treatment of ordination and other multivariate techniques were begun.

The chlorine bioassay program, initiated in the previous biennium, was continued in order to evaluate the effects of chlorine to additional estuarine species, notably decapod

crustaceans, including larval stages. Equipment to conduct bioassays with oyster and crab larvae in continuously flowing systems was designed and tested. The program was expanded to consider the toxicity of bromine chloride, which is a possible alternative to chlorine as a disinfectant. Results suggested that the two halogens have nearly equal toxicity. Other alternative disinfectants, and/or protocols for application, were being considered for subsequent laboratory analysis.

#### Ecology--Pollution Studies

The Ecology--Pollution Department provided analytical services and support to other departments of the Institute as well as other state and federal agencies. Routine analyses of salinity and dissolved oxygen were performed on water samples collected by Institute oceanographers and biologists. Nutrient analyses of sediments and water were also performed.

The Department undertook some projects under contract with the U. S. Army Corps of Engineers to do analyses on sediments and elutriates to determine the feasibility of dredging or overboard disposal of dredged spoils.

#### Metals in Sewage

As more people move to the coastal zone its waters receive more sewage effluent. One estimate was that two percent of the fresh water entering the Chesapeake Bay is treated sewage. It was imperative that the effect of these inputs be studied and quantified. Therefore, personnel of this department, in conjunction with the Chesapeake Research Consortium, worked with other scientists in the Bay area to determine the input of trace metals to the Bay from sewage effluents. The results were important demonstrating for the first time that for the metals zinc, lead, copper, chromium and cadmium, wastewater inputs into the Bay rival natural fluvial inputs. It became obvious that as the population expands and resulting sewage inputs increase, these unnatural inputs would become more important relative to environmental effects.

#### Oil

The addition in 1974 of a high-resolution mass spectrometer to the Department's instrumentation inventory brought a new dimension in analytical capabilities to its environmental chemists. Organic compound identification had been limited to gas chromatographic analysis, which in turn made research on environmental effects of complex organic mixtures difficult, if not impossible. With the mass spectrometer, projects dealing with petroleum hydrocarbons were undertaken. One involved a controlled oil spill of No. 2 fuel oil in an estuarine environment. The spill was designed to expose hard clams, *Mercenaria mercenaria*, to the oil in a manner as close to natural as possible. Samples of the animals, water and sediment were taken and analyzed for petroleum hydrocarbon content. This research resulted in one manuscript submitted for publication and gave scientists a better understanding of how oil spilled in an estuary moves through the ecosystem.

The objective of another project, still underway is to determine the acute environmental effects of fresh and weathered South Louisiana crude oil spilled in coastal plain estuaries. The major chemical components of the oils are being followed through the ecosystem and the responses of the community to the oil are being followed as a function of time.

A tidal marsh-creek system, located at Cheatham Annex, is being used as the test site. The marsh-creek system was partitioned into areas of suitable size for dosing with oil. Replicate "mini-ecosystems" were provided for each treatment. Due to space restrictions we tested only two types of oil. The duration of study on the system is dependent upon the rate of recovery of the communities; present estimates indicate that at least an additional year will be necessary for recovery to be complete.

### *Chlorine*

In May of 1973 and 1974, major fish kills occurred in the estuarine portion of the James River. The duration of the kills (about three weeks each) allowed Department investigators to determine the causative agent—chlorine and/or its derivatives from sewage treatment plants. Although it was shown that chlorine was involved in the massive mortalities, scientists were unable to measure the halogen at the low levels which existed in the river. This problem was presented to the National Bureau of Standards, and it resulted in a cooperative effort to develop and test a portable analytical device sensitive to chlorine—chloramines at levels much lower than existing portable equipment. The project was successful and the results were reported and published. Also, the instrument was being manufactured for commercial purposes by private industry.

### *Pesticides*

The Ecology—Pollution Department had been involved in collection and/or analyses of biological samples for pesticides since 1965. This program continued in conjunction with the Environmental Protection Agency's National Pesticide Monitoring Program. Although only a few samples were being analyzed at VIMS, fish continued to be collected from the James, York and Rappahannock rivers and sent to EPA for analyses.

As a result of this program we found that the polychlorinated biphenyl (PCB) content in Elizabeth River oysters was higher than elsewhere in Virginia. Therefore, in order to determine the source area, we performed a study in conjunction with the Food and Drug Administration. Oysters were collected from the Rappahannock River, and after initial analyses for PCB, were placed in trays located at a number of locations in the Elizabeth River. Subsequent collection and PCB analyses at 30 and 60 days showed that the source was near the junction of the southern and eastern branches of the Elizabeth River.

### *Kepone*

While Kepone is a pesticide and could be placed under the "Pesticide" section, it has become such a large program

that it is better handled separately. This Department has been involved with Kepone since December 1975. Part of the project involves the collection and analysis of Finfish, Shellfish and Crustaceans for the pesticide, Kepone. The purpose is to determine the ambient levels of the substance in Chesapeake Bay Biota and by continuous monitoring to detect trends of Kepone in the animals. The data generated are shared with other members of Virginia's Kepone Task Force to aid in decisions concerning public health and possible Kepone cleanup options. Another part of our program is designed to study the following aspects:

- 1) The distribution of Kepone in bottom sediments of the James River;
- 2) The routes of sediment transport below Hopewell;
- 3) The major sediment sinks will be located and the rates of sediment deposition at these sites will be determined;
- 4) The effect of varying environmental conditions of pH and salinity on release of Kepone from sediments will be determined; and
- 5) The ability of filter feeding organisms to concentrate Kepone from contaminated sediments will be determined.

Data from this study will provide for a determination of the potential hazards which dredging poses to a variety of filter feeding organisms.

### *Ecological Effects of Power Plants*

During the period June 1973 through July 1975 work was performed on two ecological studies relating to power plants operated by the Virginia Electric and Power Company (VEPCO). The first of these studies, which began in April 1972, was conducted in the lower York River in the vicinity of the VEPCO Yorktown Power Station. The objective of this study was to obtain background ecological data on this section of the river prior to the start of operation of a newly constructed, third unit of the power plant. Communities studied included the phytoplankton and zooplankton (monthly), benthic macroinvertebrates (quarterly), and finfish (monthly). In addition the environmental parameters of temperature, salinity, dissolved oxygen, and the standard forms of nitrogen, phosphorus, and carbon were measured monthly. The field work for the study terminated in December 1974, and the final report was completed in May 1975.

In the summer of 1974 a related study, concerning the dissolved oxygen distribution in the lower York River was performed. This project was prompted by the divulgence of a plan by the Hampton Roads Sanitation District Commission to discharge a treated sewage effluent into the river, and by the knowledge that the deeper waters of the river, are subject to severe depressions of dissolved oxygen at times during the summer. Sampling was conducted weekly from May 10 through October 10, and the final report was

issued at the end of October, 1974.

The second power plant monitoring study was performed in the upper James River at the site of the VEPCO Surry Nuclear Power Station. The study had originally begun in 1969, prior to the operation of the power plant. The operational phase of the study began in the spring of 1973 with the startup of the power plant's second unit. The communities sampled in the study have been the phytoplankton and zooplankton (monthly), benthic macroinvertebrates (quarterly during most of the year, and monthly in the summer) and fouling organisms (bimonthly). Temperature, salinity, and dissolved oxygen have also been monitored in conjunction with the biological sampling. The study results have been presented to VEPCO semi-annually in the form of progress reports. The results for all of 1975 will be assembled into a comprehensive report to be completed in the fall of 1976.

#### *Water Treatment Plant Siting*

During the 1973–75 period the Department participated in two studies related to the placement of sewage outfalls for new sewage treatment facilities. One was for the proposed plant at Pig Point in the James River and the second for the Dam Neck facility in Virginia Beach. We provided data and interpretation of the potential effects of these facilities on marine life in the area.

#### **Environmental Physiology**

Research topics of the Department of Environmental Physiology during the 1973–1976 periods was centered about three topics: 1) plankton energetics, 2) jellyfish ecology, development and metabolism, and 3) the nitrogen cycle of estuarine and marine waters.

#### *Plankton Energetics*

A monthly survey of the annual cycle of the primary productivity potential (rate of photosynthesis by phytoplankton) and heterotrophic potential (rate of utilization of dissolved organic substances by microbial populations) in the estuarine waters of the lower Chesapeake Bay (below 37° 40' N) were completed. The methods employed radioactive substrates under carefully-controlled test-tube conditions for measurements of microscopic populations. With respect to primary productivity potential, there are three peaks of activity in the annual cycle in the lower Bay waters: spring, summer and autumn. This probably reflects either a succession of species or changes in grazing pressures in contrast to the two-peak cycle (spring and autumn) found in numerous other aquatic environments. The heterotrophic potential showed a sustained maximum during periods of warmer waters (June–October) and a minimum during periods of cooler waters (November–April).

The chlorophyll *a* distributions and heterotrophic potential distributions were measured in the lower Chesapeake Bay after the passing of Tropical Storm Agnes. Six weeks after its passage, a maximum in the heterotrophic potential appeared which may have been a direct effect of (1) the washing of many potential substrates into the lower

Bay waters, (2) the providing of an environment in which introduced microbial species other than those normally encountered in the Bay could flourish, or (3) the stimulation of microbial growth by the release of nutrients normally in sediments. The heterotrophic potential reached its minimum when the water returned to the winter temperatures. The chlorophyll *a* distribution reached a maximum later than the heterotrophic potential did, and it remained elevated over that measured during previous winter minimum. With respect to the phytoplanktonic autotrophic organisms, an observable effect was noted which persisted for one year after the passage of Tropical Storm Agnes.

A survey of the chlorophyll *a* content of the surface waters of lower Chesapeake Bay (Virginia waters) was undertaken in conjunction with the Ichthyology Department's summer survey of the Chesapeake Bay fishery habitat. In addition, a census of jellyfish medusae (pelagic adult form) was completed on the same cruises. These data provided a better base of information for describing the population dynamics of the lower trophic levels of Chesapeake Bay.

An aerial survey of red water blooms in Virginia waters of Chesapeake Bay and in its tributary rivers (James, York, Rappahannock, and Potomac) was completed. This survey indicated that red waters (populations of dinoflagellates and/or other phytoplankton) occur during all periods of the year, including the winter months.

A series of 7 diurnal-diel studies at the mouth of the York River during the annual seasonal cycle was completed. In these studies, the primary productivity potential and heterotrophic potential were measured over 203 tidal cycles and with respect to the night/day cycle and with respect to tidal oscillations. These studies indicated that variations in primary productivity potential are significant during the day, depending particularly on the amount of solar radiation reaching the phytoplankton. On days of high illumination, periods of maximum productivity potential were observed in the earlier and later parts of the day, with a period of light inhibition occurring at midday. The maximum of heterotrophic potential was sometimes observed late in the day, possibly coincidental with the appearance of microzooplanktonic populations. In addition, periods were observed when the water column at the mouth of the York River was highly stratified and other periods when it was homogeneous. A transition from the stratified water column to that mixed column appeared to be coupled with a lunar periodicity.

#### *Jellyfish: Ecology, Metabolism and Development*

The jellyfish research project at VIMS was primarily concerned with identifying the biochemical and developmental processes associated with the high productive potential of the sessile stage of the "stinging nettle", *Chrysaora quinquecirrha*.

With respect to the pathways of intermediary metabolism (the sequences of biochemical reactions by which the organisms convert food substances into utilizeable products for biosynthesis, development and energy), the existence of the pentose phosphate pathway was identified using 2 independent methods: 1) enzyme identification, and 2) radioi-

sotope tracer methodology. This study permitted a better understanding of how the lipid (fat) biosynthesis and pentose (carbohydrate) oxidation occurs in the scyphistomae of *Chrysaora quinquecirrha*.

Investigations into the role that iodine plays in the metamorphic process of strobilation indicated that the early strobilae accumulate iodine against a concentration gradient. The iodine is then converted to organic-bound iodine in small molecules (idotyrosines) in *Chrysaora quinquecirrha*, whereas it is retained in a free-state in *Aurelia aurita*. Thus the effect of iodine on the associated strobilation processes is different in these two Chesapeake Bay jellyfish.

Ultrastructural studies on different metamorphic stages of the stinging nettle indicated marked changes with respect to neurosecretory granules and membrane-bound particles. Such observations were consistent with the interpretations that significant sub-cellular events occur before the metamorphic stages are morphologically apparent.

In addition to distinguishing the various scyphistomae by microscopic examination of nematocyst (stinging cell) complement, other methods were developed during the period. Scyphistomae of *Aurelia aurita* and *Chrysaora quinquecirrha* may be differentiated by: 1) mouth shape — *Aurelia aurita* of Chesapeake Bay have circular mouth shapes, whereas *Chrysaora quinquecirrha* have cruciform mouth shapes; 2) Isozyme complements — Stinging Nettle: *Chrysaora quinquecirrha* has 2 sets of doublets of malate dehydrogenase (fast- and slow-migrating in an electric field) and a single fast-migrating superoxide dismutase band; Moon jelly: *Aurelia aurita* has two sets of intermediate migrating malate dehydrogenase bands and three superoxide dismutase bands; Lion's Mane: *Cyanea capillata* has two sets of malate dehydrogenase bands which migrate differently from those of *Chrysaora quinquecirrha* and a single slower-migrating superoxide dismutase bands.

These studies may help researchers to clearly identify scyphistomae found in the field.

The ecology of a tributary creek of the York River which is known to support large jellyfish populations was followed intensively. During this study, individual scyphistomae were observed to undergo three periods of strobilation during a single spring–summer cycle. In addition, the scyphistomae produce numerous cysts during the later summer. This field study confirmed previous hypotheses concerned with prolific reproductive processes of the sessile stage of *Chrysaora quinquecirrha*.

Changes in the polyp population of the nettle were monitored in a tidal tributary (Sarah's Creek) in the Spring of 1976. These observations, with particular emphasis on the timing of the strobilation process (metamorphosis and development), were a first step in gathering the necessary information for developing a model of the jellyfish population for prediction purposes. By using data from a representative test area of Chesapeake Bay and selected sampling carried out Bay-wide during specific seasonal intervals, it was anticipated that a projection of mid-summer jellyfish populations would be possible.

Excystment, an important developmental stage in the life cycle of *Chrysaora quinquecirrha*, was studied under laboratory conditions. Podocysts, a sessile stage of the nettle, were observed to form viable polyps after as long as

2 years in the dormant stage. The predominant amino acid of the podocyst and the polyp was found to be glycine, and the amino acids — cysteic acid and taurine — were found present in somewhat greater abundance in the podocyst than in the polyp. The morphological development of the newly emerging polyp was described in detail by using the experimental procedure of partially removing the cyst covering. These observations aided in the greater understanding of the state of dormancy of the jellyfish podocyst.

Polymeric carbohydrate materials of unusual monomeric composition were obtained from the mesoglea of the *Chrysaora quinquecirrha* medusae. The monomeric units consisted primarily of xylose, fucose, uronic acids, hexosamines, and mannose. These data indicated that the glycosaminoglycans (polysaccharides associated with connective tissues in higher organisms) evolved in the very early stages of metazoan evolution.

### *Nitrogen Cycle Studies*

Nitrogen, a major element of fundamental importance to all forms of life, must be available for growth and reproduction. The availability of nitrogen has been identified as an important factor in the delicate balance of aquatic ecosystems. The particular role of nitrogen, its availability in oxidized and reduced forms in the aquatic environment and the processes by which it is transformed from inert molecular form in the atmosphere were under investigation. A comparative ecosystem approach was employed using the marshes, estuarine waters, near coastal waters, open marine waters and coral reefs.

### **Wetlands**

During the report period the Wetlands Research Section participated in the education, research and advisory functions of VIMS primarily through the following seven program areas:

1. Permit Activities
2. Wetlands Inventories
3. Research and Publications
4. Advisory Activities
5. Environmental Impact Statements
6. Educational Activities
7. Coastal Zone Management

### *Permit Activities*

Wetlands Research personnel processed an average of 340 shoreline alteration applications per year during 1973–74 and 1974–75, increasing to 366 in 1975–76. Each permit involved a site visit, written report and follow-up prior to permit issuance. In addition, Wetlands personnel were in daily communication regarding permits with the 4 federal agencies (U. S. Fish and Wildlife Service, Environmental Protection Agency, National Marine Fisheries Service, and the Army Corps of Engineers), the primary State agencies involved, (State Water Control Board, Virginia Marine Resources Commission), and the local wetlands boards.

### *Wetlands Inventories*

During the report periods 9 wetlands inventories were published and distributed and others were in various stages of completion. Field work was completed on the two Eastern Shore counties, which contain more than half the wetlands in the Commonwealth, as well as Newport News, Gloucester and most of the City of Virginia Beach.

### *Research and Publications*

Research ongoing or completed by the Wetlands Research Section during fiscal years ending 1974, 1975 and 1976 included the following:

1. Remote sensing of marsh communities (VIMS—NASA);
2. Wetland propagation: seed germination and seedling success (Phase I);
3. Plant community structure in a freshwater marsh (MS thesis);
4. Effects of oil spills on saltmarshes (PhD thesis);
5. Carbon transport in two York River, Virginia tidal marshes;
6. Nutrient flux through the saltmarsh ecosystem (PhD thesis);
7. Angiosperm production of three Virginia marshes in various salinity and soil nutrient regimes (MS thesis);
8. Wetland classification and evaluation;
9. A study of tidal history of Cold Harbor Creek, Westmoreland County, Virginia;
10. A study of the aquatic impacts of a proposed LNG pipeline through Gunston Cove, Fairfax County, Virginia;
11. An environmental assessment of the impact of I-64 improvement on the Hampton River and vicinity;
12. An assessment of the natural vegetation on an artificial spoil island at Windmill Point in the James River, Virginia;
13. RAMS data system (CRC);
14. Functional ecology of an intertidal mud flat: an experimental and ecosystem modeling approach;
15. The analysis of ecological systems: marine ecosystems: marine ecosystem modeling;
16. An assessment of the environmental impact of

dredge and fill projects;

17. A preliminary characterization of a nutrient impacted aquatic ecosystem, Yorktown Creek;
18. Post-construction studies at the Windmill Point marsh development site;
19. Environmental impacts of highways on coastal wetlands, Atlantic Coast region;
20. Causeway construction in a tidal marsh system; and
21. Delineation of coastal marsh boundaries, East Coast.

Final or preliminary reports were completed for 12 of the above studies. These were in addition to the 9 wetlands inventories previously mentioned. The most significant publication produced by the Wetlands Section was *Coastal Wetlands of Virginia Interim Report No. 3, Guidelines for Activities Affecting Virginia Wetlands (SRAMSOE No. 46)*. These guidelines were promulgated by the Virginia Marine Resources Commission as an adjunct to the Wetlands Act. In addition to their intended use by the Virginia Marine Resources Commission and local wetlands boards, the guidelines were actively used by 4 federal agencies as they function in the permit process as a model by several sister states and at least one foreign country (Australia) in developing their own guidelines.

### *Advisory Activities*

During the report periods, Wetlands Section personnel responded to 609 requests for pre-application advice to shoreline owners. This activity was increasing, as evidenced by the 249 requests during the 1975–76 period alone. They involved single individuals, industries, and state and federal agencies.

### *Educational Activities*

In addition to the structured graduate school activities conducted on campus by faculty members in the Wetlands Section, guest lectures were provided semi-annually at Rappahannock Community College and at VIMS for Rappahannock Community College marine science technical courses.

Lectures and programs for secondary school groups, civic clubs, and other interested groups totaled 80 for the three periods of this report. Wetlands workshops (4 to 7 hours each) were presented on 7 occasions during the periods. These were in direct support of local wetlands boards created pursuant to the Wetlands Act of 1972.

### *Coastal Zone Management*

Wetlands Research personnel participated in numerous meetings involving various elements of Virginia's Coastal Resources Management (CRM) planning and in addition produced four draft reports pertaining to specific elements of CRM planning.

## Physical Oceanography and Hydraulics

Extensive laboratory and research facilities were acquired for physical oceanography and hydraulics work at VIMS during the report periods. Housing was also made available for a large stainless steel and glass flume which was constructed. The flume has an approximate length of 60 feet with a test section 48 ft. x 3 ft. x 3 ft. There is a controlled speed of 0-2 knots in the test section with an uncontrolled speed of about 4 knots over the raised tailgate. The flume was also being used to check meters used in plankton nets, current meter modification reactions to surface waves, direct reading current meters, and to calibrate inductive current meters.

Research in the Department of Physical Oceanography and Hydraulics was divided into three general categories:

**Physical Oceanography** – studies of the circulation patterns on the continental shelf and slope in the Middle Atlantic Bight and in Virginia Estuaries.

**Estuarine Studies** – extensive and intensive gathering of hydrographic data and development of estuarine models utilizing the collected data.

**Engineering Studies** – field studies to determine the impact of engineering projects.

### *Physical Oceanography*

During the report periods several studies were conducted to determine the flow patterns and circulation patterns in Virginia estuaries and along the continental shelf and adjacent areas.

One such study was at Wachapreague Inlet. Two field exercises were conducted to estimate the amount of water exchanged between the shelf and the marsh during the tidal cycle. Indications were that offshore flow is wind-dependent, and that the direct tidal influence of the inlet decays rapidly away from the mouth.

Development of a transponding Omega navigation buoy for additional offshore work continued. Development is being centered around a prototype buoy, which operates in the differential mode.

Project *MACONS* (Mid-Atlantic Continental Shelf Study) provided drift bottle/sea bed drifter data which will be used in coastal management. Use in siting offshore ports and sewage outfalls is being considered.

Investigations were conducted to determine tidal circulation at the sites of the proposed and existing outfalls for sewage treatment plants on Hampton Roads. The remote sensing dye buoy technique was used for the studies and results were supplied to Hampton Roads Sanitary District Commission.

A VIMS-NASA (Langley Research Center) cooperative project using drogued buoys to measure continental shelf circulation continued. Four buoy deployments were made between February 1973 and February 1974. Buoys released near the mouth of Chesapeake Bay on three occasions and near Norfolk Canyon on one occasion were tracked by the French EOLE satellite for one month periods.

Preliminary results show rapid southerly movement of water along the Virginia and North Carolina coasts with final Gulf Stream entrainment. Initial data processing was accomplished at NASA (LARC) and negotiations were underway for final data processing and interpretation at VIMS under a NASA contract.

A baseline summary of climatology and physical oceanography was done for the region from Cape Hatteras, North Carolina, to Cape Canaveral, Florida, as part of a five volume socio-economic environmental study in this area. It was found that data for the continental shelf area are crude; whereas, data for land areas, estuaries, and the Gulf Stream in the area are fair.

In 1974, papers concerning the effects of Tropical Storm Agnes were given by departmental personnel at a symposium in College Park, Maryland, sponsored by the Chesapeake Research Consortium, and at the Fourteenth Coastal Engineering Conference, in Copenhagen, Denmark. The papers dealt with changes in the salinity structure of the James, York, and Rappahannock estuaries and the lower Chesapeake Bay resulting from the Agnes flood, flood wave-tide wave interaction on the James River during the flood, and the overall effects of flooding on a coastal plain estuary.

The Department of Physical Oceanography and Hydraulics cooperated jointly with Geological Oceanography to develop a mathematical model for the sediment transport.

### *Estuarine Studies*

A great deal of time and effort was spent by the Department of Physical Oceanography and Hydraulics studying the estuaries of Virginia and the Chesapeake Bay.

The collection of hydrographic data, including tidal elevation, current velocity, temperature and salinity and water quality data including dissolved oxygen and biochemical oxygen demand was expanded beyond collection in the James, York, and Rappahannock rivers, and Chesapeake Bay to include the Back, Poquoson, Piankatank, Elizabeth, Great Wicomico, Chickahominy, Nansmond, and Pagan rivers.

The primary purpose for collecting these data was verification of both mathematical and physical models including the Chesapeake Bay Hydraulic Model being constructed under the supervision of the Corps of Engineers, Baltimore District.

Real-time dissolved oxygen models including carbonaceous and nitrogenous BOD for the James, York and Rappahannock were produced in addition to tidal-averaged salinity models for the same estuaries. A one-dimensional dynamic model has been developed for the James. Two-layer modeling, especially for some of the smaller streams with heavy bottom sludges, was also being produced.

A long-term cooperative program between VIMS and the State Water Control Board continued in order to monitor the water quality and collect hydrographic data in Virginia estuaries and tidal rivers. Mathematical models will be used in water quality management not only for Virginia estuaries and tidal rivers, but for the Chesapeake Bay as well, in compliance with the Clean Water Act.

Another project involved intensive field surveys and

slack water monitoring surveys of four small coastal basins of the Chesapeake Bay: Back River, Poquoson River, Little Creek and Lynnhaven Bay. The data will be used to calibrate and verify water quality models of these rivers. These models will be used to develop alternative waste load allocation schemes. Particular emphasis was placed on non-point sources of pollution.

### *Engineering Studies*

The department carried out many studies to determine the environmental impact of engineering projects on the physical environment. Included among these projects was a detailed description of present Chesapeake Bay water quality and quantity which will be used in determining future environmental impacts in the Bay region.

A project was initiated to determine the quantity and quality of the stormwater runoff at twenty-five sites representing a broad range of land uses and soil types. The data from these surveys will be used to estimate the non-point source loadings to the water bodies in southeastern Virginia.

A similar project was begun involving the Chincoteague/Sinepuxent/Assawoman Bay System. Runoff quantity and quality were measured from six different land use types for up to four storm events each. Data were to be used to compare magnitudes of point and non-point sources of pollution. In addition, an index of all existing information for the Coastal Basin relevant to water quality was made as well as an intensive hydrodynamic and water quality survey and twelve monthly sampling runs during slack water.

A great deal of emphasis has been placed on the effects of existing and proposed sewage treatment plants (STP). During this two year period, the circulation, hydrographic characteristics and bacteriological, nutrient and dissolved oxygen levels in Hampton Roads have been studied to determine the feasibility of constructing a STP at Pig Point. In addition, a dispersion simulation model was developed which used the results of field dye releases.

Hydrographic surveys, which determined the nature of the water quality and circulation patterns, were conducted in the Elizabeth River. These data were used to construct a mathematical model which was used to test various locations in the river to determine if the effluent distribution from the Army Base and Lambert Point STP's would be such that alternative locations would produce better water quality.

Another sewage treatment plant, the Boat Harbor STP (Newport News Point) of the Hampton Roads Sanitation District, was studied to determine whether the existing outfall should be modified or a new outfall constructed. From the dye studies conducted, it would appear that an outfall located farther from shore would achieve dispersion over a greater area than the existing site provides.

A method was developed for predicting the distribution of sewage constituents resulting from a proposed sewage outfall in estuaries or coastal seas. The method has been applied to assess the environmental impact of a proposed sewage outfall in Hampton Roads.

Water recirculation through the sewage treatment plant on the York River was studied. The percentage of recircula-

tion was determined by introducing dye into the effluent and measuring the concentration in the intake. This study was important because the Hampton Roads Sanitation District is interested in using VEPCO's outfall to discharge treated water.

Another project involved the behavior of wastewater-oriented nonconservative substances, coliform bacteria in particular. Chlorination at selected sewage treatment plants was halted for specified lengths of time and samples were then collected to determine the spatial and temporal variations of the coliform count. Data, including currents and tidal fluctuations, which were collected in previous studies were used to predict likely geometries of the effluent throughout the tidal cycle.

Other studies which involved investigating the environmental impact of engineering projects included monitoring the changes which have resulted from the sand diking of an island off Windmill Point by the U. S. Army Corps of Engineers for dumping dredge spoil. The purpose of the project was to note any changes in current direction and velocity resulting from one enlargement of the island.

The monitoring program of salinity and temperature at two stations in the Rappahannock and two stations in the York River continued. The remote monitoring stations were developed to withstand adverse environmental conditions in order that long-term changes in the physical environment could be observed.

In consultation with the state highway department, the circulation in the proximity of Newport News Point was studied to predict the effect which a proposed new bridge tunnel would have on the circulation of the lower James River. There was particular emphasis on the study of erosion due to the changed current patterns. In addition, the construction of the second tunnel for the I-64 crossing (Hampton Roads Bridge Tunnel) was investigated to note and document any changes occurring during construction. Special attention was focused on the effects of dredging on the amounts of nutrients released from bottom sediments. Flow patterns around the tunnel islands and the modification of the flow by the trench dredged for the tunnel segments were surveyed. Information gathered from the study will be used in designing the I-64 crossing. Results obtained by the Department of Physical Oceanography were coordinated with results from other departments to provide a complete multidisciplinary survey.

Additional projects done in conjunction with other departments at VIMS included a study of oyster depuration in a physically controlled environment. Recontamination by bacteria resulting from the accumulation of feces, psuedofeces and silt within the holding tanks was being investigated. The design and operation of the tank in which oysters were to be held for depuration was of special interest.

As part of the study involving regional wastewater treatment systems, data for the Hampton Roads region were reviewed and gaps in the existing data were delineated. The Department of Physical Oceanography and Hydraulics reviewed the physical data for the York and lower James estuaries while other departments reviewed data for additional parameters.

The Long Creek/Canal Channel Erosion Study was carri-

ed out in cooperation with the Department of Geological Oceanography. Its purpose was to determine causes of bank and channel bottom erosion in the Long Creek Canal connecting Lynnhaven Bay with Broad Bay. Studies were made to determine the effects of channel construction, with observations indicating that the constriction increases water velocity significantly and produces a level of turbulence that is great enough to erode both the channel bottom and side banks. Erosion was also enhanced by submerged riprap sills upstream and downstream of the bridge and by channel realignment during dredging. Proposed remedial action was to eliminate the sills and the lateral constriction at the bridge.

### *Graduate Student Projects*

#### *Two-Dimensional Jet Discharging Into Ambient Fluid of Cross Stream*

Numerical computation was performed for a two-dimensional flow field induced by a plane jet discharging into ambient fluid of cross stream. The boundary conditions simulate the flow of water from the Chesapeake Bay to the Atlantic Ocean. The Coriolis parameter was included in the calculation.

Steady flow patterns have been computed for several values of the ratio of jet velocity to ambient fluid velocity. Unsteady flow pattern is under investigation. Student: M. L. Crane, Master's thesis.

#### *A Mathematical Model of Chincoteague Bay, Virginia*

A two-dimensional time-dependent mathematical model was applied to Chincoteague Bay, Virginia.

The model yields tidal elevations, current velocities in the horizontal plane and concentration of dissolved constituents. This is done through the solution of partial differential equations by the finite difference methods. Student: John Vacarro, Master's thesis.

#### *A Two-Dimensional Water Quality Simulation Model for the James River Estuary*

The concern of this study is the quantitative assessment of various parameters related to the water quality of the Hampton Roads and James River estuary areas of Virginia. A two-dimensional intra-tidal model will be used. One environmental problem which this project will address concerns the waste load allocation for effluents discharged into the study area. Student: Mac Sission, Ph.D. dissertation.

#### *Tidal Prism Model*

An empirical theory has been developed to calculate the equilibrium distribution of pollutants introduced into an estuarine system. The theory is adapted from Ketchum's modified tidal prism method for predicting flushing time in an estuary.

The model which was applied to the Pagan River was derived from the principal of mass balance. The model was

used to calculate high water salinity concentration throughout the estuary so that the predicted results could be compared with actual field data. Student: Angela D'Amico, Master's thesis.

#### *On the Importance of Norfolk Canyon and Continental Shelf Water Circulations*

The objective of this research is to determine the significance of submarine canyons as an avenue of exchange for waters between the continental shelf and slope areas. Student: Evon John Ruzbecki, Ph.D. dissertation.

#### *Wind-Generated Inertial Currents*

Wind-generation of inertial currents in the Atlantic Ocean was studied. A mathematical model which included the effects of the wind field was used to predict the inertial currents. Student: William Saunders, Master's thesis.

#### *A Two-Dimensional Mathematical Model of Coastal Sea Circulation Around the Chesapeake Bay Entrance*

The two-dimensional continuity equation, momentum equation, and mass balance equation of salt, derived by integrating the general three-dimensional equations over depth, were applied to an area of coastal sea off the Chesapeake Bay Mouth. The purpose of the model is to study the effects of different physical factors on the circulation pattern off the Chesapeake Bay Mouth. Student: E. M. Stanley, Ph.D. dissertation.

#### *A One-Dimensional Mathematical Model of Tidal Hydraulics and Salt Intrusion in Estuarine Rivers*

A one-dimensional continuity equation, momentum equation, and mass balance equation of salt were derived by averaging the general three-dimensional equations over the cross-section of an estuarine river. The equations were applied to the James River Estuary and solved numerically with a finite difference implicit scheme. Time varying tidal currents and tidal stages were calculated along the river with upstream freshwater runoff and downstream tidal height as forcing functions. The calculated information may serve as input for a water quality model. Student: Fwu-Ding Lin, Master's thesis.

#### *The Reproduction of Short Term Tidal Data Using the Equation for the Tidal Potential*

The objective of this project was to develop a method by which tidal currents (or tidal heights) can be predicted without the necessity of taking 30 days worth of data and Fourier analyzing the data to calculate individual amplitudes and phase shifts of tidal constituents.

Results of the analysis for data at the same location but collected in different year were compared, and contour maps were made across a transect of the James River for both sets of data. Tidal velocity ellipses were also constructed and compared. Student: Jim Lewis, Master's thesis.

## Geological and Chemical Oceanography

The principal goal of the research programming in the department is to focus on those studies which enhanced the proper utilization, planning and management of the Commonwealth's coastal, estuarine and continental shelf resources. During this report period the quest for offshore petroleum resources on the Mid-Atlantic was initiated and, in response, there was a resurgence of interest on the associated onshore impacts. Within the same time frame the Commonwealth started the formal preparation of its Coastal Zone Plan. This keen focus on the resources of the Chesapeake Bay, the continental shelf and the shoreline of the Commonwealth presented a great challenge and opportunity, to the scientific community to integrate their knowledge and research with those of planners and environmental managers for the utilization of the Commonwealth.

### *Coastal and Continental Shelf Processes*

Considerable advances were made in understanding and coping with the problem of erosion of the Commonwealth's tidal shoreline. Following the completion of an assessment of the magnitude of shoreline erosion over the period of 1850–1950, a study of individual counties was initiated wherein the shore zone was classified in terms useful to planners and managers. The county reports were first line resource documents in the Coastal Zone Planning activity. Included in these county Shoreline Situation Reports was a detailed description of the erosion problem and recommendations for alleviation of the problem. During the report period approximately two-thirds of the Tidewater counties were completed with the support of NSF-RANN and OCZM funding. In the course of doing the Shoreline Situation Reports it became apparent that many of the efforts of the shoreline property owners to combat erosion were ineffective. Consequently, studies were undertaken to develop low cost erosion prevention techniques. Field demonstrations have been most encouraging. In addition, staff within the department now formally participate in the Sea Grant Advisory Service to offer erosion control advice to shoreline property holders.

A comprehensive dissertation was completed on the regional aspects of the causes of shoreline erosion on the Bay proper. One tool used in the study was a complete specification of wave refraction within the Bay which offered an explanation of some of the landforms found.

The ocean shoreline is also under study through funding from the Coastal Engineering Research Center, (CERC) U. S. Army Corps of Engineers. This study, part of a national effort by CERC, attempts to establish the erosion characteristics of the ocean shoreline. Additional studies on the behavior of coastal sand dunes in southeastern Virginia were initiated.

Management of coastal wetlands has become a prime objective in all coastal states. Recent federal interim guidelines will broaden the definition of the wetlands and the scope of federal regulatory authority. The EPA requested, and funded, a study to evolve an objective criterion to delineate the upper limit of wetlands. Our approach utilized tidal datums associated and characterized the vegetation as a function of

tidal elevation. In addition, long term tidal records were analyzed to examine the relationship between immersion frequency and the vertical limits of marshes. The techniques and results will improve wetlands management in the Commonwealth as well as play a significant role in National policy.

Work on the continental shelf continued with the completion of the *Virginian Sea Wave Climate Model*. This study, which covers the shelf and shoreline region between Cape Henlopen, Delaware and Cape Hatteras, North Carolina specifies the refraction patterns of incoming waves. This information is important to site selection of offshore facilities, oil drilling and ship routing as well as shoreline defense planning. Because of our progress in these studies the Bureau of Land Management awarded a contract to extend the study area to the north to include New Jersey and New York. This information was part of the BLM baseline information for evaluating the impacts of oil exploration in the Baltimore Trough Canyon area.

### *Estuarine Sedimentation*

The geological and hydrographical nature of the Chesapeake Bay and its tributaries is such that sediments introduced into the system become trapped. Thus, sedimentation is a major problem leading to siltation of oyster grounds and shoaling of navigation channels. In addition, many of the industrial wastes which are ultimately discharged into the system, become bound to the silt and clay and are thus trapped in the system to act as a pollutant reservoir.

Analyses of river-borne sediment loads washed into the Virginia estuaries showed that the sediment distribution were modulated by the estuarine circulation to form a zone of very high turbidity, called the turbidity maximum. With funding from the Office of Water Research and Technology a mathematical model of sediment transport in the turbidity maximum is being developed to predict the effects of hydraulic changes due to tide, river discharge and salinity. These results will aid in estuarine management so that harmful side effects of channel dredging and landfills can be avoided.

With support of the Corps of Engineers Dredge Material Research Program, a field study of turbidity and fluid mud produced by dredging in the James is in progress to improve our understanding of the basic mechanism causing the dispersal of thick suspension. This work will be of importance in assessing the procedures used in dredging.

The behavior of sediment transport during Agnes flooding, evaluated through a sequence of flood stages, indicates that although changes in bottom geometry were relatively small most of the suspended sediments were trapped in the estuaries as the flood waters passed to sea.

Additional studies were conducted in the Hampton Roads to evaluate the environmental impacts of the construction of the second bridge-tunnel crossing. Our studies dealt with the dispersion of sediment from the site during the construction phase and with the sedimentation characteristics of the subaqueous borrow areas.

Another project in service to the Newport News Shipbuilding and Drydock Company dealt with monitoring

the dispersion of suspended sediment and sedimentation on adjacent sub-tidal flats during the extraction of sand from Hampton Bar in the lower James for use in Shipyard expansion. The objective of the project was to assess local effects of dredging on a real-time basis so that operational modifications could be made to mitigate adverse impacts or prevent their occurrence.

#### *Remote Sensing in the Marine Environment*

Remote sensing from aircraft and satellites, as a tool in the marine sciences, offered several unique attributes. For example, it offered the ability to view large water bodies synoptically. In some circumstances very large dollar savings can be achieved by using remote sensing over other methods. The remote sensing program at the Institute focused on testing the applicability of the methodology by incorporating the tool in ongoing interdisciplinary studies.

In one study sponsored by NASA and Office of Naval Research techniques were developed around the "synoptic" capability to analyze dynamic features of water movement. Using the James River as a test site it proved feasible to monitor changes in water mass boundaries, sediment dispersal and turbid water quality.

As a contribution to the Skylab program imagery of Virginia's water were analyzed to define sediment transport routes. Comparison with other estuaries and coastal systems provided a means to chart offshore routes affecting dispersal of sediment and pollutants.

In other NASA sponsored work the utility of photographic mapping of wetlands flora was examined. Particular emphasis was given to the evaluation of the tonal variations that arise within single images and between successive, side by side, images of the same subject. This work is important to attempts to work with automatic mapping schemes.

A new application of remote sensing was successfully tested wherein black and white infrared film was used to determine tidal volumes for various tidal stages within marsh-lagoon systems. This work has shown usefulness in inlet stability studies and in problems dealing with tidal flushing in embayments.

One of the most valuable applications, in research cost savings, has been the development of a low cost dye-buoy-remote sensing technique to study fluid circulation in the estuarine environment. The technique was used in a number of siting problems. For example, alternate sewage outfall sites in Hampton Roads were rapidly evaluated for their potential for dispersing effluent. Dredging causing sediment dispersal near shellfish beds was monitored; the dredging contractor was there upon constrained to operate only during a "favorable" tide. Oil spill beaching zones were predicted for a proposed oil refinery. Finally, during the course of several of these studies it became apparent that the technique offered the possibility of delineating particular sites in some estuaries where the fluid circulation acted to concentrate surface materials such as oil and that these zones were, as such, natural "carpet sweeper" zones.

#### *Chemical Oceanography*

The program objectives of our chemical studies were to

investigate the baseline chemistry of the estuarine and continental shelf systems and the chemical processes active in the system. These included the geochemical transitions and biochemical mechanisms of incorporation of chemical compound.

In a joint venture with the Department of Physical Oceanography a prototype system for the measurement of benthic oxygen demand was constructed and tested. This work was useful in improving mathematical modelling techniques concerned with water quality.

A major effort was initiated, under contract with the Bureau of Land Management, to establish the hydrocarbon baseline of the Mid-Atlantic Bight continental shelf. Water, suspended particulates, surface film, zooplankton, sediment and epibenthic organisms were analysed for hydrocarbon content. These data will be later compared with results from a similar study carried out during and after oil drilling and production activities for an assessment of environmental impact.

At the request of the Naval Ship Research and Development Center a study was designed to assist the Navy in pinpointing the nature and source of suspected corrosive agent in the James River which was causing problems with Navy ships in the Yard. Sulfide, previously thought to be absent from normally oxygenated estuarine waters, was found in concentrations ranging from 5–30 ppb. Work is now underway by the Navy to establish whether such concentrations are corrosive.

#### *Office of Special Programs*

##### *Marine and Estuarine Sanctuary Study*

The Office of Special Programs conducted a policy study for the Office of Coastal Zone Management, National Oceanic and Atmospheric Administration, U.S. Department of Commerce. The study involved a review of federal legislative history, existing federal, state and private programs and an assessment of public, state, federal and local views on the needs for and objectives of such a program. In addition to the basic study, a case study using the areas adjacent to the Assateague National Seashore and Chincoteague National Wildlife Refuge in Maryland and Virginia as a potential sanctuary area was undertaken.

As a result of the study, federal regulations were promulgated for both Marine and Estuarine Sanctuary programs, and the importance of local views (state, county and municipality) were made apparent to the Office of Coastal Zone Management.

##### *Atlantic Coast Environmental Assessment*

Under a contract to the U. S. Council on Environmental Quality, VIMS personnel provided a two-part summary of the coastal environments along the Atlantic Coast for use in assessing potential effects of oil and gas leasing. The first part provided broad-scale biological and physical oceanographic summarizations from Cape Cod, Massachusetts to Cape Canaveral, Florida. The second part resulted in the production of a 5 Volume report for the Bureau of Land Management on the region from Cape Hatteras, North Caro-

lina to Cape Canaveral, Florida. The volumes in this Socio-Economic Environmental Baseline Summary discussed biological and chemical oceanography, physical oceanography, geological oceanography, meteorology and the sociology and economics area.

#### *National Assessment of Estuarine and Nearshore Marine Environments*

Under contract with the Office of Biological Sciences, U. S. Fish and Wildlife Services, VIMS conducted an assessment of the nation's estuarine and nearshore marine environments with regard to predictions on increased water resource utilization through 1985 and 2000. This study was part of the 1975 National Water Resources Assessment. The environmental, legal, and economic status of the various coastal regions of the U. S. and its territories were described, and based on projected water use for various categories of use, the potential impact of the use was determined.

#### *Outer Continental Shelf Benchmark Studies*

During 1975, VIMS received a contract from the Bureau of Land Management, U. S. Department of the Interior to conduct chemical and biological baseline studies in the Baltimore Canyon Trough area being considered for oil and gas leasing. The multidisciplinary study, including benthic and water column biology, hydrocarbon and trace metal chemistry, wave refraction modeling, bacteriology and supporting physical oceanography, would be based around seasonal sampling every three-four months beginning in the fall of 1975.

Winter and spring cruises were conducted during February-March and May-June 1976. These studies, which are designed to provide background data against which impact of possible oil and gas exploration and exploitation can be measured, will continue for at least a three-year period.

Preliminary findings indicated concentrations of organisms which serve as food for commercial fishes in the swale areas of the wide-spread and swale topography. The neuston studies were providing the seasonal distribution and abundance of eggs and larvae of commercial vertebrates, invertebrates and food organisms.

The Virginian Sea Wave Climate model covering the region from Cape Hatteras, North Carolina to Cape Henlopen, Delaware - originally developed under Sea Grant funding - was expanded to include the entire Mid-Atlantic region from Montauk Point, Long Island to Cape Hatteras as a special project in this initial year's study. This model had pin-pointed areas of increased sea activity which will be the focus of future studies.

#### *Coastal Resources Management*

The Commonwealth of Virginia initiated a formal program of Coastal Resources Management planning under the auspices of the Federal Coastal Zone Management Act. VIMS role was as technical advisors to the lead state agency, the Division of State Planning and Community Affairs.

VIMS principal inputs during the initial year were expansion of MERRMS to support Regional Planning District Reports and a strong involvement in coordinated technical approaches to Chesapeake Bay resource planning with the state of Maryland.

#### *Environmental Data Inventory*

Support for the Environmental Data Service, NOAA, U. S. Department of Commerce, Environmental Data Base Directory continued. During this period, VIMS data inventorying activities were expanded to the Carolinas and Georgia and continued in Maryland and Virginia. This project should be completed early in 1977.

#### *Chesapeake Research Consortium, Inc. (CRC) Projects*

VIMS continued participation with the Johns Hopkins University, the University of Maryland and the Smithsonian Institution in broad-scale Chesapeake Bay research. Major problems involving VIMS personnel during this period included: Biota-related studies of Chesapeake Bay funded by the U. S. Army Corps of Engineers as part of their existing and future conditions studies of the region; a summarization of the effects of tropical storm Agnes on Chesapeake Bay funded by the U. S. Army Corps of Engineers; a program on physical alterations to the edges of Chesapeake Bay and their effects on environmental quality; and a program on the relative impact of selected pollutants from diffuse and discrete sources of water quality in Chesapeake Bay sponsored by the National Science Foundation Research Applied to National Needs Program.

Important contributions resulting from VIMS participation in CRC programs included: the initial shoreline situation reports which were subsequently continued as an integral part of the Commonwealth's Coastal Resource Management program; initial work on chlorine toxicity which has led to several changes in State Water Control Board and Marine Resources Commission approaches to waste water disposal in tidal waters; and the development of the report on impacts of Tropical Storm Agnes on the Resources of Chesapeake Bay.

The true significance of continued involvement in CRC programs lies not in production of specific work products (important as these may be) but in the close interaction between personnel and institutions developed within this multi-institutional framework which enables the resources within these institutions to focus on problems and research areas that are of wide ranging importance and not readily amenable to solution with the resources of only one institution.

Areas of CRC, Inc. focus during 1975-76 period included non-point source pollution and problems associated with development pressures on the shorelines of Chesapeake Bay. A series of case studies were developed in the shorelines program which has provided local, state and federal managers in the two-state areas with an assessment of the cumulative impacts of several types of developments. These studies are providing direct input into the Coastal Resources Management programs of Maryland and Virginia.

## *Manned Undersea Science Programs*

During summer 1974, VIMS personnel participated in an international expedition involving U.S., West German, French and British scientists to Lubeck Bight in the Baltic Sea off the Coast of West Germany.

U. S. scientists along with those of other nations spent up to seven days living in an underwater habitat the UWL HELGOLAND. Using techniques developed in the York River, the U. S. scientists attempted to measure benthic respiration and partition this respiration among components of the ecosystem.

In December 1974, another group of VIMS scientists used undersea technology to study the impact of chlorine and chloramines on benthic communities while working from the U. S. underwater habitat, HYDROLAB off Freeport, Grand Bahamas.

These studies were funded by the Manned Undersea Science and Technology office of NOAA, U. S. Department of Commerce who are working with VIMS personnel in an attempt to develop and/or apply manned undersea technology to the study of mid-Atlantic estuarine and continental shelf problems.

## *Windmill Point Dredge Island Studies*

Under U. S. Army Corps of Engineers Waterways Experimental Station Dredged Material Research Program Contracts, VIMS and Old Dominion University are conducting a multi-disciplinary study of an island created from dredged material off Windmill Point in the James River. Preliminary studies of benthos and water quality were conducted prior and during the island construction. Post construction studies on fish, wildlife, plant succession and benthos, along with chemistry will be continued during the coming year.

## Department of Advisory Services

### *1973-75 Period*

The Virginia Institute of Marine Science has a mandate to serve the people of Virginia not only in research and education, but also in advisory services. Since its establishment in 1940, these advisory activities have drawn upon the expertise at the Institute — primarily in fisheries, environmental quality, wetlands, and related areas of marine science. In recent years, these advisory activities have been considerably expanded. New areas of expertise implemented into the Sea Grant advisory program include coastal zone management, shoreline processes, and economic and business management assistance.

Informal activities during the 1973-74 and 1974-75 periods included over 8,000 contacts with coastal resource users and managers. Responses to information requests fell into several categories, including commercial fishing, biology of marine species, aquaculture, legislation and regulations, seafood processing, disaster assistance, fuel allocation, and availability of recreational facilities.

The increasing number of state and federal regulations led to an accelerated effort to keep audiences better in-

formed. Noteworthy activities included collection, synthesis and dissemination of information on Environmental Protection Agency (EPA) effluent guidelines for seafood processing plants, boat and oil pollution regulations, marine pump-out and sanitation requirements, and coastal zone management criteria.

Compilation of data on the state's fishing and recreational industries, including catch statistics, employment characteristics, and customer activity patterns at marinas, continued to be a regular activity of advisory staff and researchers.

VIMS advisory personnel hosted or participated in the planning of "Fish Expo 74" (Norfolk), the "Wetlands Symposium for Members of the Bench and Bar" (at VIMS), and the "Eutrophication Workshop" (Colonial Beach). In addition, planning assistance was provided to "Seafood 75" (Ocean City, Maryland), a water quality modeling workshop for the state Water Control Board (Richmond), the annual meeting of the Citizens Program for the Chesapeake Bay (Hampton), and the National Advisory Committee of the U. S. Office of Education on marine carriers (VIMS—Williamsburg) along with half dozen other sessions.

Many of these activities were jointly sponsored by the Sea Grant and Coastal Zone Management programs at the Institute. This was facilitated by operating all or part of these programs by VIMS personnel. Planning for future workshops and seminars was initiated for marine business management, the herring industry, marine education and training, water quality modeling and aquaculture.

Assistance was provided in the preparation of articles and reports dealing with wind damage, discharge permits, oil pollution regulations, shedding of blue crabs, and the state and federal permit system for shoreline modification projects. Interviews with news media representatives resulted in the publication of widely circulated articles on oyster hatcheries, jellyfish problems and holding tank information.

Tours and presentations were given on oyster research and hatcheries, crab fishing and shedding methods, seafood processing and Virginia's seafood industry. A *Federal Register* advisory was initiated for state agencies and industry, along with plans for increased representation in trade shows through program exhibits. A new exhibit, emphasizing advisory activities, was prepared initially for "Fish Expo 74", while a second exhibit was constructed for the numerous boat shows held in Tidewater.

The need for regional advisory programs was pursued through closer cooperation with Maryland state agencies, Sea Grant programs in New York, Delaware, Maryland, and North Carolina, plus affiliation with private organizations like the Chesapeake Bay Foundation and Chesapeake Research Consortium, Inc.

Joint research, education and advisory services programs were initiated, with advisory services being a lead agent in concert with program management. Included were cooperation with the state and federal Outer Continental Shelf (OCS) programs, assistance to Mexican oyster fisheries, seafood marketing programs with the Virginia Seafood Council, education programs with the State Department of Education, and cooperative publication efforts with the Marine Resources Commission, Division of State Planning and Community Affairs and the University of Delaware.

## 1975–76 Period

During 1975–76, the programs of VIMS' advisory services staff continued to be directed at meeting the information needs of coastal resource users and managers. Working through media including publications, personal contacts, and participation in group meetings, VIMS' advisory services staff continued to be directed at meeting the information necessary to foster wise, compatible and divergent use of the Commonwealth's marine resources.

### *Commercial Fisheries/Seafood Industry*

The advisory services staff coordinated a preliminary investigation of the economic impact on the Tidewater region seafood industry of the closure of the James River due to Kepone contamination. The study was undertaken for the Governor's Kepone Task Force and was conducted in conjunction with the College of William and Mary's economic department. Other seafood industry-related projects have included compilation of historical data on catches, efforts, fishing methods and licensing requirements and dissemination of this data through publications and conference presentations; assistance and information on design, construction and use techniques of pound nets, fyke nets, and haul seines for industry representatives; and presentation of talks and tours for a number of domestic and foreign industry representatives.

### *Marine Recreation*

As part of its continued contact and interaction with Virginia's boating industry, VIMS' advisory staff played an important part in the formation of the Virginia Federation of Marine Trades, a coalition of six marine trade associations with a membership of over 100 businesses. The program also initiated a survey of marinas and boatyards within the state, and began a study of dry stack storage marinas, specialized boat storage facilities offer significant space and pollution advantages compared to traditional facilities. Other information activities included dissemination of regulations affecting marinas and boat owners, along with expanded availability of information on VIMS' shoreline permit advisory program.

### *Coastal Zone Management*

VIMS' coastal zone management advisory effort during 1975–76 was aimed at informing Virginians of the effect of the federal Coastal Zone Management Act of 1972, creating a better understanding of coastal resource management issues, and promoting involvement of citizens and government in CZM program planning. A number of articles focusing on CZM have appeared in VIMS publications, and CZM presentations were given at several conferences and seminars under VIMS' sponsorship. In addition to the public education and involvement aspect of VIMS' CZM program, the Institute's advisory specialist has provided technical input into the substantive elements of the program and has coordinated input from members of VIMS' staff into the program.

During the 1975–76 period the non-degree marine science education unit and the advisory publications unit, both sponsored by Sea Grant, became part of the The Advisory Services Department in order to more clearly coordinate activities of the various advisory components.

### *Marine Science Education*

In 1975–76, VIMS hosted over 100 educational groups with some 4,000 participants and gave presentations on the state's marine resources, Institute programs, ecological programs, and marine careers. Advisory Services also attempted to provide science education information on a more comprehensive basis through publications, cooperation with educators at the secondary, undergraduate and graduate levels, and teaching aids such as films, slides and color posters. Advisory Services staff also coordinated VIMS' participation in a number of educational conferences, science fairs and career day programs throughout the state.

### *Publications*

The subscription list for VIMS' *Marine Resource Information Bulletin*, produced by the Advisory Services staff, was over 5,000 during 1975–76. *Bulletin* topics included information on activities at VIMS, an educational question and answer column, and material from other sources of interest to VIMS' audience. The *Marine Resource Advisory* series produced two publications on crabs and an economic profile of eastern shore seafood harvesting. In addition, the Advisory Services program continued production of news releases of timely developments and announcements of VIMS activities.

## Department of Information and Education

The Department of Information and Education provided communications links between the research, advisory educational efforts at VIMS and the public. In addition, several services were maintained and managed for the Institute staff and programs.

### *Information Program*

During the report periods the Information Officers produced an average of 24 news releases per year. These were disseminated to newspapers, periodicals, and to radio and television media. The Institute received good coverage, and news stories often were picked up by national wire services and nationally-distributed publications. Communicators also maintained excellent rapport with media reporters, who visited or called frequently seeking information for special feature articles or broadcasts.

In support of the Sea Grant advisory services program (VIMS Department of Advisory Services), a major role of the communicators was to distribute marine resources information to the people who could use it. Serving as the publications arm of Advisory Services, a variety of published materials were developed and disseminated in order to provide technical or scientific information to specific user audiences.

During the 1973–75 periods, two publications, the *Marine Resource Information Bulletin* and the *Marine Resource Advisory Series*, were regularly compiled, edited and printed by the department of Information and Education and distributed to more than 4,000 readers in 39 states and 16 foreign countries. This function was relocated in the Department of Advisory Services during the 1975–76 period, and its subsequent progress is reported under activities of that unit.

The broad cross-section of users who received this information included commercial and recreational fishermen, marine engineers, marina operators, public administrators, legislators, educators, students, mass media and the general public.

The *Bulletin* covered a broad range of subjects, including both Sea Grant research and information collected from a host of sources. The *Advisory Series* was a more specialized publication; each issue treated one subject in detail.

During this report period, the format of the *Bulletin* was changed from a four-page tabloid newspaper style to the more conventional eight-page 8½" x 11", and a 14-page *Advisory "Methods of Handling and Shedding Blue Crabs, Callinectes sapidus"*, by Paul A. Haefner, Jr. and David Garten, was published. In terms of total number of requests, had been one of the most popular articles yet published in the series.

Perhaps the most significant publication during the report period, was *Legal Symposium on Wetlands, An Executive Summary*, by Roger D. Anderson, David Garten and Ted Smolen. In response to interest by wetlands boards, attorneys and enforcement personnel, a Wetlands Symposium for Members of the Bench and Bar was held at the Institute in September 1974. In cooperation with the Virginia Bar Association, Marine Resources Commission and the Division of State Planning and Community Affairs, over 5,000 people (primarily lawyers, judges and planners) were forwarded the eight-page executive summary which detailed the September meeting.

In addition to the regular issues, special bulletins summarizing the annual oyster spatfall results were distributed.

During 1974 over 1600 requests for *Bulletin* and *Advisory* subscriptions, publications and informational services were processed.

### *Education Program*

Just as dissemination of information was a necessary tool in implementing meaningful advisory work, so were the educational activities which helped round out an advisory service program. During the 1974–75 period, emphasis in the education program shifted slightly, as fewer classes visited VIMS while more programs were provided at schools around the Commonwealth. VIMS also participated with the State Department of Education in coordinating the improvement of secondary school science. Earth sciences received the initial emphasis in this program, but eventually all sciences will be included. The education program included a two-day section on marine life, taught as part of the Conservation Short Course offered to teachers at Madison College, the College of William and Mary and Virginia State College, along with many visits to assist individual teachers.

About 250 requests for audio-visual materials were filled during the 1973–75 periods, with 16mm films being the most popular. Over 1,300 letters were answered in 1974, and several teachers came to use the collection of curricula and laboratory manuals, most of which are difficult to obtain elsewhere.

Judges were provided for several local science fairs, as well as for the large Tidewater Regional Congress. The VIMS exhibit of wetlands plants and mounted algae won an award as the best educational exhibit in the Williamsburg Garden Club Show.

This non-degree marine science education effort developed as an advisory function during 1975–76, receiving considerable support from the Sea Grant program at VIMS. As a result, it was moved to the Department of Advisory Services, and its progress during 1975–76 is reported under that unit.

### *Services*

The Department of Information and Education provided form services for the Institute staff during the report periods. These included publications, printing and copying, art and photography.

Publications efforts involved receipt of manuscripts prepared for one of the VIMS report series. The Information Director designed the final version, prepared printing instructions and forwarded each to the appropriate office for printing.

Art and photography services for the staff were rendered by artists and photographers located in the department's service groups. This work regularly involved drawings and photographs for scientific, advisory and educational publications and visual aids.

A small press was acquired during the report periods, and it proved valuable in printing numerous reports, newsletters, advisory publications and various forms. In addition, convenience copy machines located at various stations in the VIMS facility were managed by the Information Office personnel.

### **Marine Environment and Resources Research and Management System**

The Marine Environment and Resources Research and Management System (MERRMS) is a small, special purpose, management-oriented information storage and retrieval system established at VIMS in 1971 to aid in the transfer of interpreted scientific data from scientists to managers and between the several scientific disciplines. Its primary purpose is to serve as a point-source of information and to provide an interface between scientists and managers.

During the report periods, information relative to the coastal zone was received, interpreted and stored to facilitate rapid access. This was achieved through the use of modern data handling techniques including microforms, random access slide displays and computer searches.

The MERRMS library was stored on standard 4" x 6" microfiche. Publications were computer-retrievable via subject descriptors which were assigned to each entry.

During the periods of this report, MERRMS holdings

grew from less than 2,000 documents to more than 5,000 microfiched references ranging from copies of hardcover books and technical publications to such "gray literature" entries as letters, informal reports and newspaper clippings. Documents were selected for relevance to the coastal zone, with emphasis upon the waters of the Chesapeake Bay and its tributaries.

MERRMS served as focal point during "Operation Agnes" in 1972 and during the James River Comprehensive Water Quality Management Study in 1973. As part of VIMS' continuing coastal zone management effort, MERRMS provided each of the nine coastal planning districts with a portable microfiche reader in 1975.

Local Planning District Commissions were provided with monthly lists of acquisitions, and pertinent publications were provided to local planners free of charge. During the 1975-76 period, approximately 330 publications were so provided. MERRMS was also active in the compilation of the Chesapeake Bay Bibliography, and microfiched all references included in the Aquaculture Bibliography compiled by Institute personnel.

MERRMS grew continuously throughout these report periods. By providing a wide variety of information to users throughout the country, it had become an ongoing coastal resource information center of major importance.

## Department of Computing and Statistics

During the report periods major reorganization and growth occurred within the Department of Computing and Statistics. In August 1973 Gerald L. Engel was named head of the department, and in September 1973, Frank Degges joined the departmental staff as a systems analysis. In November 1974 Ginny Shaw was named to a computer programmer position within the department.

The IBM computer system continued to receive heavy use both for local computing and as a teleprocessing terminal during the report periods. It became evident that while the 1130 had served the Institute well, it was inadequate for the needs in computer science. As a result, a background study was carried out to determine computer requirements at VIMS, and this resulted in the installation of a new computer in January 1975, replacing the 1130.

The machine selected was an IBM 370/115 Computer system. The system is configured with 128K bytes of main memory, and in addition to the usual card/punch and printer units, supports two 3340 disk drives, each capable of running 70 million bytes disks, and two 3411 tape drives. The system conversion was smooth with all programs from the 1130 running on the new system within a month after installation. In several cases new programs were designed and implemented to better take advantage of the more powerful resource available. The 370 system is being run under DOS/VS, and supports multiprogramming for local computer programming work as well as supplying the option for teleprocessing to the 360/50 and later the 370/145 at the College of William and Mary.

The department continued in its activities of education and service by providing consulting aid to the staff and students, and by program development as required by the other departments of the Institute. It also continued to

support both the administrative data processing activities and the scientific activities of VIMS. Of particular note in this area, work was begun to design and implement an integrated data base for the administrative activities of the Institute. Also, the hydrographic data base system and supporting information storage and retrieval system which had been resident at the College of William and Mary, was implemented on the 370/115 at VIMS, thus allowing easier access and faster turnaround on requests for these data encompassing the physical characteristics of the Chesapeake Bay and adjacent waters.

Two major specially funded projects were undertaken by the Department during the 1975-76 period. The Data Management portion of the base line study of the mid-Atlantic Outer Continental Shelf, under sponsorship of the Bureau of Land Management of the Department of the Interior, was the first. This work involved development of a project data base system, the development of user programs, and interaction with the federal agencies involved in the program.

The second project, funded by the National Marine Fisheries Service of the Department of Commerce, was to handle data reduction and analysis of the interview data collected in the surf clam industry. This project led to the development of a data base of the interview data and a number of statistical routines for interpretation of the data.

The department maintained an active professional role in the computer science community throughout the report periods. Papers were presented at several technical meetings including the Offshore Technology Conference in Houston, Texas, and the Second International Conference on Computer Education, Marseilles, France, both occurring during the 1975-76 period. Engel served as general chairman for the Conference on Computer Science Education held in Washington, D. C. in February 1975. Several meetings, sponsored by the department, were also held at the Institute including a meeting of the Curriculum Committee on Computer Science of the Association for Computing Machinery in July 1974, and the steering committee of the Curricula in March 1974 and March 1975 respectively.

Additionally, members of the department were involved with the Technical Symposia on Computer Science Education of the Association for Computing Machinery, and the Seventh Conference in Computers in the Undergraduate Curricula during the 1975-76 period. For this latter conference, the selection of papers for the technical program was performed at VIMS.

Department members were also active in a project of the Association for Computing Machinery to assess the computer impact on society. Several committee meetings of that project were held at VIMS during the 1975-76 year. This work was funded by the National Science Foundation.

## Oceanographic Library

During this period the Library increased its services as well as its acquisitions. Our total number of books and bound periodicals grew from 17,500 to 21,000. Many serial titles were added to support new subject areas, e.g. coastal zone management, and environmental law.

We continued to service more interlibrary loans and photoduplication requests. There has been a substantial growth in circulation of all library material. Within this period we began to acquire a considerable increase in the number of patrons from outside the Institute representing other state agencies, academic institutions, and private consultants as well as international clientele.

VIMS contributions for 1973 and 1974 were compiled and printed for our updated exchange program with the world-wide marine science community.

A bookstore was created under the Assistant Librarian to supply textbooks as well as personal books for students and staff.

VIMS publications have been receiving greater distribution therefore considerable time was required to list, provide easy access storage and mail out this material. The Library maintains a standing order list for the shoreline situation reports as they are published.

In January 1975 we published the Chesapeake Bay Bibliography, Maryland Waters. During this period we continued to develop the Chesapeake Bay Bibliography computer file. Our primary purpose in preparing this series is to develop a comprehensive research and information services program for those interested in management of and research on the environments and resources of the Chesapeake Bay region. At this time the file contains about 3,400 citations and proves to be most useful in answering reference questions concerning the Bay.

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