MONITORING THE HEALTH OF THE NORTHEAST CONTINENTAL SHELF

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ABSTRACT

Since 1978, the Ocean Pulse Program, and more recently the Northeast Monitoring Program, have been involved with measuring the levels, and trends in levels, of contaminants in various compartments of the marine ecosystem over the continental shelf between Cape Hatteras and the Canadian border.

In addition to chemical measurements which are made monthly or quarterly, we have been attempting to determine how the biota is affected by various toxic substances. In some cases we have measured the body burdens of specific toxic substances in individual species. We have also measured benchmark responses for certain physiological and biochemical variables in waters known to be contaminated, as well as in relatively uncontaminated habitats.

We have also collected specimens in polluted and unpolluted areas to determine the incidence of certain disease syndromes in marine finfish and shellfish, and have also attempted to establish the relationship between genetic change and ambient levels of pollution throughout the area of interest.

To accomplish the foregoing, scientific personnel have participated in cruises which in some cases have occurred on a monthly basis and, in other instances, have occurred quarterly or semi-annually. Since the programs are multidisciplinary in nature, a range of field and laboratory procedures have been applied. In most instances, samples have been collected within several temporal schemes and analyses have begun onboard the vessels. In other cases, samples must be returned to land-based facilities for final chemical analysis or for routine sorting and taxonomic workup.

Our findings to date were recently summarized in the first annual report of the Northeast Monitoring Program. During the past year we have found that specimens of fish collected far from immediate sources of pollutants did show what are regarded as significant levels of substances such as PCB's and petroleum hydrocarbons. We have

also determined the benchmark characteristics for the standing stocks of chlorophyll and for primary production over the entire continental shelf. Benthic community structure was defined for stations located throughout the area of interest, as well as at the offings of major estuarine systems. Progress was made in establishing various levels of physiological and biochemical responses to several ambient habitat conditions.

INTRODUCTION

During the past decade the proceedings of numerous workshops and symposia have recommended that monitoring programs be developed in relation to problems of increasing gross and site specific pollution in the oceans.^{1,2,3} In other instances there were warnings that specific pollutants, i.e. petroleum, should be measured periodically in a monitoring mode.⁴ In some cases the recommendations have suggested that it is important to monitor pollutants in water and sediment, as well as the body burdens of contaminants in key or sentinel biota;² recent papers have suggested the need for special attention to specific compartments of the marine ecosystem, i.e. marine sediments. Also, there is growing attention being given to monitoring the biological effects of certain contaminants as well as gross multisource pollution on marine organisms.⁵ It is well known that the different species of marine organisms respond in definite but different ways to changes in the levels of a variety of inorganic⁶ and organic contaminants⁷ as well as biostimulants (eutrophication) and gross pollution such as emanates from sewer outfalls.

Many biologists have noted that the responses of biota can be arranged in a hierarchical manner; behavioral responses to the perception of a contaminant will occur within a matter of minutes or seconds where as physiological, pathological, and population and community response or change occur over periods of hours, days or months.⁸ (Fig. 1).

Techniques used in monitoring have, therefore, varied accordingly, with some investigators favoring the measurement of a single variable in water or sediment while others advocate a suite of measurements, including several biological

effects measurements. Moreover, there has been considerable discussion about the definition of monitoring and what the role of research is or should be in regard to short- and long-term monitoring. We have defined monitoring as the periodic measurement of 1) critical chemical and physical variables at specific sites or generalized sampling strata over periods of years, 2) similar chemical variables in biological tissues (as body burdens of contaminants), and 3) biological effects due to changes in the physical and chemical environmental conditions and increase in the body burdens of contaminants. It is most important to recognize that in monitoring programs one must assess biological change due to natural variation as well as anthropogenically induced change, i.e., pollution. To deal effectively with concepts such as multiple use of resources or assimilative capacity of receiving waters, we must know how contaminants, individually or collectively, affect important fisheries resources and the food chains which support them. If we are to manage effectively these resources for the future well-being of mankind, it is necessary to know how man's activities presently impinge upon them and to make intelligent judgments (models) as to how humans and their societies will affect them in the future.

During the past two years we have begun the long-term monitoring of the continental shelf off the northeast United States coast between the Canadian border and Cape Hatteras. The monitoring program is being tailored to serve the needs of a pilot National monitoring program⁹ but also includes the aspects of field and laboratory research necessary for attaining the goals and objectives of the NEFC and the NMFS habitat protection programs (see appendix A) and interpreting data from our spatial and temporal monitoring efforts.

The NEFC, beginning in early 1976, started to develop a program called Ocean Pulse.¹⁰ This program was designed to conduct research and monitoring activities which would result in data indicative of the relative health of fisheries habitats on the continental shelf between the Canadian border and Cape Hatteras. Elements of the program were responsible for measuring amounts of contaminants in sediments, water and biota which habituate the shelf area of concern. Other components of the program dealt with the community structure of plankton and demersal and benthic populations of the shelf.

In addition to ongoing contaminant monitoring and ecological assessments, disciplines such as biochemistry, genetics, pathobiology, and physiology were used to establish benchmarks or baselines in relation to responses to contaminants as they were measured in the physical components of the continental shelf ecosystem or in the laboratory (Fig. 2).

Through time, the monitoring activities have allowed us to begin to establish the variability

in levels of biologically important contaminants, including biostimulants and their effects in relation to eutrophication, in the physical compartments as well as the biota. At the same time, changes in physiological, biochemical, and pathobiological responses were also measured. Using these early data, and information from other agencies, it has become possible to select key or sentinel species and to begin to establish the fates and potential effects of contaminants or gross pollutants as these enter coastal and continental shelf waters.

In late 1979, elements of the Ocean Pulse program which had developed under the aegis of the NEFC, were combined with ongoing monitoring activities being conducted by other units of the National Oceanic and Atmospheric Administration (NOAA). The key objectives of NOAA's new Northeast Monitoring Program (NEMP) are similar to those indicated in appendix A.

At the present time, the NEMP is finalizing its first annual report (for calendar year 1980). This information will soon be released in the form of a published report. It includes findings coming from 50 different work units, about half of which were done under contract with universities or consultants.

DISCUSSION

A considerable portion of the first full year of effort conducted under the Ocean Pulse and NEMP has been involved with establishing the distribution and levels of certain contaminants (Fig. 3, 4, and 5) and the variability in a variety of biological responses. In the area of benthic ecology, much of our effort has been concerned with attempting to determine if, within a specific area, or at a precise station, there is sufficient stability in numbers of species and numbers of individuals to warrant using benthic community structure, diversity, and responses as variables for monitoring environmental change (Fig. 6). We have also begun to establish benchmarks for phytoplankton populations, especially in regard to how certain key variables (primary production, standing stocks of chlorophyll, etc.) may be related to changes induced by nutrients (biostimulants) having their origin in discharged or dumped sewage and runoff from the land mass (Fig. 7). Finally, we have monitored extensively how the levels of physiologically critical variables, such as dissolved oxygen (DO), have varied in relation to other years such as 1976, when extremely low DO levels affected fisheries over thousands of square kilometers (km²).¹¹ In relation to this we have continued our seabed respiration and nutrient flux studies at polluted and clean stations to determine how organic wastes affect seabed metabolism.

Conventional assessment and monitoring programs, have measured contamination in terms of chemical loadings; analyses of material from the various compartments of the environment can provide a sensitive indication of the concentrations of

substances that have been selected for study. But pollution, precisely defined, implies deleterious effects, and these are usually assessed in relation to a biological system. In monitoring, therefore, biological information is required at some stage, but there has been considerable discussion as to what sort of biology is most appropriate, and at what stage in an assessment program it may be most effectively applied.^{8,12} Recognizing that no one biological discipline can, alone, provide the requisite, definitive indication of pollution effects under all conditions,⁵ we are, in the pilot phase of the program, applying numerous techniques so as to evaluate their relative efficacy in terms of both long- and short-term monitoring and assessment strategies. Moreover, biological effects data are a prerequisite to any waste disposal program based on the assimilative capacity of the ocean's concept. During the past year we have made considerable progress in understanding the degree of variability in natural systems, whether of an ecological nature or in relation to biochemical, physiological, and genetic systems or behavioral responses.

Of necessity, the foregoing description of NEMP tasks and results is extremely brief and not at all inclusive of our findings or conclusions. The annual report, and the reports on findings by task, contain far more information. These are available by writing to the: NEMP Program Manager, NMFS/NOAA, Sandy Hook Laboratory, Highlands, New Jersey 07732.

With our present data we are in a far better position to describe the status of the health of coastal and shelf habitats than was the case only a few months ago. We are now able to make comparisons between the present and up to five years ago, based on historical data. More important, we have begun the necessary process of establishing benchmarks to assess changes in habitat quality and associated biological effects in key or sentinel species so as to interpret long-term changes and evaluate the effects of sudden, often catastrophic events such as tanker sinkings, plankton blooms and hypoxic situations.

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ILLUSTRATIONS

Figure 1. This scheme indicates how pollutant inputs are followed by changes in water quality and in biological responses to the pollutants. From it, it can be noted that certain biological effects occur immediately, for instance, in the case of behavior and biochemical responses. Subsequently, changes in behavior may result in changes in feeding activities and reproduction.

Likewise, pollution results in abnormal physiological conditions in individual organisms within hours. Over periods of days to months, these may result in impaired recruitment and survival and, ultimately, changes in populations and community structure.

Figure 2. The Ocean Pulse and Northeast Monitoring Programs are concerned with normal variability and the effects of pollution in the physical and chemical environment and the sublethal and lethal effects on resource species, and the food chain organisms that support these populations. Therefore, a variety of monitoring measurements are performed at stations that are polluted or likely to receive pollutants in the future.

Figure 3. Shows the distribution of copper in sediments in parts per million (ppm) dry weight, at stations located throughout the New York and Middle Atlantic Bights, as well as Long Island Sound. It can be noted that extremely high values for copper obtain in sediments collected at stations within the New York Bight apex, immediately off Raritan Bay. These values are the result of dumping of dredged materials and sewer sludge, as well as materials which may be carried seaward in the Hudson River plume. For the first time we have developed values at stations located over the entire continental shelf; these same stations will be monitored to determine changes due to trace metal loading. It can be noted that elevated values are found in the finer sediments along the Hudson Shelf Valley far from any apparent sources.

Figure 4. This figure indicates the distribution of coprostanol (in ppm) over the continental shelf. There is evidence of a seaward distribution of low levels of coprostanol to the east of the New York Bight apex off of the Hudson River-Raritan estuary. Coprostanol is a steroid found associated with mammalian wastes and is taken as indicative of contamination by fecal materials.

Figure 5. Indicates the amounts of PCBs and petroleum hydrocarbons in silver hake muscle tissue taken at stations on the continental shelf off the northeast coastline. The left vertical column indicates levels of PCBs within the sample and the right column indicates values for petroleum hydrocarbons in ppm. It is apparent that fish taken at the shelf-slope break have "significant" amounts of both contaminants in their musculature. It is presently believed that since these fish are migratory forms, the trace contaminants are taken up during those parts of their life history when they are in inshore areas that contain elevated levels of these contaminants within the physical habitat.

Figure 6. To establish benchmarks for the distribution and abundance of benthic organisms, especially forms such as the amphipods which are sensitive to trace levels of certain contaminants, it is essential that benthic populations be censused both temporally and spatially so that the patterns of distribution and abundance of

benthic species can be understood, and natural variability taken into account when assessing the effects of man's activities. This figure indicates the number of species per station above the horizontal line and the number of amphipods below the horizontal line, for different years in which samples were taken.

Figure 7. This figure indicates the standing stocks of chlorophyll in coastal waters off the Middle Atlantic Bight. By making such measurements on a frequent (monthly) basis, it is possible to assess how eutrophication of coastal waters results in changes in the standing stocks of chlorophyll, as well as changes in phytoplankton diversity and dominant species. There is some evidence that enrichment of coastal waters has resulted in a change from the larger diatom species to smaller dinoflagellate species, which are not as desirable as the basis for marine food chains.

Figure 1.

Figure 2.

Figure 3.

Figure 4.

Figure 5.

Figure 6.

APPENDIX A

1. Identify the primary causes of environmental alteration affecting nationally important living marine resources and their habitats:
  - 1.1 Identify the habitat requirements of living marine resources of primary importance;
  - 1.2 Characterize the causes of and measure environmental degradation and determine present and anticipated levels.
2. Determine the interactions between environmental alterations and habitats supporting living marine resources to provide a sound basis for evaluation and prediction of environmental effects:
  - 2.1 Determine the immediate fates of contaminants and develop long-term cumulative predictions as to their effects on habitats;
  - 2.2 Determine change due to physical habitat alterations;
  - 2.3 Predict effects of environmental perturbations on organisms at the individual, population and community level.
3. Develop and utilize effective mechanisms to disseminate information on the effects of habitat alterations and increase understanding and awareness of such modifications by the citizenry, legislatures, and managers:
  - 3.1 Increase the effectiveness of NOAA's National Marine Pollution Program and NMFS' Environmental Habitat Assessment programs;
    - 3.1.1 scope of alterations addressed,
    - 3.1.2 multidisciplinary expertise involved, and
    - 3.1.3 concentration of effort on key habitats and species.
  - 3.2 Adjust activities to address the primary issues; and
  - 3.3 Develop and capitalize on most effective media and forums for disseminating information to the public.

Figure 7.