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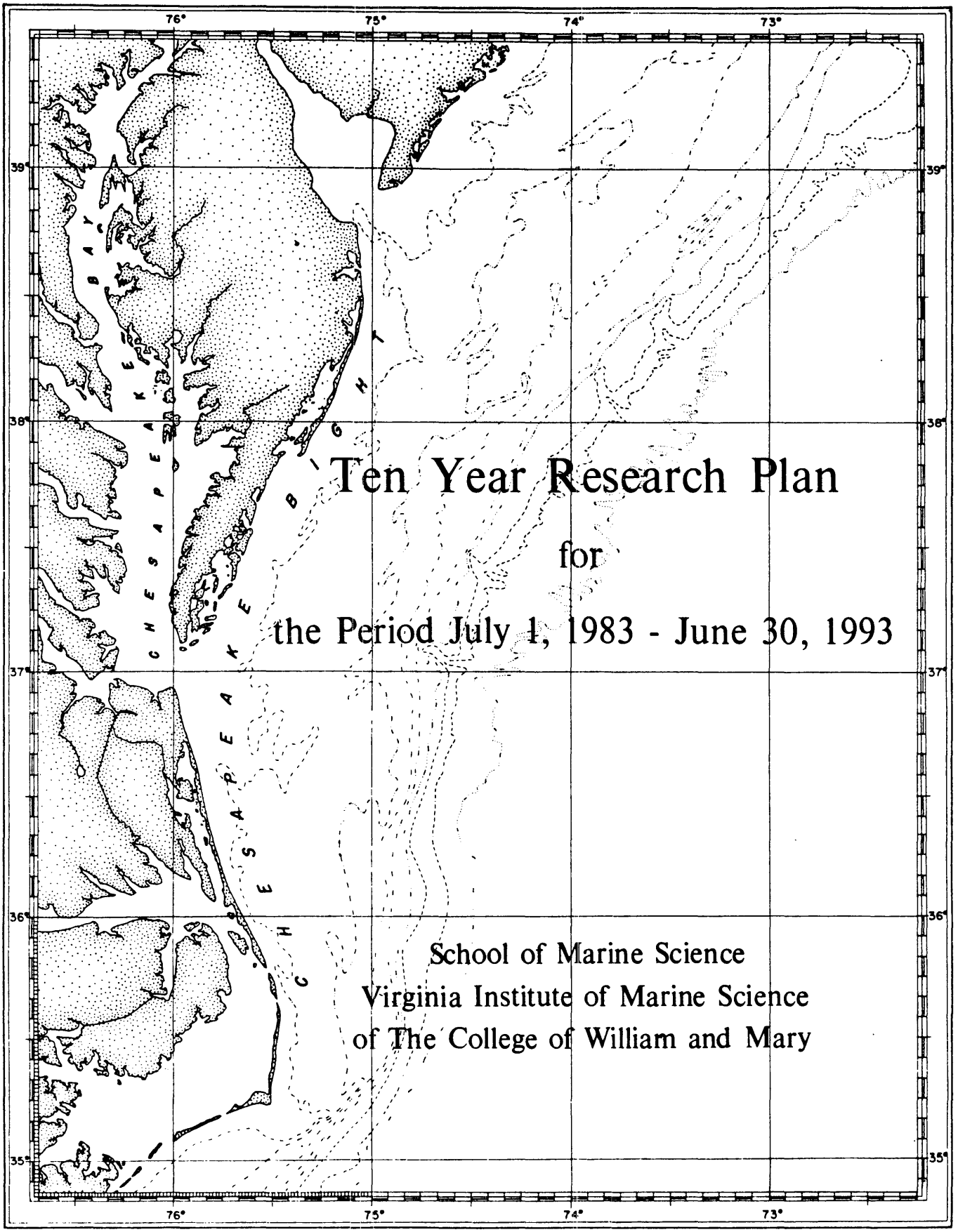


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School of Marine Science, Virginia Institute of Marine Science, College of William & Mary. (1983) Ten Year Research Plan for the Period July 1, 1983- June 30, 1993. Virginia Institute of Marine Science, College of William and Mary. <http://dx.doi.org/doi:10.21220/m2-e2e0-6q63>

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Ten Year Research Plan
for
the Period July 1, 1983 - June 30, 1993

School of Marine Science
Virginia Institute of Marine Science
of The College of William and Mary

TEN YEAR RESEARCH PLAN

FOR

THE PERIOD JULY 1, 1983 - JUNE 30, 1993

School of Marine Science
Virginia Institute of Marine Science
of the College of William and Mary

Executive Summary

A formal plan, developed to improve the efficiency and effectiveness of research activities at the Virginia Institute of Marine Science, is presented. It is a comprehensive and long-term plan, constructed from the deliberations of the entire VIMS research staff and interaction with management agencies and industrial interests. It addresses those management issues perceived to be of greatest importance to the Chesapeake Bay system over the next ten years.

Research needed to provide information of pertinence to management issues has been clearly separated from monitoring programs routinely conducted to assess water quality, abundance of economically important living resources and other aspects pertaining to the "health" of Virginia's waters. The latter provide the baseline and background information needed to weigh and predict effects of natural and man-made perturbations to the ecosystem.

Basic and applied research plans at the Institute have been divided into 15 program areas: fisheries, benthic communities, plankton, tidal freshwater ecosystems, wetlands, diseases, aquaculture, toxic chemicals, nutrient cycling, nutrient enrichment, benthic boundary layers, circulation, shoreface processes, geologic history, and marine resource management. Each program plan includes a list of management issues pertinent to research results, a statement of the need and justification for the research, and details of specific research objectives within the program.

Specific research objectives in the body of the plan include (but are not limited to) the following:

- determining the mechanisms of recruitment of larvae to the James River oyster seed beds and causes of the decline in seed oysters
- studies of factors affecting blue crab larval recruitment and survival of post-megalopal stages within the Chesapeake Bay
- studies of the recruitment, growth and mortality of anadromous fishes, ocean spawners, and endemic Bay fishes
- evaluation of the relative value of various bottom habitats to the estuarine ecosystems
- understanding of the effect of physical features such as neap-spring destratification of the water column and estuarine fronts on the plankton community
- assessment of the structure, function and value of tidal freshwater reaches of major rivers to the estuarine ecosystems
- studies of the structure and function of mesohaline wetlands (marshes and submerged aquatic vegetation) and their value as habitat for juvenile blue crabs
- definition of life cycles, distribution and effects of oyster and finfish pathogens
- development of practical and economical techniques for the culture of important estuarine and marine species

- determining the fate and effects of toxic chemicals, including PNA's, polar organic compounds, Kepone, hydrocarbons, humates and trace metals in the estuarine environment
- descriptions of spatial and temporal distribution and rates of transformations of nutrients in the estuary
- examination of factors leading to damaging nutrient enrichment from non-point sources
- understanding interactions of physical, chemical and biological processes at the important benthic boundary layer
- determining and explaining temporal and spatial variations in estuarine circulation
- examining the relationship between coastal environmental conditions and shoreface changes

A separate and final section of the Plan is devoted to monitoring activities required at the Institute in the foreseeable future. The eight programs consist of monitoring plans for fisheries, plankton, bacteria, parasites and pathogens, benthic invertebrate, estuarine plant communities, coastal erosion, and physical and chemical parameters.

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I. FOREWORD

Formed in 1940, the School of Marine Science/Virginia Institute of Marine Science has been involved for decades in providing advice to managers of Virginia's marine and estuarine natural resources. In 1962 the mandates of the Institute were formalized in the Code of Virginia, Chapter 9, Section 28.1-195 (see Appendix A). Those mandates include the charge to conduct advisory services, research, and education activities in the marine and estuarine environment. The Institute has taken those duties seriously and has performed well in all three areas.

The purpose of this document is to present a formal plan which will improve the efficiency and effectiveness of research activities conducted by the faculty and staff over the ten years starting July 1, 1983. The Plan will guide the allocation of State funds and assist in determining which grants and contracts are sought in efforts to supplement the Institute's research capabilities.

Most Virginians recognize the importance of fisheries whether as a source of food, a recreational experience or the basis of an industry which supports thousands of people. Fish and shellfish are renewable resources that can be harvested indefinitely, so long as the harvest does not exceed the capability of the animals to maintain the populations. Maintenance of a self-perpetuating stock would be facilitated if we could accurately estimate the size, distribution and rates of removal from the population. However, the populations are not enclosed where conditions can be kept favorable, where no climatic events can harm them, or where the stock-size can be determined with high accuracy. The stocks live in an open system (the Chesapeake Bay and Continental Shelf waters) where numerous and diverse naturally occurring events can and do impact the populations. It is not a simple matter to estimate the numbers of striped bass, menhaden, crabs or other organisms present in our waters at any one time. Yet, without such information the Institute cannot intelligently advise the management agencies on policies for marine resource management. This translates into a mandatory need for a thorough, sophisticated, long-term monitoring program to keep track of the fish and shellfish populations. A monitoring plan is therefore included with this document as an essential part of the research plan.

Many natural changes are not beneficial to fish and shellfish. A severe winter, a prolonged drought, a hurricane or a very wet year can devastate a population. Therefore, it is important to understand the natural environment in physical terms and to be able to recognize the effects of physical events on fishes or other animals and plants. The Virginia Institute of Marine Science employs physical oceanographers,

chemists and geologists to work with the biologists to meet those needs. A major goal of this research plan is to ensure that the physical scientists conduct research which develops an understanding of how living systems function and respond to stress. The living systems of greatest interest include commercially and recreationally important finfish, shellfish, and the organisms that are their predators or prey.

Fish and shellfish populations not only must survive these natural pressures but must contend with fishing pressures. Corrective measures are difficult to institute because many who fish for a living resist efforts to control the catch if it means reducing catches over the long term; however, if irrefutable scientific data are available and properly interpreted, harvesters can be more readily convinced by managers that purposeful reduction in catch is prudent and reasonable.

Man uses the Bay as a disposal area for many kinds of waste, including sewage, industrial wastes, hot water, and sediment. Many wastes are harmless unless they are released at the wrong place or time; some are toxic, not only to fish but to people. Some wastes are high in nitrogen and phosphorus and can trigger red tides or other plankton blooms. Eventual die-off of these blooms may reduce dissolved oxygen to levels stressful to finfish and shellfish populations.

The measurement of long-term effects and predictions of water quality require continuous monitoring. How to protect the fisheries and the quality of the Bay itself from these man-made problems requires not only scientists to measure and analyze the environment but marine resource managers to use the information once the effects are known. Management itself lies outside the mandate of the Virginia Institute of Marine Science but research on management is an important and integral part of the Institute's activities. In short, if we want the Bay and Shelf to perpetually produce desirable finfish and shellfish, it is clear that we have to learn as much as possible about the system and manage it wisely.

Although fisheries are very important commercial and recreational entities in Virginia, and it would be difficult to imagine living in Virginia without them, these are not the only industries which are supported by the Bay. In fact, if one uses dollars as a criterion then the business dollars generated by fisheries are small compared with those generated by recreation, shipyards, real estate, and marine transportation. The value is also small compared with the business generated by those who retire near the Bay simply because of the quality of life they find here. However, it would be hard to find someone who would accept a "dead" Bay for use solely as a dumping site for heavy industry and for use as a medium on which to float vessels because it might be cheaper to destroy it than maintain its biological viability. The Virginia Institute of Marine Science, therefore, focuses its efforts on providing information for management of the living resources of the Bay in a manner which permits maximum

sustainable use. The Code of Virginia recognizes the need to aid all segments of the economy and citizens of the Commonwealth who engage in Bay- and ocean-related activities.

Man needs timely technical information about the effects of his activities if he is to use the Bay in a harmonious manner without degrading it. He needs to know the effects of port modifications, placement of dredged spoil, addition of more waste, erosion control measures, and the construction of marinas before he spends time and money planning and executing the activity. Often definitive information is lacking; therefore, until the appropriate research is completed one cannot give the best advice. The research plan, therefore, is put forward as a guide in our efforts to implement and satisfy the mandates stated in the Code of Virginia. It will be amended and refined in the future as the need arises.

II. DEVELOPMENT OF THE PLAN

A. Goal and Uses of the Plan

The general goal of the RESEARCH performed at the Virginia Institute of Marine Science can be phrased as follows:

GOAL

To conduct general and applied research for the purpose of providing timely and accurate information to the Governor, General Assembly, State and local agencies, industry and citizens of the Commonwealth of Virginia regarding utilization, conservation and enhancement of the resources both living and non-living of the Chesapeake Bay system and coastal waters of the Commonwealth.

The research plan for the Institute was, therefore, designed to be one which significantly advances the general "state of knowledge" of a marine and estuarine science; is in accord with the mandates of the Code; addresses problems pertinent to issues of importance to the Commonwealth; and effectively utilizes the talents and research interests of personnel.

There are four principal uses of this research plan:

1. To identify the scope of the research needed to meet the requirements of the Commonwealth, and in particular to give focus to those problem areas needing the most urgent attention.
2. To provide a planning mechanism for efficient programming of State funds, and to identify those research areas where particularly aggressive effort should be placed in gaining extramural funding.
3. To ensure that any pursuit of extramural funding is controlled and within the context of a long range coherent plan.
4. To identify the additional personnel and equipment resource needs which must be obtained for satisfactory completion of the coherent plan.

B. Constructing the Plan

Before discussing the steps which were taken to arrive at the plan, one should note some of the resources which went into this formulation. The plan development utilized the entire research staff (approximately 800 man-years of research experience on the Bay and coastal waters)! By virtue of the mandate of the Code of Virginia to advise State agencies and officials, and the public, the research staff has always associated its basic and applied research with marine resource issues. Thus, the research needs identified are derived from seasoned expert opinions.

The plan was formulated following the four steps listed below:

1. The important management issues arising from conflicts among the primary users of the Bay were identified. As well, the role of marine related research in resolving these issues was evaluated.
2. Eighteen interdisciplinary task forces, representative of the major required research elements, were formed. This facilitated the identification of research needs across the spectrum of existing programs. Each group identified their major goals and appropriate objectives, assigned priorities to the research elements, and identified gaps in our research capabilities. These reports were the building blocks for the plan. Examination of the reports indicated strong commonalities between objectives of the independent task forces. From these, it was possible to frame a general set of research objectives for the entire program.
3. Since sufficient funding is not likely to be available to advance all of the identified studies simultaneously, priorities for major programs and objectives were established and identified in terms of starting dates: July 1, 1983, July 1, 1984, and after July 1, 1985.
4. The draft plan was circulated and/or discussed with Virginia State Agencies, industry representatives, Legislators, and the public. Feedback was evaluated and incorporated into the final plan.

C. Uses of the Bay and Associated Management Issues

In order to ensure that the research plan is relevant to the important issues facing the Commonwealth three questions were posed:

1. How does Virginia use its coastal waters and the Chesapeake Bay system?

2. What will be the issues in the next ten years which will affect the uses of the Bay and coastal waters?
3. To what extent can marine related research be helpful?

In answer to the first question, "What are the uses of the Bay?": a panel of VIMS scientists concluded that virtually all uses would fall into one of six broad categories.

The Bay and coastal waters are used mainly for:

1. A source of fish, crabs and shellfish for both commercial and private use.
2. Recreation in all its forms: sailing, hunting, fishing, swimming, etc.
3. Commercial marine transportation and all its ancillary industries: shipbuilding, shipping, military, etc.
4. Improved quality of life for human habitation: the reason why many people live near or along the fringes of the Bay or coastal beaches.
5. A source for non-living resources such as sand and gravel.
6. A depository for waste of all types: human, industrial, thermal, etc.

To answer the second question, "What will be the issues which will affect the uses of the Bay system and contiguous waters in the next decade?", we drew on the hundreds of man-years of expertise of the scientific staff at the Institute and their involvement with management issues to identify the most likely relevant issues (Table I).

The final question "To what extent can marine research be helpful?" was addressed utilizing matrix analyses. A group of scientists representing all the major disciplines at VIMS individually rated the effect that research could have on issue resolution. A cross-impact analysis determined the overall ranking (Table II).

Readers should keep in mind that Table II is simply a guide to help focus research. The table does not imply that because "offshore facilities" happens to rank tenth that research on the subject is unimportant. It could be quite important in the next ten years. The table simply provides a means to identify on a relative basis where research efforts have the highest probability of significant yields, utilizing resources now in existence at the Institute or resources that are attainable in the near future. For example, we do not anticipate building a strong ocean engineering program in the near future to answer questions relative to offshore facilities. On the

TABLE I

MANAGEMENT ISSUES

1. Water Quality - Impacts and Control:
 - a. Toxic Chemicals
 - b. Nutrient Enrichment
 - c. Microbial and Viral Contaminants
 - d. Thermal Additions
 - e. Other Nontoxic Wastes

2. Fisheries
 - a. Resolution of Fisheries Conflicts
 - b. Maintenance or Enhancement of Desirable Fisheries Stocks
 - c. Freshwater Diversion and Impoundments
 - d. Conservation of Marine Species Protected by Law (Endangered, Threatened, etc.)

3. Maritime Commerce
 - a. Port Development
 - b. Dredging and Dredge Spoil Disposal
 - c. Construction and Siting of Offshore Facilities

4. Shoreline Development
 - a. Wetlands Protection and Use
 - b. Shoreline Erosion Control

5. Non-Living Resource Use
 - a. Sand and Gravel Mining
 - b. Oil and Gas Extraction
 - c. Geothermal Energy Extraction

TABLE II

MANAGEMENT ISSUES WHICH WILL AFFECT USES OF THE BAY
AND COASTAL WATERS LISTED IN THE ORDER IN WHICH
MARINE RESEARCH IS MOST LIKELY TO HAVE AN IMPACT

1. Impact and Control of Municipal, Industrial, Residential, and Agricultural Waste
2. Resolution of Fisheries Conflicts
3. Maintenance or Enhancement of Desirable Fisheries Stocks
4. Wetlands Protection and Use
5. Port Development
6. Shoreline Erosion Control
7. Impacts of Dredging and Dredge Spoil Disposal
8. Freshwater Diversion and Impoundments
9. Non-living Resource Use
10. Construction and Siting of Offshore Facilities

other hand, some involvement with research on offshore facilities could occur with existing Institute resources, particularly with respect to siting.

III. RESEARCH PLAN

The following plan is presented in 15 disciplinary areas or programs, all of which, to one degree or another, are designed to obtain pertinent information to address management issues. Two of the larger programs (I. Fisheries and VIII. Toxic Chemicals) are divided into subprograms. The individual programs include a list of management issues likely to benefit from the program's objectives, a statement of justification and purpose of the program, research objectives, and planned starting dates.

PROGRAM I. INVESTIGATE THE FISHERIES OF VIRGINIA AND FACTORS AFFECTING
FLUCTUATIONS IN ABUNDANCE

A. Issues:

1. Effects of Toxic Chemicals on Water Quality
2. Effects of Microbial and Viral Contaminants on Water Quality
3. Resolution of Fisheries Conflicts
4. Maintenance or Enhancement of Desirable Fisheries Stocks
5. Conservation of Marine Species Protected by Law (Endangered, Threatened etc.)
6. Freshwater Diversion and Impoundments
7. Dredging and Dredge Spoil Disposal
8. Construction and Siting of Off-shore Facilities
9. Wetlands Protection and Use

B. Purpose:

The once seemingly infinite marine fishing resources that have been the foundation for the economy and lifestyle of Tidewater Virginia since pre-Colonial times are now recognized as critically finite. Only through sound, informed management can these limited, but infinitely renewable resources, be maintained in perpetuity. The Code of Virginia clearly directs the Virginia Institute of Marine Science to conduct such assessment programs as are necessary to provide the managers of the resources with required data and information.

Fishing pressure, water quality degradation, and natural changes in the environment exert interwoven pressures on the living resources of the Bay. This Program's biological research is focused on isolating or identifying the impacts of these pressures and exploring means by which they may be alleviated.

- C. There are five principal subprograms in Fisheries Research, dealing with shellfish (primarily oysters), blue crabs, finfishes and endangered species.

SUBPROGRAM I(a): INVESTIGATE THE CAUSES FOR THE POST-1960 DECLINE AND INTERANNUAL FLUCTUATIONS IN RECRUITMENT OF OYSTERS ON THE JAMES RIVER SEED BEDS

The oyster seed beds of the James River, serving as a source of seed for planting on public and privately-leased bottoms for the last 100 years, constitute one of the major natural resources of the Commonwealth. A sharp decline in the abundance of spat since 1960 has resulted in a much reduced abundance of seed oysters. Productivity of the beds is adequate today only because of low demand. If demand increases or a further decline occurs, oyster production will be largely eliminated from leased bottoms in Virginia. Causes of the post-1960 decline have not been defined. Present and future studies are designed to elucidate those factors that operate to maintain natural productivity of the James River seed beds and gain knowledge necessary for management agencies to prevent further deterioration of the environment and to enhance productivity.

Objectives:

1. Determine biological factors which influence settlement of oyster larvae on shell substrate and subsequent spat survival during the first growing season

Long-term studies at VIMS show that oysters set in the James River seed area from late June through early October. They demonstrate consistent weekly and seasonal changes within 3 distinct areas. A relationship is suggested between weekly setting patterns and neap-spring tides. The data have also demonstrated a major decline in set since 1960. Moreover, since 1960, wide variation in annual set and survival rates have been demonstrated.

While the preceding aspects are well documented, the cause of the decline has not been determined. Almost no quantitative data exist for the James River on factors which determine initial attachment rates, intensity of set and the causes of the subsequent mortality during the first growing season.

It is necessary that we fully understand the biological factors which influence spat attachment and survival and determine whether these factors are in any manner associated with human activities. By understanding these factors we may be able to develop adequate management techniques to support setting.

Therefore, we propose to obtain quantitative data on mortalities associated with fouling organisms such as mussels, barnacles, bryzoans, and polychaete worms, and predators such as Odostomia and Stylochus. Microfouling by blue-green algae within oyster shell substrate will be investigated with respect to setting intensity. Exploratory searches for possible mortality-causing bacteria and viruses will be conducted as well. Starting Date: July 1, 1983

2. Develop an understanding of how hydrographic factors affect distribution and abundance of oyster larvae on the seed rocks, in relation to their point of origin

Oyster larvae are planktonic for a period of about 2 weeks after fertilization. Therefore, the site where larvae eventually set at the end of the planktonic stage could be near to, or remote from, the location of the spawning broodstock. In any event the final distribution of larvae will largely be determined by the circulation patterns of water masses in the James River. While the general circulation patterns of the James are known in the classical sense, almost nothing is known of the small scale details or secondary circulation. We must, therefore, establish a general overview of circulation in the estuary as a whole over extended periods of time (months, seasons) as well as circulation over smaller areas over shorter time intervals. This information will eventually be applied to describe the sources and distribution of oyster larvae in the estuary (cf. PROGRAM XII on Circulation).

Specifically, we should study exchanges between: upriver and downriver portions of the James; north and south sides; channel and shoals areas; surface and bottom waters; and over and in the vicinity of the seed beds. These studies should extend over sufficient time periods to include fortnightly tidal variations and seasonal phenomena.

Exchanges between James River water and waters of the Chesapeake Bay and other tributaries of the Bay, and between the James and its smaller tributaries should also be studied in relation to the transport of oyster larvae as should the effect of frontal regions and convergence zones on larval distribution and setting (cf. PROGRAM XII).

Starting Date: July 1, 1984

3. Determine long-term trends in survival of yearling and older oysters on the seed beds in the James River

The decline in spatfall noted in 1960 over the seed beds makes it desirable to monitor them to determine if the trend is continuing. The seed beds are heavily fished each year and there is a strong possibility that some areas may be harvested so heavily (in addition to the existing level of natural mortality) that annual recruitment will not be sufficient to maintain a viable seed area.

Since it is necessary for scientists, industry, and management to understand all factors which impact on the seed area we propose bi-annual surveys of the seed rocks. Incidence of Minchinia nelsoni and Perkinsus marinus will be monitored. The stocks will be evaluated as in the past, for numbers of older oysters per unit volume of cultch and abundance of shell substrate. Data on catch per unit volume will be obtained from the Virginia Marine Resources Commission.

Starting Date: July 1, 1983

4. Estimate the relative contribution of oyster stocks to the oyster larval pool in the James River, Virginia

The James River oyster beds have been and remain today the primary source of plantable oyster seed for the leased oyster beds in Chesapeake Bay. The source of larvae recruited to these seed beds remains unknown. The marked decline in productivity of the seed beds has been attributed to many causes, two of which are:

- elimination of broodstock oysters in the Hampton Bar area by MSX,
- reduction in fecundity of broodstocks as a result of increasing pollutant loads in the James River estuary.

One cannot go back in time and determine what oyster stocks supplied the seed beds in the pre-1960 era. We can, however, determine where significant quantities of adult oysters exist in the James River today and their potential contribution of larvae to the system.

There are several steps to this project. First, we must identify those areas in which there exist adult oysters and determine their abundance in each area. Second, the gamete production of oysters from

specific locations in the James River must be determined. Third, a standard and reliable procedure to evaluate spawnability of the oysters and viability of the resultant larvae must be developed and applied to potential broodstocks.

Starting Date: July 1, 1984

SUBPROGRAM I(b): INVESTIGATE THE INTERANNUAL FLUCTUATIONS AND STOCK RECRUITMENT OF THE BLUE CRAB

The blue crab fishery is one of the leading crustacean fisheries of the United States. It is particularly important to the economy of Chesapeake Bay. The species is characterized by the production of large numbers of young, rapid growth, early attainment of maturity, high natural mortality and a short life span. This allows high levels of fishing effort, but also renders the resource highly subject to variation in the physical environment. These physical mechanisms affecting year class strength require further study if an understanding of catch fluctuations and predictions to the industry are to be improved.

Objectives:

1. Define the spatial and temporal distribution of planktonic stages of the blue crab and elucidate biotic and abiotic factors which control their distribution

The first zoeal stages of the blue crab appear in summer months (June-August) over a broad area including the Chesapeake Bay mouth and the inner shelf of Virginia. Behavior of the first 3 or 4 stages places them in surface waters where they may be dispersed by currents, some being carried out of the Bay and subjected to shelf currents and further transport. Return to the Bay probably depends on behavioral changes through development, in the form of descent of advanced zoeae and megalopae to inflowing deep waters. A less favored hypothesis, proposed by others, suggests transport of late stages in surface waters around Cape Charles that in turn depends upon seasonal changes in wind direction and in peculiarities of current patterns off the Bay mouth.

Although predictions of crab harvests in any given year may be adequately constructed from assessment of juvenile crab abundance in the preceding months, numbers of juveniles in the Bay are governed by the magnitude and success of larval drift into, and retention within, the Bay. Present knowledge is contradictory and inadequate for a full understanding of the mechanisms and factors affecting the return of early stages of the blue crab to Chesapeake Bay.

The depth distribution of crab larval stages belonging to specific cohorts and the water circulation patterns in the vicinity of the mouth of the Bay will be studied concurrently and in detail (cf. PROGRAM XII on Circulation). This entails intensive sampling in lower Chesapeake Bay, the Bay mouth and the inner continental shelf off Virginia from June through early September, using depth-discrete samplers. Occurrence of early vs. late stages of developing blue crab larvae by depth and

proximity to the Bay mouth, related to measurements of net water movements, will provide the information necessary for testing of hypotheses advanced thus far to explain blue crab recruitment.

Starting Date: July 1, 1984

2. Develop an understanding of the influence of biotic and abiotic factors on distribution and abundance of blue crabs in all post-megalopal stages

Maintenance of the population of blue crabs in the Chesapeake Bay is dependent on the successful completion of all the life functions characteristic of the species while exposed to all the variations in the biotic and abiotic features of the environment.

Details of growth, reproduction, respiration, nutrition, osmoregulation and migration, for example, must be known so that proper interpretation can be given to determining when and how variations in the environment and their ecological relationships affect these functions. One hypothesis is that year class strength is determined by environmental factors acting on critical stages in the life history of the blue crab. Environmental variables such as temperature, river and Bay discharge, incident sunlight and wind components will be selected for study of their relationship to survival which is represented by commercial fisheries landings and by estimates of juvenile crab abundance (cf. Monitoring Program I).

Starting Date: July 1, 1983

3. Determine the relative importance and functional role of various estuarine habitats as nursery areas for juvenile blue crabs

Although much research has been conducted on the blue crab in the Chesapeake Bay and other areas along the Atlantic and Gulf seaboard, the identity, relative importance and functional role of different estuarine habitats, e.g., submerged aquatic vegetation (SAV) beds, marshes, unvegetated shoals and deepwater channels, remain poorly understood. This is particularly true with respect to the juvenile segment of the blue crab populations. We do not know how, if at all, the various estuarine habitats operate as nursery areas for juvenile crab stages. Analyses of different estuarine habitats will include determinations of several characteristics of the resident crab stock (e.g., abundance, sex and size frequencies, residence time, feeding habits and the nutritive value of food consumed). Such information is paramount to determining implications of natural and man-induced perturbations on critical nursery habitats for blue crab stocks within the Bay. Thus, comparative studies which will enhance our understanding of the relative value and functional role of the various nursery habitats are of extreme importance for successful management of the blue crab resource (cf. PROGRAM V on Wetlands Ecology).

Starting Date: July 1, 1983

4. Evaluate the behavioral and physiological responses of blue crabs to chemical and physical pollutants

During the past decade the landings of blue crabs have shown fluctuations, sometimes attributed to the effects of chemical, and to a

lesser extent, physical pollutants. To date few studies have addressed the effects of toxicants on the blue crab; studies have mainly involved the effects of chlorine and Kepone. It has been shown that juvenile blue crabs are more sensitive to chlorine than adults. Responses of early stage juveniles should be determined for various toxic chemicals common in Chesapeake Bay. Studies of decreased ability to resist parasites as a result of exposure to toxic chemicals are also needed (cf. PROGRAM VI and VIII).

Starting Date: July 1, 1984

5. Develop new predictive models of blue crab abundance

Predictions of the potential yield of the blue crab fishery may provide managers, industry and the general public with the basis for devising effective regulations and directing the intensity of fishing effort, processing and marketing. Results from monitoring juvenile crab abundance (cf. Monitoring Program I) and studying the relationship between environmental variables and crab survival (Objective 2) will be used to develop a new predictive model.

Starting Date: After July, 1985

SUBPROGRAM I(c): INVESTIGATE BIOLOGY AND INTERANNUAL FLUCTUATIONS IN RECRUITMENT OF FISH

Recreational and commercial fisheries, changes in water quality, and natural environmental fluctuations are placing increasing pressure on the finfish stocks of the Chesapeake Bay and contiguous Atlantic Ocean. Management agencies, reacting to this pressure and the need to conserve the resource, are requiring increased data and information flow to develop informed management plans.

Much pressure comes as conflict between the commercial and recreational users, forcing the Virginia Marine Resources Commission or regional agencies such as the Atlantic States Marine Fisheries Commission to allocate the available resource. We must, with accuracy, predict on an annual basis, the size of the harvestable resource and the biomass needed to sustain recruitment. Changes in water quality and natural climatic shifts also influence the recruitment capability of the stocks. We must be able to quantify this alteration.

Objectives:

1. Study the dynamics of recruitment, growth and mortality of striped bass, shad and river herring in selected Virginia rivers, with emphasis on eggs, larvae and juveniles

Striped bass, shad, and river herring, as anadromous species, exemplify the dilemma of the harvestable coastal fish stocks. Both commercial and recreational fishing interests consider those stocks as priority target species. As such, overfishing is a very real problem. Fishing pressure has, in fact, increased despite declining stocks. Further, these anadromous stocks spawn in the very regions of the rivers where significant pollutants are introduced and available wetlands threatened or altered.

Significant interannual fluctuations in juvenile abundance have been observed throughout the Chesapeake Bay. These have been reflected in subsequent and corresponding fluctuations in commercial catch statistics.

We propose to intensify our efforts to understand the spawning stock and environmental relationships to eggs, larvae, and juveniles, and the subsequent dynamics of recruitment into the stock. Commercial catch data will be used as indices of spawning stock size, our juvenile survey indices as recruitment estimates, and both archived and field-measured physical data as the environmental input in spawner-recruit models. Daily growth rates for larvae will be investigated from otoliths. Also investigated will be larval and juvenile food and feeding habits in an effort to determine causes of early life history mortality.

We also plan to examine predator-prey relations and intraspecies competition as sources of mortality, particularly among juveniles. This will be accomplished through stomach analyses of: 1) various size classes of striped bass, shad, and river herring; 2) those species such as white perch that may, as juveniles or adults, compete; and 3) those species that may be predators including adult striped bass, flounder, and bluefish.
Starting Date: July 1, 1983

2. Assess the recruitment to Bay waters of larvae and juveniles from ocean and Bay mouth spawners, such as menhaden, croaker, spot, weakfish, summer flounder and bluefish

Many of the most important species of fish in the Chesapeake Bay spawn in the ocean or Bay mouth. The summer fish population in the Bay is dominated, both in numbers and biomass, by these oceanic transients.

Preliminary investigations have shown a strong relationship between the physical environment and recruitment of many of these species. Changes in atmospheric conditions appear to be particularly important. Understanding and developing models to quantify the relationships between spawning stock size, physical environmental factors and subsequent recruitment are the key to accurate forecasts of abundance and catch. Indices of upwelling, times of seasonal wind shift, temperature and streamflow will be developed from VIMS and Federal environmental archives. These will be modeled statistically with standard spawner-recruit population models.

Roles of these fish (e.g. bluefish) as predators, particularly during periods of abundance may also be a key in determining year class survival for smaller prey species (e.g. juvenile croaker). Quantification of the biomass of prey consumed must be made and the energy pathways measured.

Starting Date: July 1, 1984

3. Continue refinement of juvenile fish sampling and data management methodology, critical to prediction of future landings

The juvenile fish survey has primarily used an otter trawl during the 25 years encompassed by the program. Several changes in gear and vessels during this period and changes in sampling strategy necessitate that these

sources of variation in the data be accounted for, and a final standardized technique and gear be used. The Bi-State Working Committee has directed Virginia and Maryland to coordinate and standardize this effort. A beach seine has also been used sporadically during the past decade. This too will be standardized with Maryland's survey methodology.

Rapid analyses, storage, and retrieval of the data following each cruise is essential if the data are to be used both in research and as a source of information for the management agencies and industry. Computer programs to facilitate the flow of data and information will be developed.
Starting Date: Continuing

4. Study the dynamics of intra-estuarine recruitment

Several of the more important prey species, including killifish, anchovies, and silversides spend their entire life cycle within one estuarine ecosystem such as a Spartina or freshwater marsh. Their role as secondary producers of energy for larger predators is often keyed to the dynamics of the local system from which they originate.

Development of an understanding of the energy flow, its efficiency and fluctuations, will help us to better understand the fluctuations in the other links in the food chain. We propose to measure the local migrations, food and feeding habits, and fluctuations in recruitment of these forage species in various habitats. (cf. PROGRAM V on Wetlands Ecology).

Starting Date: July 1, 1984

5. Pursue descriptive studies of the biology of species having actual or potential fisheries value or ecological significance

Preliminary estimates of the abundance of several oceanic-shelf species such as shark, butterfish, monkfish, and deep water hake suggest that a commercial fishery potential exists, yet often nothing is known of their basic biology. Information on age and growth of the stock, fecundity, age of maturation, and spawning grounds and season are undocumented. The level of exploitation that can be tolerated by the stock is unknown. The same is true for many forage species.

We propose to continue descriptive studies of the biology (food habits, growth rates, reproduction, migration), taxonomy and stock identification, and population dynamics (mortality and survival) of species of potential fishery value, or of species which may be ecologically important but have no direct economic significance.

An important supporting facility for all of these studies is the VIMS' Fish Museum which acts as a regional repository for voucher specimens.

Starting Date: Continuing

6. Study ecosystem structure and function particularly trophic interactions in both nursery grounds and adult fish habitats

An ecosystem is an elaborate system of interconnected energy pathways. Disruption of any one of them through overfishing, pollution, or natural

events (such as Tropical Storm Agnes) can result in changes in economically important stocks, possibly far removed from the perturbed link. If we can develop an understanding of how the system functions, we will be able to eventually predict how the ecosystem will respond to perturbations or changes.

Efforts here are dependent upon the results of other studies, mentioned above, drawn together into ecological models. These may be statistical, energy flow, or spectral models requiring quantified data on recruitment, mortality, and energy flow from each segment of the system to be modeled.

Starting Date: Continuing

7. Study comparative ecosystem structure and function in different marine habitats to better understand the basic principals that control fish communities

In order to better understand how fish communities function it is instructive to compare ecosystem structure among different habitats with different energy availability or varying complexity in structure. Thus an understanding of the structure and function of demersal fish communities on the continental slope and rise may lead to a better understanding of general ecological principals that control communities in all habitats. Deepwater ecosystems can be easier to understand because of little or no seasonal effects, and smaller species numbers. Other kinds of comparative community studies that may be of great value are comparisons of Chesapeake Bay communities with those from comparable habitats and latitudes in the southern hemisphere. These basic scientific studies are crucial to the understanding of the basic biological principals upon which all applied studies ultimately depend. Comparative community studies (in addition to their scientific value) have contributed much to the academic program of the last ten years, through direct student participation.

Starting Date: Continuing

SUBPROGRAM I(d): CONDUCT INVESTIGATIONS RELATED TO THE CONSERVATION OF MARINE ORGANISMS PROTECTED BY THE FEDERAL ENDANGERED SPECIES ACT, MARINE MAMMAL ACT, OR INCLUDED ON THE OFFICIAL VIRGINIA LIST OF ENDANGERED AND THREATENED BIOTA

All marine turtles and marine mammals are protected by Federal laws, and/or by inclusion on the VA list of endangered and threatened biota. In addition, the shortnose sturgeon (Acipenser brevirostrum) is listed as endangered both in Virginia and on the Federal list. Of these, the marine turtles appear to be of foremost research interest because they once were so abundant in Chesapeake Bay as to support a commercial fishery, and because they are currently subject to incidental mortality by the pound-net fisheries.

Objectives:

1. Assess the magnitude and causes of sea turtle mortalities in Virginia, and make recommendations to alleviate the major causes of mortalities

We will continue to monitor turtle strandings to determine major causes of mortality. In addition, we are monitoring selected pound-nets

to determine what factors make some nets lethal at times. This program also will continue to work closely with the pound-net fishermen to solve the problem of turtle mortalities.

Starting Date: Continuing

2. Assess the population size of turtles in Chesapeake Bay

This study includes aircraft line-transect surveys to estimate turtle abundance in Chesapeake Bay during the summer. These data are analyzed using input from behavioral studies concerning temporal diving behavior of sea turtles. In addition, separate abundance estimates are being calculated from a classical tag-recapture study.

Starting Date: Continuing

3. Study the behavior of turtles in Chesapeake Bay and on migration

This study utilizes remote sonic and radio transmitters to study the local movements of sea turtles in Chesapeake Bay in the summer, including their interactions with pound-nets. In addition, radio tracking provides information on the speed, and direction of migration and may provide data on the whereabouts of the wintering grounds of Chesapeake Bay turtles.

Starting Date: Continuing

4. Monitor strandings of marine mammals in Virginia

An effort is being made to identify and measure all marine mammals stranded on Virginian shores. These data are forwarded to the U.S.N.M. Division of Mammals for regional analysis by Dr. James Mead.

5. Assess the possibility of re-establishing short-nose sturgeon in Virginia

This is a future objective of the subprogram.

Starting Date: Post 1985

SUBPROGRAM I(e): INVESTIGATE CRITERIA AND METHODOLOGY FOR PROMOTION OF MICROBIOLOGICALLY SAFE SHELLFISH

A minority of microorganisms possesses the capacity to produce disease in human, animal and plant hosts. In the case of human pathogens, discharge of sewage and other sources of enteric pathogens into shellfish growing areas has led to an elaborate regulatory system for the harvesting of a product safe for human consumption. However, recent research has questioned the validity of the bacterial indicator used to classify shellfish growing waters and assess product quality, as well as the assumed relationship between indicator and pathogen presence. Continued research is necessary to assess the adequacy of this system as applied to management of shellfish-growing waters and production of shellfish in the Commonwealth.

Objectives:

1. Perform research designed to understand those factors affecting the survival of microorganisms of public health significance in shellfish and shellfish-growing waters and evaluating these results with respect to current standards, management and production strategies

Coliform bacteria are widely used as indicators of the sanitary quality of receiving waters and products. Despite widespread use and acceptance, relatively little is known of their fate in marine waters under a wide range of environmental conditions. Similarly, ignorance surrounds the fate and survival of enteric pathogens. Research at VIMS and other institutions suggests that assumptions made concerning the relationship between indicator density and pathogen-presence is a variable function of local biological and physico-chemical variables. Furthermore, the recovery of cells stressed during exposure to the marine environment can affect the results of standard enumeration procedures and therefore influence harvesting of shellfish products. Thus it is necessary that fundamental information concerning factors which influences fate and recovery of indicator and pathogen be obtained.

Starting Date: Continuing

2. Provide regulatory and industry personnel with assistance regarding the development, evaluation and application of techniques for enumeration of microorganisms of public health significance in shellfish and shellfish-growing waters

Regulatory and industry personnel concerned with seafood products must deal with microbiological criteria and associated problems. Institute microbiologists assist these personnel through maintenance of an extensive research literature collection, through active participation in quasi-regulatory programs such as the Interstate Shellfish Sanitation Program and have extensive experience with approved enumeration techniques for shellfish and shellfish-growing waters. In addition, bacteriologists are and have been active in development and evaluation of enumeration techniques, especially related to shellfish. An ongoing program of this type is required in order to focus experience and current understanding at contemporary and topical microbiological problems.

Starting Date: Continuing

3. Evaluate and study methods and microbiological criteria for the production of marketable shellfish by depuration and/or relaying processes

Reductions in shellfish growing areas due to factors such as pollution, development, poor production and increased reliance on shellfish from non-Virginia waters, provide sufficient impetus for the study of controlled cleansing or depuration as well as greater reliance on relaying. The Institute has already contributed a significant body of data related to the depuration of coliform bacteria from the oyster. During 1984-1985, a study will be initiated to evaluate the microbiological quality of shellfish cleansed through relaying under in

situ conditions. It is anticipated that results of this study will yield information needed for the development of relaying process guidelines.
Starting Date: Continuing

PROGRAM II. INVESTIGATE AND DEFINE THE DISTRIBUTION OF BENTHIC ANIMALS AND COMMUNITIES AND THEIR INTERACTIONS WITH THE BIOLOGICAL, PHYSICAL AND CHEMICAL ENVIRONMENT

A. Issues:

1. Effects of Toxic Chemicals on Water Quality
2. Effects of Other Non-toxic Wastes on Water Quality
3. Maintenance or Enhancement of Desirable Fisheries Stocks
4. Port Development
5. Dredging and Dredge Spoil Disposal
6. Sand and Gravel Mining

B. Purpose:

In the Chesapeake Bay system there are diverse benthic environments ranging from intertidal flats of sand and mud to seagrass meadows and deep, muddy channels. These environments possess unique physical, biological and chemical characteristics depending upon where they occur along the gradient of Bay and river salinity.

Estuarine circulation and salinity not only play key roles in determining the biological character of the benthic environment, but also determine the distribution of the various benthic habitats around the Bay. For the most part, all Bay bottoms south of the Rappahannock River are sand. North of the Rappahannock River the Bay bottom is predominantly muddy, except for the extensive sandy shoal on which Tangier and Smith Island sit. Knowledge of how the physical and biological components of each environment interact with each other and with the products of man's activities (toxics, erosion, nutrients) is of great importance for the proper management of the Bay's resources.

The presence of organisms in and on the bottom modifies the physical structure and stability of the bottom sediments, processes collectively termed bioturbation. Benthic organisms, through their living activities, can greatly influence or even control the movement of chemicals (both toxic and non-toxic) between overlying water and sediments. Examples of modifications by benthic organisms include burying of new sediments and resurfacing of older sediments, ventilating deeper sediments through burrows thereby redistributing oxygen and other dissolved substances, stabilizing sediments through tube-building and mucus secretion, increasing sedimentation rates by filter-feeding and formation of pellets, or destabilizing sediments by increasing water content. Microorganisms can affect sediment stability through production of polymeric exudates. Different species, among the hundreds inhabiting Bay sediments, exert different effects. Their distribution and relative abundance are critical to sediment character.

The fundamental significance of benthic invertebrates pertains to energy flow, in that they serve as a major link in the food web of the Bay, passing energy from primary producers to top carnivores (fish and crabs). Much of the production from fisheries in the Bay would be lost without the even greater production of benthic invertebrates.

C. Objectives:

1. Evaluate biologically mediated physical and chemical interactions at the benthic boundary layer (cf. PROGRAM XI Benthic Boundary Layer)

The benthic boundary layer, here defined as the inter- and sub-tidal zone about one meter above and below the sediment surface is the most important interface in any estuarine and coastal ecosystem. It is involved in every major material cycle, from elements to toxic substances. Current understanding of how the biota mediate important physical and chemical processes across the benthic boundary layer is inadequate to optimally manage our estuarine and coastal areas.

We propose to obtain quantitative information on organism-sediment interactions in selected representative habitats of the Bay and associated tributaries. Our studies will focus on: a) biological control of sediment stability, b) the effects of sediment stability and accumulation rate on benthic community structure and dynamics, and c) biologically mediated flux of dissolved and particulate materials across the sediment-water interface.

Starting Date: July 1, 1984

2. Evaluate man-induced effects as they impact the benthic environment

Man, in some way, has impacted all aspects of the Bay's functions. The vast majority of the products of man's activities (toxics, nutrients, upland erosion) eventually arrive at the bottom of the Bay and rivers, where they are temporarily or permanently stored. The extent and mechanisms by which these products affect the benthic environment has a direct bearing on the health of the Bay. Benthic communities need to be evaluated to show dynamic responses to toxic substances and other man-made imports. Quantitative investigations of species distribution and abundance relative to major pollutant sources in the Bay system will be conducted. Comprehensive chemical data will be interfaced with these biological data as a means of assessing the degree and extent of impact. Reproduction and recruitment success, as well as microbial and metazoan secondary production measures, will provide additional information on benthic community "health." Determining the flux of toxic substances through benthic systems, an important aspect of this objective, will require development of laboratory methodology for assessment of toxic effects in benthic communities. Studies using microcosms and parallel field experimentation provide an excellent opportunity to monitor pollutant flux through all benthic compartments in a system (i.e. macro- and meio-faunal and microbiotic). Tests will be conducted with a wide variety of pollutants

Starting Date: July 1, 1983

3. Evaluate resource values of different bottom habitats

The benthos represent a major link in the food chain of the Bay. By transforming primary production to secondary production, which is then passed up the food chain to species to commercial and recreational

importance, the benthos importantly affects the harvest. The short- and long-term dynamics of bottom communities within the various classes of estuarine bottom habitats will be evaluated in terms of the functional importance of those habitats to fisheries resources.

Quantitative assessments of benthic species standing stock, production and availability to predators will be made. Relationships between benthic production and fisheries production can then be evaluated.

Starting Date: Continuing

PROGRAM III. DEVELOP AN UNDERSTANDING OF PLANKTON PROCESSES IN THE CHESAPEAKE BAY SYSTEM AND VIRGINIA COASTAL WATERS

A. Issues:

1. Effects of Nutrient Enrichment on Water Quality
2. Effects of Thermal Additions on Water Quality
3. Effects of Toxic Chemicals on Water Quality
4. Effects of Microbial and Viral Contaminants on Water Quality
5. Effects of Other Non-toxic Wastes on Water Quality
6. Maintenance or Enhancement of Desirable Fisheries Stocks
7. Freshwater Diversion and Impoundments
8. Dredging and Dredge Spoil Disposal

B. Purpose:

Plankton are typically very small organisms which passively drift with the water or swim weakly, in contrast to nekton which are strong swimming organisms. The marine and estuarine plankton communities constitute a diverse assemblage of organisms, both in terms of size and feeding habits; their interactions are poorly understood. The components of the plankton community considered herein include: 1) bacteria, 2) phytoplankton, i.e. microscopic plants which utilize sunlight and inorganic nutrients, 3) zooplankton, i.e. microscopic animals which eat either phytoplankton or other zooplankton, 4) ichthyoplankton, i.e. larval and juvenile stages of fish which utilize either stored food reserves (e.g. the yolk sac) or eat smaller planktonic organisms, and 5) other planktonic larvae including the larval stages of invertebrates such as oysters and clams, which eat smaller planktonic organisms. Most of the primary production in the Chesapeake Bay system is derived from phytoplankton photosynthesis and it is this production which ultimately accounts for the high productivity of the Bay in terms of fish and shellfish. A substantial proportion of this production is also consumed within the plankton community. Since the plankton constitute both the base of and a substantial part of the aquatic food web, many if not most ecological processes in the estuary are directly or indirectly related to planktonic processes. It follows, therefore, that our understanding of estuarine biological/chemical processes is dependent to a large degree upon our understanding of planktonic processes.

C. Objectives:

1. Understand biological and physical processes related to the plankton community with emphasis on the environmental controls

It is well established in phytoplankton ecology that primary production is greatest in those marine systems which combine (either spatially or temporally) inorganic nutrient replenishment to the euphotic zone (via vertical mixing) and maintenance of the phytoplankton in the well lighted, near-surface zone (via stratification). This is a seeming "paradox of stability" since instability is necessary to provide nutrients from deep water but stability is required to maintain the phytoplankton in

the near-surface, high light environment required for optimal growth. Classic examples of high production based on this dual process are upwelling systems on the western boundaries of major continents and spring blooms in temperate coastal waters. We now recognize that the vertical 2-layered structure of estuaries can change dramatically over short time periods in response to a variety of environmental factors and that chief among these factors is the neap-spring tidal cycle. We propose that phytoplankton production in the saline portions of the James and York rivers is regulated primarily by a tidally induced cycle of stratification-destratification, and that the fortnightly frequency of this physical process confers a greater productivity on these estuaries than estuaries such as the Chesapeake Bay or the Potomac River with fewer (i.e. seasonal) or no alterations in their stratified state. We further propose that increased growth of key phytoplankton species occurs just after the return of stability to the water column and that the timing of larval emergence of commercially important species must be properly synchronized to this hydrographic-biological event if successful first feeding and subsequent year class survival are to occur. The relative abundance of commercially valuable juvenile and adult fishes (e.g. menhaden) which feed directly on phytoplankton may also directly depend on phytoplankton abundance-production.

We will undertake a detailed and comprehensive investigation of the plankton ecology of the James and/or York river estuaries, including but not limited to: 1) plankton abundance, distributions and growth rates, 2) nutrient-plankton interactions, 3) hydrographic processes and their influence on plankton and nutrient distributions, and 4) aspects of grazing on phytoplankton by larvae and by zooplankton which serve as food for larvae and planktivorous adults. The question of the extent to which food availability and species success are controlled by stratification-mixing cycles will be addressed (cf. PROGRAM XII on Circulation).
Starting Date: July 1, 1984

2. Identify and quantify the effect of man-induced pollutant sources on plankton communities

It is relatively well documented that pollutant sources which alter local nutrients or physical-chemical conditions change the structure of the impacted plankton community. Considering the importance of plankton as the base of the food web, it is of obvious importance to understand the effects of man's activities on plankton communities. Several potential research sites have been identified including: 1) the lower York River which is scheduled to receive about 15 million gallons a day from a Hampton Roads Sanitation District sewage treatment plant in combination with heated VEPCO effluent; 2) the heavily polluted Elizabeth River; and 3) the James River. We will contrast the plankton communities from polluted and "control" areas, and we will carry out laboratory bioassays of the pollutants from pollutants study areas. Assays will be carried out with the oyster embryo and selected small phytoplankton species. An evaluation of the laboratory assays and field observations will be used to formulate hypotheses related to the impact of the pollutant upon the receiving system.

Starting Date: After July, 1985

3. Investigate impacts on plankton communities resulting from interaction between adjacent water bodies of the Chesapeake Bay system

Along the axis connecting Virginia's offshore waters to the tidal freshwater zone are found many different adjacent systems which interact with each other (e.g. the Chesapeake Bay proper with the coastal shelf waters on one hand and its tributary rivers on the other, waters of marsh creeks with those of Eastern Shore embayments, and Eastern Shore embayments with coastal and shelf waters). Few studies of the estuarine or coastal waters can ignore the interactions of these adjacent water bodies which exchange organisms, nutrients and pollutants under the control of complex water movements. These phenomena have significance for practical questions ranging from the recruitment and retention of the planktonic larvae of commercially important species to the question of whether wetlands and marshes can significantly modify nutrients entering the system from sewage or agricultural runoff. Our initial approach will be directed toward Chesapeake Bay and shelf interactions related to retention/recruitment of several targeted commercially important species (e.g. the bay anchovy, the croaker, the summer flounder and the blue crab).

The development of a descriptive model useful in understanding the complex physical, chemical, and biological processes occurring at the Chesapeake Bay mouth is a long range research goal which will require careful planning, considerable support and multiple years to accomplish. Certain critical hypotheses, however, targeted at individual species or species groups will be tested initially to provide the necessary data base for further refinement of the experimental approach. Foremost among these are questions relating to the individual behavioral adaptations of important species, the temporal and spatial variability of their occurrence and, especially, the details of changing vertical position in the water column with respect to time, place, tide, temperature and salinity. These data, coupled with some knowledge of circulation patterns with respect of depth, should serve to provide an adequate basis to predict recruitment and/or retention of commercially important planktonic larvae (cf. PROGRAM XII on Circulation).
Starting Date: Continuing

4. Develop or acquire technological and methodological support for the efficient and expeditious accomplishment of plankton research

Within reasonable economic constraints current technology is not adequate to sample with sufficient resolution or to analyze the large quantity of samples required for adequate description of the variability in the estuarine plankton community. Eventually, automated remote monitoring systems should be the most efficient and economical means of maintaining an adequate awareness of the ongoing state of the estuarine planktonic system. Efforts will continue to be made to develop or acquire automated planktonic identification, enumeration and high resolution sampling technology.

Starting Date: July 1, 1983

5. Describe and quantify trophic (predator-prey) interactions within the plankton community with an emphasis on quantifying in situ growth rates

Most of the biomass produced by planktonic organisms is consumed by other planktonic organisms. The quantity of the plankton available for or actually utilized as food by commercially important species in their plankton stages as well as during the rest of their life cycle is at present unknown. A knowledge of predation rates, growth efficiencies, and reproduction rates of organisms in situ is necessary to quantify this food supply. We will at first identify the smallest predators and quantify biomass and determine growth rates. The same measurements will be made on their prey. These data will be used to evaluate the flow of natural energy resources from the plankton to commercially important species such as menhaden, bay anchovy and oyster.

Starting Date: July 1, 1984

6. Conduct basic research on identification and systematics of planktonic organisms and establish an archived reference collection, and develop an atlas of the Chesapeake Bay System planktonic fauna and flora

Knowledge of the classification (taxonomy) and evolutionary relationships (systematics) of planktonic organisms is essential to a comprehensive understanding of marine and estuarine plankton biology. The ability to identify the various species in the complex aquatic habitat is prerequisite to a wide variety of research activities ranging from descriptive, regional checklists to investigations of biological/ecological processes. More importantly, effective management of our aquatic resources requires a thorough knowledge of the kinds of organisms likely to be affected by man's activities. To aid in this research, the present reference collection will be continued and expanded as required to support systematic research. VIMS culture facilities will also be used to supply a variety of organisms for research purposes including the maintenance of conditioned oysters for spawning. Efforts to continually upgrade species checklists will result in the publication of an atlas of planktonic forms emphasizing identification and distribution in the Chesapeake Bay System. Such an atlas will assist the scientist, naturalist, manager and layman alike.

Starting Date: Continuing

PROGRAM IV. DESCRIBE AND EVALUATE THE TIDAL FRESHWATER ECOSYSTEMS OF VIRGINIA'S MAJOR RIVERS

A. Issues:

1. Effect of Nutrient Enrichment on Water Quality
2. Effect of Thermal Additions on Water Quality
3. Effect of Other Non-toxic Wastes on Water Quality
4. Resolution of Fisheries Conflicts
5. Maintenance or Enhancement of Desirable Fisheries Stocks
6. Freshwater Diversion and Impoundments
7. Dredging and Dredge Spoil Disposal
8. Wetlands Protection and Use

B. Purpose:

The upper reaches of our major river systems, beyond the limits of salt intrusion but still influenced by tides, are poorly known as biological systems. The importance of tidal fresh waters stems from their role as spawning and nursery areas for important anadromous fishes, such as the shad, herrings and striped bass, and for their production of plant detritus, a base of many estuarine food chains. Knowledge of these systems and their importance is becoming increasingly critical as expanding human populations place increasing demands on freshwater supplies. We must be able to predict the consequences and effects of proposed water impoundment and diversion projects on these important systems.

The research program to address the scientific and management questions will involve all the disciplines represented at the Institute. The multi-year effort will be divided into a number of distinct projects all of which are designed to integrate, over a five or six year period, a basic understanding of the biological and physical components of tidal freshwater systems. The initial research efforts will be descriptive in nature and will provide both qualitative and quantitative studies of the system's components. The data generated by these projects will be utilized in the design of future research programs as we formulate a conceptual model of the system and then develop the ability to simulate the functioning of major components.

C. Objectives:

1. Study the structure and function of oligohaline and tidal freshwater marsh systems

Despite the abundance and suspected importance of oligohaline and tidal freshwater marshes, little information is available about either the structure or functioning of these systems. The effort to develop the necessary information about these marshes will first focus on describing the structure of the marsh floral and faunal communities and subsequently on analysis of their functioning as follows:

- a. Description of the floral community will employ classical techniques to analyze plant associations, distribution, dominance

and diversity. Net productivity (above ground and below ground) and edaphic factors will also be analyzed. The objective is not only to obtain a quantitative physical description of the community but also to collect relevant ancillary data which will be important to subsequent analysis of community level processes.

Specific short-term objectives include:

- Analysis of seasonal dominance patterns in marshes
- Development of net annual production estimates for individual species and analysis of decomposition/deposition rates for macrofloral biomass
- Description of the marsh/swamp transition zone

Specific long-term objectives include:

- Description of the spatial and temporal patterns of macroflora and microflora production
 - Description of the export and/or deposition of primary production from the community
 - Analysis of potential impacts resulting from natural or man-induced perturbations to the system
- b. Description of the faunal community will also employ classical methods to analyze abundance and diversity. This effort will focus initially on benthic macrofauna and infauna. The objective is to obtain quantitative description of the community which will permit correlative analysis with floral and edaphic aspects of the system.

Eventually descriptions of the faunal community will be extended to include both ichthyofauna and avifauna. Development of adequate sampling methodologies will necessitate a delay in addressing this particular objective.

Specific short-term objectives include:

- Analysis of benthic species abundance and diversity
- Description of animal/sediment relationships in the system
- Description of seasonal patterning in distribution and/or activity of benthic species

Long-term objectives include:

- Analysis of ichthyofauna/marsh community relationships
- Description of the role faunal communities play in processing and/or transport of materials through the system
- Analysis of potential impacts resulting from natural or man-induced perturbations to the system

Starting Date: July 1, 1984

2. Measure the flux of nutrients through oligohaline and tidal freshwater systems

This objective directly addresses the question of what the oligohaline and freshwater portions of an estuary export to mesohaline reaches. The long-term objective is to understand the sources, sinks and transformation of nutrients passing through the system. As a first step the entire system will be treated as a single unit and the objective will be to quantify the net flux of nutrients into and out of the system. From this "black box" approach, future efforts will be designed to subdivide the system into major components (i.e. marsh, swamp, river, and mudflats) and analyze the functioning of each. The initial study will involve sampling at only two locations, near the upstream and downstream boundaries of the oligohaline-tidal freshwater reach of the Pamunkey River. Subsequent studies will require characterization of upland inputs throughout the reach as well as intensive studies of selected representative sites within the reach.

Starting Date: July 1, 1984

3. Describe the composition, seasonal succession and abundance of the phytoplankton community in tidal fresh waters

The Pamunkey River will be the principal focus for initial phases of research on this objective. Intense blooms of filamentous algae during spring months are a known feature of this environment, but the factors contributing to their sudden appearance, sharply limited distribution and then disappearance are largely unknown. Studies of these phytoplankton populations in the Pamunkey River concurrent with those of objectives 1 and 2 in this Program will provide measurements of all the principal factors likely to influence and control such blooms. At the same time, we will obtain the data necessary for long-term investigation of the relative roles of marsh-produced detritus and phytoplankton biomass in upper estuarine food webs.

Specific short-term objectives include:

- Description of the spatial and temporal patterns of phytoplankton species in the tidal fresh waters of the Pamunkey River
- Analysis of seasonal dominance in phytoplankton populations
- Development of net annual production estimates
- Description of the effect of nutrient flux with bordering marshes and runoff waters from uplands
- Description of filamentous bloom formation and dissipation
- Description of the transition zone between tidal fresh waters and the upper limit of salt intrusion in terms of effect on the phytoplankton community

Starting Date: July 1, 1984

4. Study the seasonal abundance and reproductive cycles of dominant zooplankton species in tidal freshwater systems

Two species of zooplankton have been noted as preeminent in the diets of developing larvae of both white perch, Morone americana, and striped bass, M. saxatilis. These are the cladoceran, Bosmina longirostris, and

the copepod, Eurytemora affinis. The similarity apparent in the spawning seasons, spawning areas (tidal fresh waters) and diets of developing larvae of the two closely-related Morone species suggests a strong possibility of significant competition for food.

Specific targets for initial research on this objective include:

- Description of the reproductive biology, distribution and abundance of B. longirostris and E. affinis during the critical spring months (March-June) when they serve as prey for Morone larvae in the Pamunkey River
- Evaluation of the nutritive value of these two food sources through the spring season, employing both field and laboratory examination
- Laboratory studies of the possible significance of a third competitive predator, the cladoceran Leptodora kindtii

Starting Date: July 1, 1984

5. Investigate the relationship between larval fish food availability, predator abundance and successful recruitment of young anadromous fishes in Virginia freshwater systems

Predation and starvation are the two most important components of larval fish mortality. These factors, together with stock size and resultant egg production, meteorological and hydrographic factors and man-induced effects (fishing pressure and water quality), determine the degree of successful recruitment of young shad, herring, striped bass and white perch to fishable stocks. As previously noted, several species of freshwater zooplankton constitute the primary diet of larval Morone spp. and, presumably, small scale contagion of high density patches of these forms are pre-requisites for successful feeding and growth. In addition, various species of large zooplankton forms as well as larval insects are potentially important predators of larval fishes. When food is constant, the abundance and distribution of these predators may directly affect larval survival and subsequent recruitment. The ability to describe these relationships will facilitate prediction of annual fluctuations in year class success.

Specific objectives are:

- Assessment of egg production and calculation of stock size based on ichthyoplankton census (cf. II, Plankton Monitoring)
- Description and correlation of small scale contagion of zooplankton prey, predators and larval fishes
- Assessment of differential survival and growth rates based on birth data distribution as measured by daily otolith growth rings
- Laboratory studies of food densities, potential predator densities, larval growth, survival and the inter-relationships of these factors.

Starting Date: July 1, 1984

PROGRAM V. INVESTIGATE STRUCTURE AND FUNCTION OF MESOHALINE MARSHES AND SUBMERGED AQUATIC VEGETATION

A. Issues:

1. Effects of Nutrient Enrichment on Water Quality
2. Effects of Microbial and Viral Contaminants on Water Quality
3. Maintenance or Enhancement of Desirable Fisheries Stocks
4. Freshwater Diversion and Impoundments
5. Port Development
6. Dredging and Dredge Spoil Disposal
7. Wetlands Protection and Use

B. Purpose:

Virginia is endowed with a broad diversity and extent of marine and estuarine wetland communities. These natural resources include emergent, intertidal marshes ranging along a continuum from seaside to tidal fresh waters, subtidal and submerged aquatic macrophyte beds, and intertidal and subtidal non-vegetated flats. These wetland areas interact with coastal and estuarine nearshore waters in a complex web of biological, physical and chemical processes. The purpose of this program is to advance our understanding of these processes and their role in maintaining the high value of Virginia's coastal wetland resource.

C. Objectives:

1. Studies of the structural and functional ecology of a recently established mesohaline wetland ecosystem: Goose Creek, Elizabeth River, Chesapeake, Va

Recently a popular option has been considered by the managing authorities to require replacement (mitigation) in kind of damaged wetland areas as a result of development.

The marsh replacement strategy has theoretical appeal but for the most part lacks demonstrated success relative to accomplishing the implicit goals of wetlands resource management (i.e. maintaining the ecological integrity of the system and specifically the role and value assigned wetlands).

To our knowledge, there is no specific information available that compares the internal structural and functional relations (as well as external interactions with contiguous waters) between recently established and mature marshes.

The proposed study of a recently established mesohaline marsh has both basic and applied merit. First, by initiating studies during the first growing season of a "new" marsh coupled with a monitoring (over several growing seasons) of the processes of plant growth, biomass production, chemistry of the developing substrate, and the mass balance properties of an entire marsh ecosystem in various successional stages will provide important information.

Secondly, the studies will provide a relative index of success of the mitigation strategy and suggest where, when and perhaps how that strategy may be better exercised.

Routine studies are proposed in three categories:

- a. Plant communities
 - 1) distribution and abundance
 - 2) biomass
 - 3) production (derived from biomass)
- b. Soils
 - 1) physical parameters
 - 2) chemical characteristics
 - 3) chemical flux (in situ chamber exchanges)
- c. Mass balance
 - 1) tidal exchange (27 hr) studies

Starting Date: Continuing

2. Study of the primary productivity of non-vegetated wetlands (intertidal sand flats)

Intertidal and shoal benthic non-vegetated substrates constitute a significant estuarine habitat in the Chesapeake Bay and, compared to other components of the estuary, there are significant information gaps. We have recently completed an intensive, field-oriented research program that indicated production (microautotrophic) and metabolism (respiration) in these areas are relatively high and are comparable to other better studied substrate types (i.e. marshes and eelgrass sediments). However, without more detailed treatment of spatial and temporal aspects of these communities than is typically incorporated in experimental designs, their ecological role will remain unresolved and questions relative to resource management cannot be adequately answered. The need for such answers was emphasized by the modification of Virginia's 1972 Wetlands Act which added non-vegetated habitats.

The overall objectives of the proposed research program are to design and implement a field sampling program and experimental laboratory study that will adequately address in terms of both temporal and spatial scales the productivity and environmental controls on microalgae; the dominant autotroph of tidal flats and shoal-benthic environments. Spatial and temporal scales of productivity will be addressed through an intensive study of a sand flat habitat adjacent to our laboratory facility. The potential controls of light as photosynthetically active radiation, nutrients as NH_3 and grazing using a dominant, lower level consumer, Ilyanassa obsoleta, will be addressed.

- a. York River sand flat field studies to:
 - 1) test experimental design for data and sample collection, processing and data management, and provide environmental data (light, temperature, NH_3 in sediments and water) for experimental, laboratory designs
 - 2) establish spatially and temporally scaled field program to address in situ rates of production, taking into consideration tidal, diurnal and seasonal changes in rates

3) monitor environmental conditions relative to light and NH₃

b. Microcosm studies to:

- 1) test experimental designs as above
- 2) complete short-term microcosm studies relative to light, nutrient and grazing as principal controls
- 3) conduct long-term microcosm studies as above

Starting Date: July 1, 1984

3. Design, implement and analyze computer simulation models of wetland ecosystems

Over the past ten years a modeling strategy has been developed in collaboration with other colleagues and applied to various wetland systems and contemporary issues in marine ecology. A particular strength of the modeling technique developed over this time is that all assumptions of the mathematical structure are testable through field and/or laboratory studies. As a technological tool, models provide a conceptual framework for analysis of specific studies and evaluation of experimental designs; identify areas where information or data is lacking or considered inadequate; determine in a qualitative sense, at a minimum of cost, processes that are sensitive to perturbation or that control compartmental behavior; and provide an experimental tool for analysis of integrated processes which aids future research, suggests new experimental designs, and is applicable to general resource management issues. Analyses using simulation models often lead to refocusing of effort and conceptual changes in our view of ecosystem structural and functional relationships. Simulation modeling is constantly evolving toward better predictive capability. The potential for simulation modeling to significantly contribute to resource management issues is widely recognized. Both basic and applied efforts in ecosystem modeling and simulation analysis contribute to this goal.

Ecosystem modeling and simulation analysis should be considered a continuing project at the Institute. The effort is an interactive process that builds on feedback both from simulation analysis and new information that entails both structural and functional design.

For our specific objectives, the ordered listing approximates a prioritization of effort:

- a. Complete digital simulation analysis of the present version of the submerged aquatic vegetation (SAV) trophic level model.
- b. Develop species-specific models of photosynthesis for Zostera marina and Ruppia maritima production with special reference to light, nutrients, epiphytic colonization (fouling) and grazing interactions.
- c. Continue analysis and development of carbon-nitrogen flux model of salt marsh ecosystems.
- d. Continue general mathematical evaluation of model(s) as both a theoretical and applied tool in ecosystem analysis.

- e. Evolve present SAV and marsh models to include socioeconomic interactions.
- f. Develop modeling strategies for analysis of long-term data sets.
- g. Develop more vigorous ecosystem level models of biological, physical and chemical interaction.

Starting Date: Continuing

4. Determine the value of marsh and SAV habitats in both established and newly transplanted areas as nursery grounds for juvenile blue crabs

In the last 10-15 years, numerous references have been made to salt, brackish and freshwater marshes, and beds of SAV as key nursery areas for many fish and invertebrate species, several of which are commercially important. However, conclusive proof of this long held dogma is currently lacking. There is almost no information on how marshes and SAV may even function as nursery areas. In the Chesapeake Bay, marshes and SAV are a dominant aspect of this estuarine ecosystem although SAV has declined baywide since 1972. This is even more evident in the Maryland portion of the Bay where SAV is now almost completely absent.

Because of the dearth of information on the value of marsh and SAV habitats, and because of the recent restricted distribution of SAV, we propose to direct our research towards defining the resource value of these habitats to the blue crab. Our hypothesis is that these vegetated habitats are key nursery areas for the blue crab (see also SUBPROGRAM Ib).

We have identified the blue crab as the prime species for this research for the following reasons: 1) in the Chesapeake Bay it is the second most important shellfish species in economic terms to the Commonwealth (50-60% of the total hard blue crab catch in the U.S. and between 60-70% of the soft shell catch); 2) the recent decline of SAV beds has often been used as one explanation for the decline of the commercial catch of blue crabs; 3) the blue crab is one of the most important predators on benthic animals in the Bay and can be considered a keystone species because it determines the structure and species composition of Chesapeake Bay shallow water benthic communities; 4) the entire life cycle of the blue crab is relatively short (<24 months) with well defined year classes enabling one to follow an individual year class through time; and 5) this species ranges over the entire salinity regime of the Bay and is found in virtually all habitats. Physiologically, it is a hardy species, and can be experimentally manipulated with few detrimental affects. By identifying the prime nursery areas for the blue crab, managers have a stronger case for protection of valuable nursery grounds.

Our approach to understanding the value of these habitats will involve a detailed, quantitative sampling program to determine the abundance, size-frequencies, molt stage and sex of crabs utilizing each of these habitats. We propose to examine time integrated feeding habits using stable carbon isotope ratios and possibly sulfur and nitrogen ratios in tissues of blue crabs from each habitat. We also propose to determine residence times of blue crabs using sonic and/or mechanical tags. This approach will also be taken to determine the influence of transplanted

eelgrass beds on the recruitment and abundance of blue crabs when compared with adjacent non-vegetated areas.
Starting Date: July 1, 1983

PROGRAM VI. STUDY DISEASES OF MARINE AND ESTUARINE ORGANISMS

A. Issues:

1. Maintenance or Enhancement of Desirable Fisheries Stocks
2. Effect of Degraded Water Quality

B. Purpose:

Disease in populations of commercially and ecologically important finfish, shellfish and crustaceans and the organisms which serve as their food sources almost always results in an undesirable condition which warrants corrective efforts. Disease can result directly from the activities of microbes, viruses, metazoan parasites or from exposure to toxic chemicals. Corrective measures may include: 1) prevention of the disease from occurring; 2) disease control; and/or 3) avoidance of exposure to the disease agent. However, such measures are difficult or impossible to implement without a basic knowledge of the mechanisms of disease induction, identity of the disease agent, and a knowledge of the developmental biology and ecology of living agents.

It is the purpose of this program to provide managers of commercially important organisms and water quality with information to prevent losses and enhance resources. The most significant microbial, viral and chemical agents of diseases in the Chesapeake Bay and Virginia's coastal waters will be studied.

C. Objectives:

1. Elucidate the life cycles, distribution, and effects of the oyster pathogens *Minchinia nelsoni* (MSX), *Minchinia costalis* (SSO), *Perkinsus marinus* (Dermo), and the flounder pathogen *Trypanoplasma bullocki*

Highly significant microbes, if not the most significant, are the protozoan pathogens *M. nelsoni*, *M. costalis*, *P. marinus*, and *T. bullocki*, found in the Chesapeake Bay and Virginia's coastal waters. Much is known about these pathogens from earlier studies at the Institute. However, considerable information for use in resource management is still lacking. For example, the reservoir of infective elements is not known for *M. nelsoni* and *M. costalis* nor is it known how infections are transmitted. Also lacking is knowledge of where *P. marinus* over-winters since it cannot be detected during the coldest months of the year. It is believed that if a thorough knowledge of the life cycles is acquired, the probability of formulating effective management strategies is increased. Other species of pathogens may be identified later which are of enough relative importance to warrant similar studies. However, at this time the aforementioned organisms are clearly the most important to the Commonwealth's fisheries and since a considerable background of information is available, those species will be studied most intensely in the early stages of this plan. The general temporal and spatial distributions of these disease organisms is fairly well known; however, details are not known with respect to timing as to when infections, and

subsequently mortalities, appear as a function of changes in salinity and temperature. For example, if in an M. nelsoni endemic area, the salinity increases by a mean value of 5 ‰ and the change lasts for 4 months during the summer, will more oysters die from the disease, and, if so, when will they die? If the salinity change is of shorter or longer duration or occurs at a different time of year, how will mortalities be affected? Such predictive capability would be available if an adequate knowledge of the life cycles and epizootiological patterns is generated. The management of oyster plantings and harvesting would be markedly improved if such predictions could be made with confidence. This research effort is designed to provide such capability. M. nelsoni, M. costalis, and P. marinus are markedly limited in their ability to kill oysters in waters of salinities below 15 ‰; therefore, epizootiological studies will focus on those reaches of the Bay's tributaries. This research will allow prediction of host mortalities and effects on host-population dynamics in relation to environmental conditions.

Starting Date: July 1, 1983

2. Determine the role of toxic chemicals in disease induction in important estuarine and marine species

Human activities in or near the Chesapeake Bay have created a diverse variety of waste materials that impact our estuaries. Concentrations of toxic chemicals resulting from discharge of petrochemicals and heavy metals are present in the Elizabeth River estuary. Studies of other severely impacted estuarine and marine systems such as Puget Sound and the New York Bight have shown that toxic substances can have far reaching consequences. The effects of chemical pollutants on the ecosystem and animal populations in estuaries are of concern with respect to loss of fisheries resources and to possible harmful effects on consumers of these resources. One means of determining these effects is through the histopathological examination of fishes and other estuarine organisms from impacted areas.

Using this approach, preliminary studies have shown that both resident and migrating fishes in the Elizabeth River system have a greater prevalence of pathological lesions than do the same species of fishes from less polluted or "control" study areas in the Chesapeake Bay. Necrotic lesions of skin, fins, pancreas, and liver have been found in populations from the Elizabeth River and we have been able to induce some of these lesions through experimental exposure to Elizabeth River sediments. Long-term chronic exposure may be required to produce lesions in deeper tissues. The presence of toxic chemicals, including known carcinogens, have been linked to liver neoplasms in fishes in the Puget Sound area. Similar chemical species also exist in the Elizabeth River system so the possibility of similar lesions occurring is real. To date, only necrotic lesions have been found but many more animals need to be examined including invertebrates. Because of the presence of toxic materials and potential carcinogens in Virginia waters, we shall continue and broaden these studies. The resulting information will be provided to resource and water quality management personnel for development of water quality standards and protection of the Commonwealth's fisheries resources.

Starting Date: Continuing

3. Determine the effects of toxic chemicals and other environmental stressors on disease involving microbial and viral pathogens in important estuarine and marine species

Chronic exposure to sublethal concentrations of toxic chemicals and other man-induced stressors are suspected to predispose organisms to disease by microbial and viral pathogens. In many areas of the world, a distinct perception exists, especially in the seafood industry, that chronic chemical pollution has contributed to the expression of microbial disease in important fisheries resources (e.g., M. nelsoni in the Chesapeake Bay and Marteila sydneyi in New South Wales, Australia). Unfortunately, the validity of this perception cannot be determined in the absence of rigorous scientific evidence. Since such statements will continue to be made, research efforts will be conducted to determine whether estuarine sediments and waters containing toxic materials can predispose selected organisms to biological disease under conditions of chronic exposure. Such experiments require sublethal chronic exposure and detection of the onset of disease using sensitive measurements of host response and pathogen presence. Capabilities to perform such difficult experiments will be developed through implementation of other objectives in this program.

Starting Date: After July 1, 1985

4. Develop understanding of host-defense mechanisms with regard to environmental stressors and pathogens

Acutely toxic substances often operate directly on some functional control mechanism in the affected organism. In contrast, sublethal or low concentrations of these same toxicants may exert a chronically debilitating effect which lowers host resistance to disease causing agents such as bacteria, viruses and parasites. Of particular importance in this regard is the cellular immune system which serves to eliminate invading pathogens and therefore reduce the effects of infection. Research is needed to determine if chronic exposure to selected environmental toxicants affects the immune response mechanism. Evidence has previously been obtained, using finfish exposed to Elizabeth River sediments, which indicates that although the number of phagocytic cells increased in response to toxic exposure, the activity of the macrophages and the neutrophils was depressed. Neutrophils and macrophages function to protect the host by phagocytizing disease-causing agents. To this end, commercially important finfish and invertebrates will be exposed to specific toxicants and the effects on macrophage and/or neutrophil components of the immune system determined.

Starting Date: Continuing

5. Develop protocols and techniques for the detection and study of disease

The study of disease in mammalian systems has undergone extremely rapid evolution, in part owing to the development and application of sophisticated analytical techniques and methodologies. Pathobiologists at VIMS believe that advances in the study of disease in estuarine and marine

organisms will occur through application of these same techniques. These include immunology, tissue cultivation, and sophisticated gas chromatographic-mass spectrometric analytical techniques for detection of host response and pathogen occurrence.

The ability to culture infective agents of significant diseases can facilitate development of an immunological assay for its detection in the environment or in hosts. Application of modern immunological procedures can be used to determine if and how a host responds to a given pathogen. Understanding the biochemical nature of the host response can be the first step in disease prevention.

Application of modern clinical analytical techniques to the study of disease has yielded extraordinarily useful information about mammalian systems. In human medicine, this has resulted in the routine testing for specific biochemicals for characterization of host health. Application of similar techniques to the study of disease in marine and estuarine organisms would further our understanding of the disease process.

Two approaches are to be evaluated. The first is to determine the types and concentrations of specific biochemicals in healthy and diseased species. This will provide a basis for understanding the biochemistry of the host response and may eventually be used as a diagnostic tool for detection of disease in the absence of gross symptoms. Primary candidates for specific biochemicals include amino acids, fatty acids and sterols.

The second approach focuses on the characterization of specific biochemicals produced by the pathogen. Emphasis would be placed on the search for unique biochemical fingerprints of the pathogen. Biochemical detection would be useful in pathogen detection and assessment of the status of the disease process.

Starting Date: After July 1, 1985

PROGRAM VII. DEVELOP AND PERFECT METHODS AND TECHNIQUES FOR ECONOMICAL CULTURE OF MARINE AND ESTUARINE ORGANISMS

A. Issues:

1. Effects of Toxic Chemicals on Water Quality
2. Effects of Nutrient Enrichment on Water Quality
3. Effects of Microbial and Viral Contaminants on Water Quality
4. Effects of Thermal Additions on Water Quality
5. Effects of Other Non-toxic Wastes on Water Quality
6. Maintenance or Enhancement of Desirable Fisheries Stocks
7. Dredging and Dredge Spoil Disposal

B. Purpose:

An ongoing aquaculture program is a useful and productive biological research tool, and should be given a high priority in the Institute's future plans. A flexible, well-planned aquaculture program can fulfill numerous functions, contributing to both basic and applied research in a number of scientific disciplines, offering multidisciplinary educational opportunities, and functioning in an advisory role. An aquaculture program can provide an inventory of experimental animals for other research programs, develop a repository of useful information on culture and life history of the animals and develop continually improved methods for maintenance.

The Virginia Institute of Marine Science is fortunate in having maintained a strong viable program in aquaculture since 1962. Over 100 species of marine organisms have been cultured. All of these species have been cultured through the early life stages, and a number of them have been grown through multiple generations. The Institute has successfully operated a pilot scale operation for two molluscan species (oysters and hard clams) and has furnished millions of seed or spat for repopulation attempts or experimental use. It has provided advisory service to both state and national seafood industries.

C. Objectives:

1. Identify commercially important molluscan species that are amenable to culture, and develop practical, economical techniques for growing these species on a commercial scale

Most marketable species of mollusks found in Virginia have been cultured using hatchery grown seed and field growout methods. The published methods used for each species will be evaluated and improved. New techniques will be developed where applicable. A careful cost evaluation of each method will precede development, where possible, of more economically viable methods. Each new method will be tested on a pilot scale to evaluate its commercial potential.

Successful culture requires development of juvenile growout methods which are economical and practical. Genetic selection of stocks with

preferred traits, and intensive outplanting techniques to better utilize the improved stocks, including the development of predator exclusion or control techniques, are required. The nutritional requirements of all life stages must be determined, and inexpensive formulated diets with extensive shelf life will be developed. Such foods can be supplemental or they can fulfill all the essential nutritional requirements of a complete diet, and they must be in a suitable form with the proper characteristics of buoyancy, size, solubility and digestibility.

Studies on the identification and control of disease and parasites, especially those which are enhanced by monoculture, must necessarily be concurrent with the above research.

Starting Date: Continuing

2. Identify commercially important fish and crustacean species that are amenable to culture in Virginia, and develop economical techniques for growing these species on a commercial scale

There are published accounts of culture methods for a number of marketable fish species and several crustaceans common to Virginia waters. The same research and development methods described for mollusks can be applied to culture of these species, although the growout and predator control methods may be quite different. Certain commercial diets available for finfish and crustacean species may be found to be adequate for other species, as well. An important part of the research toward this objective will be a screening of such published diets for general use in culture of finfish and crustaceans.

Starting Date: July 1, 1983

3. Identify ecologically important non-commercial species, develop techniques to culture these species through multiple generations and conduct studies on their life history, autecology and interaction with other organisms

Methods for mass culture of selected organisms to be used as food for other species or as research animals (i.e. for studies in toxicology, physiology, pathobiology) will be developed. Certain forage and food chain species (e.g. anchovies, silversides, mysids and small shrimps) are indispensable links in the Bay's food chain. Methods for large and small scale culture of these species are needed, in order to provide living specimens for studies on the gonadal cycle, spawning, fecundity, life history, and requirements for each early life history state. Diet, disease, environmental requirements, and other aspects of the biology of these species will be studied.

Production of these food chain organisms will facilitate research in many other areas, and help in understanding causes of fluctuations of commercial stocks.

Starting Date: July 1, 1984

PROGRAM VIII. DETERMINE THE FATE AND EFFECT OF TOXIC CHEMICALS IN THE
CHESAPEAKE BAY SYSTEM

A. Issues:

1. Effects of Toxic Chemicals on Water Quality
2. Maintenance or Enhancement of Desirable Fisheries Stocks
3. Port Development
4. Dredging and Dredge Spoil Disposal

B. Purpose:

The introduction of exotic chemicals or anomalous levels of those naturally occurring may result in the most striking of man's diverse impacts on the Bay. In order to minimize the impact of chemical pollution on the Bay in the future, we must understand the interactions of these chemicals with their living and non-living surroundings, and the factors controlling these interactions. The subprograms proposed will address the current status of contamination, where increased contamination occurs, and the effects these compounds exert on the biota of the Bay system. Since the highest concentrations of toxic chemicals occur in the highly industrialized metropolitan areas, much of our research will focus on the James River system.

SUBPROGRAM VIII(a): DETERMINE THE FATE AND EFFECTS OF ENERGY AND
INDUSTRIAL RELATED ORGANIC COMPOUNDS IN THE BAY SYSTEM

During the formation, burning and/or refining of fossil fuels, a large number of organic compounds are produced. Concern with these compounds center on the fact that some are known toxicants in mammalian systems and some have long residence times in sediments and in marine organisms. Only recently has the impact on the marine ecosystem been clearly demonstrated.

Recent surveys of organic compounds in sediments of the Chesapeake Bay indicate that energy related organics are among the most prominent organic pollutants present. With the likely increase in fossil fuel combustion around the Bay as human population densities increase, it is probable that the input of these compounds will increase. In addition, several sub-estuaries of the Bay, such as the Elizabeth River, are grossly polluted by coal tar-related compounds and biological effects are evident.

Industrial organics are primarily petrochemicals or coal distillate products. Included in this category are biogenically produced toxins and/or toxic metabolic products. Chemicals in this group may enter the Bay through a variety of routes, including runoff, industrial outfalls, and spills. As is the case with the energy related compounds, we must know the behavior of these chemicals found in Virginia's waters.

Objectives:

1. Determine the fate and effects of polynuclear aromatic hydrocarbons (PNA's) in the Elizabeth River

In the course of the EPA/Bay Program very high concentrations of PNA's were found in the sediments of the Southern Branch of the Elizabeth River. These concentrations, associated with the use of creosote, are the highest yet reported in any estuary. Field studies indicate areas barren of benthic community activity. Laboratory studies using the contaminated sediments indicate profound impacts on finfish. Given these early findings a comprehensive program to ascertain biological impacts has been formulated. Three subobjectives will be addressed:

- a. Determine the acute toxicities of PNA's to estuarine organisms
- b. Assess the effects of coal-tar derived compounds in sediments on benthic communities and secondary microbial production
- c. Determine the chemical fate and bioaccumulation of these compounds and their derivatives in the organisms, sediments and water
- d. Predict the transport of PNA's within the Elizabeth River system and transport out of that system (cf. Program XII. Circulation)
- e. Utilize microbial assay systems for the detection of mutagenic/carcinogenic compounds in sediment extracts

Starting Date: Continuing

2. Determine the energy related polar organic compounds in the Chesapeake Bay ecosystem

Many of the energy related compounds cycling in the Chesapeake Bay contain functional groups, which require different analytical approaches than for those without such groups. These compounds are often present in the parent fuels or are produced by combustion of the fuels. In addition, the biota of the Bay may transform a compound from nonpolar to polar. Likewise, under the normal physical and chemical conditions existing in our estuaries such transformation may occur, and many of these transformed compounds are toxic. We will develop the analytical methods to determine polar organic compounds.

Starting Date: Continuing

3. Determine aqueous leaching of low molecular weight organics from bituminous coal particles

Coal particles present in sediments are subject to oxidative degradation and concurrent solubilization over long periods. Yet unidentified compounds may be mobilized and made available to marine biota. Previous analyses have shown the concentration of coal particles in several areas of Chesapeake Bay to be quite high.

This program will identify and analyze low molecular weight organic compounds in solutions from aqueous leaching of Appalachian bituminous coals. Effects of variations in pH, oxidation potential, and coal source on leaching will be investigated. The results will permit estimation of the long term fate of coal particles present in estuarine and coastal sediments of the Eastern United States.
Starting Date: July 1, 1983

4. Determine the fate and effects of Kepone in the James River

Extensive studies of the fate and effects of Kepone in the James River have been conducted over the past few years. Results of these studies indicate that direct biological effects from Kepone exposures at levels found in the estuary are unlikely. However, monitoring of residue levels has shown that we lack the ability to predict bioaccumulation from laboratory studies. We will investigate the role of food chain accumulation on estuarine fish. In addition, a new estimate of the Kepone reservoir in the river sediments will be calculated to answer questions related to dredging and time trends in the observed residue levels in animals.

Starting Date: July 1, 1983

5. Determine the solubilities of hydrocarbon mixtures in water

The results of this study will be used to predict hydrocarbon concentrations produced by releases of hydrocarbon mixtures in natural waters, and to estimate concentrations resulting from spills of petroleum fuels. As well, the results will be useful in evaluating potential toxicity by improving our ability to predict the dissolved concentrations of compounds from hydrocarbon mixtures. Finally, the study forms the experimental basis for describing the ground water transport of nonpolar organics and provides data relevant to hydrocarbon migration studies.

Starting Date: Continuing

6. Determine the fate and bioavailability of petroleum refinery wastes in the lower York River

As a preliminary step in an overall assessment of the refinery's contribution of potentially toxic organic compounds in the York River, this study will establish the concentrations of selected organic compounds in the effluent and attempt to relate these to levels found in surrounding sediments and biota (particularly bivalve molluscs). An initial sediment survey will be conducted to delineate the sphere of the effluents influence, then a more detailed grid survey will be conducted along with the sampling of indigenous clams. If the results indicate a significant contribution from the effluent, a second year effort will focus on a determination of the rates of bioaccumulation utilizing planted clams and/or other benthic organisms.

Starting Date: Continuing

SUBPROGRAM VIII(b): DETERMINE THE FATE AND EFFECTS OF HUMATES (HUMIC AND FULVIC ACIDS) IN THE BAY

Soil chemists have established that humic acid and soil organic content govern agricultural fertility. In aquatic environments humates are present in solution or suspension and associated with mineral particles in marine sediments. These substances interact with potentially toxic metals to form complexes and with toxic polynuclear aromatics and pesticides to form less toxic molecular pairs or associations.

The importance of these compounds in determining the toxicity, bioavailability and stability of both metals and toxic organics in Bay waters is not known. In order to explain and predict the fate and effects of toxic or biostimulating compounds, we must examine their interactions with humic materials.

Objectives:

1. Determine the stability of humate-metal and humate-toxic organic complexes

Reductions in toxicity and bioavailability may be related to the stability of the formed complex. The factors which determine stability must be known if we are to predict the fate of a substance. Studies will be undertaken which determine the effect of humic acid structure and functionality on the stability of complexes.

Starting Date: July 1, 1985

2. Determine the bioavailability of humate complexed substances

The ability of organisms to accumulate specific compounds is influenced by many factors. We know that organic complexation of metals, for example, can significantly alter their bioavailability. Studies on the natural complexation of metals by humate substances will be conducted.

Starting Date: July 1, 1985

3. Investigate the effects of humates on phytoplankton productivity

Several theories have been advanced regarding the effects of humates on phytoplankton productivity. At present, we do not know if these substances are important in determining species composition or production in Chesapeake Bay. Studies designed to investigate the interactions between humates and production in Bay waters will be conducted.

Starting Date: July 1, 1986

SUBPROGRAM VIII(c): DETERMINE THE FATE AND EFFECTS OF TRACE METALS IN THE CHESAPEAKE BAY SYSTEM

Trace metals are biologically important both as nutrients and as toxic substances. Excessive concentrations of metals (e.g., Hg, Cu, Zn and Pb) can be toxic as hydrated ions, as inorganic complexes with anions, or as metallo-organic associations. Man-related sources of trace metals are

associated with energy production (fossil fuel combustion), corrosion of refined metal structures, metals from batteries, sewage, paint pigments, mining operations, electroplating, etc. Marine organisms concentrate these metals from solution and particulate matter. The uptake of certain elements is necessary for the normal function of many enzyme systems, but excess uptake can lead to toxicity or bioaccumulation to levels which make the organism unfit for human consumption. The environmental factors governing trace metal speciation, and hence bioaccumulation and toxicity, are poorly known. In order to determine the potential effects of man's activities or explain natural phenomena, studies of trace metal chemistry in estuarine systems are necessary.

Objectives:

1. Determine the source of metal complexes

As discussed in the section on humates, an understanding of the interactions between metals and organic compounds is vital to a determination of their fate and effects in estuarine waters. However, metallo-organic complexes are not limited to those of natural origin. Metallo-organics are added to Virginia's waters as detergents, dyes, anti-fouling compounds, lubricants, etc. At present we know little about the fate or effects of these various complexes after they reach the estuary. Studies directed toward identifying the sources, chemical composition and fate of these complexes will be conducted to provide a better estimation of potential impacts.

Starting Date: July 1, 1984

2. Determine the speciation of trace metals

In natural waters the speciation of metals (and hence availability to organisms) is a result of complexes and natural environmental variables, e.g., salinity. Predictions of potential impacts, i.e., from man's activities, cannot be made until we understand, at least, the most important of these interactions. Investigations will be undertaken to describe the speciation of trace metals in our estuaries as controlled by natural variables, e.g., salinity and humate concentrations. Results from these studies are necessary in order to describe the fate of trace metals in natural systems and to provide a basis for the studies of toxicity and uptake.

Starting Date: July 1, 1985

SUBPROGRAM VIII(d): ORGANISMIC RESPONSES TO POTENTIALLY TOXIC CHEMICALS AND ENVIRONMENTAL CONDITIONS

Detailed laboratory studies of the responses of organisms to allochthonous chemicals, many of which are potentially toxic, is necessary if man is to assess properly the impact of these chemicals on biotic communities. These studies must be carried out at several levels of biological organization (single species and multi-species, population or community) and from various perspectives (acute, chronic, behavioral, physiological, and biochemical).

The simplest measure of the acute effect of a chemical on an organism is often death, but such an acute response is only rarely measurable in the field with any precision. Therefore to assess the potential for acute effects, one must have recourse to laboratory studies. Similarly with respect to reproductive and growth effects, it is generally impossible in field situations to differentiate between responses to environmental factors and those to exotic chemicals, whereas these types of responses can be evaluated in the laboratory to provide information of importance in interpretation of field observations. While it is straightforward to determine the concentration of a chemical in an organism collected from the natural environment, it is usually not possible to estimate bioaccumulation rates from these data alone or to determine with any degree of certainty which of several possible routes of uptake are responsible for observed concentrations. Similarly, physiological responses may be observed in the field, but often defy attribution to specific causes without detailed laboratory studies.

Objectives:

1. Evaluate acute and chronic toxicity of allochthonous chemicals of various types on selected estuarine biota

An ongoing program will be maintained to assess the potential acute and chronic effects of various heavy metals, pesticides and various other anthropogenic and xenobiotic chemicals on estuarine phyto- and zooplankton, invertebrates, and fishes. Selection of specific substances for study will be based on perceived needs such as observed accumulation, known high use rates, potential for widespread application through agricultural or industrial practices, or in response to management needs of the Commonwealth of Virginia and the nation. These studies will be used also to assist in the design of other laboratory studies to evaluate physiological, behavioral, and other responses.

Starting Date: Continuing

2. Determine the rates and routes of uptake of exotic and other chemicals

Biological effects of chemicals are generally expressed only after the chemicals have been incorporated into the body of an organism and after a certain threshold concentration is reached. Substances may enter an organism either directly from water or may be assimilated with its food. While for many compounds, uptake from water seems to be the dominant route, uptake from food has long been thought of as a highly significant route as well. The purpose of the studies in this area are to examine the rates of uptake along these two routes, and from suspended or bed load sediments. We will attempt to determine importance of various uptake routes and develop information essential to the evaluation of field observations of the concentration of a compound in various compartments. Attention will be focused on fishes and selected invertebrates, mainly those of economic importance in the Chesapeake Bay system.

Starting Date: Continuing

3. Study physiological and biochemical responses to chemicals

At a more subtle level, chemicals can affect the physiological and biochemical levels of biotic organization. It is at these levels that one would ideally like to recognize an organism's response so that remedial action may be taken before damage, perhaps irreversible, occurs at either the population or the community level. An analysis of chemical effects on osmoregulation, selected enzyme systems, immune response systems, disease resistance mechanisms, organ and tissue structure, and carcinogenic activity, as well as an examination of potential behavioral mechanisms by which an organism can accommodate elevated concentrations of certain compounds are essential activities in understanding the fate and effect of toxic chemicals. Studies related to these types of organismic response are conducted through collaborative interactions between various researchers at the Institute.

Starting Date: Continuing

PROGRAM IX. STUDY NUTRIENT CYCLING PROCESSES AND CONTROLS IN RIVERINE,
ESTUARINE AND COASTAL MARINE ENVIRONMENTS

A. Issues:

1. Effects of Toxic Chemicals on Water Quality
2. Effects of Nutrient Enrichment on Water Quality
3. Effects of Other Non-toxic Wastes on Water Quality
4. Maintenance or Enhancement of Desirable Fisheries Stocks
5. Freshwater Diversion and Impoundment
6. Dredging and Dredge Spoil Disposal
7. Wetlands Protection and Use

B. Purpose:

Nutrient cycles, or perhaps more accurately those biogeochemical processes and their controls that govern nutrient dynamics, are essential to the maintenance of all living resources. For riverine, estuarine and near-shore coastal environments, nitrogen, phosphorus, sulfur and iron are the principal elements of interest. Past and contemporary research in this important area has clearly demonstrated that the rates of supply and the specific biogeochemical transformations of these mineral nutrients regulate various aspects of biological community structure and function (e.g., species diversity, organic matter production, trophic relations and rates and pathways of organic matter cycling). It is equally clear that until we gain better understanding of the processes effecting the more important transformations (both chemically and biologically) and their environmental controls, we can expect little significant advance beyond present knowledge. The classic representation of nutrient flows as monospecific elemental cycles is not only misleading but scientifically inaccurate. It is the understanding of the interactions among the elemental nutrient cycles and their relation to biological productivity in estuaries that will provide the best information for management of natural estuarine resources.

Historically, nutrient cycling and/or dynamics has often been inferred from time-series, nutrient concentration data taken at geographically fixed (both horizontally and vertically) positions in the estuarine water body. For a large number of past studies and some current efforts, nutrient dynamics are presented as depth distribution data blocked on river miles that were collected at regular calendar-day intervals (e.g. monthly sampling regimes). Although these data are useful for other purposes, it is impossible to derive meaningful rate estimates from them or investigate control mechanisms. We suggest that future efforts must incorporate carefully designed experiments with appropriate time and space scales of sampling.

In contrast to but complimentary of those investigations proposed under the nutrient enrichment program (cf. PROGRAM X), our efforts will be devoted to the investigation of specific nutrient transformation processes

and their controls. In this research program we propose several objectives that will provide the following:

1. Better spatial and temporal descriptions of the concentration behavior of selected mineral nutrients.
2. Rate estimates for specific transformations considered dominant or rate limiting in the nutrient cycle.
3. Evaluation of the principal environmental controls on the rate estimates determined under 2 above.
4. The effect of selected natural and/or man-induced perturbations on both specific transformations and general nutrient cycling behavior.
5. The principal mechanisms which couple the cycles of essential nutrients with each other and the more general cycling of organic matter.
6. Better conceptual and simulation models for nutrient cycles in riverine, estuarine and coastal marine environments with particular reference to the management of natural resources.

Our following proposed scenario for investigations on nutrient dynamics in estuarine environments and specifically the Chesapeake Bay system is predicated on both past and current information. In large part the overall goals of this enterprise must be not only basic understanding of nutrient cycles per se but an understanding that is applicable to contemporary resource utilization and management concerns. We believe that the approach outlined can effectively and efficiently satisfy both goals.

C. Objectives

1. Determine specific rates of transformation for selected nutrient species that are considered dominant in estuarine nutrient cycles

Due in large part to technological advances and better methodological approaches only in recent times have we been able to determine the rates of transformation of specific mineral and gaseous nutrients. Over the last decade, various researchers have reported rate measurements from a variety of marine environments including salt marshes, seagrass meadows, intertidal and subtidal sediments and the water column. This has led to revision of our conceptual models of nutrient cycling in estuarine environments relative to both specific transformations that appear to control the cycle and the areas within the estuary where the highest rates are occurring. These advances have also provided better data against which to judge both the conceptual structure and dynamic (simulation) behavior of our models. Specifically, the pycnocline, intertidal and subtidal sediment-water interfaces, the rhizosphere in aquatic vegetation communities, aerobic-anaerobic interfaces in sediments and water, and the vertical discontinuities characteristic of estuarine fronts appear to be the zones of highest activity relative to nutrient transformations. These interfaces, of course, cross several more observationally defined habitats and/or environments. We will concentrate our measures of nutrient flux

and transformation at these interfaces. We will attempt to quantify the rates of exchange of O_2 , NO_3 , NH_3 , PO_4 and SO_4 across the interface; the rates of microbially mediated transformations of NH_3 to NO_3 (nitrification); and NO_3 to N_2 (denitrification, which makes nitrogen unavailable to most of the biological realm) as well as rates of oxygen based respiration and sulfate reduction. These data will provide information for coupling our current nutrient cycling paradigms with measured dynamics, better information for mass balance calculations, and insight for designing adequate experiments to investigate control mechanisms (objective 2).

Starting Date: July 1, 1983

2. Evaluate the principal environmental controls on the rate of transformation of selected nutrient species

A current area of research attracting much attention is the investigation of the controls on the various nutrient transformations. Physical and chemical properties of the environmental milieu (i.e. temperature, salinity, oxygen concentration, substrate concentrations, water column stratification state) and the biological properties are all interactive to some degree in controlling specific rates. However, without information (even qualitative) on the principal controls, our ability to accurately represent the cycles of essential nutrients, negate or support current hypotheses, or eventually predict nutrient behavior under natural and perturbed conditions will be seriously limited. We will initially determine the degree to which temperature and oxygen concentration control nitrification rates. Subsequently, we will identify the principal controls on other specific processes (e.g. those mentioned in objective 1), define conditions for maximum and minimum realized rates, and determine the boundaries for simulation model studies. Perturbed behavior as well as the rationale for construction of realistic model system equations will be determined. We will use a laboratory or combination laboratory-field study approach. Once we are satisfied that the rate estimates (objective 1) are realistic and we have identified the principal controls on the process of interest (this objective), studies will be undertaken to better evaluate the effects of man-induced perturbations (e.g., nutrient enrichment, toxics, organic enrichment and thermal loadings).

Starting Date: July 1, 1984

3. Develop more realistic ecosystem simulation models of nutrient cycling in estuaries

Implicit in all the above is that we have a conceptual structure for nutrient cycling operating on variable spatial and temporal scales, characterized by dominant processes that can be measured and the principal controls identified and quantified. In order to manage information transfer as well as provide an analytical tool, we will develop and test ecosystem simulation models. Our first efforts in this area will be devoted to modeling the nitrogen cycle and coupling it as a control with carbon productivity and food web transfer. The modeling effort will provide a method for "bookkeeping," a tool for intermediate data analysis

and, hopefully, an eventual tool of predictive capability. The model(s) will be designed and mathematically constructed to couple the principal elemental nutrient cycles in estuarine waters and their controls with the more general cycle of organic matter production and flux (i.e., those processes and their controls that determine, in part, secondary production by both ecologically and economically important species populations).
Starting Date: July 1, 1984

PROGRAM X. EVALUATE FACTORS LEADING TO, AND THE CONSEQUENCES OF, NUTRIENT ENRICHMENT

A. Issues:

1. Effects of Nutrient Enrichment on Water Quality
2. Maintenance or Enhancement of Desirable Fisheries Stocks
3. Freshwater Diversion and Impoundments
4. Wetlands Protection and Use
5. Dredging and Dredge Spoil Disposal

B. Purpose:

Nutrients in the present context are considered to be the elements utilized by green plants, such as algae and seagrasses, to produce the food consumed by the organisms residing in the Chesapeake Bay system. The primary elements of concern are carbon, nitrogen, and phosphorus, and to a lesser extent silicon. Estuaries are thought to be quite productive because physical and biological processes tend to concentrate nutrients in estuaries to higher levels than in either the freshwater or seawater sources of these materials. In addition, man's activities often increase nutrient inputs to estuaries (e.g., sewage discharges and agricultural runoff). Unfortunately, knowledge of what happens when nutrient inputs are increased or reduced is still largely descriptive and incomplete. Experiences in the Potomac River estuary over the past thirty years show that high levels of nutrient inputs can produce undesirable environmental conditions and that proper management of nutrient inputs can reverse the enrichment process. However, water quality goals relative to nutrient enrichment are not well defined nor do we understand the nutrient cycling processes sufficiently to determine the best means of altering the situation. Effective management of Virginia's biological resources depends in large part upon improving our understanding of nutrient cycles and the ways that they affect the biota.

C. Objectives:

1. Work with management agencies on the development of water quality standards related to nutrient enrichment in estuaries

Many are familiar with the eutrophication process in lakes and how the addition of wastewaters can accelerate that process, as illustrated by the problems encountered in Lake Erie and elsewhere. Estuaries show similar effects to excessive nutrient enrichment. For example, in the 1960's the upper tidal Potomac River experienced persistent massive algal blooms. For that case it was apparent that some reduction in nutrient inputs was desirable, and the removal of nutrients from wastewaters has brought about an improvement. The costs of that wastewater treatment are high and there is a need to better define the water quality goals to guarantee that expenditures are necessary and funds are being spent wisely.

Because estuaries respond to a number of physical phenomena (e.g., freshwater inflow, winds, tides, salinity intrusion, storm surge) it is difficult to relate nutrient inputs directly to biological responses, as was done in lake ecosystems. Additionally, it appears that estuaries show greater variability in terms of biological responses, so it is difficult to specify desirable and undesirable characteristics. Nonetheless, a working hypothesis must be developed to organize existing data into a single, coherent scheme. To do so a small number of enrichment levels will be defined and the biological responses to those levels characterized. When possible, dominant routes of nutrient cycling and other important aspects of the system will be incorporated.

Once an acceptable conceptual model describing the range of responses to nutrient enrichment has been formulated, it will be possible to begin setting water quality goals and to develop methods to monitor conditions in the environment appropriate to those goals. When goals have been established, it will be possible to assess current conditions relative to those goals. It is likely that mathematical models of water quality will be required to complete the step between water quality goals and system specific standards or limits.

Assessment of standards will be complex and require strong interplay between water quality managers and scientists. We will be working with the water quality management agencies, specifically the State Water Control Board (SWCB), in providing assistance and technical support as required to meet the objective.

Starting Date: July 1, 1983

2. Assess water quality conditions in the coastal waters of Virginia and relate changes in quality to the causative factors

In order to anticipate problems as they develop rather than to wait until a crisis situation is at hand, water quality is monitored (water quality in this section does not include consideration of toxic substances). During the 1970's water quality conditions in many areas changed as a result of upgraded treatment of wastewaters, and of changes in population and land use. The past decade also included some extreme environmental conditions (e.g., the flooding associated with tropical storm Agnes of 1972 and the drought of 1980-81). The mid-1980's is an appropriate time for a review of present and past conditions.

Water quality data for the major tributaries of Virginia will be interpreted to determine temporal trends. Changes in water quality due to specific point source discharges, runoff from the land, natural phenomena and other factors will be noted and, where possible, quantified.

Because the expenses associated with both sample collection and the laboratory analyses are high, an alternate arrangement to conventional monitoring will be assessed. Existing mathematical models of water movement, salinity intrusion and water quality will be used along with routinely collected data, such as river flows at the fall line and tidal heights. It is anticipated that statistical relationships derived from

the historical data base will allow reasonable estimates of many factors influencing water quality. If this proves to be the case, water quality during "normal" conditions could be estimated using the math models and field efforts reserved for critical or unusual periods. Initial efforts to assess this approach will be devoted to the James and York rivers due to availability of tidal height measurements at Sewell's Point, and salinity and tidal height measurements at Gloucester Point.

Starting Date: July 1, 1984

3. Maintain, refine and add to the library of mathematical models used to predict conditions in the estuaries of Virginia

Primarily as a result of the Cooperative State Agencies program between VIMS and SWCB, there exists a large number of mathematical models for Virginia's estuaries. For the major rivers, such as the James, there are models of water movement, salinity intrusion, and water quality. Due to the rigorous mathematical formulations incorporated in these models, they are useful tools for projecting system responses to altered conditions; specifically, water quality changes due to altered waste loadings can be assessed.

The current library of models will be maintained. When management needs require it, existing models will be applied to water bodies heretofore not treated. The models also will be refined to reflect new data and advances in our understanding of processes.

Because model development has been so successful in the past decade, it is anticipated that less effort will be required in the future. The areas in which continued model development is planned are sediment/water column exchanges, sediment transport, and toxic substances transport. No timetable for completion of these efforts can be given at this time because progress on the models depends on the availability of better field data and advances in our understanding of some of the physical, biological and chemical processes.

Starting Date: Continuing

4. Improve our understanding of sediment-water column exchanges

As the ability to simulate water quality conditions through use of mathematical models has improved, deficiencies in our knowledge and data gaps have become apparent. Perhaps the greatest source of uncertainty lies with the so-called nonpoint sources of pollution, one of which is the exchange of materials between the sediments and the overlying water column. Sediments often act as reservoirs, sometimes storing a substance while at other times releasing it. In shallow systems these exchanges are very important.

The first step in the elucidation of the processes at work is that of gathering appropriate data. Initial efforts will be focused on systems with known problems and where sediments have been identified as important factors, specifically the Potomac embayments, Chowan River, Back Bay, Pagan River, and Nansemond River. Efforts will emphasize first the sediment oxygen demand, then the exchange of nitrogen and phosphorus, and finally the release of silicon.

When the exchanges are measured, sediment samples will be collected and analyzed for grain size distribution, organic content and other variables in order to determine surrogate features which might be used in place of the difficult and expensive in situ measurement of exchange rates.

Data from these studies will be interpreted and conceptual models postulated. These hypotheses will be tested using mathematical models of specific water bodies. When the conceptual model proves to be both accurate and useful, existing water quality models will be modified to reflect the new understanding of sediment-water column exchanges.
Starting Date: July 1, 1983

PROGRAM XI. UNDERSTAND THE DYNAMICS OF BENTHIC BOUNDARY LAYERS AND ASSOCIATED PROCESSES OF SEDIMENT RESUSPENSION, TRANSPORT, AND ANIMAL-SEDIMENT INTERACTION IN COASTAL AND ESTUARINE ENVIRONMENTS

A. Issues:

1. Effects of Toxic Chemicals on Water Quality
2. Effects of Non-toxic Wastes on Water Quality
3. Maintenance or Enhancement of Desirable Fisheries Stocks
4. Port Development
5. Dredging and Dredge Spoil Disposal
6. Construction and Siting of Offshore Facilities
7. Shoreline Erosion Control
8. Sand and Gravel Mining

B. Purpose:

The benthic boundary layer constitutes the primary linkage between water movement and sediment movement. The complex processes of interaction which take place within the benthic boundary layer affect the intensity and direction of particulate transport, the configuration of the bottom, and the communities of animals which live on and within the bottom. Before we can completely predict or model the entrainment and transport of sediment, adsorbed toxic wastes, or particulate wastes, we must gain a better understanding of the workings of the benthic boundary layer throughout a range of coastal and estuarine environmental conditions. The benthic boundary layer studies will provide information germane to such management questions as: 1) where to place dredge spoil; 2) where to expect the accumulation or erosion of different types of sediment; 3) where to dredge and not to dredge; 4) how to anticipate and avoid possible buildup of toxics adsorbed to certain types of sediment; 5) how to predict whether specific locations are likely to provide good or bad habits for benthic organisms; and 6) whether or not certain development practices (such as dredging, construction of engineering works, and landfilling) are likely to exacerbate or alleviate shoreline erosion on a site-specific basis.

C. Objectives:

1. Explain the characteristics and consequences of benthic boundary layers in different environmental conditions including: inner shelf, shoreface, Bay mouth, Bay stem, and subestuarine (e.g. James, York, and Elizabeth rivers) environments

To determine the manifestations of benthic boundary layer processes in the various subenvironments of the Chesapeake Bay System and its adjacent shelf, we will first examine the spatial and temporal variations in subaqueous morphology, bed roughness characteristics (e.g. bedforms), sediment characteristics, and benthic fauna. Bed roughness and sediment type exert a fundamental influence on boundary layer behavior and must be known before meaningful experiments on boundary layer hydrodynamics can be carried out.

In all of the environments, the infauna and epifauna of the benthic community not only depend on but also condition the sediment and influence substrate stability. Hence, another aspect of this objective involves mapping the associations between sediments and benthic biological communities and examining the nature of "patchiness" in the resulting spatial distributions (cf. Program II)

Starting Date: July 1, 1983

2. Elucidate the hydrodynamic process signatures which prevail in different benthic environments

The structures of geophysical boundary layer flows vary depending on the combination of different types of flows (e.g. wave, tide, or wind generated) and bed roughness. Natural boundary layer structures are incompletely described and understood. Thus, in many instances, it is difficult to specify the distribution of instantaneous, or average, shear stress acting at the sediment interface. This renders problematic the application of laboratory-derived results which relate transport intensity to mean values of applied shear. Hence, we need more field data on benthic process signatures and associated boundary layer structures. Specifically, we will investigate how the boundary layer structure varies with different relative magnitudes of flows due to waves, tidal currents, and wind-driven currents over beds of differing roughness (cf. Program II).

Starting Date: July 1, 1984

3. Understand and predict the resuspension of sediment and the vertical diffusion of particulate matter

There is a serious knowledge gap on specification of critical shear stress for the initiation of motion when the sediment materials are a mix of cohesive and non-cohesive components and when, as is generally the case, there is significant biological activity within or on the sediment interface. Most laboratory studies have focused on mineral components, either granular sediment mixtures or "ideal" clays devoid of organic materials. Research over the past two decades has clearly demonstrated that epifauna, infauna and microbial activity can dramatically influence sediment stability. In addition, there is little information as to the critical shear stress necessary to resuspend cohesive materials under various levels of consolidation or the rates of resuspension under different process signatures. We will carry out field experiments to obtain these data in order to develop meaningful predictive models.

Once sediments and other particulates have been lifted from the bed, they are diffused upward into the water column by turbulent processes where they become subject to net movement. We, therefore, need to understand and be able to predict the vertical diffusion of particulates.

To address this objective, it will be necessary to carry out a series of field experiments utilizing bottom-mounted current profiling and instrumentation pods as well as a sea bed flume. Some aspects can be carried out concurrently with experiments related to objectives of Program II.

Starting Date: July 1, 1984

4. Understand and predict the net rates, directions, and gradients of transport of sediment

The resuspension and vertical diffusion of sediment do not directly imply any horizontal transport. We must also gain understanding and predictability of the rates and pathways of sediment transport. This is fundamental. Furthermore, the net transport of sediment may or may not involve any net erosion or deposition locally; it may simply involve balanced transfer. From the point of view of harbor siltation, shoreline erosion or deposition, etc., it is the spatial gradients in sediment transport and consequent rates and patterns of deposition and erosion that are important. We need to understand and predict these. Part of this problem (long-term effects) can best be addressed by way of the sedimentology, stratigraphy and geologic evolution problems (cf. Program XIV). However, the basic physics of the problem is essentially a benthic boundary layer problem. Specifically, we will conduct field experiments aimed at elucidating the mechanisms responsible for the horizontal advection of sediment in different environments and explaining why the transport rates and directions vary spatially and temporally.

The same instrumentation used for objectives 2 and 3 will be utilized here although experimental designs, including spatial arrangements, deployment period, and sampling programs, will differ. To a large degree, data related to this objective may be collected concurrent with that for objective 3.

Starting Date: July 1, 1985

PROGRAM XII. DESCRIBE AND UNDERSTAND THE CIRCULATION OF WATERS IN THE ESTUARINE AND COASTAL ENVIRONMENT

A. Issues:

1. Effects of Degraded Water Quality
2. Maintenance or Enhancement of Desirable Fisheries Stocks
3. Freshwater Diversion and Impoundments
4. Port Development
5. Dredging and Dredge Spoil Disposal
6. Construction and Siting of Offshore Facilities
7. Wetlands Protection and Use
8. Shoreline Erosion Control
9. Sand and Gravel Mining
10. Oil and Gas Extraction

B. Purpose:

The salinity regime and water movements within the estuarine and coastal waters of the Commonwealth controls, in large measure, the distribution and movement of the living marine resources. For example, the dispersion and transport of shellfish, crab and fish larvae as well as their food supply, the phytoplankton and zooplankton, depend upon these water movements. The fate of sediments and pollutants introduced into the system is inextricably tied to the circulation of water within and between components of the system. A thorough understanding of the component processes, when combined result in the circulation of water, is central to understanding important biological responses and ultimately to predicting the fate of sediments and pollutants.

C. Objectives:

1. Determine and explain temporal and spatial variations in estuarine circulation

Research dealing with transport processes in estuaries has been dominated by the conceptual framework postulated by Pritchard in the 1950's, (i.e. the two-layered salinity/density structure arising from freshwater discharge overriding, and mixing with underlying saline water resulting in a net seaward flow in the surface layer and a net landward flow in the bottom layer). More recent efforts have demonstrated that this model only applies approximately one-half of the time. Thus, major emphasis needs to be placed in understanding the component processes so that improved conceptual models may be developed.

Temporal patterns of the density structure and circulation result from changes in the "forcing functions" which drive the system. These are: tides, winds, river flow, and downstream conditions (for Chesapeake Bay the conditions existing on the continental shelf; for the James River, conditions existing in the lower Chesapeake Bay). Recent investigations at VIMS and elsewhere have demonstrated that the tributary estuaries (James, York and Rappahannock), and segments of the lower Bay tend to

become vertically homogenous during the fortnightly higher tides. Several hypotheses may explain the phenomenon. Only if we verify the correct hypothesis will we be in the position to correctly predict the consequences of man's modification of the system. The cyclic destratification is thought to play an important role in phytoplankton dynamics as nutrients in the lower water column are brought to the surface photic zone.

Studies of the destratification processes will be studied initially in the York and James rivers with subsequent concentration in the Rappahannock River. These studies, involving both field observation and analytical considerations, will be part of an interdisciplinary effort involving nutrient cycling (cf. Program IX) and plankton dynamics (cf. Program III).

Spatial variations in circulation are also important in estuarine processes. These localized circulation can result in convergence zones and/or zones of intense shear, as well as other features which may persist for relatively long-time scales. Most of these features arise from either transverse or longitudinal variations in bottom geometry. Localized circulation patterns which parallel the deep channels may play an important role in determining sedimentation patterns and in larval dispersion processes. Those circulations arising from depth changes along the channel axis may play an important role in localized vertical mixing. Initial effort will focus on the physics of longitudinal fronts associated with the depth transition between the channel and flanks in the tributary estuaries (York, James, and Rappahannock).
Starting Date: Continuing

2. Develop appropriate conceptual and analytical models of turbulent mixing processes in estuaries

Studies are needed which define and describe the scales and intensity of turbulence under a variety of stratification and tidal conditions. Most turbulence models have been based on laboratory experiments of turbulent flows in which the mean flows are steady in time or of homogenous density. It is often inadequate to apply such models to estuarine environments in which the mean flow is stratified as well as unsteady due to tidal forcing and transient wind events. The distribution of organisms, especially plankton and their food supply, as well as the transport of toxic substances and sediments, are all affected by turbulent mixing. Advanced understanding of these processes is essential to predicting these distributions. In particular, a proper formulation of turbulence is required for construction of sediment transport models which will predict the location and magnitude of shoaling of waterways and port facilities.

Comprehensive field measurements will be conducted to describe the characteristics of turbulence throughout the water column under varying conditions of density stratification, and bottom boundary configurations. In addition, particular emphasis in near bottom flow will specify the time history of boundary shear stress in terms of turbulence and mean flow

characteristics. This effort is central to the benthic boundary layer studies (c.f. Program XI) for the determination of sediment resuspension. Initial field studies will focus on the James River estuary.
Starting Date: July 1, 1984

3. Study the principal characteristics of circulation in components of the Chesapeake Bay system and coastal waters

As well as process oriented studies additional information is needed in specific geographic areas.

a. Bay circulation:

The main stem of the Virginia portion of the Chesapeake Bay is poorly understood with respect to the basic circulation patterns. The ongoing circulatory study of the entire Bay stem by National Oceanic and Atmospheric Administration (NOAA) (in which VIMS participates) will provide an important framework upon which to build. Upon completion of interpretation of the NOAA data we will design specific observation programs to test hypotheses arising from the initial analysis. Included will be a series of drogued buoy studies to verify the dominant routes of water movement at different depths. These studies will include the interactions between the tributary estuaries as well as the main stem of the Bay itself. The net movement and rate of movement of water in the lower meter of water is of particular relevance to sediment accumulation patterns in the Bay. In order to ascertain these movements, bottom following drogues will be used (cf. Program XI Benthic Boundary Layer).
Starting Date: July 1, 1985

b. Bay mouth-shelf circulation:

Circulation processes at the entrance of the Bay and interactions between the Bay and the nearshore coastal waters (the coastal boundary layer) will be better defined in order to gain a understanding of the exchange of materials between the oceanic and estuarine systems. Do nutrients and detritus expelled from the Eastern Shore seaside marshes enter the Bay? How does the circulation at the Bay mouth region control blue crab recruitment in the Bay? How does the Bay effluent mix with oceanic waters and what is the fate of these waters under varying seasonal conditions? These questions will be addressed by specific interdisciplinary projects (cf. Programs I and III).
Starting Date: July 1, 1984

c. Continental shelf circulation:

Present theoretical models of continental shelf circulation and the interaction between the coastal boundary layer on one side and the continental slope waters on the other, either yield conflicting results or have not been verified by direct

observation. Field observation will be conducted to test alternate hypotheses.

Starting Date: After July, 1985

d. Lower James River:

The oyster beds of the James River are still the primary source of plantable oyster seed for the leased oyster beds in Chesapeake Bay. It is not known which broodstock areas are particularly productive in spatfall on seed rock areas. Circulation studies will be conducted to determine which oyster broodstocks are particularly important in maintaining the oyster larvae pool of the James River (cf. Program Ia).

Starting Date: July 1, 1984

e. Elizabeth River-Hampton Roads circulation:

Recent studies have indicated very large concentrations of polynuclear aromatic hydrocarbons (PNA's) in the Southern Branch of the Elizabeth River with gradients of concentrations diminishing toward the mouth of the Elizabeth River. One important question (cf. Program VIII) is whether these toxic compounds escape the Elizabeth River into the Hampton Roads and lower James River. To address this question we will develop a vertical two-dimensional hydrodynamic model of the Elizabeth River system. The model will predict the transport of dissolved PNA phases under varying stratification and provide some insights into transport of particulate material.

Starting Date: July 1, 1984

4. Evaluate the impacts of shifts of salinity patterns in the principal tributary estuaries, and in the Bay, due to droughts, freshwater diversion and impoundments

The circulations in partially stratified estuaries is controlled by mixing of the riverine freshwater inflows with the saline marine waters. The resulting average salinity patterns control most of the habitat characteristics along the longitudinal axis of the estuary. Under conditions of prolonged drought or man-induced diversion of fresh water the salinity distribution shifts upstream. This response can shift the zonation of salinity dependent pathogens and parasites, shift fisheries nursery grounds, modify wetland species distribution, shift sedimentation patterns, and potentially, lead to changed wastewater allocations along the system so impacted.

Existing mathematical flow models will serve to identify the salinity distribution response to variable freshwater input and salinity boundary conditions at the mouth of the estuary. Effort will be devoted to identifying salinity responses for various expected conditions at the boundaries. The resulting modified salinity patterns will then be examined as to anticipated impact on the above noted functions of the systems.

Starting Date: July 1, 1983

PROGRAM XIII. DEVELOP A BETTER UNDERSTANDING OF SHOREFACE, SURF ZONE AND BEACH PROCESSES

A. Issues:

1. Shoreline Erosion Control
2. Wetlands Protection and Use
3. Port Development
4. Dredging and Dredge Spoil Disposal
5. Construction and Siting of Offshore Facilities
6. Sand and Gravel Mining

B. Purpose:

Coastal erosion as well as accretion are responses to complex processes which operate to considerable depths seaward of the shore. There is no single cause of coastal erosion; different mechanisms dominate under different circumstances. Consequently, the same management or engineering practice may cause erosion in one case and prevent it in another case. Guidelines for proper and effective coastal utilization and protection must be based on a thorough understanding of the processes which operate to redistribute nearshore sediments and reshape the coast. The purpose of this program is to elucidate those processes and apply our knowledge by developing guidelines for rational management and protection of the shores of Virginia.

C. Objectives:

1. Explain the relationships between different sets of coastal environmental conditions and the dynamic behavior of nearshore/surf zone and beach systems

Beach and nearshore changes as well as the physical mechanisms which drive these changes vary spatially and temporally. They are highly dependent on local environmental conditions, particularly on the incoming wave characteristics, the shoreface profile configuration, and the nature of the nearshore and beach sediments. The associations which exist between shoreface and beach morphologies, mobilities and dominating hydrodynamic processes are partially understood for certain parts of the world. However, relatively little is known about the particular environments which prevail in Virginia.

Through our ongoing project in nearshore morphodynamics, we have some reasonable understanding of the general associations between beach and surf zone forms and processes. We will utilize available data, remote sensing imagery, and, where needed, new experimental data to gain a better understanding of the specific cases which exist in Virginia. Together with this effort we will begin to acquire long-term data on wave climate inside and outside of Chesapeake Bay. Research related to this objective is already underway; it needs to be sustained for several years.

Starting Date: Continuing

2. Develop a model capable of providing predictions of short-term beach change

We must greatly improve our ability to predict, over the short-term, the likely response of any particular beach and its associated shoreface regions to different wave or storm conditions. This is essential if we are to assess the nature and range of nearshore and beach hazards for management or long-range planning purposes. Furthermore, it would be very valuable to provide an "early warning" program for beach erosion probabilities on a sector by sector basis.

Models for beach stability which couple the forcing phenomena (waves and nearshore currents) with change in the form of the beach will be developed. Attention may then focus on stability criteria governing the range of departures of shoreface profiles from modal or equilibrium states and on zonal discrimination between sites to temporary storage and permanent deposition. The successful model would predict how much beach change would occur for a stated change in wave characteristics and the initial beach configuration. This implies the need to plan and conduct both long- and short-term studies in accordance with the appropriate time scale of the morphodynamic processes at work within a given shoreface system.

We are already working on a generalized predictive model. Over the next few years we will develop a parallel model applicable to the special and "unique" environmental characteristics of Virginia.
Starting Date: Continuing

3. Develop criteria for acceptable modifications in the shore zone

Today land along the shore zone is at a premium and although shore engineering has come a long way, there are still inadequate and/or inappropriate modifications being made to the shore zone. Poorly designed and/or constructed bulkheads, groins, revetments, dredge and fill, etc., make the shore zone a hodge-podge of structures in various states of disrepair. Often, there may be as many different shore modifications along a given reach as there are property owners. Recent studies have demonstrated that shoreface mobility and the mechanisms which operate to cause erosion will differ depending on the particular condition of the beach and shoreface. Whereas a particular management or "erosion control" practice may be beneficial for one condition, the same practice may be damaging for another. We will map and classify shoreface and beach environments according to their existing conditions and then plan the appropriate management practices.

Researching the recent shore history (last 125 years) as recorded by maps and aerial photography, will supply data on recent shoreline evolution. Shore orientation change and sand movement can be plotted in response to man's activities to provide historical perspective. Using the results of these studies and research from other areas, effective management practices and also alternatives to extensive modification of the shore will be developed. The geographic area includes all of the tidal waters of Virginia.
Starting Date: Continuing

4. Develop and evaluate low-cost erosion control structures

A low-cost erosion control method does not necessarily mean low quality. If the effectiveness of a given low-cost method in preventing or controlling erosion cannot be demonstrated, then it should not be implemented. In order to develop low-cost structures and techniques and to verify their effectiveness in Virginia's estuaries, it is necessary to determine the physical limits and conditions under which they will perform their intended function. These limits will largely be determined through the study of local coastal processes and geological features while the latter are interacting with the structure. Both the development of new types of protective structures and evaluation of the effectiveness of "nonstandard" constructional materials should be included in the program. How these structures or techniques affect and are affected by sediment transport will also be of concern. Finally, short- and long-term monitoring of demonstration sites will provide essential information on the implementation of these methods at various coastal locations in Virginia.

Starting Date: Continuing

5. Understand and predict the behavior of tidal inlets and associated inlet-basin interactions

Tidal inlets are important as "valves" connecting lagoonal, estuarine, and back-barrier environments to the nearshore and offshore zones. Long- and short-term inlet channel stability is determined by the relative balance between and supplied via littoral drift which tends to close the inlet, and tidal currents which tend to scour the channel. The balance between wave power and tidal power at a stable inlet is usually the result of several complex interacting factors, beginning with local wave climate and mean range of tide as the primary forcing functions. Other variables that modulate the primary forcing include the adequacy of the local sand supply to allow a significant littoral transport and the hydraulic "impedance" characteristics of the inlet which determine what fraction of the potential tidal prism (a function of the ocean tide range and basin surface area) will be admitted via the inlet.

Recent advances in our knowledge on the behavior of inlet systems suggest that mathematical indices may be found that will allow one to categorize their innate stability potential. Some inlets remain open with little change for long periods of time; others may have a tendency to close and then reopen again. Still others have only a tendency to close and would never have existed but for the transient effects of a coastal storm or an ill-advised coastal construction project. Achieving predictive capability for inlets still requires further work but is crucial if we are to properly advise the Commonwealth on inlet stability, especially where new modifications to existing inlets are planned.

Recent work at VIMS has led to hypotheses on how the mutual interaction between the entrance channel and the basin may evolve as the basin becomes filled with sediment. This hypothesis will be tested using specific inlet configurations and measurements of the flow fields and sediment transport tendencies.

Starting Date: After July 1, 1984

PROGRAM XIV. DESCRIBE AND EXPLAIN THE LATE QUATERNARY SEDIMENTOLOGY,
STRATIGRAPHY AND GEOLOGIC EVOLUTION OF THE CHESAPEAKE BAY AND
COASTAL WATERS

A. Issues:

1. Effects of Toxic Chemicals on Water Quality
2. Dredging and Dredge Spoil Disposal
3. Construction and Siting of Offshore Facilities
4. Shoreline Erosion Control
5. Sand and Gravel Mining

B. Purpose:

The benthic boundary layer program is aimed at utilizing primarily a site specific approach in elucidating the short-term mechanics and processes of sediment entrainment and transport. However, sediment distribution patterns and subsurface stratigraphy express the time integration of the transport processes. Information as to the long term net trends of sediment erosion, transport, and accumulation can only be ascertained from studies of the sediments themselves and their vertical and areal sequences. Such studies are also needed to complement and provide baseline information to benthic boundary layer studies. They are essential to assessments of sand and gravel resources and they enable us to field check the long term validity of computer models for predicting sediment dispersal.

C. Objectives:

1. Map and explain the distribution and patterns of surface and subsurface sediment properties of the Chesapeake Bay and its interconnecting shelf, estuarine, and nearshore environments

In order to understand the sources, pathways, and sinks of sediment entering and leaving the bay and its tributaries, we must know the sediment properties which typify each subenvironment and we must know how the sediment units interdigitate and overlap each other. By mapping sediment distribution patterns, both at the surface and in the subsurface, we will infer where sediments are coming from and where they are going. In addition, sediment distribution patterns will provide essential input to the benthic boundary layer program and can provide a check as to the long term validity of predictive models.

To obtain the necessary information, it will be necessary to utilize existing data and to carry out additional sampling, coring, sub-bottom profiling, and side-scan sonar surveys. Considerable information has already been obtained through the sand inventory program. Continued analyses and field work will better define the subenvironments of deposition and origins of the sediments. A special application of this objective is to predict the location of geological resources, particularly sand and gravel.

Starting Date: Continuing

2. Understand the history and evolution of the shorelines of Virginia in order to predict local, long-term changes in the shore zone

It is known that sea level along the U.S. East coast is experiencing a slow but progressive rise. In many localities in Virginia, this slow rise is made more crucial by the fact that fine-grained marsh deposits are undergoing compaction and hence slowly subsiding. Over the long term, certain sectors of coast are experiencing gradual retreat. These trends obviously have an important impact on planning for future development. Because the process is a low one, historical and geological evidence must be used to assess the net rates of retreat, or, as the case may be in some instances, advance of the shore.

Comparisons of historical maps and photographs combined with coring and stratigraphic interpretation of sediments in the shore zone will be used to achieve this objective. To a considerable degree, this objective is related to the shoreface dynamics program (cf. Program XIII).

Starting Date: Continuing

3. Develop a model for the stratigraphy of large estuarine systems

Although the literature contains many models of depositional environments such as delta and barrier complexes, the diagnostic features of estuarine and bay depositional sequences have been only sparsely described. However, large scale depositional systems like the Chesapeake Bay and its tributaries probably have important analogs in the rock record. Development of a coherent model for recognizing these environments would contribute significantly to the exploration for mineral resources, including exploration for petroleum. Since the Chesapeake Bay system is probably one of the largest and most ideal systems of its type, it is appropriate that the Virginia Institute of Marine Science should be involved in developing a general depositional model applicable not only to Virginia but to other parts of the world as well.

The coring and sub-bottom profiling data collected in connection with objective 1 will be utilized here. However, generation of a general depositional model will require somewhat different statistical analyses as well as analog comparisons with other systems. This activity can most effectively be carried on concurrently with other facets of the sedimentology, stratigraphy and geologic evolution objective.

Starting Date: July 1, 1984

4. Develop conceptual and analytical models for the long term movement of particulate material within and between components of estuarine systems

Recent studies have indicated large local concentrations of toxic materials in estuarine sediments, specifically those in the Southern Branch of the Elizabeth River. Questions arise as to where these materials might go and how they might affect the water quality of other parts of the estuarine system if remobilized or resuspended by dredging. There are related questions concerning the redistribution of sediments

from dredge disposal sites. In order to provide timely advice as to possible fates of toxic material over extended periods of time, we will develop models for the pathways and ultimate sinks of sediments originating from explicit sources. An immediate concern is to model the fate of particulate material flushed from the Elizabeth River (cf. Programs VIII, XI, XII)
Starting Date: July 1, 1984

PROGRAM XV. CONDUCT INVESTIGATIONS RELATED TO THE DEVELOPMENT, UTILIZATION,
AND MANAGEMENT OF RESOURCES OF SIGNIFICANCE TO THE MARINE
ENVIRONMENT

A. Issues:

1. Effects of Toxic Chemicals, Nutrient Enrichment, Microbial and Viral Contaminants, Thermal Additions, and Other Non-toxic Wastes on Water Quality
2. Resolution of Fisheries Conflicts
3. Maintenance of Enhancement of Desirable Stocks
4. Effects of Freshwater Diversion and Impoundments on Fisheries
5. Maritime Commerce and Port Development
6. Dredging and Dredge Spoil Disposal
7. Construction and Siting of Offshore Facilities
8. Shoreline Development and Erosion Control
9. Wetlands Protection and Use
10. Sand and Gravel Mining
11. Oil and Gas Extraction
12. Geothermal Energy Extraction

B. Purpose:

The Virginia Institute of Marine Science has the responsibility under the Code of Virginia (Chapter 9, Section 28.1-195) to conduct studies related to the conservation, development, and replenishment of marine resources and to investigate all aspects of the marine economy. One of the purposes of the Institute is to provide advice which contributes to the wise management of the marine resources of the Commonwealth. In order to satisfy statutory requirements, a program of research related to the conservation, development, utilization, and management of marine resources must be undertaken by the Institute. Inherent in such a program is the need to evaluate, modify, and develop scientifically, economically, socially, and legally sound resource use strategies for individuals and institutions utilizing Virginia's living and non-living marine resources. A concomitant element of such a program is the creation of an understanding of the importance and value of marine resources through public education.

Questions pertaining to marine resources are often multi-faceted involving studies in the areas of science, law, economics, and other disciplines. The marine resources of Virginia cannot be considered in the abstract. These resources are impacted by activities and other resources that are beyond what is traditionally considered the marine environment. To effectively fulfill the mandate expressed for the Institute, comprehensive studies must be pursued and result in recommendations useful to the management of the marine resources of Virginia.

C. Objectives:

1. Conduct investigations related to the management of subaqueous bottoms, beaches, and wetlands

Basic to the concept of management of marine resources is the identification and assessment of legal rights associated with these resources. Although Virginia has been settled for more than 350 years, serious questions regarding the rights of ownership of subaqueous bottoms, beaches, wetlands, and fisheries are being raised. Ownership of coastal and marine resources has been the subject of recent court rulings. Such issues will continually develop as the demand and competition for coastal and marine resources increases.

As a result of the implications of state statutes dating back to Colonial times and a recent ruling of the Virginia Supreme Court recognizing common concepts applicable to beaches and wetlands, an inventory of potential common lands and public lands in Virginia's coastal zone will be developed. This inventory and accompanying report will serve as tools to enable the State to assess its rights, responsibilities, and alternatives associated with these lands.

A recent United States Supreme Court case recognized the rights of private owners of submerged lands to exclude the public from navigation. Subaqueous lands in heavily trafficked harbor areas are claimed by private individuals in Virginia. An investigation will be conducted into the implications of these claims and the court ruling for Virginia. Potential conflicts between a paramount Federal navigational servitude running to the high water mark and Virginia's minority rule permitting private property ownership to the low water mark will also be examined.

The relationships between Federal, state, and local governments regarding the management of wetlands is undergoing substantial modification. Paralleling this modification in governmental relations is a re-evaluation of wetlands values by the scientific community. These events may bring about challenges to existing wetlands regulatory regimes. Implications of these events for Virginia's wetlands statutes and regulations will be studied. The scientific basis for, and the development of, a submerged aquatic vegetation management scheme for the state of Virginia will be assessed. It will also be determined if there has been an historical net increase in wetlands acreage in Virginia. If such an increase has occurred, the implications for management of wetlands will be analyzed.

The role of local, state, and Federal governments in regulating the marine environment is often confusing to coastal property owners. Many are unsure of their rights and responsibilities. In an effort to provide shoreline property owners with a clear understanding of their legal rights and responsibilities under state and Federal laws, a handbook for these owners will be developed.

Starting Date: July 1, 1983

2. Conduct investigations related to the management of water resources

Chesapeake Bay is the largest and richest of more than 800 estuaries in the United States. The Bay is approximately 190 miles long and is fed by more than 150 rivers and tributaries. It has a drainage basin of approximately 64,000 square miles covering several states and has over 8,000 miles of shoreline. The main body of the Bay and associated portions of the major river systems (the Susquehanna, Potomac, Rappahannock, York, and James) are shared primarily by the states of Maryland and Virginia. However, approximately 50 percent of all the fresh water entering Chesapeake Bay comes not from Virginia or Maryland but from Pennsylvania. The waters emptying into the Bay from the upper reaches of Virginia watersheds and from watersheds in other states contain pollutants potentially harmful to Virginia's marine resources.

Water resources in Virginia include 5,000 miles of tidal shoreline, highly productive seed oyster grounds, and more than 330,000 acres of wetlands that support 95 percent of the State's commercial and sport fishing industries. Also within the State are found nine major river basins, 1,500 square miles of the Chesapeake Bay, and the Port of Hampton Roads. Water resources in Virginia are diverse as well as problem-laden. Some areas within the State are flood prone; others experience severe water shortages. Water quality, in addition to quantity, is also an issue of great concern.

Virginia is in need of improved mechanisms for the comprehensive management of its water resources and the coordination of that management with other states which share or have an impact on these resources. Laws dealing with water resources contain contradictory policy statements. Additionally, ownership, control, and rights of use are often unclear. Research to clarify these issues is needed to provide decision makers with information on all aspects (i.e. legal, scientific, institutional, economic), of problems associated with water resources. The legal framework surrounding surface water uses and the relationship of such uses to marine resources will be investigated. Means to facilitate needed interstate cooperation will be studied. Local government authority over waterways and the implications of the impoundment of tidal tributaries will also be explored.

Subobjective 2a. Conduct investigations of issues related to the management of water quality and point and non-point source pollution

Over the past decade considerable progress has been made in water quality management primarily as a result of improved treatment for municipal and industrial wastewaters. Many problems have been eliminated or ameliorated but others remain. In the tidal freshwater portions of estuaries, such as the James and Potomac rivers, biological oxygen demands and nutrient loadings are often greater than the assimilative capacity of the receiving waters. In other areas, such as the Nansemond and Pagan rivers, non-point sources of pollution are sufficiently large to compromise water quality. In portions of other estuaries, management

strategies must be developed on a case-by-case basis to ameliorate the impacts of specific point sources. New management approaches are needed to alleviate non-point source discharges. As scientific understanding of problems created by sedimentation, nutrient loading, toxic, and bacteriological pollution increase, the Institute will investigate management alternatives applicable to these problems.
Starting Date: After July 1, 1985

Subobjective 2b. Conduct investigations related to management issues raised by dredging, dredged material, and channel deepening

The long term viability of Virginia's ports is potentially threatened by two trends--ever increasing channel depth requirements to accommodate deep draft vessels and diminishing options for placement of dredged material. Deepening the Hampton Roads channel to 55 feet has been proposed to provide access for larger draft vessels. Costs associated with this dredging operation have been estimated to be in excess of \$400 million.

The current dredge spoil site, Craney Island, is approaching its capacity. Disposal requirements for dredging to maintain existing channel depths suggest that a new disposal site will be required in the future. If channel deepening projects are undertaken, the disposal requirements could be much larger and the need for a new site could become more immediate. The Institute will investigate management issues raised by the identification and assessment of alternative disposal sites and by the potential uses of such sites.

Associated with dredge spoil disposal are certain pollution problems. In some cases certain pollutants are heavily regulated as effluents but unregulated as components of dredge spoil. An investigation will be conducted relative to the regulation and liability associated with such pollutants.
Starting Date: July 1, 1984

3. Conduct investigations related to the management of fisheries

The seafood industry has been important to Virginia since colonial times. The Institute has a direct role in the protection of this resource by virtue of the Virginia Code mandate which charges the Institute with the responsibility "to conduct studies and investigations of all phases of the seafood and commercial and sport fishing industries." Economically, the impact of the fishing industry is substantiated by the fact that it generates at least \$427 million within the state alone. Dollar values associated with the recreational fishing industry are not as easily quantified. Protection of this valuable resource requires sound management and conservation of fishery stocks attainable only through studies including scientific as well as managerial relationships which often involve a combined economic, legal, and institutional orientation.

Subobjective 3a. Conduct investigations related to the management of commercial and recreational fisheries

Recent Federal court decisions have recognized the rights of non-residents to participate in Virginia fisheries. These cases have specifically dealt with commercial finfish and crab fisheries. However, such a right may exist in regard to Virginia's commercial oyster and clam fisheries. Therefore, an investigation will be conducted into the applicability and importance of these court rulings to these fisheries.

As issues of importance to the development, utilization, and management of Virginia's fishing industries arise, such issues will be addressed by the Institute. Existing information will be combined with new research, where necessary, to develop solutions providing for the wise management of fisheries resources.

Starting Date: July 1, 1983

Subobjective 3b. Conduct investigations related to the development and management of aquaculture in Virginia

In recognition of a national policy to encourage the development of aquaculture and to enhance the potential of Virginia's fishing industry, the Institute will study the development of model aquaculture legislation for Virginia. Included in this investigation will be a study of the uses of dredge spoil sites for aquaculture activities and an analysis of zoning as a tool to enhance aquaculture.

Starting Date: July 1, 1983

4. Promote and implement studies to encourage the wise use of the marine environment and its resources through the development of methodologies to improve public understanding and awareness of the historical, present, and future importance of the marine environment

The results of basic and applied research may not achieve their fullest potential if the desirable changes in practices and modes of thought do not reach target audiences and/or are not accepted and assimilated by appropriate user groups. Research provides the means of identifying these user groups, and the methodology through which these groups may be most effectively approached. The invention of new knowledge pertaining to the transfer of information and resultant technologies for information dissemination contribute to improved decision-making capabilities. Integral to this objective is the development of overall scientific literacy by means of formal, informal, and nontraditional education in the context of higher education, precollege education, and continuing education. Also integral to this objective, are identifying and assessing the impact of developments in the natural sciences and social sciences and the integration of these developments into the theory and practice of wise use of the marine environment. Environmental issues are not problems which can be solved only by searching scientific bodies of knowledge for answers or generating new scientific knowledge: a human component is involved. Interdisciplinary scholarship, research and education are relevant to addressing environmental issues. Uses of basic

and applied research and the ramifications of new technology cross into the domains of humanities and social sciences. The only effective way to view many environmental problems is through an interdisciplinary approach.

New theories and strategies will be developed by the Institute to better identify, educate, and disseminate information to target audiences. This will include: identifying and analyzing the characteristics and needs of marine resource user groups; hypothesizing and testing new strategies; evaluating new and/or competing strategies; publishing research results; and implementing appropriate activities. Developments in the natural sciences, law, economics, sociology, education, and other disciplines need to be constantly assessed for their applicability to the promotion of wise use of the marine environment. Models, theories, and techniques from other disciplines will be reviewed, tested, and evaluated; the findings published; and the usable developments incorporated into our public education programs.

Starting Date: July 1, 1984

5. Identify and quantify the economic value of marine resources, and related economic activities of the Chesapeake Bay and adjacent waters to the overall productivity of the Commonwealth

The economic development of the Commonwealth has been based in large part upon the natural resources of Chesapeake Bay and adjacent coastal waters. It is vital that the relative contribution of all marine resources to the overall economic viability of the Commonwealth be quantified for proper management decisions to be made on future usage and/or allocation issues. Economic studies may contribute a significant conceptual framework to provide technical input for management, allocation, and development activities.

Exploitation of living resources through fishing activities will continue to play an important role in the economic framework of the Commonwealth. Continuing analysis of harvesting sector economics and baseline studies of support industries are necessary for inclusion into statewide input-output models. Identified as a task relating to these models is the development of improved estimations of fishing-effort and resultant yield functions. In conjunction with this task will be the development of cost-and-result data for various Virginia commercial fisheries. The Institute will analyze the overall economic and harvesting impacts of the marine recreational fishery, as well as examine contributions made by individual fishery sectors (e.g. Chesapeake Bay fishery, offshore fishery, charter/head boat fishery, pier fishery, etc.). Starting Date: July 1, 1983

6. Develop and evaluate alternate harvesting strategies, gear technology, and use options in the commercial and sport fishing industries to improve the economic potential of the resource

This objective addresses the current and potential utilization of marine fisheries in terms of enhancing the economic potential of the resource. An estimate of the magnitude of marine fishery resource

exploitation can be obtained from published commercial harvesting data and sport fishing user surveys. The techniques currently used to harvest these resources are well known and new technologies are developing at a rapid pace. However, these methods may not necessarily be the most efficient or desirable means available. The use of new or alternate harvesting gear for the commercial and recreational fisheries may have far-reaching effects on the resource and those who harvest them. New developments in harvesting strategies, gear technology and use options, must be assessed and implemented to improve the economic potential of established and underutilized marine fishery resources.

Studies on the design and efficiency of offshore trawl nets, scallop dredges, electronics, and deck machinery will be undertaken using industry vessels in Virginia and tow-tank facilities in Maryland and Rhode Island. Investigations are ongoing into the opportunities presented by joint ventures and the use of catcher/processor vessels for the expansion of Virginia-based vessels. Offshore fisheries development will focus upon the development of underutilized resources (i.e., squid) with the use of new fishing gear technology and harvesting strategies. Efforts will be undertaken to develop feasibility studies for alternate seafood waste-recovery, rock crab shedding, deep-water trawling, and a variety of mariculture opportunities. It is anticipated that the overall direction of research activities will be dictated by the prevailing economic conditions in the fishing industry and the status of fishery stocks.
Starting Date: July 1, 1983

7. To evaluate and develop systems for the production of economically valuable materials from fishery waste products or from fishery products of lesser value

Advances in biotechnology coupled with the utilization of microbial industrial processes such as fermentation, could benefit the seafood industry in areas of waste processing and/or production of high protein products from those of lower value. Currently, a preliminary analysis is being performed of a process involving the anaerobic fermentation of commercial crab waste for the production of biogas or methane. Additional applications are now being considered and it is evident that this is an area of great potential.
Starting Date: Continuing

IV. MONITORING PLAN

The Virginia Institute of Marine Science, as the major marine research institution in Virginia, is continually called upon to express opinions and comments on the probable effects of industrial development and other perturbations on our estuarine and coastal waters. This requires extensive, background information on the system being impacted, so that one can distinguish "normal" ranges of fluctuations from aberrations caused by man's activities.

Table III summarizes the items which have been and are being monitored at the Virginia Institute of Marine Science. The entity to be monitored was selected with consideration of the issues of importance, however, virtually all monitored information can be and is used for multiple purposes (i.e. for descriptive background information helpful in basic research, as well as provision of data for advisory services).

With the above needs and previously conducted monitoring efforts in mind, the following Monitoring Plan for the Institute was formulated.

TABLE III
Monitoring Activities at the Virginia Institute of Marine Science

<u>Activity</u>	<u>Date Begun</u>	<u>Status</u>
I. Fisheries:		
Finfish	1955	Continuing
Blue Crabs	1956	"
Oyster Spatfall	1946	"
Eggs and Larvae of Commercial Species	1983	"
II. Plankton:		
Zooplankton	1971	Continuing
III. Bacteria		
Lower York River	1977	Continuing
In Oil-Impacted Marshes - York River	1975	Completed 1979
IV. Parasites and Pathogens of:		
Finfish	1972	Continuing
Oyster (Dermocystidium)	1950	"
Oyster (NSX)	1959	"
V. Benthic Invertebrates:		
Lower York River	1962	Continuing
VI. Estuarine Plant Communities:		
Tidal Wetlands	1973	Continuing
Wetlands - Back Bay	1977	"
Submerged Aquatic Vegetation	1978	"
VII. Shoreline Erosion	1973	Continuing
VIII. Physical and Chemical:		
Slack Water Runs - Major Tributaries [Temperature (T), Salinity (S), Dissolved Oxygen (DO)]	1971	Completed 1975
Slack Water Runs - Major Tributaries (T, S, DO and Chlorophyll, Phosphorus, Nitrogen)	1975	Continuing
Fixed Station - VIMS' Pier (Tide, T, S)	1952	Continuing
Other Fixed Stations - VIMS' Campus (Sunlight, Air Temperature)	1970	Continuing
Intensive Surveys - Lower York (DO, T, S)	1972	Continuing

Table III. (continued)

Kepone - James River - Lower Bay	1975	Continuing
Toxic Organic Chemicals	1979	Continuing
Fixed Station - Wachapreague Pier (T, S)	1962	Continuing

PROGRAM I. FISHERIES

A. Issues:

1. Effects of Toxic Chemicals on Water Quality
2. Effects of Microbial and Viral Contaminants on Water Quality
3. Resolution of Fisheries Conflicts
4. Maintenance and Enhancement of Desirable Fisheries Stocks
5. Freshwater Diversion and Impoundment
6. Dredging and Dredge Disposal
7. Construction and Siting of Off-shore Facilities
8. Wetlands Protection and Use

B. Purpose:

The once seemingly infinite marine fishing resources that have been the foundation for the economy and lifestyle of Tidewater Virginia since pre-Colonial times are now recognized as critically finite. Only through sound, informed management decisions can these limited, but infinitely renewable resources, be maintained in perpetuity. The Code of Virginia clearly directs the Virginia Institute of Marine Science to conduct such assessment programs as are necessary to provide the managers of the resources with required data and information.

Fishing pressure, water quality degradation, and natural changes in the environment exert interwoven pressures on the fisheries resources of the Bay. Often these result in a slow but constant decline in abundance, vitality, and marketability.

These pressures, and the population fluctuations that result are often hard to assess. Is a decline due to reduced spawning stock resulting from over harvesting, or resulting from reduced egg or larval survival caused by pollution? How does a drought or flood change the population abundance and distribution?

Only through a long term commitment to sampling the population, or monitoring, can changes be detected, and sorted out according to cause. Measurements over time of distribution and abundance of eggs, larvae, juveniles and spawning adults provides us with a baseline assessment from which to gauge changes.

Data from oyster monitoring surveys are used to inform industry when and where to plant shell so as to receive maximum strike (larval set) and where to move seed so as to avoid MSX mortalities. Crab surveys provide a measurement of survival and mortality of young crabs, a means of measuring the next year's potential harvest. The fish surveys track the effects of drought, cold winters and predators on the survival of year classes of young anchovy, croaker, spot, weakfish, flounder, river herring and striped bass. Assessments can be made rapidly and agencies and industry informed when a problem is perceived. Further, these data, along with those collected by the physical and plankton scientists, help provide data input to research efforts directed at separating and explaining the causes for interannual fluctuations and declines.

C. Objectives:

1. Oyster recruitment (spatfall) and mortalities

Currently oyster recruitment is measured throughout the Bay and tributaries by counting the number of spat on shellstrings. Those spat are further observed with respect to parasites and predators and their potential impact on spat survival. Shellstrings are examined weekly during the spawning season. Survival of spat in the fall are measured as are incidence of disease and predators.

Surveys of adult oysters and yearlings are also made seasonally. Counts of dead or dying oysters and condition indices are made at those times. The above mentioned surveys will be continued.

Starting Date: Continuing

2. Monitor blue crab abundance and mortalities

Surveys using an otter trawl are conducted seasonally. Young and yearling crabs are enumerated and measured for growth and mortality. The data are used to forecast abundance and as input to stock-recruitment models. These surveys will be continued but possibly modified with refinement derived from research outlined in SUBPROGRAM I(b) of the Research Plan.

Starting Date: Continuing

3. Monitor juvenile fish abundance and mortality

Fish stocks in the Bay and open waters of the tributaries are monitored by monthly surveys using plankton nets, trawls and beach seines. Sciaenids (croaker, spot, weakfish), anchovies, flounder and yearling striped bass are adequately sampled by otter trawl. Young shad and river herring are best sampled by a push net, and young-of-the-year striped bass, killifish, and silversides by a beach seine. Eggs and larvae are sampled with "bongo" plankton nets. Fish are counted, measured and stomachs saved for later analyses. Some are retained for examination of toxicant body burdens, disease, and parasites. These surveys will be continued.

Starting Date: Continuing

4. Manage data from monitoring surveys

The real-time need for survey information by managers, and the long term data requirements of scientists often result in a significant commitment of time to prepare appropriate data formats.

We are converting all fishery data holdings to the Scientific Information Retrieval (SIR) system. This will allow better service to those who need data/information quickly, cross analyses by scientists, and analyses of physical environmental data. This effort will continue.

Starting Date: Continuing

PROGRAM II. PLANKTON

A. Issues:

1. Effects of Degraded Water Quality
2. Maintenance or Enhancement of Desirable Fisheries Stocks
3. Freshwater Diversion and Impoundments
4. Dredging and Dredge Spoil Disposal

B. Purpose:

Adequate information on which to base opinions on the probable effects of industrial development and other perturbations on plankton communities and their constituents requires long term observations on these plants and animals. Actual effects of man's activities are not easily distinguished from natural changes in population structure and size, and the distinction cannot be made with short term studies. Carefully planned and regularly scheduled assessments of plankton in Chesapeake Bay and its adjacent waters are needed to provide the long term information required for judgement of what is "normal" as opposed to aberrations or degradations caused by man's activity.

C. Objectives:

1. Monitor the distribution and abundance of phytoplankton, microzooplankton and smaller herbivores (i.e. the lower trophic levels)

Monitoring of lower trophic levels must be conducted at more frequent intervals of time than required for larger, longer-lived species. Responses of such populations to tidal or other short-term environmental factors are rapid, requiring frequent sampling and therefore, physically limiting spatial extent of coverage to a relatively few pre-selected stations. Frequency of sampling at these stations is set according to life-spans of the target organisms (e.g. a minimum of twice weekly for phytoplankton and weekly for microzooplankton) and may be increased during meteorological or tidal events identified as important factors in plankton dynamics.

Lower trophic level monitoring will provide a base of data on seasonal composition, succession and abundance of primary producers and small herbivores against which effects of natural or man-made perturbations can be weighed, as well as generate useful hypotheses for basic research.

We will establish fixed stations in each of the three principal tributaries of the Virginia portion of the Bay: the James, York and Rappahannock rivers, with potential sites identified as bridges and piers. Sampling will be conducted twice weekly, with upper and lower water column samples analyzed for pigments, cell counts and identification. Epifluorescence microscopy will allow enumeration with respect to total heterotrophic bacteria, procaryotic and eucaryotic phytoplankton, heterotrophic flagellates and ciliates. Ancillary data will include temperature, salinity, dissolved oxygen and nutrients (especially Si, NO₃,

NO₂, NH₄, and PO₄). Sampling for microzooplankton will be initially restricted to one location in the York River, once weekly.
Starting Date: July 1, 1983

2. Monitor the larger (meso-) zooplankton communities of the lower Chesapeake Bay

Annual differences in distribution and abundance of zooplankton species, including decapod crustacean larvae and fish eggs and larvae, were found to be significantly large during early surveys of lower Chesapeake Bay in 1971-1973. Knowledge of the extent and characteristics of these natural cycles and variations is prerequisite to advising management agencies on effects of man's activities in the tidal Virginia. Such knowledge must be gained from a long series of annual observations made during carefully selected key months.

Earlier surveys of lower Chesapeake Bay zooplankton revealed peaks of alternating communities in February or March (winter-spring fauna) and July or August (summer-fall fauna). Meroplankton, principally the early life stages of commercially important fishes and crustaceans, are present primarily in the summer months of June through August. Based on this knowledge, a monitoring program was initiated in 1978 to provide essentially synoptic appraisals of zooplankton communities in March and August of each year, additional summer surveys limited to meroplankton assessments. Sampling is conducted day and night at randomly-selected stations. A variety of samplers and mesh sizes are used, providing both surface and subsurface collections. Ancillary data include temperature, salinity and dissolved oxygen at 2-meter intervals or, when available, from CTD traces.

Starting Date: Continuing

3. Monitor spawning activity and success among anadromous fishes in freshwater tidal portions of Virginia estuaries

Documentation of spawning activity in the form of eggs and larvae of striped bass in Virginia rivers has only recently (1980-82) been undertaken, through the auspices of a Federal Emergency Striped Bass Fund. Similar data on American shad and the herrings (Alosa spp.) are lacking. Continued monitoring for this important information cannot depend on outside funding and is the responsibility of the State. We need to examine the relative contribution of each river system to spawning activity, the annual fluctuations in spawning activity and success, the relationship of spawning success to recruitment, and the effects of man's encroachment on anadromous spawning grounds.

The emergency striped bass study provided valuable information on the geographic and seasonal extent of striped bass spawning activity in the York River system (1980), the James River (1981), and the Rappahannock River (1982). These data bases provide a firm basis for the design of a long term monitoring program that covers all three rivers each year, but are cost-effective and efficient. Collections for the striped bass study also included larvae of the herrings, and therefore provide the basis for

a monitoring plan for all anadromous fishes. Stations and frequency of sampling will be determined on the basis of these collections, made with standard ichthyoplankton sampling techniques.
Starting Date: July 1, 1983

PROGRAM III. BACTERIA (LOWER YORK RIVER)

A. Issues:

1. Effects of Degraded Water Quality
2. Maintenance or Enhancement of Fisheries Stocks

B. Purpose:

Urbanization, recreational activities and waste disposal in the lower York River contribute to known and potential sources of pollution. Introduction of human and animal wastes result in an increase in the levels of fecal coliform bacteria which may indicate the occurrence of pathogens. Since the fecal coliform indicator system is utilized as an index of water quality regarding shellfish growing and recreational waters, long-term monitoring is required for detection of transient or gradual changes in sanitary water quality. This monitoring is especially relevant considering the imminent discharge of a 15 MGD sewage treatment plant effluent through the VEPCO condenser discharge pipe. Other types of pollutants which have been introduced into the York River include toxic organics such as petrochemicals. Regular monitoring of bacterial groups or processes which respond to the presence of these pollutants provide a sensitive biological tool for detection, location, and qualitative assessment of pollutant fate.

C. Objective:

1. Monitor selected bacterial parameters in the lower York River

The densities of fecal coliforms, petroleum-degrading and heterotrophic bacteria will be determined at bimonthly intervals in the waters and sediments of the lower York River. In addition, bacterial productivity and selected human pathogen(s) densities will be monitored at critical locations, e.g., the combined VEPCO-HRSD effluent diffuser.
Starting Date: Continuing

PROGRAM IV. PARASITES AND PATHOGENS

A. Issues:

1. Maintenance or Enhancement of Desirable Fisheries Stocks
2. Effects of Degraded Water Quality

B. Purpose:

Regular monitoring of parasite/pathogen burdens and an assessment of host-defense response in selected species of desirable fisheries stocks provides for a comparative data base of parasite/pathogen prevalence and geographic range. Such data are used to assess the spread of known pathogens over extended time periods, lead to recognition of new potentially dangerous agents or parasites, provide indirect information on the quality and state of the host's environment, and provide indices by which to judge the "health" of a resource. This information is used by resource managers, industry, advisory personnel and water quality control agencies for prediction of mortalities and implementation/development of actions to maximize continued productivity of fisheries resources.

C. Objectives:

1. Determine the levels of parasites and pathogens in local finfishes

The protozoan and metazoan parasite prevalences and burdens will be monitored in selected finfishes. Selected physiological indices will be measured and assessments made of certain aspects of host-defense mechanisms in selected species, including summer flounder, spot, hogchoker, etc.

Starting Date: Continuing

2. Determine levels of parasites and pathogens in shellfishes

The prevalence of oyster pathogens Minchinia nelsoni (MSX), Minchinia costalis (SSO), and Perkinsus marinus (Dermo) in both selected native populations and in "control" trays will be determined. Oysters will be sampled at appropriate locations including salinity regimes where the pathogens exhibit marginal pathogenicity. This will reveal prevalence and penetration of the pathogens either upstream or into non-endemic waters. Information used to predict probable mortalities and spread of pathogens will be provided to resource managers, industry and advisory personnel.

Starting Date: Continuing

PROGRAM V. BENTHIC INVERTEBRATES

A. Issues:

1. Effects of Water Quality
2. Maintenance or Enhancement of Desirable Fisheries Stocks

B. Purpose:

In order to assess accurately the effects of pollutants and other man-induced disturbances, it is essential to have an understanding of the natural patterns of population fluctuations. This is the only way to separate changes that are man-induced from changes that occur naturally. Long-term monitoring of benthic communities also lends insight into the natural causes of change in communities. It is important that we understand the possible synergistic interactions which occur when the environment is altered so that we may better provide insight to predict future alterations.

Long-term trends in benthic community production are of interest because of the trophic support provided to important fisheries species. The benthos form the base of a trophic pyramid that is closely tied to fisheries yield. Understanding of this trophic pyramid will provide insight into cause of variation in the fisheries.

C. Objective:

Follow the long term changes in benthic communities

Long-term changes in the benthic communities are as follows with respect to:

- a. Community structure - diversity and species changes
- b. Community function - secondary production and life history changes
- c. Habitat differences - how community structure and function are related to habitat type

At three sites between 8 and 13 m depth in the lower York River five replicate Smith-MacIntyre grabs will be collected quarterly for macrobenthos. Cores will also be collected for meiobenthos and sediment analysis. Yearly box cores will be collected for biogenic structures and detailed sediment stratigraphy. At a shallow site (1.5 m) adjacent to the VIMS' pier weekly samples will be collected for macrobenthos and recruitment patterns.

Starting Date: Continuing

PROGRAM VI. ESTUARINE PLANT COMMUNITIES

A. Issues:

1. Wetlands Protection and Use
2. Shoreline Erosion Control
3. Maintenance or Enhancement of Desirable Fisheries Stocks

B. Purpose:

Scientific research over the last twenty years has described the importance of estuarine plant communities such as marshes to the maintenance of commercial fisheries stocks. Marshes are also important as a buffer to shoreline erosion and are effective in trapping sediment from upland sources. The General Assembly in 1972 consequently passed protective legislation for these communities which recognizes the importance of monitoring to a management program and directed VIMS to classify, evaluate and inventory the tidal wetlands of the Commonwealth (Code of Virginia, Chapter 2.1, Section 62.1-13.1). The inventory was completed in 1977.

Using the wetlands inventory as a baseline, long-term monitoring will allow measurement of future trends and changes in the plant communities. This will provide VIMS with the scientific data it needs for advising the regulatory agencies such as VMRC and the wetlands boards in their planning and permitting phases of the Commonwealth's wetlands management program.

Submerged aquatic vegetation (SAV) is also important to the overall integrity of the Bay, but in addition has experienced severe declines in distribution and abundance. The effects of SAV distribution and abundance fluctuations on fisheries, particularly the blue crab, are of major importance to Bay managers and the fishing industry. For these reasons a monitoring program, begun under the EPA Chesapeake Bay program, must be continued in order to facilitate investigations of the factors controlling distribution and population sizes of the SAV.

C. Objectives:

1. Re-evaluate the extent and the health of the tidal wetlands at five year intervals

Remote sensing resolution has increased substantially since the early 70's when the first VIMS' inventory program began. Consequently the expense and effort of in situ verification will be greatly reduced. It is anticipated that VIMS will obtain electronic equipment that will provide computerized interpretation of Landsat 4 imagery. This will be in cooperation with the Commonwealth Data Base System. Landsat 4 imagery is superior to previous Landsat images and will be used for meso- and euhaline wetlands. Oligohaline and tidal freshwater wetlands, however, will probably have to be assessed via vertical color or color IR photographs taken by the VIMS' aircraft at altitudes between 10,000 and 12,000 feet because those plant communities are far too complex for

accurate interpretation using Landsat 4. All wetlands will be mapped at a scale of 1:24,000 so they can be used in concert with standard USGS topographic maps.

In order to produce a more comprehensive product, the wetlands will be mapped in natural geographic units (e.g. the wetlands of the York River and its tributaries). The present inventory, which is formatted on a political unit basis (county or city), is inadequate for use other than on a local level. In its present form, a user would have to refer to seven different reports in order to obtain information on all the wetlands of the York River and its tributaries.

The scale of resource values in current use is based in part on the contributions certain vegetative communities provide to the estuary. There are over 40 primary species that make up the tidal wetlands in the State and 15 different communities, so interpretation will need to be as accurate as possible.

Starting Date: Continuing

2. Re-evaluate the extent and health of submerged aquatic vegetation every two years

Monitoring of SAV involves the application of aerial photography for acquisition of data on distribution and abundance. Vertical color imagery will be taken of all SAV beds in Virginia with image scale at 1:24,000 to conform to standard USGS topographic maps. All mapped SAV beds will be digitized for area based on designated scales and summed for each topographic quadrangle. Grass beds identified in the imagery will be mapped directly onto topographic quadrangles. Present information for each major area in the lower Bay will be compared to the past data bases for the estimation of increases or decreases.

Starting Date: Continuing

PROGRAM VII. COASTAL EROSION

A. Issue:

1. Shoreline Erosion Control

B. Purpose:

The Commonwealth of Virginia has a shoreline of approximately 5,000 miles, of which 3,000 miles erode at rates over a foot per year. Shoreline property is among the most valuable property in the State; therefore, great efforts are made to protect and enhance it. A major activity at the Virginia Institute of Marine Science is to aid property owners and local and State officials with shoreline problems. This obligation is mandated by the Code of Virginia, Chapter 5, Section 28.1-195 (H). Knowledge of the amount, type, and local rate of erosion is needed in order to give timely and accurate advice.

The underlying cause of erosion in Virginia is the relative rise of sea level with respect to the land (approximately one foot per century). Nothing can be done to change this cause. However, the rate of erosion at a particular point is due to multiple, interacting variables such as the amount of open water, the direction faced by the land, the nature of the shoreline being eroded, land runoff, etc. To some extent some or all of these can be controlled and the rate of erosion reduced. On the other hand, the needed engineering is usually costly and often involves unwanted side effects. Therefore, it is prudent to know ahead of time the economic implications of managerial decisions involving coastal protection.

C. Objective:

Measure the rate of erosion of the Virginia shoreline

Rates of shoreline erosion in Virginia which took place approximately between the years 1880 and 1950 were measured by comparing the shoreline positions from maps. Since 1950 changes in the shoreline can be measured by comparing sets of photographs taken at different times and this has been done for selected locations. In the future, VIMS will continue to monitor erosion by comparing shoreline changes shown on vertical aerial photographs taken approximately ten years apart.

In addition to these long term shoreline changes, erosion is measured at specific sites on the ground at Virginia Beach, Norfolk, Newport News, Cape Charles, Colonial Beach, Stafford County, and Gloucester by standard surveying techniques. These measurements are made by those localities which participate in matching grant funding from the Commission for the Conservation and Development of Public Beaches. The measurements are made at least four times each year, more often if there are storms. These surveys will continue to be made in the future.
Starting Date: Continuing

PROGRAM VIII. PHYSICAL AND CHEMICAL

A. Issues:

1. Effects of Degraded Water Quality
2. Maintenance and Enhancement of Desirable Fisheries Stocks
3. Resolution of Fisheries Conflicts
4. Wetlands Protection and Use

B. Purpose:

Many managerial decisions are made (at least in part) on the basis of whether a proposed action will harm the environment. This is particularly true of water quality decisions. Therefore, in order to provide a technical basis for managerial decisions it is necessary to know the existing physical conditions and trends of quality of waters which will be impacted by man-induced alterations in the system (i.e. "loading").

A major purpose, therefore, of a monitoring plan is to provide an evaluation of trends and existing conditions of water quality so impacts of proposed loading can be evaluated. Another goal is to provide long-term evaluation of changes in water quality. Even though no single impact might be great, collectively through time, a series of small impacts might destroy the quality of the receiving waters. Only long-term monitoring is likely to discover these collective impacts in time to correct them. Properly designed monitoring will permit the effects of nonpoint source pollution to be evaluated separately from point source pollution. The management options for corrective action are different for each of these.

Still another purpose of chemical monitoring is to keep track of toxic chemicals which find their way into the waters of the Bay. Some of these chemicals are toxic to man as well as animals and the appropriate regulatory agencies expect VIMS to keep track of the levels of toxic substances.

A broad area which requires physical monitoring involves studies which correlate biological activity with the physical environment. Some of these studies are managerially oriented, such as the relationship between water temperature and closure of shellfish grounds by the Bureau of Shellfish Sanitation. Other studies are more basic in nature, but require a knowledge of the variation of some physical characteristic such as the relationship of phytoplankton to the incidence of light or the role played by cold temperatures in the survival of larval fish.

In summary, the type of monitoring effort is determined by the issues facing the Commonwealth; however, a multitude of research studies are enhanced by the information gained.

C. Objectives:

1. Measure the temperature, salinity, dissolved oxygen, chlorophyll, phosphorus and nitrogen in the tributaries at low slack water

Slack water run surveys were initiated in order to answer engineering-type questions raised by the State Water Control Board. These questions are usually concerned with award of permits to municipalities or corporations who wish to add additional effluent to the tributaries. The basic question is usually stated in terms of what would be the quantitative effect on the levels of dissolved oxygen, biological oxygen demand, or nutrient levels if a certain amount of pollution were added at a particular place. The answer is to give a series of optional levels which are calculated from a mathematical model based on different loadings. The model calculations often require information from slack water runs. In addition to mathematical model predictions the slack water runs provide a basis for calculating long term trends of any particular variable which has been measured.

The slack water runs within the tributaries will be continued during the ice-free months. Temperature, salinity and dissolved oxygen will be measured in all the tributaries but nutrients will be measured only in one tributary each year. The data are stored in the VIMS' data bank and are readily available. Reports of the state of the rivers are sent each month to municipalities and regulatory agencies. Intensive surveys will be conducted, if needed, in order to calibrate or verify models.

Starting Date: Continuing

2. Measure tides, water temperature, air temperature, salinity and incident light from fixed stations on the VIMS' campus

Tides, salinity, water temperature, air temperature, and rainfall (freshwater inflow) are the physical properties fundamental to the very definition of an estuary. Since circulation and stratification depend on these variables they indirectly affect the distribution and behavior of a great many estuarine animals. Due to their central importance, it is necessary to monitor each of these variables so that we may know their precise long-term mean values, the nature and range of normal departures from the mean (e.g. daily, monthly and annual cycles) and the frequency and magnitude of observed extremes. In the absence of a continuous monitoring program much of our information regarding the effects of extreme events (storms, droughts, etc.) becomes conjectural.

Starting Date: Continuing

3. Determine the quantity of Kepone in James River sediments and in resident organisms

Kepone contamination of the James River has created two major management concerns; 1) are the contamination levels causing biological effects? and 2) when can residues be expected to decline, so that important fisheries resources can be harvested? Results of past studies indicate that biological effects are unlikely from Kepone exposures at levels found

in the estuary. However, monitoring of residue levels has shown that we lack the ability to predict when the natural burial process, (i.e., of contaminated sediments), will be sufficient to lower residues in seafood organisms below the action level. Therefore, further monitoring will be conducted at the Institute to answer these important questions.
Starting Date: Continuing

4. Determine the quantity, identity and distribution of toxic organic compounds in the Chesapeake Bay

We are concerned about whether toxic organic compounds are affecting the biota of the Bay. Therefore, we must determine if such compounds are increasing or decreasing in the system. Without this information, managers cannot make informed decisions regarding the potential impacts of chemical pollutants on the Bay's living resources.

Potentially toxic organic chemicals can enter the Bay system through such a variety of sources that a meaningful monitoring system is nearly impossible. If we are to make informed judgements as to the potential impacts of these chemicals, the receiving body itself must be monitored. We have recently established a baseline for the Bay and certain of its tributaries for potentially toxic organic compounds. This baseline makes it possible for us (by continued monitoring) to determine whether changes in concentrations are occurring or whether new compounds are entering the system. In addition to resampling certain of the previously occupied stations, expansion of the program into other tributaries will be done.
Starting Date: Continuing

V. CONCLUDING STATEMENT

The foregoing plan, a culmination of hundreds of man-years of experience on Chesapeake Bay problems and the end result of six months of prodigious effort by the administration and staff of the Virginia Institute of Marine Science, will serve as our blueprint for research over the next decade. Design changes will undoubtedly become necessary with the advancement of time and appearance of new challenges and problems, but the basic structure will hopefully remain.

Implementation of the plan is immediate, in the sense that we are now organizing efforts within prescribed programs and viewing possible outside funding in terms of its fitness within our research programs. We have also developed procedures for tracking expenditures for individual research programs while maintaining financial control along existing, recently reorganized, departmental and divisional lines. Full and complete implementation of all programs could only occur, of course, with added funding sufficient to address all of the plan's objectives. Until this is achieved, prioritization will govern which aspects of the plan receive initial attention.