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MITIGATION OPTIONS RELATED TO PORT DEVELOPMENT FOR FISH AND WILDLIFE RESOURCES IN TAMPA BAY, FLORIDA

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Introduction

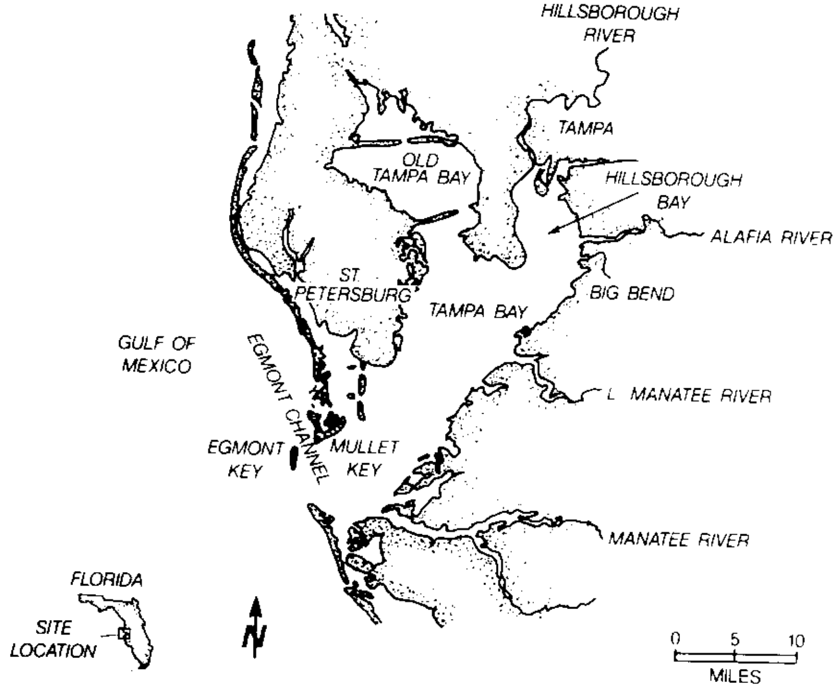
For several years, there has been an evolving effort among local agencies and individuals to develop a better understanding of the environmental problems of Tampa Bay, Florida (Figure 1), and to develop an overall strategy for improving and protecting the bay's resources. Starting as information discussions among local scientists, this effort resulted initially in a week-long symposium (Bay Area Scientific Information Symposium, May 1982) where local scientists attempted to consolidate the existing knowledge about the bay in more than 40 subject areas.

During the symposium, it became apparent that there was a broad-based concern over the lack of a regional strategy for improving the bay or managing its resources. Participants decided to establish a program through the Regional Planning Council to develop such a strategy. With funding from a Coastal Zone Management grant, a Regional Bay Study Committee was established. The committee spent almost a year identifying and assessing the relative importance of perceived problems in the bay. A corollary effort to identify solutions to these problems was unsuccessful.

The Tampa Port Authority (Authority) has been an active participant in these activities from the beginning. As the owner of a large portion of the bay bottom and as a local regulatory agency for marine construction, the Authority will play a role in the implementation of any bay improvement strategy. In addition, a significant portion of past dredging and filling activities, which have greatly altered the shoreline and the historic natural habitat of the bay, has been associated with projects either sponsored or conducted by the Authority and other port-related industries.

Figure 1.

GENERAL LOCATION MAP OF TAMPA BAY.
PORT OF TAMPA IS LOCATED IN HILLSBOROUGH BAY.



The Regional Bay Study Committee identified two priority needs that relate directly to the port's long-term development potential. These are a long-term, bay-wide strategy for disposal of dredged material and an overall plan for mitigating the environmental impacts of future dredging projects. The latter need attracted the attention of the United States Fish and Wildlife Service (FWS) in late 1982.

The FWS and the Authority entered into a Cooperative Agreement in Summer 1983 to develop a factual basis and alternatives analysis for the bay, which might also be used as prototype for future agreements between the FWS, the Authority, and possibly other agencies. The specific objectives of the Agreement were (1) to identify management and mitigation options that will allow development and maintenance of the Port of Tampa to proceed in an environmentally acceptable fashion, (2) to develop an information base in mapped and text-tabular formats for analyzing and evaluating mitigation and management options, and (3) to develop a management plan to guide the Authority in the development and maintenance of the port.

Study Tasks

Five major study tasks must be completed to accomplish these objectives: (1) prepare 1:24,000-scaled wetland, seagrass, and land-use maps for the 1956, 1972, and 1978, (2) prepare 1:24,000-scaled environmental atlas depicting biological and physical characteristics, (3) develop a geographic information system (GIS) for mapped data, (4) prepare a synthesis document (estuarine profile) on the ecology of the bay, and (5) prepare a mitigation options document.

Mapped Information

FWS and the Authority will prepare wetland, seagrass, and land-use maps for 1956, 1972, and 1982 at a scale of 1:24,000 for the entire bay region. These maps will make it possible to identify trends in wetland and seagrass losses and to determine what wetlands were changed to and the location of these changes. This task will provide valuable locational data for planning future mitigation sites.

Characteristics to be shown on the 1:24,000 biological and physical maps for the bay include the following:

1. Biological-shellfish harvest areas (approved); oyster beds (private and public); clam beds; finfish distribution (by habitat for spawning, nursery, and harvest); shorebird colonies; wading bird colonies; manatee habitat; seagrass beds; macroalgae beds; and artificial reefs.

2. Physical - salinity, point source discharges (municipal and industrial), dredged material disposal sites, tide stations, water quality stations, turbidity, conductivity, total chlorophyll, total nitrogen (from data 1978 to 1983), bathymetry, intertidal zones, sediments, tidal currents, and freswater-saltwater interfaces.

Additionally, a narrative accompanying the maps will include references for mapped data and textual information for the various characteristics portrayed. These maps should provide valuable data for planning future mitigation sites in the bay.

Geographic Information System

The FWS will digitize the maps it prepares using its Analytical Mapping System. All digitized data will then be entered into the FWS Map Overlay Statistical System for analysis. Analyses to be performed include identifying habitat trends or changes and evaluating mitigation sites. Examples of potential outputs include (1) the proximity of sites to manatee habitat or point source discharges; (2) modeling habitat suitability for selected species such as pink shrimp, brown pelican, and flounder; and (3) determining habitat changes (type and area) for future dredge disposal sites. Products from these analyses include computer-generated color maps, tables, and figures.

Estuarine Profile

The Estuarine Profile synthesize existing information on Tampa Bay. Ecological components, values, functions, and processes will be integrated from a comprehensive review of current research results and scientific literature. The Tampa Bay profile will be a concise and holistic treatment of the bay. Topics will include geological, physical, and chemical setting; habitats; biological components; ecosystem couples and linkages; impacts and management implications; and identification of information gaps.

Mitigation Options Document

The last task will be to develop a mitigation options document for Tampa Bay. It will analyze past mitigation actions and recommend a range of measures that may be included in future mitigation plans. This document will include a feasibility analysis of the various mitigation options such as marsh creation and seagrass transplants. It will also identify specific sites for future mitigation and the type of mitigation feasible for each site. Lastly, the document will develop site-specific environmental management and restoration recommendations for the bay.

Outlook

These efforts will themselves provide valuable new information on Tampa Bay and on the potential impacts of future port projects. More important, however, they may eventually form the nucleus of a broader effort to establish a long-term strategy for dredged material management in the bay.

Concurrent with these efforts, the Port Authority is planning the development of a 25-year permit for maintenance dredging throughout the port. Such a permit will require a long-term plan for the use and management of existing and future enclosed maintenance dredging disposal areas, including two large disposal islands in the bay. The production of such a plan will require port interests and the Corps of Engineers to reach some agreement at least on the disposal of dredging material from future construction.

All involved hope that these future disposal plans will be linked to the mitigation options developed in this current effort to produce a broader dredging, disposal, and mitigation plan that is sensitive to economic, engineering, and environmental considerations.

Implementation of the findings of this study will be affected by four major factors: (1) the ability of federal agencies to enter into long-term agreements regarding mitigation efforts that are not part of a specific project, (2) the development of workable rules for long-term mitigation programs by State of Florida, (3) the ability and willingness of port interests to limit their long-term options, and (4) the development of mechanisms to finance long-term mitigation efforts before beginning specific projects.

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A COMPARISON OF THE ABUNDANCE AND DIVERSITY OF FISH AND SHRIMP IN BARNEGAT BAY AND A REPRESENTATIVE LAGOON SYSTEM IN NEW JERSEY

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Introduction

New Jersey's shoreline includes extensive man-made lagoon or canal systems created to provide waterfront residential lots. These lagoon systems were created by the dredging and filling of salt marshes and some forested wetlands prior to passage of the Wetlands Act in 1970 and subsequent promulgation of wetlands maps. Most of these lagoons were dredged 20-25 feet deep in order to obtain sufficient fill to construct houses on the wetlands, but most have a shallow shelf along each side.

In 1980, the State of New Jersey asserted its jurisdiction over development activities conducted in man-made lagoons, including dredging, bulkheading and filling. Prior to that time, these lagoons were regulated solely by the U.S. Army Corps of Engineers. In 1982, 267 permit applications were submitted to the N.J. Department of Environmental Protection for work in man-made lagoons; in 1983, the number of applications was 287, and in 1984 229 applications were submitted by October 1. About 40% of these applications proposed dredging or construction of a bulkhead and filling outshore of the mean high water line. Typically, the area to be filled or dredged consisted of shallow waters, less than 4 feet deep.

The New Jersey Coastal Zone Management Program includes rules which govern permit decisions. These rules, adopted in 1978, discourage filling in all water areas, except for minimum fill for water dependent uses where no alternatives are available.

The question soon arose as to the applicability of these rules to lagoons. Although the ecological importance of natural shallow estuarine waters has been well documented in the scientific literature

(Odum et al., 1974; Tatham et al., 1978; Tyrawski, 1979), the shallow and intertidal zones of man-made lagoon systems have not been extensively studied.

A study conducted by Rutgers University and the N.J. Department of Environmental Protection (Sugihara et al, 1979) compared physical, chemical and biological parameters of a tidal marsh system to a nearby lagoon system. The lagoon exhibited a strong summer thermocline and a lesser winter thermocline. The deep bottom waters in the center of lagoons were anoxic in summer and frequently had low oxygen levels the rest of the year. The oxygen depression and stratification were more intense further into the lagoon system. Net primary productivity was significantly lower in the lagoon system than the marsh system. Benthic sampling indicated lower numbers and biomass of benthic invertebrates in the lagoon than in the bay, with lesser amounts further into the lagoon. Species diversity was also lower in the lagoon. Fish were sampled using seines and trawls. Seine catches were not quantitative, but those fish species which were most abundant were caught at each station type (i.e., bay, creek and lagoon), although no comparison can be made as to relative abundance in each waterway. Trawl sampling was standardized and, during the winter, spring and summer samplings, few or no fish were caught in lagoons by trawl, while the creek and bay stations yielded fish all year.

Generally, studies have shown lagoons to have very low oxygen levels in deep waters and much lower primary and secondary productivity than the marshes from which they were created. Accordingly, creation of new lagoons is prohibited in New Jersey under the Wetlands Act of 1970 and New Jersey's Coastal Zone Management Program. However, numerous undeveloped lagoon lots exist in the State, requiring permit review and decisions. Based on the Rutgers/DEP study, the poor circulation and long length of lagoons, the fact that a productive and valuable system has already been destroyed in constructing a lagoon and personal observations, several options for regulating lagoon development were discussed among state and federal officials. These options were:

1. Permit filling and bulkheading to property lines in lagoons.

2. Permit filling and bulkheading on lagoon lots located more than 500 feet from a natural waterway.

3. Permit filling and bulkheading on lagoons already substantially bulkheaded.

4. Permit filling and bulkheading to the existing limit of fill in all lagoons.

In the summer of 1983, the Division of Coastal Resources established guidelines which require that bulkheads be placed along the mean high water line in lagoons, except on individual lots 75 feet or less in width which are located between two existing bulkheaded lots. In such cases, filling is allowed. Meanwhile, the Division, in cooperation with the Divisions of Fish, Game and Wildlife and Water Resources, undertook a sampling program to evaluate the habitat value of lagoon edges less than four feet deep. These areas are commonly the subject of permit applications. This paper addresses fisheries results. The Division of Water Resources aspect, only touched upon here, focused on water quality and the benthos.

Materials and Methods

A lagoon system off Barnegat Bay in Lacey Township, Ocean County, New Jersey was selected for the study. Two unbulkheaded bay stations and six lagoon stations were selected (Figure 1). The lagoon stations were chosen to compare (1) bulkheaded shorelines to unbulkheaded shorelines, (2) unbulkheaded shorelines at different distances from the bay, and (3) a lagoon less than 50% bulkheaded to one more than 80% bulkheaded.

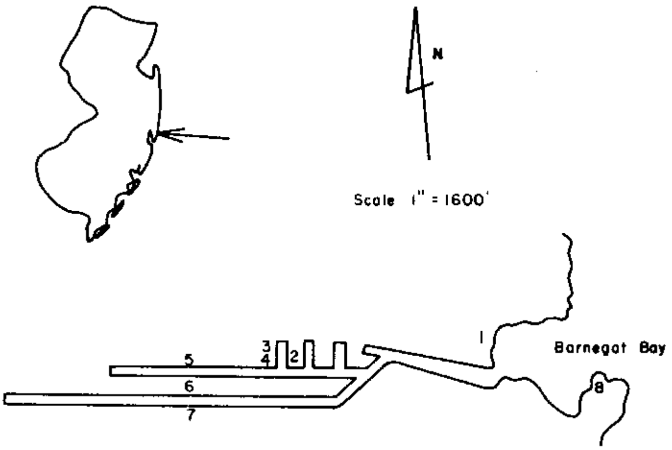

Figure 1: Site and station location map

Each station was seined biweekly for one year, beginning in March 1983, and using a 25 foot x 4 foot bag seine with a 0.25 inch mesh. Each station was sampled twice (morning/afternoon) on each date, and water temperature, salinity and oxygen concentration measured.

Each catch was counted by species and a total wet weight for each species determined. Samples which were too large to be counted in the field were preserved and sorted, counted and weighed later in the lab. The catches for the two replicates at each station have been averaged and converted to catch per 50 square meters. Data has not yet been statistically analyzed. Results for seven of the eight stations will be discussed. The eighth station, a bay station will not be discussed. On sampling days, there were often small waves at this station, water was shallower than the other stations, and catches lower and not comparable.

In addition to the fisheries sampling program, the Division of Water Resources gathered water quality (nutrients, oxygen and coliform), phytoplankton, benthic algae and benthic invertebrate data. The data will not be discussed here, except to indicate that 68 benthic invertebrate species were collected, with the bay dominated by filter feeders and all lagoon stations dominated by detritovores, particularly polychaetes and crustaceans.

Results and Discussion

Water chemistry

Temperatures ranged from 0 to 30°C during the study period. Salinity ranged from 14 to 22 ppt at 7 of the 8 stations until February and March of 1984, when it was only 6 to 12 ppt. One of the bay stations (Station 8) had generally higher salinities (19-24 ppt). Oxygen reached low levels of 5-6 mg/l in July, August and September at all stations, but generally ranged from 8 to 11 mg/l the rest of the year.

Species collected

The most abundant fish were mummichogs, rainwater killifish, tidewater silversides, sheepshead minnows, and bay anchovies. Both grass shrimp and sand shrimp were also common. These species are all important forage fish for many recreationally and commercially important finfish species.

Comparison of bay to lagoon and effect of distance from bay

Unbulkheaded bay (Station 1) and lagoon (Stations 4 and 5) stations were compared. The study indicated that lagoon Stations 4 and 5 were utilized as much as bay Station 1 most of the year in terms of biomass, with the catch at Station 5 frequently exceeding the catch at the bay station (Figure 2). The catch at the second lagoon station, Station 4, was more comparable to the bay. Station 5 is 4,200 feet from the bay; Station 4 is 3,000 from the bay. Note that distance from the bay did not result in a lower biomass in the shallow waters of the lagoon. It is possible that some fish escaped the seine at Station 4, due to the bank overhang. All other stations had either a beach or bulkhead along the shoreline, simplifying seining.

While the biomass caught in the bay at Station 1 exceeded that caught at Station 4 in late summer, this was much less apparent in terms of numbers caught, because shrimp were more abundant at the lagoon Stations 4 and 5 than at the bay station, particularly in the fall. Station 5 exceeded the bay in both number and biomass on all but two days.

Although the catches were generally higher at Station 5 than at the bay station, the number of species caught was greater in the bay during the summer and fall, and similar most of the winter and spring (Figure 3). Distance into the lagoon did not affect species composition.

Bulkheaded versus unbulkheaded lagoon shorelines

In order to compare bulkheaded shorelines to unbulkheaded shorelines, two sets of paired stations were selected, each pair consisting of a station with bulkheaded shoreline (Stations 3 and 6) and a station with unbulkheaded shoreline (Stations 2 and 5). These stations were located across the lagoon from one another. The data for one of these pairs (Stations 2 and 3) is shown here. For both pairs, higher biomass and greater numbers were collected at the unbulkheaded stations than at the bulkheaded stations most of the year (Figure 4). This relationship did not hold in the late winter/early spring. When data on number of individuals was broken down into fish and shrimp, this trend held true for fish only. The number of shrimp was similar at bulkheaded and unbulkheaded stations from late winter through summer. In addition to finding higher numbers and biomass along an unbulkheaded lagoon shoreline than a bulkheaded lagoon shoreline, more different species were found on a given day at the unbulkheaded station in the pairing of Stations 2 and 3 (Figure 5). This trend was not noticeable at the other paired stations (5 and 6).

The data indicate that the shallow waters along unbulkheaded lagoon shorelines support more fish and shrimp than those along bulkheaded shorelines. However, even the shallow waters in front of bulkheads are productive.

Developed nature of lagoons

In order to look at the effect of lagoon bulkheading on the remaining unbulkheaded shorelines, two unbulkheaded lagoon stations, each located 4,200 feet from the bay, were sampled. Station 5 was located along a 2,000 foot long stretch of unbulkheaded shoreline, on a lagoon less than half of which is bulkheaded. The other station, Station 7, was located on a lagoon more than 80% bulkheaded, and is a 75 foot wide lot with bulkheads on each side.

Results indicated that in the summer and fall the biomass was generally greater at Station 7 than Station 5 (Figure 6). Numbers were also higher at Station 7, with one exception due to a catch of several thousand grass shrimp. In addition, more species were collected at Station 7 than Station 5 (Figure 7).

This indicates that the bulkheading of most of a lagoon's shoreline does not negate the value of the remaining unbulkheaded lots on that lagoon. Indeed, perhaps it results in increased value to the shallow waters of the unbulkheaded lagoon edge.

Summary

As a result of this study, five generalizations can be made.

1. Lagoon shallows are utilized by both fish and shrimp, some areas supporting larger numbers and biomass than the nearby bay station and some supporting less.

2. Species diversity is greater in the bay than in the lagoon.

3. Increased distance from the bay does not result in decreased shrimp and fish utilization.

4. Shallow waters along unbulkheaded lagoon shorelines support more fish and shrimp, both numbers and biomass, and may have higher species diversity, than shallow waters along bulkheaded shorelines.

5. Shallow waters along unbulkheaded lagoon shorelines do not lose habitat value even when up to 80% of the lagoon is bulkheaded.

The study supports the Division's policy of discouraging filling of lagoon waters even when bulkheading is approved. Furthermore, the study indicates that shoreline stabilization by vegetation would be preferable to bulkhead stabilization from the point of view of preserving the value of the lagoon habitat. The preservation of lagoon shallows is all the more important as they may be the only significantly productive portions of lagoons.

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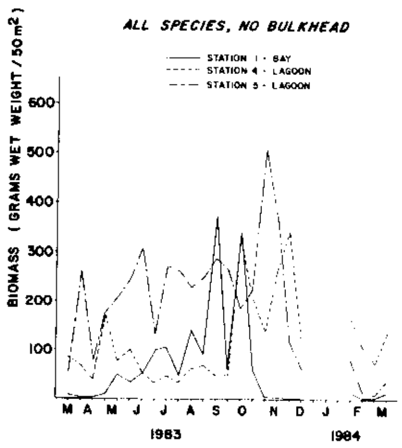

Figure 2. Seasonal variation in biomass at unbulkheaded bay and lagoon stations.

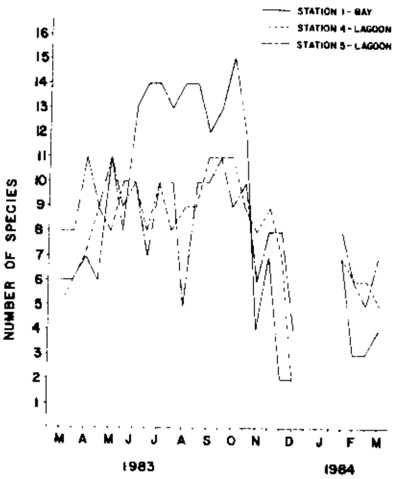

Figure 3. Seasonal variation in number of species at unbulkheaded bay and lagoon stations.

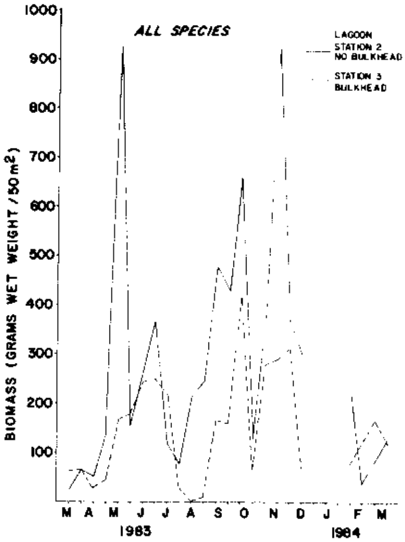

Figure 4. Seasonal variation in biomass at bulkheaded and unbulkheaded lagoon stations equidistant from Barnegat Bay.

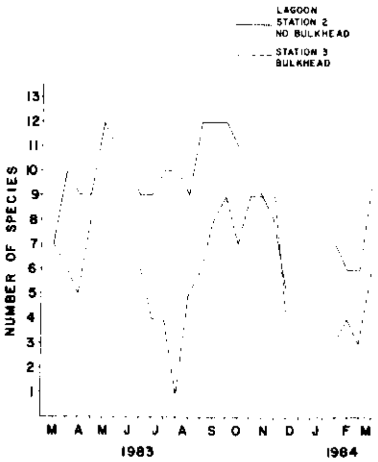

Figure 5. Seasonal variation in number of species at bulkheaded and unbulkheaded lagoon stations equidistant from Barnegat Bay.

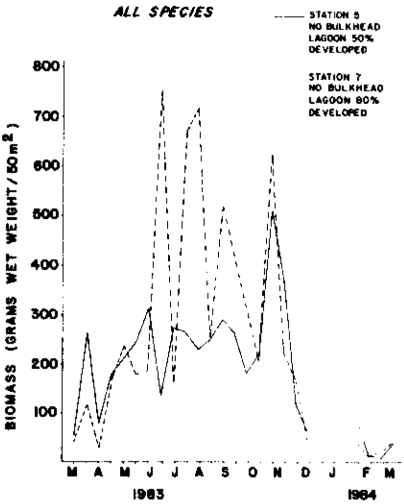

Figure 6. Seasonal variation in biomass at unbulkheaded stations on two lagoons equidistant from Barnegat Bay.

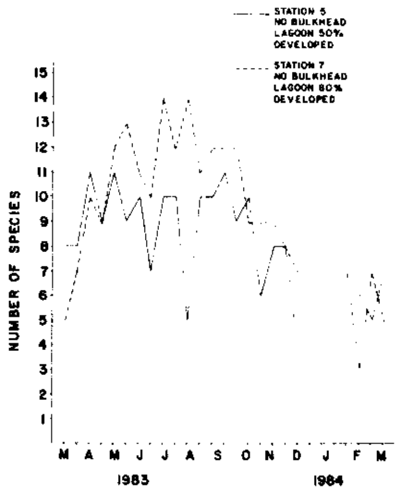

Figure 7. Seasonal variation in number of species at unbulkheaded stations on two lagoons equidistant from Barnegat Bay.

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USING SENTINEL ORGANISMS TO MONITOR CHEMICAL CHANGES IN THE COASTAL ZONE: PROGRESS OR PARALYSIS

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Introduction

Increasing pollution of coastal areas by xenobiotic chemicals such as synthetic organic compounds, petroleum, trace metals and radionuclides has led to the search for an effective monitoring program that has a capability to discern spatial and temporal trends in the environmental concentration of chemicals of concern. One strategy that has been tested in prototype monitoring programs is the use of bivalve filter-feeding molluscs as sentinel organisms. Because of their sedentary habits and their ability to bioconcentrate the pollutants of interest, mussels and other bivalve species appear to be appropriate sentinels for the detection of chemical changes that may be deleterious, over the long term, to the integrity of the coastal environment and to the health of man.

While no single approach is perfect, sentinel organisms have proven to be a good tool for monitoring chemical contamination. During the 1970's a few national and international programs were established to investigate the use of such organisms as indicators of pollution. Particularly important among these programs were those of the Organization of Economic Cooperation and Development and of the International Council for the Exploration of the Sea. During the past few years the United Nations Environment Programme Regional Seas Program has placed a major emphasis on the development of capabilities for measuring the levels of pollutants in coastal and marine environments. The Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization has also recently sponsored the formation, from representatives of West Pacific region nations, of a task team to investigate marine pollution research and monitoring by using commercially exploited shellfish as indicator organisms.

National governments in many countries are initiating their own programs as a part of the effort made to provide longer-term protection of coastal zones from the deleterious effects of chemical contamination.

In the United States, the Mussel Watch Program was begun in the mid-1970's and built upon earlier regional and national programs. This program has used mussels (and oysters) as indicators of concentrations of several major classes of chemical pollutants in coastal waters; principally the higher molecular weight synthetic organic compounds, petroleum and its derivatives, other fossil fuel compounds, a number of trace elements, and the radioactive transuranic elements produced in the nuclear fuel cycle and weapons testing. Sample collections were made over a three-year period and the results of chemical analyses of this national collection have been reported. Additional work in several regions has continued since the original 3-year program and an improved perspective on the role of sentinel organisms in coastal monitoring has been gained. However, no further national collection has been made although such a program is currently under discussion within NOAA and EPA.

The results of these national and regional programs now permit a more comprehensive assessment of the sentinel organism concept and its application to other coastal areas. In November of 1983 an international workshop was held to discuss the detection and measurement of chemical changes in the coastal environment and to assess the concepts and methodologies used in obtaining monitoring data. Fifty-three representatives from twenty-eight countries met and the results of their discussion are now being edited for publication. We present here a brief summary of our interpretation of some of the major points generated from discussions at this workshop. We will not present Mussel Watch data here as it is available in technical reports and journal articles published elsewhere (see References).

The Need for Monitoring Coastal Contamination

Several areas of the U.S. coast have been found to contain chemical contaminants in sufficient concentrations to cause concern for the health of human consumers of seafood and this situation is the same in many other countries. Chemical contamination of this magnitude also raises questions concerning the viability of populations of commercially valuable organisms. In spite of efforts to improve husbandry, industrialized society continues to lose chemicals to the environment via point source and non-point source release. This continuing input of contaminants requires a continuing assessment of chemical concentrations in coastal areas.

Random measurements of specific chemical contaminants in arbitrarily selected field samples do not address issues such as natural variability and results may be actively misleading. In order to produce an unbiased estimate of variation in the natural system, a monitoring program needs to be designed to address specific questions. The questions must be asked first and then data gathered to answer them; randomly accumulated data cannot often be applied to answer questions asked after the fact.

Is the reduced use of specific chemicals of environmental concern (e.g. lead, DDT) reflected in a corresponding reduction in environmental concentration? What will be the consequences of increasing ocean dumping activities or of shifting ocean dumping to deeper water? Specific questions such as these can be addressed by a monitoring program that is designed to meet specific objectives. We can formulate a series of objectives:

1. protection of human health, i.e. tracing the route back to man
2. protection of commercially valuable living natural resources
3. protection of special groups of organisms such as marine mammals or birds
4. protection of the ecosystem that supports biotic diversity.

These objectives can be met in a variety of ways but increasingly complex information is required as we proceed through this list. For example, the analysis of market samples would be a straightforward and relatively inexpensive way to provide a substantial protection for human health. Objectives 2 and 3 can be met in part by monitoring only species of concern and this again could be done quite easily. However, if we wish to obtain information concerning sources of contaminants, concentration trends in space and time and a regional assessment of contamination then a different approach is needed. This approach includes research into the processes that affect the input, transport pathways and ultimate fate of contaminant chemicals in the coastal environment.

Although analyses of sediment and water samples can legitimately be part of a monitoring program, we emphasize the use of sentinel organisms here primarily because of bioavailability. The issue of bioavailability is an important one because sediment-bound contaminants are not necessarily as available to uptake by organisms as they are to chemical extraction.

Several workers have discussed the ideal attributes of a good sentinel organism and these are listed here:

- The organism should be cosmopolitan in order to minimize problems inherent in comparing data from the analysis of different species with varying life histories and relationship to their habitat.

- A simple correlation should exist between the pollutant content of the organism and the average pollutant concentration in the surrounding water.

- The organism should accumulate the pollutant without being killed by the levels encountered in the environment.

- The organism should be sedentary in order to be representative of the study area, although territorial species may be chosen if information on a regional scale is sought.

- The organism should be abundant throughout the study area and be found in stable populations that can be sampled repeatedly.

- The organism should be sufficiently long-lived to allow the sampling of more than one year-class if desired.

- The organism should be of reasonable size, giving adequate tissue for analysis.

. The organism should be easy to sample and hardy enough to survive in the laboratory, allowing defecation before analysis (if desired) and laboratory or transplant studies of pollutant uptake.

. The organism should tolerate a wide salinity range.

. The organism should have minimal (or well understood) enzyme systems that metabolize the contaminants in question so that an assessment of the magnitude of contamination in the environment can be made.

. Organisms that are of commercial value or can be cultured are of immediate interest and work with them will have immediate economic value.

. Background data on such parameters as kinetics of uptake and release, taxonomy, sexual cycle, lipid chemistry, growth rates, etc., should be known or obtained early in a monitoring program.

Sentinel organisms can be selected to address specific questions and it should not be inferred that bivalves are the only appropriate monitoring organism. Although migratory, territorial species might be used to serve as monitors of regional areas: e.g. finned fish and birds may bioaccumulate certain contaminants at very high concentrations thus making analysis easier. When including organisms other than bivalves, rates of bioaccumulation and metabolism must be assessed prior to interpretation of monitoring results. In some cases metabolism of contaminants can be a positive factor in that it permits study of the more recalcitrant chemicals.

Strategies for Monitoring

Measurements of contaminant levels in even a well chosen sentinel organism are not very meaningful unless they are made within the context of the processes that affect their input, transport, degradation and storage. Taking a holistic approach, analysis of contaminants needs to be done simultaneously with physical and chemical measurements of water, water movement and sediment transport processes. These factors need to be integrated with the biological factors. However, resources available to any monitoring program are finite, therefore, the compounds to be assessed and the method of assessment must be chosen with care. In order to make efficient use of available monitoring resources we need to continually phrase associated research questions so that the results can be applied generically to the greatest extent possible and are not inherently constrained by site specificity.

An order of priority in establishing the methodology and sequence of measurements when extending monitoring programs into new or unknown areas should be considered. The following general guidelines are suggested to achieve a cost effective multistage approach:

- site selection should be based on a preliminary assessment of all relevant background information, supplemented if necessary by a preliminary survey of sentinel organisms.

- establishment of a longer term monitoring program in coastal sites selected to identify hot spots of contamination and unpolluted reference sites.

- determine temporal and spatial trends from a more comprehensive study of selected sites.

- create a heirarchical analytical scheme to identify specific samples for high resolution analysis following identification by simpler scanning techniques.

- investigate biological impact and long term accumulation of toxicants in local ecosystems.

Developing Countries and International Cooperation

Monitoring of chemical contamination in developing countries involves the same principles and the lessons already learned by industrialized countries can be applied to new areas. Background information may not be as available as it is in the more industrialized countries, therefore, acquisition of basic background information might necessarily be a larger component of monitoring programs in some situations. Other requirements such as trained personnel and sophisticated instrumentation may not be easily available in developing countries and a realistic assessment of available resources should be incorporated into the design of these monitoring programs. It will not be possible to institute state-of-the-art monitoring in many places but joint efforts with the more developed countries will permit a significant effort to be made. Recent efforts by UNEP and IOC-UNESCO indicate the need for training and for assistance with modern chemical and biological techniques. Training programs are making substantial progress in some regions and further joint efforts with laboratories in developed countries can only increase this progress. We suggest that laboratories currently using high resolution analytical techniques participate in in-country training programs and analyst exchange programs as a way to increase analytical expertise around the world. Intercomparison/intercalibration exercises should continue to improve reliability of data and the search for reliable, simpler, less expensive analytical techniques should continue while present techniques are applied to monitoring needs.

Research

Basic research into fundamental processes continues to be important because understanding of the functioning natural systems affected by chemical contamination remains imperfect and will remain so for the foreseeable future. We have learned much in the recent past and have begun to place such processes as input, fate and effects into perspective. However, quantitative information on these processes is still being produced and while major questions remain unresolved any monitoring effort must be able to respond to new developments as they occur. As our understanding becomes more sophisticated we will need to ask different questions (or ask the same questions differently) and a monitoring program should not be so rigidly designed that it cannot be adapted to the new information. Knowledge is not adequate at present to establish several aspects of desired monitoring programs and a major part of a monitoring effort should be a continued attempt to understand the natural processes that make up the system being studied.

Monitoring Programs: The U.S. Experience with Mussel Watch

The bivalve sentinel organism concept can be used in the assessment of the current status of coastal contamination and the estimation of spatial and temporal trends. We believe that the U.S. Mussel Watch experience has shown the validity of the sentinel organism concept and that valuable environmental data can be obtained from a monitoring program that incorporates bivalves as a component. Confusion about the goals of the initial U.S. Mussel Watch program is perhaps one factor that is impeding the establishment of an operational monitoring program at this time. The greatest challenge in a monitoring effort is the definition of the objectives. The monitoring effort must be designed to answer specific questions and these objectives must be widely understood from the start. The objectives of the U.S. Mussel Watch program were to assess the current status (1976-78) of contamination by a selected group of chemicals in waters of the U.S. outer coast. The focus was on 1) the detection of regional trends, 2) the identification of "hot spots" of elevated concentrations, 3) the accumulation of a valid data set for one time period that could be used to assess long-term trends, and 4) the determination of monthly, seasonal, and annual variability of pollutant chemical concentrations in organisms. Data obtained from the U.S. Mussel Watch program have been successfully applied to the original objectives of the program and the experience provides the foundation for new monitoring efforts. The major deficiency we have identified in the data is that sampling intensity was insufficient to detect many local "hot spots". This deficiency reflects a lack of sufficient funds, not an error in planning or strategy.

The U.S. Mussel Watch program contained a substantial research effort that addressed specific questions as they arose but an operational program might not contain that level of research effort. In addition to a clear definition of goals, the creation of an operational monitoring program that can adequately assess the chemical contamination of coastal waters will require continuing research at some level. Once goals are established, scientific and technical capabilities will probably need to be developed to meet some of the goals. Our knowledge of the natural system is not complete and the results of research will have to be continually incorporated into existing monitoring efforts if the monitoring data is to remain credible.

While design of an operational program is possible, non-scientific impediments exist that block implementation. Interagency rivalries and conflicting or undefined jurisdictions are a frustrating reality. The continuing re-examination of monitoring goals is an ongoing activity that seems to delay action. Issues such as these are being addressed but real progress at times seems sluggish. The paralysis of inaction risks the loss of valuable data and we urge a vigorous effort to resolve the existing problems. The recently established program of National Status and Trends in NOAA's Ocean Assessment Division is a step toward a national monitoring program. This program seeks to "assess and document the status and long-term changes of environmental quality of the nations' coastal and estuarine environments." A request for proposals, issued in July, 1984 and quickly withdrawn, is but one example of the erratic progress being made toward the creation of a national coastal environmental quality monitoring program. We suspect that the primary impediments to the establishment of a monitoring program are not simply related to lack of scientific and technical information. Rather, problems in the definition of the goals of such a program and relating these goals to a vaguely defined national policy are probably paramount.

Conclusion

Given that contamination by chemicals in coastal areas can have an adverse effect on human health and on natural resource populations, it would be desirable to be able to predict such effects and to govern our waste disposal practices accordingly. Ideally, we would like to have data on the concentrations of pollutants in all segments of the ecosystem, pathways and rates of transfer of pollutants between these segments and the adverse effects of these pollutants from the subcellular to the ecosystem level. This holistic approach will continue to be the ultimate goal of scientific research in coastal environmental quality.

The complexity of nature is a reality and will inherently introduce some uncertainty into monitoring data. This is not an acceptable excuse for the paralysis of inaction in establishing a monitoring program for chemical contamination in coastal areas. Part of the success of previous efforts has been the recognition that such complexity exists and that monitoring programs must be designed and operated within that context. Uncertainties are inherent in scientific and technical knowledge and our decision making process needs to incorporate these uncertainties. Decisions that have environmental, economic and social impacts will be made and we cannot permit the uncertainty caused by the complexity of natural systems to paralyze research, environmental assessment and resource management in coastal areas. A monitoring program is important, not only to warn us of an existing or impending problem but also to inform us that a chosen practice is functioning as predicted.

An operational monitoring program to monitor chemical contamination in coastal areas can be implemented now and the concept of sentinel organisms can be an effective component of a monitoring program.

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