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Coastal marine science and the Virginia Institute of Marine Science in the International Year of the Ocean, 1998

Virginia Institute of Marine Science

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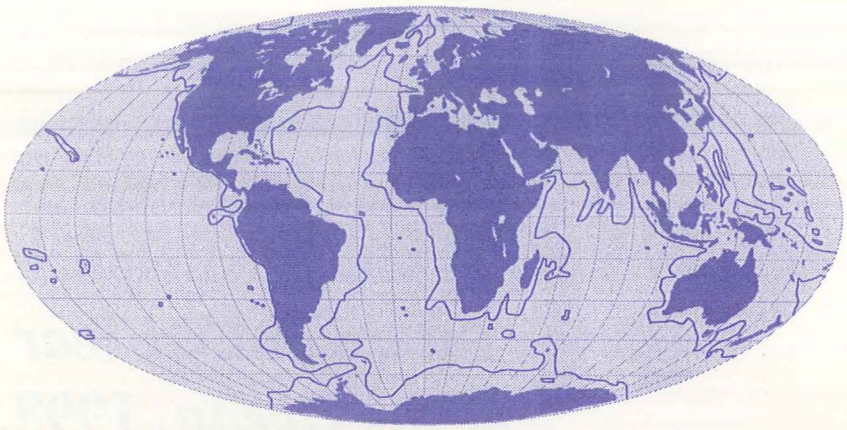
It is appropriate that the *International Year of the Ocean* heralds the new millennium. The oceans, and their peripheral coastal zones, hold crucial keys to the future of humankind. The world ocean is a vital component of the coupled atmosphere-ocean system and a dominant factor in climate change. More than half of the world's people and two-thirds of Americans now live within 50 miles of the sea. Projections by the World Bank indicate that these percentages will increase dramatically by the year 2020. Coastal waters and wetlands will continue to be a major source of food, particularly for developing countries. Coastal dwellers face important, complicated issues pertaining to national defense, biodiversity, environmental quality and prediction of and response to coastal hazards. Conflicting pressures on coastal and ocean resources will increase as the population swells and certainly will be exacerbated, perhaps critically, if global warming and sea-level rise predictions come to pass. The oceans in general, and the coastal oceans in particular, are highly complex, fragile and absolutely essential systems. We simply cannot afford **not** to understand and properly manage them. This is true both globally and locally, especially where the Chesapeake Bay and Middle Atlantic Bight are concerned. Fortunately, scientific knowledge of marine and coastal systems is growing at an ever quickening pace, particularly in Virginia. The College of William and Mary's Virginia Institute of Marine Science is playing a leading role in the generation, application and communication of this knowledge through research, education and advisory service.



The coastal domain and its significance

The coastal ocean, as it is currently defined, extends in political terms, to the outer limits of the Exclusive Economic Zone (EEZ; 200 miles offshore), or, in physical terms, to the base of the continental slope (water depths ~ 600 feet). The inland extent of the coastal zone is less easy to define, some assume it to extend upstream in estuaries to the limit of saltwater or tidal influence, while others include the entire watershed of the rivers that discharge into the oceans.

Coastal systems are highly complex. Relatively modest changes in key factors, such as frequency and intensity of storms, relative sea level, water temperature, freshwater runoff, or nutrient influx can cause large and often unexpected changes in coastal dynamics and ecology. It is crucial that we understand how this environment might respond to global warming or to other possible global change scenarios. The projected increase in coastal population, when combined with the effects of global warming, could have profound socio-economic consequences, especially in developing countries.

The coastal ocean and contiguous estuarine environments, such as the Chesapeake Bay, are geologically young and are continuing to undergo natural changes. Human-induced effects, such as inputs of nutrients and toxic substances, alterations of freshwater inputs and runoff, harbor development and shore protection are producing even more dramatic changes. Added to these already profound alterations, we must now consider the likely impacts of global climate change scenarios.

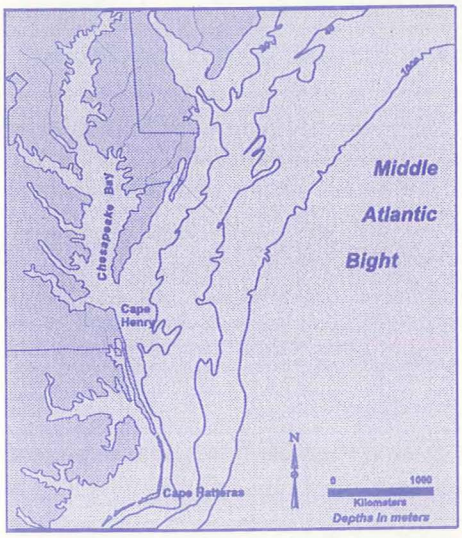
The coastal environment of Virginia

The Chesapeake Bay is the defining feature of Virginia's coastal environment. This has been recognized since the early settlement of Virginia. In 1676, Thomas Glover delivered to the Royal Society of London a report entitled *An Account of Virginia* which included the following description of the Bay's resources: *In the rivers are great plenty and variety of delicate fish. ...At the heads of rivers there are sturgeon and in the creeks are great store of small fish, as perch, croakers, taylors, eels, and divers others whose name I know not. Here are such plenty of oysters as they may load ships with them. At the mouth of the Elizabeth River, when it is low water, they appear in rocks a foot above the water...*

However, we can trace a progressive decline in the environmental quality of the Chesapeake Bay beginning with the Colonial period. Dr. Grace Brush's reconstruction of a 2000 year history of water quality in the Bay suggests that by the year 1760, land clearing had already brought about increases in sedimentation, reduction of dissolved oxygen and excess nutrient levels in Bay waters. By the late 1800s, significant declines in the oyster harvests of the Chesapeake Bay had become apparent. (Present harvest is less than 10% of what it was 100 years ago). Despite these declines the Chesapeake Bay has continued to be blessed with valuable living and non-living resources. Recent economic impact analyses, performed by Dr. James Kirkley of VIMS, show that commercial fishing contributes roughly $500 million annually to Virginia's

economy and a comparable impact can be attributed to recreational fishing. Nevertheless, the ecology of the system has experienced notable shifts in historic times.

Although the Chesapeake Bay is the centerpiece of Virginia's coastal environment, it is by no means the entirety of that realm. In fact, it is now clear that the Bay can only be adequately understood in the context of the other components of the large-scale coastal system of which it is a part. The lower reaches of the Bay are intimately coupled with the conti-



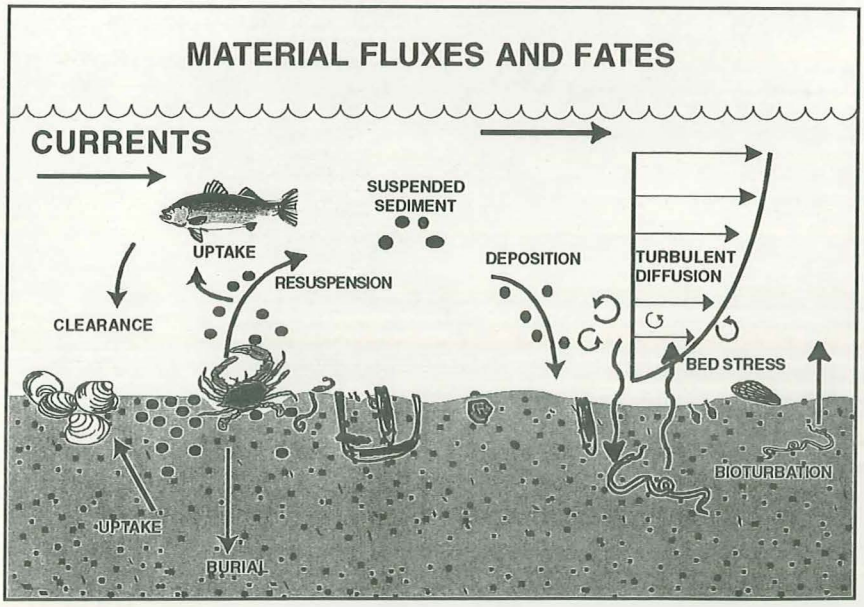
nental shelf regime of the Middle Atlantic Bight which extends from Long Island to Cape Hatteras. (This shelf environment is bounded to the west by the Virginia Barrier Islands north of the Bay mouth and, south of the bay, by extensive beaches and barrier islands extending from Virginia Beach to the Outer Banks of North Carolina.) This is a storm dominated environment. The relatively frequent mid-latitude "Northeasters" and occasional hurricane produce energetic waves and strong currents that cause beach erosion and property destruction along the open Atlantic coast. These same weather systems force intense large-scale current oscillations and storm surges and

Some of the important attributes of coastal systems and their significance can be summarized as follows:

1. At present, fisheries contribute about $70 billion annually to the global economy, provide employment for 200 million people; and provide protein for nearly one billion people. About 90% of the world's fish catch comes from the coastal ocean. In Virginia, the fishing industry is worth $500 million annually and employs over 10,000 people. About 60% of the population of developing countries derive more than half their dietary protein from coastal marine sources.
2. Because terrestrial inputs to the coastal ocean come from the entire watershed, land-based activities and the coastal ocean are closely linked. Increases or decreases in freshwater runoff, for instance, can produce major shifts in coastal process and ecological regimes.
3. Coastal ocean and estuarine environments respond rapidly to storm events and increases in the frequency or intensity of storms can have catastrophic impacts on coastal ecosystems.
4. Coastal ocean environments change rapidly and dramatically in distance and time. Hence, moderate shifts in salinity or temperature are felt quickly and important coastal flows can be altered measurably.
5. The coastal ocean is very young. Sea level fluctuations during the past ice ages (last 1.6 million years) caused the area now occupied by the coastal ocean to be alternately emergent and submerged. Only 18,000 years ago sea level was about 400 feet below its present position and the coastal ocean was basically non-existent. Most modern- day estuaries were flooded by the sea within the last few thousand years and have not yet achieved equilibrium. Even without anthropogenic influences, most coastal systems would be evolving toward an as-yet-unrealized state of equilibrium.
6. Over the last century, the world's coasts have experienced a rise in sea level that has averaged 4 to 6 inches. A greatly accelerated rate of rise is predicted to accompany global warming which could cause loss of coastal lands as well as intrusions of higher salinity into estuaries and bays and salinization of ground water. World Bank projections suggest that a sea level rise of 18 inches would reduce Asian rice production by 25% and a rise of 40 inches would reduce production by a full 50%.
7. Inputs of nutrients and organic matter to the coastal ocean and estuaries are high. Excessively high nutrient inputs and primary productivity can yield harmful consequences such as eutrophication and anoxia (low dissolved oxygen in the water) as well as blooms of toxic or harmful algae (e.g. "red tides"). Such nutrient inputs may have been implicated in the recent outbreaks of the toxic dinoflagellate *Pfiesteria piscicida* in the mid-Atlantic region.

affect freshwater runoff in the lower Bay. In turn, the density stratification associated with the low-salinity plume issuing from the Bay onto the shelf affects shelf circulation and the across-shelf transport of sediment and organisms as far south as Cape Hatteras.

The elongate riverine estuaries that enter the Bay, notably the Susquehanna, Potomac, Rappahannock, York, and James Rivers, are also elements of the coastal environment of Virginia. Traditionally, marine scientists confined their attention to the estuarine portions of these rivers where freshwater and seawater mix and the effects of tides are felt. However, it is now recognized that land-based activities throughout the entire river catchment affect coastal and estuarine processes, water quality and ecology in profound ways. Attempts to model and explain coastal phenomena must take into account activities in the catchments. From that perspective, we must consider our interest to extend to the western part of Virginia and beyond.



Some critical coastal issues and scientific questions

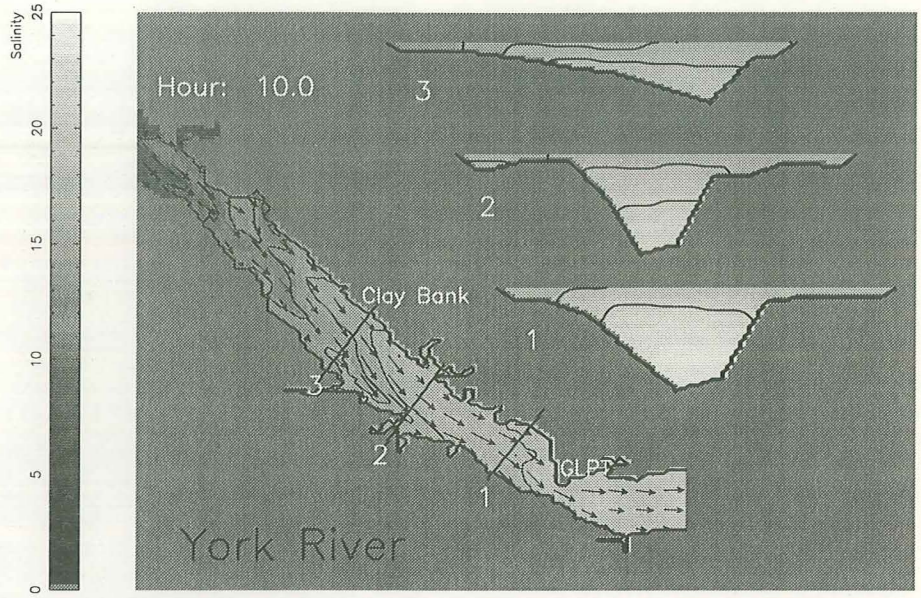
Many coastal systems are already severely stressed by human activities, and these stresses are certain to increase as the population of the coastal zone grows. Global warming can be expected to add a new set of stresses. Even if the global warming predictions prove wrong, changes in sensitive and complex coastal environments are inevitable. This need not be a cause for pessimism provided we gain the essential understandings of how these systems operate, project these understandings into alternative future scenarios, and develop the appropriate new management strategies. However, rigorous and sophisticated understandings of the complex phenomena that intersect in the coastal zone are essential. Such understanding will enable us to reconcile conflicting pressures, support economic development and food production, sustain natural resources and anticipate and mitigate against natural hazards. Reliable and accurate forecasting of the potential outcomes of alternative global change scenarios is needed to guide management decisions and engineering options. These forecasts must be based on computer models that integrate fundamental knowledge and understanding of highly complex interdisciplinary processes. Such modeling efforts are already underway at VIMS, and many other marine science institutes.

Interdisciplinary approaches will be required to address all of the pressing coastal problems. However, the strength and validity of any interdisciplinary solution or paradigm can only be as good as its underlying, discipline-specific, scientific principles and models. This means that advances in basic research in each of the key disciplines of physical, chemical, biological, geological, fisheries science and oceanography as well as immunology, disease research and genetics must proceed in parallel with interdisciplinary advances.

Coastal marine science in Virginia: VIMS and its role

In 1940, the Virginia Fisheries Laboratory, which later became the Virginia Institute of Marine Science (VIMS), was founded on the shores of the York River under the direction of Dr. Donald W. Davis, a biology professor at the College of William and Mary. Unlike oceanographic institutes, such as Woods Hole Oceanographic Institution and Scripps Institute of Oceanography, which became heavily focused on the deep sea, VIMS had a mandate, ultimately embodied in the Code of Virginia, to gain better understandings of phenomena that prevailed in the Chesapeake Bay and its contiguous coastal and estuarine waters. With the establishment of this laboratory, the Commonwealth of Virginia set a valued precedent of staff support for the study of its coastal and estuarine resources.

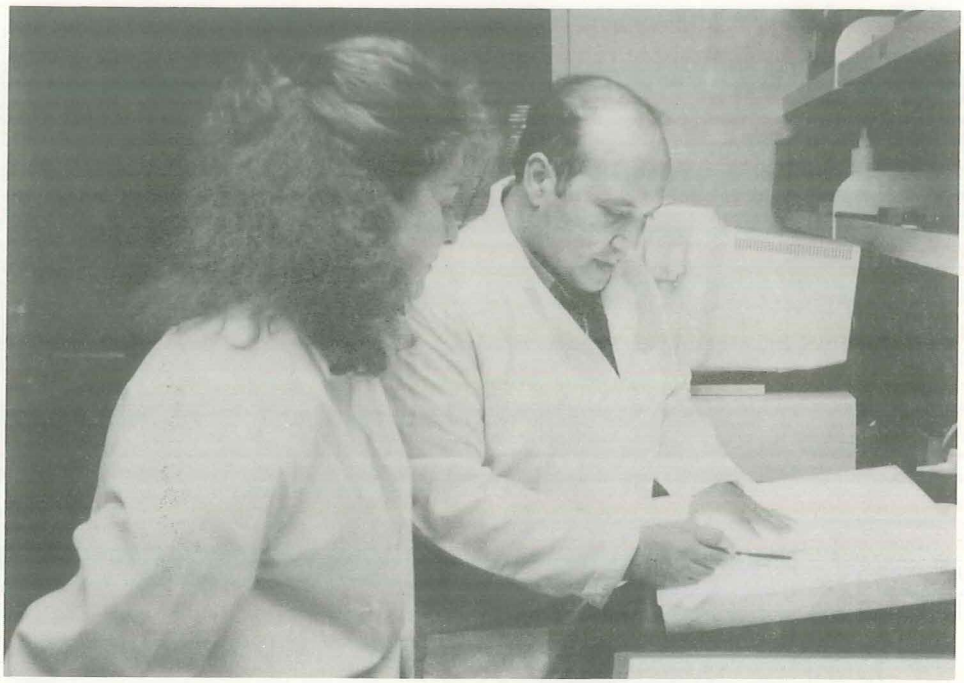
In 1962, the Virginia General Assembly, recognizing that the Lab's programs had expanded well beyond fisheries biology, changed the name of the Virginia Fisheries Laboratory to the Virginia Institute of Marine Science. By the late 1970s, VIMS had become truly interdisciplinary and was actively engaged in research, teaching and the provision of advisory service in fisheries science and stock



The most challenging questions confronting coastal marine scientists are motivated by the need to reconcile conflicting socioeconomic and environmental concerns. Rarely can these questions be answered by specialists from a single discipline; increasingly, acceptable solutions require an interdisciplinary approach. Scientific emphases can change quickly as new knowledge is gained and new questions are posed. However, some of the more compelling coastal issues facing us in the *Year of the Ocean* are sure to linger well into the 21st Century. These concerns are likely to motivate, but certainly not constrain, much future research. These issues include:

1. Fisheries management, stock assessment and forecasting;
2. Marine Aquaculture, including genetics and breeding;
3. Coastal protection, erosion, engineering and hazard prediction;
4. Estuarine and coastal water quality including eutrophication and hypoxia;
5. Harmful and toxic algal blooms and related nutrient dynamics;
6. Nutrient reduction and associated strategies for managing agricultural runoff;
7. Military and economic security;
8. Disease control;
9. Port and harbor development and maritime shipping;
10. Fluxes and fates of chemicals;
11. Coastal sea-level rise;
12. Wetlands management;
13. Biodiversity;
14. Recreation and tourism; and
15. Coastal real estate development and land reclamation.

assessment, biological oceanography, wetlands ecology, physical oceanography and estuarine hydrodynamics, chemistry and toxicology, geological oceanography and sediment transport processes, and shore protection. In 1979, the General Assembly placed VIMS fully under the auspices of the College of William and Mary.



The advent, in the 1980s, of sophisticated new field instrumentation, satellite-borne remote sensing tools, and high-speed computers supporting elaborate numerical models enabled both "blue water" and coastal marine science to enjoy unprecedented advances. VIMS evolved to become an internationally-recognized center of knowledge. It was also in 1990 that NOAA began its Coastal Ocean Program (COP) and the National Science Foundation planned its new Coastal Ocean Processes (CoOP) initiative. In 1992, shortly after the Cold War ended, the Office of Naval Research shifted its focus from the deep sea to the coastal ocean and called for CoOP proposals. A new era of U.S. coastal ocean science had begun and VIMS was already in a leadership role.

The Virginia Institute of Marine Science (VIMS) School of Marine Science (SMS) enters the *Year of the Ocean* with a unique tripartite mission to provide cutting-edge research, education and adviosry service in marine science. The Institute is committed to generating new knowledge of coastal and marine processes and providing practical management, engineering, and policy solutions to complex sets of marine-related problems and needs. Solutions to coastal problems must be underpinned by rigorous and innovative fundamental science. The new understandings that are gained through research must then be effectively transferred to students through the SMS graduate education program and to client groups through VIMS advisory service programs.

The five academic departments

at the Institute engage in all three of the Institute's missions but each has rather broad discipline-based foci. These departments are:

1. Biological Sciences;
2. Environmental Sciences;
3. Fisheries Science;
4. Physical Sciences; and
5. Resource Management and Policy.

Cutting across all five departments are ten interdisciplinary Core Research Programs. These programs address issues of importance to the Commonwealth; are interdisciplinary; are relevant to all three of the Institute's missions; contribute directly or indirectly to economic development; address compelling generic questions; involve rigorous scholarship; and are synergistic with the graduate education program. Core programs are defined on the basis of issues or problems rather than disciplines.

The School of Marine Science (SMS) is a part of, not separate from, the Virginia Institute of Marine Science. The SMS offers both Masters and Ph.D. programs and attracts outstanding students, who are one of the keys to our future. By integrating with VIMS research and advisory missions, students not only learn how to generate new knowledge and understanding of the marine environment, but also, learn to communicate the knowledge to users. Our future ability to cope with conflicting human pressures while sustaining natural resources and environmental quality will depend on our students and their students.

A guiding objective for VIMS/SMS is to play a leading role in coastal oceanography for Virginia, the nation and the world. To be on the leading edge in such a rapidly evolving area of scientific pursuit, scientists and studentc not only must stay abreast of scientific develop-ments throughout the world but also must constantly look ahead and be prepared to plunge into new, unexplored realms.

The VIMS core programs are:

1. Aquaculture including genetics and breeding of disease-resistant strains of shellfish and finfish;
2. Environmental Risk Assessment and Hazard Evaluation;
3. Fisheries Ecology & Stock Assessment;
4. Wetlands, Shore and Harbor Processes and Management including shore protection and harbor maintenance;
5. Ecosystem Processes and Modeling;
6. Disease Research;
7. Water Quality Processes and Modeling;
8. Material Fluxes and Fates dealing with the sources, pathways and fates of chemicals, sediments and other substances that enter, leave or are sequestered within the Chesapeake Bay and its tributaries;
9. Biodiversity and Conservation; and
10. Plankton and Nutrient Dynamics including research on the toxic dinoflagellate *Pfiesteria piscicida.*

In addition, the VIMS mission-specific programs include the Marine Advisory Services Program which is devoted to economic development with emphasis on maritime industries.

The International Year of the Ocean: Anticipating the 21st Century

Over the next few decades, environmental and oceanographic laboratories must play major roles in determining the quality of life for people all over the world. To do this, however, scientific research must be highly sophisticated and meet impeccable standards; scientists face significant challenges. The greatest challenges of all probably pertain to policy formulation and to convincing coastal inhabitants, politicians, managers and decision makers world wide to heed scientists recommendations and make short-term sacrifices or pursue new management strategies in the interest of sustaining the world's ocean and coastal resources. The United Nations was motivated by a desire to stimulate a search for international consensus on ways to meet these challenges when it declared 1998 *The International Year of the Ocean*. Throughout 1998, the oceans and coastal environments and their importance to humankind will be showcased around the world. An exposition on The *Year of the Ocean* will be held in Lisbon from June through September. In early June, The Oceanography Society and the Intergovernmental Oceanographic Commission will cosponsor a conference in Paris focused on *Coastal and Marginal Seas*. The U.S. marine science community and several members of Congress have requested that President Clinton host a White House Conference on the oceans during 1998. And, here in Virginia, VIMS has already launched a series of public events that will run through the year.

Oceans, coasts and estuaries are crucial to the future of all people. We may be poised on a brink and as scientists, citizens, leaders and stewards, we must rise to new challenges. The *Year of the Ocean* is only a prelude to the *Era of the Oceans*—the 21st Century.

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