Chesapeake Executive Council

Living Resources Monitoring Plan

Chesapeake Bay Program

Agreement Commitment Report

July 1988

Living Resources Monitoring Plan

An Agreement Commitment Report from
the Chesapeake Executive Council

Annapolis, Maryland
July 1988

ADOPTION STATEMENT

We, the undersigned, adopt the **Monitoring Plan for Chesapeake Bay Living Resources**, in fulfillment of Governance Commitment Number 5 of the 1987 Chesapeake Bay Agreement:

> *"...by July 1988, develop a Bay-wide monitoring plan for selected commercially, recreationally and ecologically valuable species."*

We agree to accept the Plan as a guide to collection of the biological data necessary to measure progress towards meeting the living resources objectives set forth in the Agreement.

We further agree to work together to implement, according to the time line set forth in the Plan, the major recommendations of the Plan: (1) to establish a consistent and coordinated, Bay-wide core program to monitor the productivity, diversity, and abundance of commercially, recreationally, and ecologically important living resources; (2) to ensure the long term accessibility and integrity of monitoring data, and the timely dissemination of information generated by the core monitoring program; and (3) to permit analysis of the data for trends, correlations, and relationships between water quality, habitat quality, abundance, distribution, and health of living resource populations.

We recognize the need to commit long-term stable financial support and human resources to the task of monitoring Chesapeake Bay living resources for many years in the future. In addition, we direct the Living Resources Subcommittee to work with the Monitoring Committee to prepare an annual report addressing the progress attained in meeting the Plan's goals.

For the Commonwealth of Virginia	
For the State of Maryland	
For the Commonwealth of Pennsylvania	
For the United States of America	
For the District of Columbia	
For the Chesapeake Bay Commission	

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EXECUTIVE SUMMARY

The 1987 Chesapeake Bay Agreement set forth three goals addressed, in part, through the adoption of this Plan:

o "Provide for the restoration and protection of the living resources, their habitats and ecological relationships";

o "Support and enhance the present comprehensive cooperative and coordinated approach toward management of the Chesapeake Bay system"; and

o "Provide for continuity of management efforts and perpetuation of commitments necessary to ensure long-term results."

Based upon the recognition that the "productivity, diversity and abundance of living resources are the best ultimate measures of the Chesapeake Bay's condition," the Agreement signatories committed to, "by July 1988, develop a Baywide monitoring plan for selected commercially, recreationally and ecologically valuable species". The Chesapeake Bay Living Resources Monitoring Plan establishes the framework for a Baywide long-term living resources monitoring program addressing three major objectives:

I. Document the current status of living resources and their habitats in Chesapeake Bay.

II. Track the abundance and distribution of living resources and the quality of their habitats over time.

III. Examine correlations and relationships between water quality, habitat quality, and the abundance, distribution and integrity of living resources populations.

The Living Resources Monitoring Plan was developed by a joint work group of the Chesapeake Bay Living Resources and Monitoring Subcommittees. Because of the interacting relationships between monitoring and stock assessment of finfish and shellfish populations, close communication and joint membership was maintained between the Living Resources Monitoring Work Group and the Chesapeake Bay Stock Assessment Committee, which was responsible for the development of a Baywide stock assessment plan (CBSAC 1988).

The Living Resources Monitoring Work Group has given the language of the Bay Agreement ("selected . . . species" and "living resources") a broad interpretation in the development of this plan. A comprehensive plan, with attention to all important groups of organisms in the ecosystem provided the best opportunity for reviewing existing programs, recommending further integration of Bay monitoring, and achieving monitoring objectives. Tidal and non-tidal wetlands, although not "species", are included because of their great importance as habitats and regulators of water quality.

An important criterion applied in this plan is the focus on long-term, baseline monitoring which will provide data for the characterization of living resource populations and for tracking trends in their abundance over time. It is evident also that research into problems of living resources and stock assessment will be served well by accessible, consistent, long-term, baseline data on the abundance and distribution of important species. The Work Group determined that short-term objectives for biological data collection should be addressed in the Chesapeake Bay Research and Stock Assessment Plans.

A goal beyond the immediate commitment to develop a living resources monitoring plan is the full integration of living resources and water quality monitoring within Chesapeake Bay. Ultimately, there will be a comprehensive and integrated Chesapeake Bay Monitoring Program that with both water quality and living resources components. The Living Resources Monitoring Plan is a significant step towards that goal. Many areas of integration between living resources and water quality monitoring are identified. Appendix A, a plan developed for the Tidal Potomac River, is a model of this kind of integration on a regional scale.

The major recommendation of this plan is to institute a Baywide, core living resources monitoring program, built upon existing programs. Many of the detailed recommendations call for continuation, sometimes with modification or review, of existing programs. New data collection elements have been recommended in cases where important long-term information needs are not being met; these are accompanied by an asterisk (*) in the list below. A summary of the core program follows:

FINFISH
A. Seine Surveys
B. Trawl surveys
    1. Bay-wide survey* (pilot program at present)
    2. Supplementary trawls (upper tributaries, shallow waters)
C. Early Life Stage (Egg and Larval) Surveys
    1. Bay anchovy & other pelagic estuarine species (first tier)*
    2. Anadromous fish (second tier)

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    1. Dredged shell surveys (first tier)
    2. Habitat monitoring (second tier)
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    1. Existing Bay-wide program with improvements
D. Mesozooplankton
    1. Existing Bay-wide program with improvements
E. Gelatinous Zooplankton
    1. Existing Bay-wide program with improvements

TOXICITY AND TOXICANT BURDENS
A. Existing body burden monitoring with improvements
B. Develop ambient toxicity biomonitoring program*

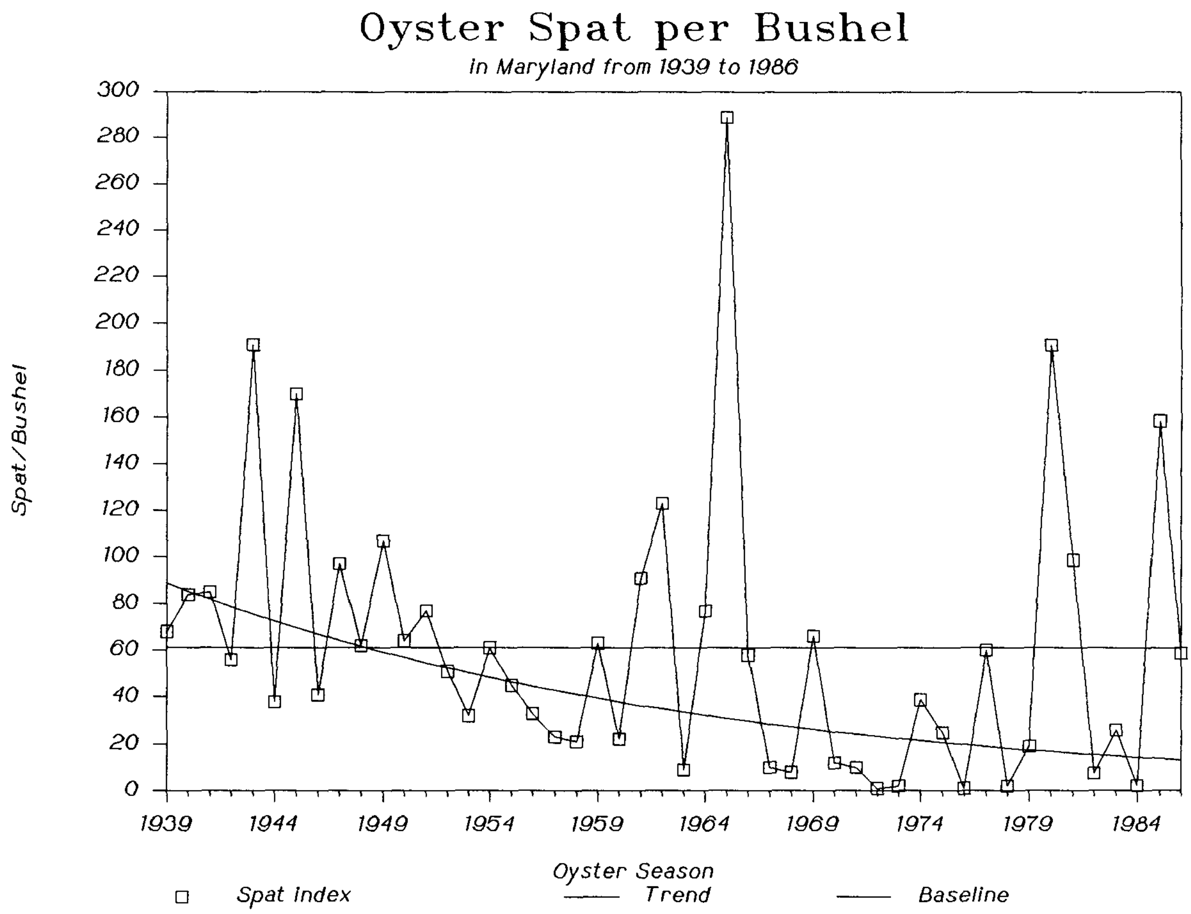
ECOSYSTEM MONITORING
A. Initiate program in selected tributaries*

First tier surveys are designed primarily to meet living resources monitoring objectives I and II, and second tier surveys to meet objective III. Examples of the kinds of information generated by each type of effort are shown in Figures 1 and 2.

A second major recommendation is the institution of a data management and reporting system for living resources monitoring data, building upon the existing facilities of the Chesapeake Bay Program Computer Center, and the Chesapeake Bay Program Data Management Plan for Biological Data (USEPA 1987). New resources required to meet this recommendation are (1) additional staff to ensure that monitoring data are entered, analyzed and reported promptly, and (2) improved methods of making data accessible to the Bay community. The new staff will be assigned to appropriate state agencies, but will work closely with the Chesapeake Bay Program Computer Center staff to ensure that all requirements for data management, analysis and reporting are met.

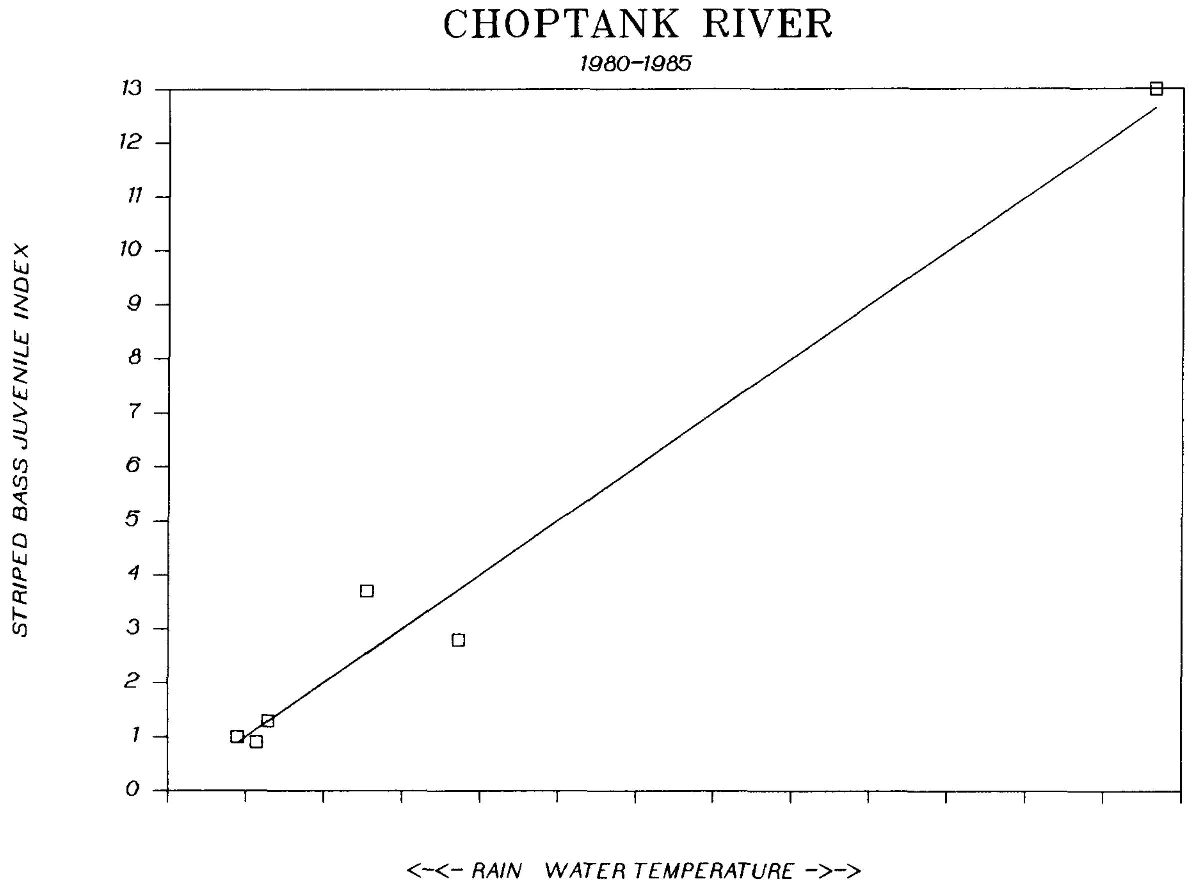
Estimated costs of the proposed living resources monitoring program are tabulated in Chapter IV, which also outlines the costs of existing programs, responsible agencies and oversight committees, and offers suggestions for stable and consistent means of long-term funding. Implementation of the plan is scheduled to occur over a two and one-half year span beginning in late 1988 and ending in early 1991. The total cost of Baywide living resources monitoring appears large: an estimated $4.01 million annually for complete implementation of the plan, a 77% increase over the $2.26 million annual cost of existing living resources monitoring programs. However, the cost is a small fraction of the funds that will be required to restore the Chesapeake Bay to a healthier condition. Living resources monitoring will be an important means of maintaining accountability for large-scale water quality and habitat improvement measures for many years to come.

Figure 1



This graph shows the value of first tier, or baseline monitoring, when sustained for many years. The annual oyster spat index for Maryland has shown a significant declining trend over the entire 48-year period of record, in spite of several years with very high indices. Baselines, or long term averages, can be used as target levels of abundance. Deviations from a baseline (for example, three consecutive years of an index below baseline) can be used as action levels to trigger management actions to protect stocks from overharvest or environmental threats.

Figure 2



This graph shows that the annual juvenile index for striped bass in the Choptank River from 1980-1985 could be modeled as a function of rainfall during the most critical larval period and water temperature during the peak of the spawning season. Higher values of the index were associated with low rainfall and high temperature. Low water temperatures (< 12^oC) are lethal to striped bass eggs. Intensive water quality monitoring during the spawning season has shown that rainfall in the poorly-buffered tidal fresh waters of the Choptank River is associated with low pH, dilution of beneficial dissolved salts, and with toxic contaminants such as dissolved aluminum and herbicides. This is the kind of information that is generated by second tier monitoring programs.

ACKNOWLEDGEMENTS

The Chesapeake Bay Living Resources Monitoring Plan is the product of the Living Resources Monitoring Work Group. The participation and contributions of all Work Group members are gratefully acknowledged. Those who took large portions of time from their regular duties to help with the development of the plan include Herbert Austin, Richard Batiuk, Bert Brun, Roland Fulton, and Steve Jordan. Eric Barth and Bess Gillelan helped to provide detailed coordination between the development of the Stock Assessment and Living Resources Monitoring Plans. Harley Speir made valuable suggestions for improving the Finfish and Shellfish sections of the Plan. Verna Harrison, Chair of the Living Resources Subcommittee, and Ed Christoffers provided guidance and support throughout the long process of developing this plan. Finally, the many constructive comments provided by public, academic, and governmental reviewers of the first draft of the plan contributed greatly to its improvement.

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CHAPTER I
INTRODUCTION

Several thousand species of plants, animals and microorganisms live in the Chesapeake Bay. These thousands of species, collectively, are the Bay's living resources. Along with the diversity of forms, there is great diversity in size, distribution, function, and behavior. A million-fold difference in size separates the smallest (bacteria less than 1 micron in diameter) and the largest organisms (fish over a meter in length). Abundances may be in the millions in a few drops of water (bacteria) or as low as a few hundred individuals in the entire Bay (porpoises, for example).

Each species has its own set of habitat requirements or preferences. Most have seasonal cycles of abundance, reproduction and metamorphosis. Migration patterns may range from day-night cycles of movement from deep to shallow water (plankton) to the oceanic migration of striped bass and other anadromous fish, which may last for years. Some species are valuable economic resources, while others are pests to desirable species or to people. Some have enormous ecological significance and some are appreciated mainly for their rarity or beauty.

In working toward the goal of restoring the abundance and diversity of living resources in the Bay, monitoring is essential. Many of the actions necessary to improve the quality of Bay habitats have been identified and are being implemented. Regional fisheries management plans, now under development, have the potential for preventing overharvest of commercial and recreational species. But plans for improving water quality, habitats, and management of resources will always be based on imperfect knowledge. In order to measure progress, it will be essential to maintain the best possible records of resource abundance, distribution, diversity, and reproduction. This requirement can be met by a well-designed living resources monitoring program. In addition to tracking living resource trends, monitoring will gradually improve our knowledge of Chesapeake Bay species, their natural cycles, their habitat needs, and how they respond to human activities. To meet these goals, a living resources monitoring program must be integrated with biological research, water quality monitoring, ecological modeling, fisheries management, and stock assessment. Cooperation and coordination among agencies, programs, jurisdictions, and disciplines are essential.

The Governance Section of the 1987 Chesapeake Bay Agreement commits the States and the Federal government to develop a plan for monitoring "selected commercially, recreationally, and ecologically important species of living resources", by July 1988. The Chesapeake Bay Program's Monitoring and Living Resources Subcommittees formed a joint work group in November 1987 to develop the monitoring plan. The membership of the Living Resources Monitoring Work Group also includes representatives of the Chesapeake Bay Stock Assessment Committee.

The work group began its task by defining three major objectives of living resources monitoring:

I. Document the current status of living resources and their habitats in Chesapeake Bay;

II. Track the abundance and distribution of living resources and the quality of habitats over time; and,

III. Examine correlations and relationships between water quality, habitat quality, and the abundance, distribution and integrity of living resource populations.

The work group also defined the objectives of the Living Resources Monitoring Plan:

I. **Provide a framework for Baywide monitoring of living resources;**

II. **Achieve coordination and data compatibility among living resources, habitat, and water quality monitoring programs;**

III. **Establish biological data collection methods which will ensure data comparability among jurisdictions and programs;**

IV. **Establish an efficient, coordinated system of data management and reporting responsive to the objectives of living resources monitoring; and**

V. **Review existing programs, identify components that should be added or modified, and develop recommendations for implementation of the plan.**

To develop a Baywide living resources monitoring plan is clearly a formidable task. No single set of sampling procedures can be devised to track the abundance, health, and reproductive success of all, or even a representative subset, of Bay resources. Despite the complexity of this problem, many important groups of Bay species are being monitored by some means. Many biological sampling programs have provided useful information in estimating resource status and trends. These range from consistent, long-term monitoring over large areas of the Bay to short-term, single-site research projects.

Traditional biological data collection generally has not provided:

1. A comprehensive view of the health of the Chesapeake Bay ecosystem;
2. Data of sufficient quality and quantity to discriminate long-term trends or sudden changes in abundance from the background variation in living resources populations.
3. Confident estimates of true abundance;
4. Comparability of data among jurisdictions for species of regional importance;
5. Compatibility of data with results from ongoing water quality monitoring programs;
6. Composite data on resources and habitats necessary to evaluate relationships between living resources and their environment.

It is the consensus of the Living Resources and Monitoring Subcommittees that implementation of this comprehensive living resources monitoring plan will go far toward correcting these deficiencies.

A goal beyond the immediate commitment to develop a living resources monitoring plan is the full integration of living resources and water quality monitoring within Chesapeake Bay. Ultimately, there will be a Chesapeake Bay Monitoring Program that will include both water quality and living resources components. The Living Resources Monitoring Plan is a significant step towards that goal. Many areas that require further integration between living resources and water quality monitoring are identified in the plan.

The Living Resources Monitoring Work Group has given the language of the Bay Agreement ("selected . . . species" and "living resources") a broad interpretation in the development of this plan. A comprehensive plan, giving attention to all trophic levels provides the best opportunity for reviewing existing programs, recommending further integration of Bay monitoring, and achieving the stated objectives. Tidal and non-tidal wetlands, although not "species", are included because of their great importance as habitats and regulators of water quality.

Another criterion applied to the development of this plan is the focus on long-term, baseline monitoring which will provide data for the characterization of living resource populations and for tracking trends in their abundance over time. It is evident that research into problems of living resources and fisheries stock assessments will be served well by accessible, consistent, long-term, baseline data on the abundance and distribution of important species. The work group felt that short-term objectives for biological data collection should be addressed in the Chesapeake Bay Research and Stock Assessment Plans.

The collection of environmental and living resources data for Bay research and stock assessment activities will require a degree of flexibility and responsiveness to new technology and immediate resource management needs that will not always be compatible with long-term monitoring. However, these activities should be kept consistent with the objectives of this Plan, whenever possible, to support the further development of a comprehensive living resources data base. The Baywide living resources monitoring program will, in turn, benefit from research and stock assessment efforts.

Several of the data collection programs for finfish and shellfish recommended in this plan are identical with stock assessment programs: e.g., Baywide trawl surveys, seining surveys for juvenile finfish, and oyster dredged-shell surveys. These programs will provide long-term records of abundance and diversity to meet monitoring objectives. It should be emphasized, however, that the objectives of stock assessment and monitoring are quite different, and that these differences preclude the complete integration of plans and programs. Stock assessments are tools, developed by scientists and used by fishery managers, to manage harvests and prevent overfishing. The consistent, long-term records of abundance required for monitoring purposes are useful, but far from complete, elements of the data needs for stock assessments. Management of living resources populations (Chesapeake Bay Stock Assessment, Fishery Management and Resource Management Plans) and governance of the overall Bay restoration effort (Living Resources Monitoring Plan) both require monitoring of living resources. The work group made every attempt to identify and integrate correspondences between the two goals and to include them in the plan recommendations. Efforts to achieve further integration will continue in the future, building on the close communication that has been established between the Living Resources and Monitoring Subcommittees and the Chesapeake Bay Stock Assessment Committee.

Two basic kinds, or tiers, of data collection are recommended for living resources monitoring. The first tier is designed primarily to meet monitoring objectives I and II, and includes monitoring that is done over broad spatial (the whole Bay) and temporal (monthly to biennial) scales. Over the very long-term (10 years or more), in combination with the Baywide water quality monitoring program, these programs will also serve objective III. The second tier addresses objective III at higher resolution in time (daily to monthly) and space (critical habitat areas of selected tributaries). Second tier monitoring has been recommended for selected anadromous fish spawning areas, oyster habitats, and submerged aquatic vegetation habitats. Second tier programs will provide information on associations between water quality and living resources over shorter times (3-10 years) than first tier programs. The two-tiered approach to living resources monitoring builds on recommendations from an earlier phase of the Chesapeake Bay Program (USEPA 1981) and subsequent experience with the valuable information these programs provide.

Additional recommendations for data collection programs include: (1) the development of standard monitoring techniques for assessing the toxicity of ambient waters and sediments to living resources; and (2) an "ecosystem" monitoring effort, which targets a few small tributaries for comprehensive monitoring of water quality and living resources. The latter program is intended to provide insight into the ways in which changes or differences in land use, pollution control programs, and other local activities are associated with changes in abundance and diversity of living resources and the structure of the estuarine ecosystem.

Recommendations are made in Chapter 3 for the development of a data management and reporting system for living resources data. Chapter 4 contains recommendations for how the program should be implemented, including timelines, costs, and suggestions for stable, long-term funding.

The Living Resources Monitoring Plan provides a framework for consistent, sustained monitoring of Chesapeake Bay living resources: monitoring that is responsive to the information needs of those who must manage the Bay's habitats and living resources, and to the public, who ultimately will judge the success of efforts to restore the Bay.

CHAPTER 2
DATA NEEDS, EXISTING PROGRAMS, AND MONITORING RECOMMENDATIONS

In this chapter, several broadly defined groups of organisms are considered as "ecosystem components": finfish, shellfish, wildlife, plant communities, benthic communities, and plankton. Each group represents a multitude of species; generally, only the most abundant and prominent species are mentioned individually. Some groups are further divided into subgroups. Each ecosystem component is described briefly with sections on all the subgroups of functionally related species. Each subgroup's importance and the uses of information to be gained from monitoring are described in summary form. Existing monitoring programs are summarized also, generally without reference to the many biological field research efforts (all of which involve monitoring) that are under way or have been conducted in the past. Program deficiencies and recommendations for correcting them are identified, primarily from the perspective of the monitoring objectives set forth in the Introduction. Requirements for integration of data collection efforts and information exchange between programs and monitoring components are identified. Finally, a list of important habitat quality variables is presented for each component.

Descriptions of existing monitoring programs focus on long-term environmental data collection programs. They are structured to provide general information on spatial coverage, sampling frequency, and measurement and collection procedures currently employed. Locations of stations are given in accordance with the Chesapeake Bay Program's geographical segmentation scheme to assist with comparisons between programs (Figure 1). More detailed descriptions of existing, long-term monitoring programs are found in the living resources section of the Monitoring Subcommittee's Chesapeake Bay Basin Monitoring Program Atlas (USEPA 1988).

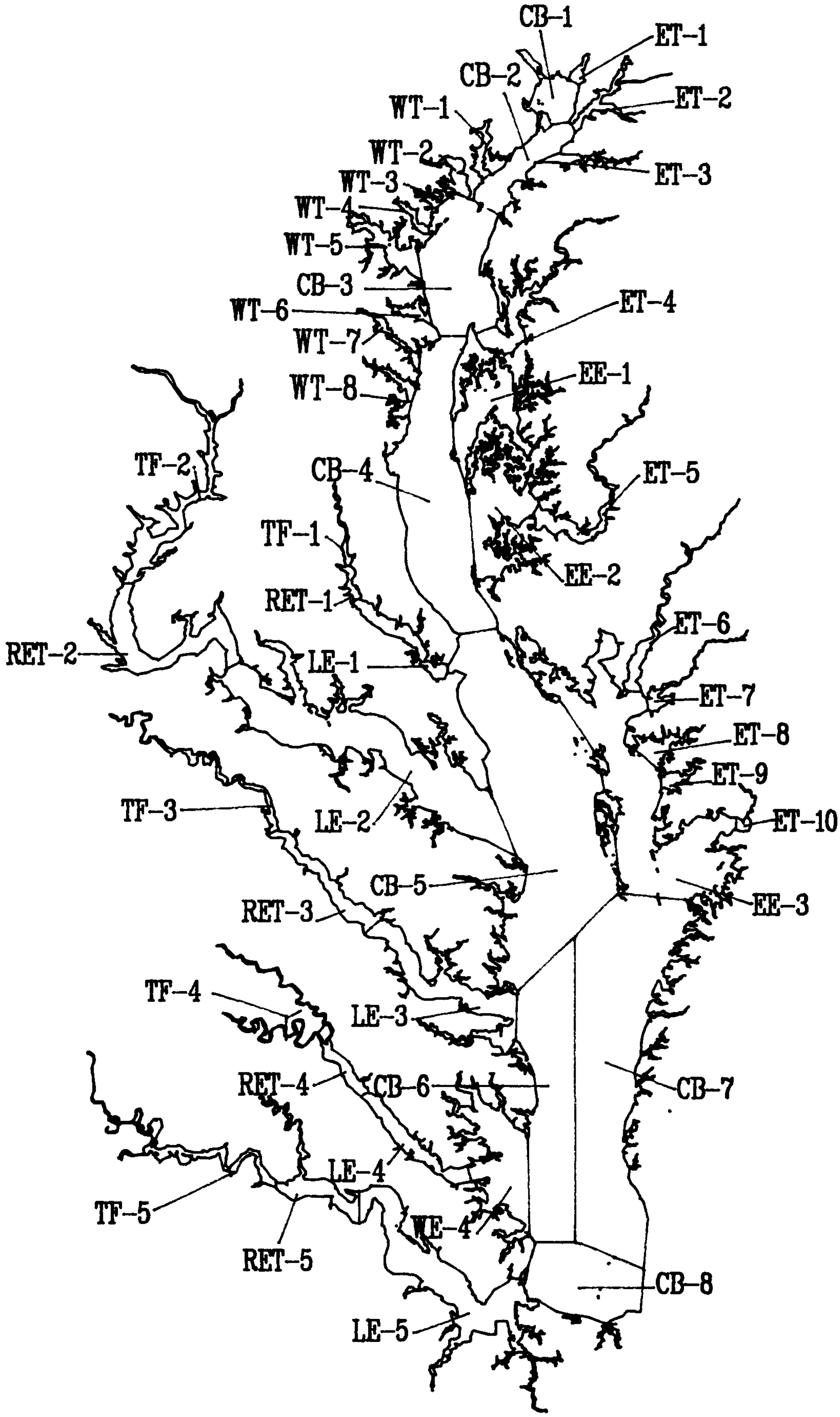
Program deficiencies have been identified through a comparative review of existing living resource monitoring programs, the data they are providing, and an understanding of the information needs for managing Chesapeake Bay living resources and their habitats. Areas where existing programs are incompatible with those of other jurisdictions and where data necessary for management decision-making is not being collected are identified as deficiencies.

The recommendations which follow address each previously identified program deficiency. Emphasis has been placed on providing specific recommendations which can be implemented in the form of a new or continued data collection effort, enhancement or expansion of existing monitoring programs, increased integration with ongoing water quality monitoring programs, reviews or studies of specific technical issues, or increased information exchange between programs.

Areas where data collection efforts and information exchange between existing or proposed monitoring programs can be further integrated to meet the objectives of living resource monitoring are identified in a separate section. Specific recommendations for integration between existing monitoring programs are provided where possible. When new data collection efforts are proposed, planning considerations for integration with existing programs are outlined.

In the final section under each subgroup, a list of important habitat quality variables is presented. The purpose of this section is to indicate the key habitat parameters which should be monitored as part of a planned or existing living resources

Figure 3 Chesapeake Bay Program Segment Map



monitoring programs, or through ongoing water quality monitoring programs at representative temporal and spatial scales.

FINFISH

This group can be subdivided for descriptive purposes into anadromous fish (marine and estuarine fish that return to fresh water to spawn), resident freshwater fish, resident estuarine fish, and marine-spawning fish. Important anadromous Chesapeake Bay species include striped bass, white perch, American shad, river herrings, and yellow perch. Resident freshwater species include largemouth bass, bluegill, sunfish, and catfish. The most abundant resident estuarine species are bay anchovies, killifish, hogchokers, toadfish, and silversides. Marine-spawning fish that use Chesapeake Bay habitats include bluefish, weakfish, spot, croaker, flounder, menhaden, eels, cobia, rays and sharks.

Several species of anadromous fish traditionally have supported large commercial and recreational fisheries in Chesapeake Bay. In recent years, these stocks have declined to the point where fisheries have been threatened or closed. These declines have been attributed to a combination of environmental factors and overharvesting. Anadromous fish spawning habitats are sensitive to degradation, and to that extent, the reproductive potential, recruitment, growth and abundance of these species are indicators of ecosystem health. Climatic variations (e.g., water temperature and streamflow) may interact with the effects of environmental degradation.

Freshwater resident fish also support important fisheries. Much of the catch is recreational, although commercial harvests of catfish have increased in recent years.

Fish that are year-round residents of the estuary, including the freshwater reaches, experience all of their environmental exposure within Chesapeake Bay. They do not migrate to areas where they could be exposed to exogenous contaminants or could depurate those accumulated in the Bay. The anchovy and silverside are important prey for commercially and recreationally important species, including the striped bass, bluefish, and weakfish. Killifish are a key prey item for wading birds. The anchovy and silverside are important consumers of zooplankton; the killifish is a detritivore and predator of marsh organisms; the hogchoker feeds on benthic epifauna and could be an indicator of sediment contamination.

Marine species have significant economic importance as commercial and recreational fisheries. Bluefish, flounder, and weakfish are climax predators (at the top of the food chain). Spot and croaker are major feeders on benthic organisms. Menhaden filter huge quantities of plankton. With the exception of menhaden, members of this group tend to accumulate the highest body burdens of contaminants because of their position at the top of the food chain. Because of their migratory habits, these fish import and export contaminant loads to and from Chesapeake Bay.

For the purposes of this plan, finfish are treated as a unified group, because both existing and recommended long-term data collection programs generally are gear-oriented (e.g., seine or trawl) and capture a mix of species from various subgroups, depending upon season and area sampled. Attempts to segregate finfish monitoring programs or recommendations by species, habitats, or other ecological groupings tend to be confounded by overlaps and the lack of specificity of the major gear types.

Much of the extant data collection for finfish is done to meet specific objectives related to stock assessment or harvest management. These objectives often require the flexibility to revise methods and add or terminate studies according to immediate needs. Therefore, some existing fishery data collection programs do not meet the criteria of long-term consistency or Baywide comparability necessary for a living resources monitoring program. This section documents only those programs that reasonably can meet the Monitoring Plan's objectives.

Harvest statistics are vital information for monitoring populations of commercially and recreationally important species, and for determining fishing mortality. This fishery-dependent data will supplement long-term fishery-independent monitoring in meeting the objectives of the Monitoring Plan. The Chesapeake Bay Stock Assessment Plan (CBSAC 1988) includes a careful analysis of the means for improvement of fishery statistics.

SEINE SURVEYS

Beach seine surveys capture primarily juvenile fish that use shallow-water habitats during the summer. Although originally designed to track the annual recruitment of striped bass to Maryland populations, the different jurisdictional programs appear to produce consistent, if not representative, information on the relative juvenile abundance of several species, including shad, white perch, and herrings and some estuarine resident species.

Existing Monitoring Programs

Maryland Estuarine Juvenile Finfish Survey

This program produces Maryland's annual juvenile index for striped bass. Many other species are collected and enumerated in the seine hauls.

Spatial Coverage:

Twenty-two permanent stations have been established: three in the upper Chesapeake Bay (1 in CB1, 1 in CB2), three in the Elk River (ET2), two in the Sassafras River (ET3); four in the Choptank River (ET5); four in the Nanticoke River (ET6); and seven in the Potomac River (TF2, RET2, LE2). Twenty-three auxiliary stations (not included in the standard juvenile index) in the Potomac, Patuxent, Choptank, Nanticoke and Wicomico Rivers and in the upper Chesapeake Bay.

Sampling Frequency:

Monthly from July through September.

Measurements and Collection Procedures:

Sampling is performed with a 100 x 4 ft. haul seine with 1/4 in. bar mesh. Duplicate hauls are made at 30-minute intervals during each sampling event. Counts of each species captured as well as individual measurements of length, sex, and age are recorded for striped bass and white perch.

Virginia Juvenile Striped Bass Survey

This survey is comparable to the Maryland Estuarine Juvenile Finfish Survey.

Spatial Coverage:
Eighteen fixed stations are sampled: six in the James River (TF5, RET5, LE5); seven in the York River (TF4, RET4, LE4); and five in the Rappahannock River (TF3, RET3, LE3).

Sampling Frequency:
Four sampling events from mid-July through September.

Measurements and Collection Procedures:
Two replicate hauls are taken at 30-minute intervals with a 100 x 4 ft., 1/4 in. bar mesh haul seine. Counts of species captured, as well as individual measurements of length are recorded.

District of Columbia Resident and Anadromous Fish Surveys

Spatial Coverage:
Four transects on the Potomac River (TF2) and one transect on the Anacostia River (TF2).

Sampling Frequency:
Monthly from May through November.

Measurements and Collection Procedures:
Counts of species captured as well as individual measurements of length, weight, and sex are recorded.

Program Deficiencies

1. Striped bass is the only targeted species in existing seining programs; inadequate attention is given to other species captured.

2. Data analysis and reporting of results from existing seining surveys are inadequate.

3. Pennsylvania lacks an anadromous fish recruitment (i.e., seining) program comparable to the other states' programs. However, until fish passage facilities are constructed at Conowingo Dam, no recommendation will be made for anadromous fish except as a part of the Shad Restoration Program.

Recommendations

1. Continue comparable beach seine surveys in Maryland, Virginia and the District of Columbia.

2. Target juvenile seining surveys at a broader range of species: white perch, shad, herrings, bay anchovy, menhaden, and other commercially, recreationally and ecologically valuable species. For a few species, implementation will involve only increased effort in data management, analysis and reporting of the current surveys (e.g., white perch). By adding stations in specific habitats, consistent data on additional species can be obtained.

3. Perform a detailed review of data from seining surveys in Maryland, Virginia and D.C. The review should address: (1) within- and among-year variability and trends in relative abundance for all individual species; (2) variability and trends in the number of species captured; (3) covariation among species; and (4) the value of the data in representing true variations in abundance for each species and for tracking the diversity of finfish in the shallow-water habitats surveyed. Prepare a report detailing the analytical results, recommendations for improving the surveys to better represent the species complex captured, and directions for more complete data analysis and reporting.

Program Integration

Integration of data analysis and reporting with trawl surveys will provide a comprehensive view of juvenile anadromous and resident finfish species. Annual or biennial reports should be published as a part of, or in conjunction with, other Baywide living resources and water quality monitoring reports, such as the *State of the Chesapeake Bay.* Valid application of long-term water quality and plankton monitoring data sets to investigate associations with juvenile finfish recruitment statistics will require a review of water quality monitoring stations to ensure that spawning and nursery habitats are characterized.

Important Habitat Quality Variables

Water quality measurements taken in conjunction with seining surveys should include water column profiles of temperature, pH, dissolved oxygen and salinity. On a long-term basis, existing and recommended monitoring of water quality, plankton and aquatic plant communities will provide appropriate habitat quality information.

TRAWL SURVEYS

Existing Monitoring Programs

Chesapeake Bay Mainstem and Tributary Pilot Trawl Program

A Baywide (Maryland and Virginia) trawl survey was initiated in 1987 as a pilot program, with the assistance of the Chesapeake Bay Stock Assessment Committee. The primary objective of this program is to investigate the usefulness of large-scale trawl surveys in measuring the occurrence, abundance, and biological characteristics of various (primarily juvenile) finfish and blue crabs. Although the pilot study has yet to be evaluated, a Baywide trawl program is expected to become a key component of a long-term monitoring and assessment program. Maryland and Virginia have committed to continue the trawl program beyond the pilot phase.

Spatial Coverage:

Mainstem Chesapeake Bay and selected tributaries in Maryland and Virginia. Stations are selected randomly within established strata (depth, substrate, Bay segment, etc.). Some fixed stations are to be sampled in Maryland (segments CB3, CB4, CB5, EE3, EE2 and others) for comparison with trawl data collected on Chesapeake Biological Laboratory cruises between 1965 and 1975.

Sampling Frequency:

Twice a month from March through October; monthly November through February.

Measurements and Collection Procedures:

During the pilot phase (Year 1), trawl durations, distances, replication, and possibly trawl type will vary as the sources of variation in sampling are explored. All finfish, shellfish, and invertebrates will be identified, counted, and measured. Additional biological data such as sex and age will be collected for subsamples of selected species.

Virginia Juvenile Finfish Survey

Spatial Coverage:

Four transects on each of three rivers: the James (TF5, RET5, LE5), York (TF4, RET4, LE4), and Rappahannock (TF3, RET3, LE3), starting at river mile 5 and continuing up each river at 5-mile intervals.

Sampling Frequency:

Monthly from May through November.

Measurements and Collection Procedures:

Sampling is performed with 30 ft. semi-balloon trawls with 1/4 in. mesh cod end liners. Counts of species captured as well as individual measurements of length are recorded.

District of Columbia Resident Fish Survey

Spatial Coverage:

Four transects on the Potomac River (TF2) and one transect on the Anacostia River (TF2).

Sampling Frequency:

Monthly from May through November.

Measurements and Collection Procedures:

At each transect, 16 ft. semi-balloon trawls are used in the main channel, the nearshore zones are electrofished, and beach seines are used in shore zones. Counts of species captured as well as individual measurements of length, weight, and age are recorded.

Program Deficiencies

1. The Baywide trawl program, as presently conceived, will not represent shallow waters or upper tributaries because of the large boats and gear used.

2. Because it is a pilot program, the current Baywide trawl survey lacks standard sampling protocols.

Recommendations

1. Continue existing Virginia and District of Columbia tributary trawl surveys.

2. Maryland and Virginia should initiate supplementary, generalized trawl programs

employing small boats and gear (16 ft. trawls are suggested) for sampling shallow waters and upper tributaries.

3. Develop and implement a standard set of protocols for the Baywide trawl survey, as planned.

Program integration

Integration of data analysis and reporting with seining surveys will provide a rather comprehensive view of juvenile anadromous and resident finfish species. Annual or biennial reports will be published as a part of, or in conjunction with, other Baywide living resources and water quality monitoring reports, such as the *State of the Chesapeake Bay.*

Important habitat quality variables

Water quality measurements taken in conjunction with trawl surveys should include water column profiles of temperature, pH, dissolved oxygen and salinity. On a long-term, broad-scale basis, existing and recommended monitoring of water quality, plankton and aquatic plant communities will provide appropriate habitat quality information.

EARLY LIFE STAGE (EGG AND LARVAL) SURVEYS

Special attention has been paid in monitoring programs to the early life stages of anadromous fish, particularly striped bass. The young (or pre-recruits) of these species are very susceptible to adverse water quality conditions and habitat degradation. The water quality requirements for anadromous fish larvae are known reasonably well through research and hatchery experience. Therefore, monitoring of early life stage and water quality in anadromous fish spawning and nursery habitats can reveal direct *associations*[4] between water quality and recruitment to populations of important species at the top of the food chain.

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[4]Associations between habitat or water quality and biological observations such as abundance, condition, or relative survival are not proof of cause and effect. In natural systems, observed effects usually are associated with a variety of confounding and often interacting variables. The concept of "cause", in fact, has no rigorous meaning in an environmental context. The second tier monitoring programs recommended in this Plan will provide information on: (1) whether water quality meets known tolerances during critical seasons and over appropriate time scales; (2) the abundance and apparent survival rates of the critical life stages of target species; and (3) water quality and climatic conditions that are *associated* (correlated) with high or low rates of apparent survival. The ideal of determining "causes" of poor survival in nature can be approached only by comparing field monitoring data with theory and experimental results. Only when both of these types of information are available can specific factors be judged to have "caused" the success or failure of reproduction or survival.

Existing Monitoring Programs

Maryland Striped Bass Early Life Stage Monitoring

Spatial Coverage:
Stations are selected randomly from grids covering the spawning areas of the Choptank River system (ET4) and the upper Chesapeake Bay (CB2, CB3), Sassafras River (ET2), and Bohemia River (ET1). One fixed station is sampled in the Chesapeake and Delaware Canal, near Chesapeake City. Sampling is stratified by depth, and grids are adjusted according to isohalines (salinity gradients).

Sampling Frequency:
Sampling is done four days each week from early April through mid-June.

Measurements and Collection Procedures:
Mid- and bottom-water trawls with 1-meter openings and 500 μm liners are used in channels and deeper water. In shallow zones, only the bottom trawl is used. In the upper Bay, plankton nets (500 m) are towed at the surface, midwater and bottom to supplement the collection of eggs and newly hatched larvae, which are not captured efficiently by the trawls. Samples are preserved in 5% buffered formalin. Water column profiles of temperature, salinity, dissolved oxygen and pH are recorded at each station. In the laboratory, samples are sorted, fish eggs and larvae identified to species if possible, and striped bass larvae are measured. Pumped midwater composite samples are taken at selected early life stage stations for water quality analysis (nutrients, turbidity, alkalinity, Ca, Mg, SO_4, trace metals, herbicides, insecticides, and other organic contaminants).

Virginia Striped Bass Early Life Stage Survey

Spatial Coverage:
York River

Sampling Frequency:
Three sampling events per week from April through June.

Measurements and Collection Procedures:
Sampling is performed with a 500 μm mesh, 60 cm diameter bongo net.

Program deficiencies

1. Striped bass is the targeted species; inadequate attention is given to other species captured.

2. The Maryland program does not monitor phytoplankton and zooplankton abundance and species composition concurrently with egg and larval monitoring.

3. The District of Columbia lacks an early life stage program.

4. Early life stages of bay anchovy, an important target species, are not routinely monitored.

5. Data analysis and reporting of these studies are inadequate.

Recommendations

1. Continue existing early life stage monitoring programs.

2. Extend the sampling periods and sampling areas for high-frequency early life stage sampling to obtain better information on relative abundance and survival of early life stages of shad, herrings, white perch and yellow perch and the quality of their habitats. The increased sampling period should extend from February through mid-June. Additional sampling areas should include the uppermost tidal and lower fluvial reaches of selected tributaries (currently, the upper Bay, Choptank and York Rivers are monitored). The addition of other important spawning tributaries (Susquehanna, Potomac, Patuxent, James, and Rappahanock Rivers) to the program should be considered as a part of the program review workshop recommended below.

3. Include high-frequency water quality, phytoplankton and zooplankton sampling as a part of anadromous finfish early life stage programs. Recommendations 1, 2 and 3 constitute the second tier monitoring program for the early life stages of anadromous fish.

4. Include early life stage sampling either as a part of the Baywide plankton monitoring program, or in conjunction with the Baywide trawl survey, with bay anchovy as the primary target species.

5. Conduct a program review workshop to evaluate existing early life stage monitoring programs for finfish. Workshop participants should include members of CBSAC, the Chesapeake Bay Program Monitoring Subcommittee, investigators from existing programs, and representatives of similar programs outside the Chesapeake Bay region.

Program integration

It will be important to make comparisons between high-frequency water quality and plankton data, collected as a part of the anadromous fish early life stage programs, with lower frequency data collected by existing and recommended water quality and plankton monitoring programs. Because of the habitat orientation of the recommended early life stage program, information will be closely linked to implementation of land-based controls on water and habitat quality, especially those affecting non-point sources of pollution.

Early life stage monitoring is related closely to the *Recruitment Processes* component of the *Chesapeake Bay Stock Assessment Plan* (CBSAC 1988). Monitoring of egg and larval abundances at appropriate frequency (daily) during spawning seasons, in combination with high frequency environmental monitoring, will provide multiple-year time series data of great value to recruitment processes research.

Habitat quality variables

Temperature, pH, dissolved oxygen, salinity, alkalinity, hardness (Ca, Mg), turbidity (total suspended solids), nutrients (especially NO_3, NO_2, NH_3, PO_4), pesticides (especially herbicides), trace metals, river flow, rainfall, microzooplankton and mesozooplankton species composition and abundance.

SHELLFISH

OYSTERS

Oysters traditionally have been the Bay's most valuable living resource in terms of dockside value, economic multiplier values, and as a key component of the ecosystem. Oysters are also sensitive environmental indicators in that they filter large volumes of water, concentrate contaminants, and show rapid responses to fluctuations in temperature and salinity. Oyster populations have declined severely in response to a combination of disease, poor recruitment, and harvest pressure. Changes in food quality and increased hypoxia also are thought to have had negative influences on oyster health and survival.

Spat are juvenile oysters that have attached to another oyster shell or some other hard substrate. Annual spat counts have served as indices of recruitment from which future harvests have been predicted. Spatfall (counts of spat that have settled, or attached, during a summer's spawning season) has been monitored in Virginia since 1946 and in Maryland since 1939.

Existing Monitoring Programs

Virginia Oyster Spat Survey Program

Spatial Coverage:
Forty-three stations located in the James (LE5), York (LE4), Rappahanock (LE3), Great Wicomico (CB5), and Potomac (LE2) rivers, Mobjack Bay (WE4), and Pocomoke Sound (EE3).

Sampling Frequency:
Weekly, from June to October.

Measurements and Collection Procedures:
Sampling is performed by collection and replacement of twelve oyster shells previously suspended 20 inches above the bottom. Ten shells are examined under 10x-15x magnification; only the smooth side (upper, or left valve) of the oyster is examined. Counts of spat on each shell are recorded.

Virginia Spring and Fall Oyster Bar Survey

Spatial Coverage:
Twenty-six stations at oyster bars located in the James (LE5), York (LE4), Rappahanock (LE3), and Great Wicomico (CB5) Rivers, Mobjack Bay (WE4), and Pocomoke Sound (EE3).

Sampling Frequency:
Twice yearly, in May and October.

Measurements and Collection Procedures:
Sampling is performed by 5-minute dredge hauls at each station. Counts of spat, small and market-sized oysters are made, condition of the bars is estimated, and the presence of predators (e.g., oyster drills, starfish, flatworms, mud crabs, blue crabs) are recorded.

Virginia Oyster Disease Survey

Spatial Coverage:

Various public oyster bars located throughout the Virginia tributaries of the Chesapeake Bay are sampled, primarily in the James (LE5) and Rappanhannock (LE3) rivers.
Also, trays of oysters are maintained in the York River at the Virginia Institute of Marine Studies for periodic disease analysis.

Sampling Frequency:

Monthly from May through November.

Measurements and Collection Procedures:

Samples of 25 oysters are collected by dredging, returned to the laboratory, sectioned, stained and examined for evidence of disease. Percent occurrence of Dermo and MSX in oyster tissue is recorded.

Maryland Fall Oyster Survey

Fifty-three key bars equally distributed throughout the major oyster-producing river systems and mainstem of the Maryland portion of the Chesapeake Bay (CB3, CB4, CB5), Chester River (ET4), Eastern Bay (EE1), Choptank River (EE2, ET5), Tangier and Pocomoke Sounds (EE3), Wicomico River (ET7), Manokin River (ET8) and the lower Potomac River (LE2). Observations are made on 200 to 600 additional oyster bars.

Sampling Frequency:

Annually in October.

Measurements and Collection Procedures:

A random sample of oysters is taken from each location with either patent tongs or a dredge. A one-half bushel sample is sorted to determine the number of market oysters, smaller oysters, oyster spat, shell, recent mortality, new and old "boxes" (empty shells of dead oysters), and oyster condition. Observations also are made on the fouling community (barnacles, mussels, anemones, tunicates, etc.) that inhabits oyster shells.

Maryland Choptank River Intensive Oyster Habitat Monitoring

Spatial Coverage:

Four oyster bars in the lower Choptank River (EE2, ET5).

Sampling Frequency:

Weekly from June through September, monthly from October through May.

Measurements and Collection Procedures:

A sample of 60 oysters is obtained with a small dredge at each bar. Counts are made of live oysters, recent mortalities, new and old boxes in market and sub-market categories. Numbers of live and dead spat (those visible to the naked eye) are recorded. Relative abundance and viability of fouling organisms (barnacles, mussels, tunicates and anemones) are recorded from a subsample of ten live oysters. Samples for analysis of disease prevalence are taken a few times each year. Profiles of temperature, salinity, pH, and dissolved oxygen are measured at each bar, along with Secchi disk readings.

Program Deficiencies

1. Maryland and Virginia's annual dredged shell surveys appear to collect comparable data on spatfall, oyster size, and mortality, except that Maryland does not repeat the fall survey in the spring.

2. Absolute or relative abundance and biomass estimates are not obtained from the Maryland and Virginia annual surveys.

3. Maryland has no established program comparable to the Virginia spat-on-string program.

4. Data on relative abundance of oyster size classes, condition indices, and fouling communities collected in Maryland are rarely, if ever, reported.

5. Disease and condition assessment programs have not been accorded adequate priority, given the importance of oyster diseases (MSX, Dermo) as sources of mortality and poor condition.

6. Survival of spat on bottom cultch, a major determinant of recruitment to the fishery, is not monitored in Maryland except on a few seed bars.

7. The Choptank intensive monitoring program does not include (1) rigorous spat counts; (2) measurements of important water quality variables (nutrients, chlorophyll); (3) oyster condition measurements. This program is limited to one tributary. There is no comparable program in Virginia.

Recommendations

1. Maintain annual dredged shell surveys as the core of an oyster abundance, condition, recruitment, fouling organism, and disease monitoring program.

2. Maryland should improve its estimates of all the variables listed above, and comparability with Virginia data, by repeating its fall survey in the spring (late April or early May). This approach would provide Maryland with estimates of spat survival, a better recruitment index, and an independent annual estimate of harvest mortality.

3. Estimates of relative abundance should be reported as catch-per-effort for standard dredge or patent tong samples. An effort should be made to calibrate sampling procedures so that estimates of absolute abundance can be obtained.

4. The Choptank intensive monitoring program should serve as a model for second tier monitoring of oyster survival, condition and health in relation to habitat conditions. Another tributary in Maryland, and one or two selected oyster habitats in Virginia should be monitored similarly. The Patuxent River would provide a contrasting habitat to the Choptank. In Virginia, selected oyster bars should be chosen in the lower York (LE4) and James (LE5) Rivers for intensive monitoring. Rigorous spat counts, condition indices, and monitoring of nutrients and chlorophyll *a* should be performed

in addition to the current methods. This program should also include counts of spat on suspended shell comparable to Virginia's.

Program Integration

There is a strong interdependence between oyster populations, water quality, and phytoplankton populations. Current water quality and plankton monitoring programs, in conjunction with recommended first tier oyster monitoring, are adequate for analysis of long-term trends and correlations. Integration is needed primarily in reporting. Oyster monitoring data must be reported annually, and integrated into Baywide monitoring reports (*State of the Chesapeake Bay*). The recommendations for a second tier monitoring program address shorter term needs for examining associations between oyster success and water quality.

Important Habitat Quality Variables

Temperature, salinity, dissolved oxygen, phytoplankton (blooms, species, and size composition), chlorophyll *a*, ammonia, nitrate, phosphate, particulate carbon, nitrogen and phosphorus, toxicants (e.g., chlorine, TBT), sediment oxygen demand and nutrient flux.

BLUE CRABS

Blue crabs have supplanted failing oyster populations as the Bay's most important economic resource. They are ubiquitous throughout all but the freshest tidal waters of the Chesapeake and its tributaries. Although stocks appear to be healthy, increased harvest pressure may be threatening their status. Blue crabs are also ecologically important. Juvenile blue crabs provide a forage base for many species of fish. Blue crabs are important predators of oysters and clams and also may be ecologically important as scavengers.

Existing Monitoring Programs

Maryland Blue Crab Stock Assessment

Spatial Coverage:
Fifty-four stations located in the Chester (6 stations in ET4), Choptank (6 stations in EE2 and ET5), Patuxent (6 stations in TF1, RET1, and LE1) Rivers, Tangier and Pocomoke Sounds (22 stations in EE3), and Eastern Bay (6 stations in EE1).

Sampling Frequency:
Monthly from May through October.

Measurements and Collection Procedures:
Sampling is performed with a 16-ft. headrope bottom trawl towed at four knots for six minutes. Catch per trawl by size, sex and age of blue crabs and all finfish captured is recorded.

Virginia Juvenile Blue Crab Survey

Spatial Coverage:

Four trawl sites each on the James (TF5, RET5, LE5), York (TF4, RET4, LE4), and Rappahannock (TF3, RET3, LE3) Rivers, starting at Mile 5 on each river and continuing upriver at 5 mile intervals.

Sampling Frequency:

Monthly from May through October.

Measurements and Collection Procedures:

Sampling is performed with a 30-ft. semi-balloon bottom trawl. Counts of blue crabs captured are recorded by size and sex.

Program Deficiencies

1. A reliable recruitment index, comparable between states, is needed.

2. No fishery independent data are collected from the Chesapeake's mainstem, where a large proportion of the catch is taken.

Recommendations

1. Gear, sampling frequencies, and spatial coverage will be made comparable in Virginia and Maryland as a part of the development of the Baywide trawl program.

2. The existing trawl programs for blue crabs in Maryland and Virginia, with appropriate modifications, appear to be candidates for integration into the Baywide trawl programs. This should be evaluated as a part of the pilot trawl program review.

Program Integration

Trawl sampling will be integrated directly with finfish trawl programs. Continued monitoring of submerged aquatic vegetation will provide some, but not definitive, information on the quantity and quality of juvenile habitats. Benthic monitoring can provide information on food availability. Limitation of benthic infaunal habitats by low dissolved oxygen is an indicator of limitation of blue crab distribution by dissolved oxygen. Baywide abundance and recruitment estimates for blue crabs should be reported annually, and integrated with other Baywide monitoring reports (*State of the Chesapeake Bay*).

Important Habitat Quality Variables

Temperature, dissolved oxygen, salinity, pesticides, factors affecting submerged aquatic vegetation (see PLANT COMMUNITIES), benthic infauna and epifauna.

HARD CLAMS

Hard clam stocks in Chesapeake Bay are largely limited to Virginia waters. The ecological importance of this species as a filter-feeder is similar to that of the oyster where population densities are high. Burrowing activity also affects sediment properties such as grain size, oxygenation, and nutrient cycling. Commercial demand in

Virginia exceeds harvest capabilities so there is a potential for greater harvests in the future.

Existing Monitoring Programs

There is no systematic monitoring, except for landings data.

Program Deficiencies

There is no fishery independent data collection at present.

Recommendations

1. Virginia should develop a monitoring program which can produce an annual recruitment index for hard clams. Stations should be chosen at random within important clam habitat and harvesting areas and sampled during the spring and fall with appropriate gear (dredge or tongs).

Program Integration

Recruitment indices should be coordinated with recruitment information for other species of finfish and shellfish. An information link should be established with water quality monitoring programs. Because the hard clam is a target species, recruitment should be reported annually in conjunction with other Bay living resources and water quality data.

Important Habitat Quality Variables

Temperature, salinity, dissolved oxygen, turbidity and sedimentation, phytoplankton in 3-35 μm size range, factors affecting submerged aquatic vegetation (see PLANT COMMUNITIES), toxicants.

SOFT SHELL CLAMS

The soft shell clam is a northern species; commercially valuable populations are limited to Maryland waters in Chesapeake Bay. Soft shell clam populations in Maryland have suffered at times from overfishing and low salinity. The larvae are free-swimming. After settlement, the clams burrow into the sediment, leaving only their siphons above the sediment surface where they pump particles from the overlying water for food. As the clams grow, they burrow deeper (up to 40 cm).

This is an important commercial species in Maryland. Where abundant, they are ecologically important both as suspension-feeders (see OYSTER) and as burrowers (see BENTHIC FAUNA). Early recruits (before deep burrowing) are quite important as food for fish and crabs; the exposed siphons of larger clams are eaten by fish.

Existing Monitoring Programs

Maryland Soft Clam Survey

Spatial Coverage:
One station on Swan Point (CB3), additional stations in the Chester River (ET4) and Eastern Bay (EE1).

Sampling Frequency:
Monthly samples from Swan Point. Quarterly samples from the Chester River and Eastern Bay.

Measurements and Collection Procedures:
A hydraulic clam dredge is used to collect samples of soft clams. Size composition, mortality, and disease prevalence are recorded for each sample.

Maryland Chesapeake Bay Benthic Monitoring Program

Soft shell clams are collected by the benthic monitoring programs (see BENTHIC INFAUNA for details).

Program Deficiencies

1. The soft clam monitoring program is extremely limited in spatial coverage. Many soft clam habitat and harvest areas are not sampled.

2. Data from the Maryland Soft Clam Survey are not reported regularly.

Recommendations

1. Continue the Maryland Soft Clam Survey.

2. A review of the Maryland Chesapeake Bay Benthic Monitoring Program's data is necessary to determine whether it is adequate, either separately or in combination with the Maryland Soft Clam Survey, to track soft clam annual recruitment, annual variability, and estimate abundance and biomass. Because of broad spatial coverage by the benthic program, it is possible that minor modifications could enhance soft clam collection to the point where a new or expanded fishery independent program for this species will be unnecessary. Benthic monitoring data for soft clams also should be compared with harvest statistics as part of a data review, and as a continuing element of monitoring.

3. Improve reporting and accessibility of soft clam data. The soft clam is a target species.

Program Integration

There is interdependence between water quality, phytoplankton, and soft clam populations. Current water quality and plankton monitoring programs, in conjunction with adequate soft clam monitoring, should be adequate for analysis of long-term trends and correlations. Integration is needed primarily in reporting. Soft clam monitoring data must be reported annually, and integrated into Baywide monitoring reports (*State of the Chesapeake Bay*). Monitoring information should be used in conjunction with information from blue crab and benthic-feeding fish monitoring because of the important food link.

Benthic monitoring data should be analyzed in conjunction with harvest data for this species.

Important Habitat Quality Variables

Temperature, salinity, dissolved oxygen, phytoplankton (blooms, species, and size composition), chlorophyll *a*, ammonia, nitrate, phosphate, particulate carbon, nitrogen and phosphorus, toxicants (e.g., chlorine, TBT), sediment oxygen demand and nutrient flux.

A NOTE ON OYSTER AND CLAM LARVAE

The larvae of clams and oysters probably are the most critical life stages in that they suffer extremely high mortalities during their planktonic and settlement phases. However, it is very difficult and time-consuming to identify the species of bivalve larvae collected in plankton samples. Therefore, despite obvious information needs, no recommendations are made for monitoring larvae of these species. Perhaps improved identification techniques will facilitate systematic monitoring of larval shellfish in the future.

WILDLIFE

Wildlife is a broad term which covers all terrestrial, air-breathing organisms that occupy a wide range of Bay habitats, from open waters with large rafts of ducks to shrubby freshwater wetlands sheltering beavers and wood ducks. Birds are especially important components of the Bay's ecosystem. Nearly all of the animals listed are highest-order consumers, thereby reducing numbers of the more abundant organisms lower in the food chain. They are subject to accumulating high body burdens of various toxicants which can concentrate as they travel up food chains. Wildlife species can often be used as indicators of "health" in the estuarine ecosystem, especially at the fringes such as the Bay's large wetland systems.

WATERFOWL

Waterfowl are the most important wildlife component in the Bay's ecosystem by virtue of their large populations and high visibility. The term waterfowl includes migratory (geese, swans and ducks), and year-round residents such as mallard ducks and mute swans.

Some of the waterfowl are partly or largely herbivorous. When traditional submerged aquatic vegetation food sources declined sharply from the mid-1960s to the mid-1980s, redhead ducks were forced to move out of the Bay area. In contrast, canvasback ducks were able to adapt their diets to include invertebrates and thus are still present in significant numbers today. Canada geese, joined increasingly by snow geese and whistling swans, moved inland in large numbers in the 1970s. They found winter sustenance in corn and wheat fields to supplant their traditional food of submerged grasses, now in short supply.

The species discussed here are important not only because of their food chain impacts on vegetation and on animals below them, but also because of their visibility to the public. Appreciated for their aesthetic value by growing numbers of bird watchers, and for sport and food by hunters, Bay waterfowl are a major symbolic, as well as practical, component of the Bay's ecosystem.

Existing Monitoring Programs

Chesapeake Bay Midwinter Waterfowl Survey

Spatial Coverage:
Thirty-three survey areas in Maryland and twenty in Virginia.

Sampling Frequency:
Annual survey in mid-January.

Measurements and Collection Procedures:
Visual estimates of numbers of waterfowl by species are made from aircraft by experienced observers.

Atlantic Flyway Productivity Survey

Spatial Coverage:
In Maryland, areas (and species) targeted include Queen Anne's County and Snow Hill (greater snow geese); Blackwater National Wildlife Refuge (lesser snow geese); and Kent, Queen Anne's and Dorchester Counties (tundra swans). In Virginia, the lower Eastern Shore, Back Bay, and the Potomac and Rappahannock Rivers are target areas.

Sampling Frequency:
Annually from early November through mid-December.

Measurements and Collection Procedures:
The proportions of young birds to adult birds, and the number of young birds per mating are recorded.

Atlantic Flyway November Coordinated Canvasback Aerial Survey

Spatial Coverage:
All Maryland and Virginia tidewater regions are surveyed, with emphasis on areas with historical populations of canvasback ducks.

Sampling Frequency:
Annually in early November.

Measurements and Collection Procedures:
Visual estimates of numbers of canvasbacks are made from aircraft by experienced observers.

Atlantic Flyway December Swan Survey

Spatial Coverage:
Maryland and Virginia

Sampling frequency:
Annually in mid-December.

Measurements and Collection Procedures:
Visual estimates of numbers of swans are made from aircraft by experienced observers.

Maryland November Canada Goose Survey

Spatial Coverage:
Chesapeake Bay, tidal tributaries, and adjacent upland areas.

Sampling Frequency:
Annually in mid-November.

Measurements and Collection Procedures:
Visual estimates of numbers of geese are made from aircraft by experienced observers.

Maryland Waterfowl Breeding Survey

Spatial Coverage:
Tidewater and adjacent upland areas on Maryland's eastern and western shores of the Chesapeake Bay.

Sampling Frequency:
Annually in the last half of April.

Measurements and Collection Procedures:
Aerial methods on the eastern shore and boats on the western shore. Counts of breeding mallards, black ducks, blue-winged teal, and gadwall are made along transects in lower eastern shore Maryland counties, at approximately the same times.

Maryland Mute Swan Survey

Spatial Coverage:
Maryland eastern shore.

Sampling Frequency:
Twice each spring, in April and late June.

Measurements and collection procedures:
Aerial survey of mute swans. Numbers of single birds, pairs, groups, active nests, and cygnets are recorded.

Program Deficiencies

1. There is a lack of coordination and integration among jurisdictions.

2. Integration and information exchange with other Chesapeake Bay monitoring programs is almost non-existent.

3. Personnel resources are insufficient to ensure regular data analysis and reporting of results from ongoing waterfowl monitoring programs.

4. There is no existing monitoring program which addresses associations between habitat impacts and changes in populations.

Recommendations

1. Continue existing annual overflight surveys.

2. Improve information exchange with water quality and other living resources monitoring programs.

3. Examine the historical database more closely for waterfowl abundance and distribution trends in an effort to link variations in distribution and abundance to known perturbations in specific habitats or general environmental conditions.

4. Improve program integration between the Maryland and Virginia waterfowl monitoring programs, through annual meetings of the program managers and principal investigators.

5. Design a waterfowl habitat monitoring (second tier) program to investigate associations between habitat impacts and changes in waterfowl populations.

Program Integration

There have been limited efforts to correlate waterfowl data with other monitoring data. Additional opportunities for data analysis and integration should be developed. Monitoring the distribution and abundance of tidal and non-tidal wetlands and submerged aquatic vegetation can provide important habitat information for target species of waterfowl.

Important Habitat Quality Variables

Weather observations (air temperature, rainfall, snow cover, icing conditions in ponds and shallow Bay areas); salinity and other water quality variables in relation to vegetative food sources (see PLANT COMMUNITIES). Distribution and quantity of suitable habitat, submerged aquatic vegetation, tidal and non-tidal wetlands; disturbance by humans, vehicles, and boats (especially during breeding seasons).

COLONIAL BIRDS

Colonial birds include herons and egrets which use Bay tidal and non-tidal wetlands for breeding and early rearing areas in spring and summer, and (typically) migrate southward from the Bay in autumn. The major colonial species in the Bay area are the great blue heron, little blue heron, green heron, black- and yellow-crowned night herons, Louisiana heron, glassy ibis, great egret, snowy egret, and the cattle egret.

Colonial birds are aesthetically important to many members of the general public. Like waterfowl, carnivorous colonial birds play a role in "skimming off" lower trophic organisms such as insects, mollusks, and small fishes. They can therefore concentrate high toxic body burdens, as do raptors (ospreys, hawks and eagles).

Existing Monitoring Programs

USFWS Breeding Bird Survey

Spatial Coverage:
Selected locations throughout the Chesapeake Bay basin states.

Sampling Frequency:
Annually in June.

Measurements and Collection Procedures:
Qualified volunteers make observations and counts of species within 400 meters at stations along specific routes are made by qualified volunteers.

Maryland Colonial Bird Inventory

Spatial Coverage:
Colonial bird habitats in Maryland.

Sampling Frequency:
Intensive

Measurements and Collection Procedures:
Colonies are inventoried and breeding populations of all colonial species are estimated under a baseline inventory program.

Virginia Colonial Bird Survey

Spatial Coverage:
The coastal plain of Virginia.

Sampling Frequency:
Annual in late May with a follow-up survey in June.

Measurements and Collection Procedures:
Visual estimates of numbers of each species are made from aircraft by experienced observers in May. The June follow-up is a ground survey.

Program Deficiencies

1. There is a lack of coordination among jurisdictions.

2. Integration and information exchange with other Chesapeake Bay monitoring programs is almost non-existent.

3. Personnel resources are insufficient to ensure regular data analysis and reporting of results from existing colonial bird monitoring programs.

Recommendations

1. Continue the existing survey program in Virginia, and maintain a less intensive long-term monitoring program in Maryland.

2. Improve information exchange with water quality and other living resources monitoring programs.

4. Improve integration between Maryland and Virginia colonial bird monitoring programs through annual meetings of the program managers and principal investigators.

Program Integration

Information from tidal and non-tidal wetlands and submerged aquatic vegetation monitoring should be analyzed and reported in concert with colonial bird survey data.

Important Habitat Quality Variables

Weather observations (air temperature, rainfall, snow cover, icing on ponds and shallow Bay areas); salinity and other water quality variables in relation to vegetative food sources (see PLANT COMMUNITIES). Distribution and quantity of suitable habitat, submerged aquatic vegetation, tidal and non-tidal wetlands; vegetation types, disturbance by humans, vehicles, and boats (especially during breeding seasons).

SHORE AND SEABIRDS

Shore and seabirds are also largely migrants to the Bay area; some species spend the warmer months here, while others only pass through in the spring and fall. Some gull species are year-round residents of the Bay area.

Shore birds feed along the margins of shallow ponds and perimeters of marsh grasses (greater and lesser yellowlegs, dowitchers, pectoral, least and stilt sandpipers.), or on mud or sandflats near marshes and ponds (semipalmated and western sandpipers, willets, dunlins, knots and semipalmated and black-bellied plovers). Principal gulls in the Bay area include the great black-backed, herring, ring-billed and laughing gulls. Common and Forster's terns are also present, but least terns are rarely seen.

Shore and seabirds are aesthetically appealing and play important roles in the Bay food chain. Their food items, taken from open water, are believed to be less likely to take up and pass on toxicants than food sources found in shallower, more sheltered waters.

Existing Monitoring Programs

Christmas Bird Count Survey

Spatial Coverage:
Selected locations throughout the Chesapeake Bay basin states.

Sampling Frequency:
Annually for a three-week period in late December and early January.

Measurements and Collection Procedures:
Volunteers develop composite lists of species and counts based on observations at selected locations.

USFWS Breeding Bird Survey

Spatial Coverage:
Selected locations throughout the Chesapeake Bay basin states.

Sampling Frequency:
Annual in June.

Measurements and Collection Procedures:
Qualified volunteers make observations and counts of species within 400 meters at stations along specific routes.

Virginia Shore Bird Survey

Spatial Coverage:
The coastal plain of Virginia.

Sampling Frequency:
Annual in late May, with a follow-up survey in June.

Measurements and Collection Procedures:
Visual estimates of numbers of each species are made from aircraft by experienced observers in May. The June follow-up is a ground survey.

Program Deficiencies

1. There is a lack of coordination among jurisdictions.

2. There is no systematic monitoring of shore and seabirds in Maryland, however this is not considered to be neccesary in Chesapeake Bay habitats at present.

3. Integration and information exchange with other Chesapeake Bay monitoring programs is almost non-existent.

4. Personnel resources are insufficient to ensure regular data analysis and reporting of results from existing shore and seabird monitoring programs.

Recommendations

1. Continue the existing survey programs.

2. Improve information exchange with water quality and other living resources monitoring programs.

3. Improve integration between Maryland and Virginia shore and seabird monitoring programs through annual meetings of the program managers and principal investigators.

Program Integration

Information from shore and seabird monitoring should be reported in concert with reports from other living resources and water quality monitoring programs.

Important Habitat Quality Variables

Weather observations (air temperature, rainfall, snow cover, icing on ponds and shallow Bay areas); salinity and other water quality variables in relation to food sources. Distribution and quantity of suitable habitat, tidal and non-tidal wetlands; vegetation types, disturbance by humans, vehicles, and boats (especially during breeding seasons).

RAPTORS

Raptors are a highly visible and important wildlife group. The southern bald eagle is of special interest as the national symbol. This raptor, which is still classified as endangered, is making a comeback after years of decline due to toxic problems. The osprey, also on the upswing in the Bay, is seemingly ubiquitous, with breeding pairs present on many bay rivers and coves.

The bald eagle and the osprey experienced grave toxicant problems in the past. Body burdens of DDT and possibly other organic pesticides accumulated from the food chain were held responsible for reproductive failures in both species from the 1960s to the 1970s. Following bans on DDT use and consequent toxicant reductions (as found in various ecosystem sampling), their situation improved. These "top of the line" predators can easily become unwilling indicators of toxicants permeating into various life forms in the ecosystem; monitoring them is therefore essential.

Existing Monitoring Programs

Wintering Bald Eagle Aerial Survey

Spatial Coverage:
Known wintering areas within the Chesapeake Bay region.

Sampling Frequency:
Annual in early January.

Measurements and Collection Procedures:
Counts from aerial and ground surveys.

Maryland Bald Eagle and Osprey Surveys

Spatial Coverage:
Maryland tidewater with emphasis on previously active areas of eagle habitat. Selected osprey habitats are observed annually.

Sampling Frequency:
Annual in February and March. A follow-up survey is made in June.

Measurements and Collection Procedures:
Aerial counts of adult birds are made during February and March. A follow-up aerial survey of young birds is conducted in June.

Virginia Bald Eagle Survey

Spatial Coverage:
Virginia tidewater with emphasis on previously active areas of eagle habitat.

Sampling Frequency: Annual in February and March. A follow-up survey is made in June.

Measurements and Collection Procedures:
Aerial counts of adult birds are made during February and March. A follow-up aerial survey of young birds is conducted in June.

Virginia Bald Eagle Roost Survey

Spatial Coverage:
Major roost areas in Virginia (Rappahannock River, James River, Caledon, and Mason Neck).

Sampling Frequency:
Weekly from May through October.

Measurements and Collection Procedures:
Roost areas are surveyed by boat.

Virginia Osprey Survey

Spatial Coverage:
Tidewater Virginia.

Sampling Frequency:
Annually from April through August.

Measurements and Collection Procedures:
Nest sites are surveyed by boat.

Program Deficiency

1. Integration with other water quality and living resources monitoring programs is virtually non-existent.

Recommendations

1. Continue existing raptor surveys

2. Improve information exchange with water quality and other living resources monitoring programs.

Program Integration

Information from raptor monitoring should be reported in concert with reports from other living resources and water quality monitoring programs.

Important Habitat Quality Variables

Suitable nesting habitats, pesticides.

REPTILES AND AMPHIBIANS

Reptiles and amphibians are fairly well represented in tidal and non-tidal wetland areas, but because they are often secretive or nocturnal, they are rarely observed. Most of these animals are associated with fresh to brackish waters, the exceptions being the diamondback terrapin, and the eastern king, water, black racer, eastern garter, rough green and black ratsnakes, all of which can be occasionally seen in saline marshes, and sea turtles. The most common turtles are the snapper, red-bellied, eastern mud, and eastern painted species. Sea turtles occur infrequently in polyhaline and mesohaline regions of the Bay and its tributaries. Redbellied, ribbon and hognosed snakes occur, in addition to those already mentioned. The principal amphibians found in fresh to slightly brackish wetland areas are the leopard, green, pickerel, bull and spring peeper frogs. Several salamander species and the blue-tailed skink are also present.

Reptiles and amphibians probably play a relatively small role in "cropping" lower organisms. These animals can sometimes be used as indicators of contaminated surroundings or prey items because they tend to be long-lived, do not migrate, and usually stay in limited physical territories.

Existing Monitoring Programs

Virginia Sea Turtle Survey

Spatial Coverage:
Lower Chespeake Bay nursery grounds.

Sampling Frequency:
Annually from June through August.

Measurements and Collection Procedures:
Aerial counts of sea turtles.

Program Deficiencies

Because of the largely terrestrial or freshwater habitats of reptiles and amphibians, and their uncertain roles in the Bay ecosystem, any deficiencies in monitoring are of minor importance in meeting living resources monitoring objectives.

Recommendations

1. Continue Virginia Sea Turtle Survey.

MAMMALS

Mammals of the Bay's wetlands include mink and otters in rivers and nearby marshes; the nutria (an introduced species), particularly in mid-eastern shore areas where winter temperatures usually do not cause mortality; and the most abundant species, the muskrat. Muskrats are found throughout the less saline marshes of the Bay area. Beavers have been increasing in numbers in recent years in fresh scrub-shrub, swampy areas. In addition, many other mammals often come down from upland areas to drink and find food in the wetlands. These visitors include small mammals such as shrews, voles, mice, rice rats and moles; cottontail rabbits, striped skunks, the important predator and scavenger, the raccoon; longtail weasels and opossums. Larger species include whitetail and sika deer, and red and gray fox.

Mammals have aesthetic value and are of practical importance to hunters and trappers. Their survival and abundance are not thought to be greatly threatened or reduced by any particular cause, but like some birds, reptiles, and amphibians, some mammals could serve to produce toxicant-related information from tissue analysis (e.g., shrews in a marsh treated with insecticides). Some of the predators however, feed in wetlands only part of the time, and grazers such as muskrats or beavers may not ingest many toxicants from their vegetative food sources. Thus, mammals probably are inefficient indicators of toxicants in Chesapeake Bay habitats.

Existing Monitoring Programs

Mammals are monitored through harvest records, using reports from hunters and trappers.

Program Deficiencies

Because of the largely terrestrial habitats of most mammals, and their uncertain roles in the Bay ecosystem, any deficiencies in monitoring are of minor importance in meeting living resources monitoring objectives.

Recommendations

No recommendations.

PLANT COMMUNITIES

SUBMERGED AQUATIC VEGETATION

Submerged aquatic vegetation (SAV) are vascular plants which grow beneath the surface of the water, usually rooted. The distribution of species in the Bay largely follows gradients of salinity. Pondweeds, naiads, coontail, wild celery, and the exotics, eurasian milfoil and *Hydrilla* tolerate fresh or mildly brackish waters. They are found in the upper reaches of the Bay and tidal freshwater areas of tributaries. Widgeon grass, eurasian milfoil, sago pondweed, redhead grass, horned pondweed, and wild celery tolerate higher salinity and inhabit the middle reaches of the Bay and tributaries. Eelgrass and widgeon grass are tolerant of high salinity and are found in the lower sections of the Bay and tributaries.

"Communities of . . . SAV are an integral part of the Chesapeake Bay ecosystem. They provide an important habitat for many species, either as a food source or as protection from predators, i.e., as a nursery. By reducing currents and baffling waves, they allow for deposition of suspended material [thereby reducing turbidity and increasing water clarity. This process may help to increase hard clam recruitment and to maintain clean cultch for oyster settlement]. In addition, they bind sediments with their roots and rhizomes to prevent erosion of the underlying material. They are important in nutrient cycling through both the absorption and release of nitrogen and phosphorus . . ." (Simons and Orth, 1987).

Existing Monitoring Programs

Chesapeake Bay Aerial Submerged Aquatic Vegetation Survey

Spatial coverage:
Flight lines for the acquisition of aerial photography are designated to cover all shoreline and shoal areas within the tidal Chesapeake mainstem and tributaries.

Sampling frequency:
All shallow tidal waters of the Bay have been photographed annually at a scale of 1:24,000 or 1:12,000 since 1984.

Measurements and collection procedures:
Flight paths follow the direction of tide propagation to ensure that photographs are taken at the lowest possible tidal stage. Photography guidelines specify the necessary conditions for maximum delineation of submerged aquatic vegetation (SAV) beds. SAV beds are outlined on mylar map overlays through interpretation of the photographs. Density classifications are assigned to all mapped SAV beds. The mylar quadrant sheets are digitized for computer storage and analysis of SAV bed locations and areal extent.

Maryland Submerged Aquatic Vegetation Ground Survey

Spatial coverage:
Six hundred forty-two stations are located throughout Maryland portions of Chesapeake Bay and its tidal tributaries.

Sampling frequency:
Samples and data are collected once per year at all 642 stations between mid-July and late August.

Measurements and collection procedures:
At each station, depth, surface temperature, salinity, and Secchi depth are recorded. Three replicate samples are taken and biomass is calculated for each of three 1-meter quadrats per station. Percentage crown cover for each of the SAV species is also calculated and recorded.

Maryland Charter Boat Submerged Aquatic Vegetation Survey

Spatial coverage:
Areas in the Maryland portion of Chesapeake Bay identified by the previous years' aerial reconnaissance.

Sampling frequency:
Annual survey during June through September.

Measurement and collection procedures:
Charter boat captains ground-truth presence or absence of submerged aquatic vegetation beds based on previous years' maps and provide for delineation of new unmapped beds and species identification information.

Maryland Submerged Aquatic Vegetation Program for the Choptank River

Spatial coverage:
Sixteen stations located on the Choptank river (ET5).

Sampling frequency:
Monthly from April through September.

Measurement and collection procedures:
Water and sediment quality measurements are taken in waters less than 2.0 meters in depth. Abundance and distribution of submerged aquatic vegetation by species is recorded.

Maryland Submerged Aquatic Vegetation Program for the Susquehanna Flats, Elk and Sassafras Rivers

Spatial coverage:
Twenty-eight stations located on the Susquehanna Flats (CB1), Elk (ET2) and Sassafras (ET3) rivers.

Sampling frequency:
Monthly from April through October.

Measurement and collection procedures:
Water and sediment quality measurements are taken in waters less than 2.0 meters in depth. Abundance and distribution of submerged aquatic vegetation by species is recorded.

USGS Potomac River Submerged Aquatic Vegetation Survey Program

Spatial coverage:
One hundred eighty-seven stations located in the Potomac River (TF2, RET2, LE2).

Sampling frequency:
Twice annually: June-July and September-October.

Measurement and collection procedures:
All stations are sampled three times with modified oyster tongs, with each grab covering an area of 930 cm^2. All species are identified, dried and the standing crop expressed in g/sample and g/m^2 for each species. In the fall, due to increased biomass, sampling methods may be altered. At stations where SAV forms a dense, tangled mass, visual estimates of the percent of each species are recorded, but the vegetation is not collected and weighed.

Virginia Submerged Aquatic Vegetation Habitat Monitoring Program

Spatial coverage:
Six stations in the York river (LE4).

Sampling frequency:
Monthly throughout the year at all 6 stations.

Measurement and collection procedures:
Water quality and light attenuation measurements are recorded at each station. Abundance and distribution of submerged aquatic vegetation species are recorded.

Program Deficiencies

1. Annual aerial survey including complete digitization and interpretation of the entire Chesapeake Bay may be too expensive for long-term monitoring.

2. The original random distribution of the Maryland ground survey program stations resulted in the placement of some stations in areas where total water depth or physical wave action would prevent SAV growth even under pristine conditions.

3. Definitive recommendations are lacking on the use of satellite scanners or statistical sampling of aerial photography as the basis of long-term monitoring.

4. Findings from the second tier (habitat) monitoring programs in the York and Choptank Rivers and in upper Chesapeake Bay require validation in additional habitats and salinity ranges.

Recommendations

1. For the immediate future (1-2 years), top priority will be placed on continuing annual overflights so that year-to-year variations in SAV distribution and abundance can be separated from long-term trends. A multi-year SAV monitoring plan should be developed.

2. Continue existing ground survey programs.

3. The Maryland Submerged Aquatic Vegetation Ground Survey station locations should be reevaluated to determine if the program can provide more effective ground truthing for the aerial survey.

4. The utility of satellite scanners as a cost-effective alternative to annual overflights for estimating the distribution and abundance of SAV in the Bay needs to be fully evaluated following recent research efforts. Annual partial (statistical sampling) and less frequent full photointerpretation and digitization of Bay SAV distribution and abundance from aerial photography are second alternatives for a more cost-effective long-term baseline monitoring program. Final recommendations on alternative means of long-term monitoring should be made and implemented as soon as possible.

5. Evaluate additional tributaries in Maryland and Virginia for incorporation into the second tier monitoring program to validate relationships established between nutrients, light penetration and SAV regrowth and to examine these correlations under different habitat conditions (salinity, substrate, etc.). Possible tributaries for inclusion are the Chester, Patuxent, Potomac, James, and Rappahannock Rivers and Eastern Shore embayments.

Program Integration

Trends and distribution of SAV are important in interpreting long-term trends in finfish and shellfish recruitment, distribution and abundance. As sensitive indicators of nutrient enrichment, SAV trends should be followed closely by water quality programs.

Remote sensing of SAV distribution and abundance should be closely correlated with the ground survey program to maximize ground-truthing information. Additional water quality monitoring of selected parameters (listed below) should be covered in the near-shore SAV habitats at existing or future SAV ground survey stations.

The water quality information obtained in the second tier surveys is extremely valuable in characterizing the shallow, near-shore habitats of the Bay. Consistency with Baywide water quality monitoring in methods and reporting needs to be established.

Important habitat quality variables

Water column measurements of temperature, salinity and pH in shoal and shoreline habitats; selected nutrient species (ammonia, nitrate, nitrite, dissolved inorganic phosphorus); chlorophyll *a*, light penetration, total suspended solids, Secchi depth, water column and sediment herbicide levels.

BENTHIC ALGAE AND MACROALGAE

This group includes loose aggregations of single-celled plants (benthic algal mats), as well as more organized colonial plant forms (macroalgae such as sea lettuce and kelp).

Although little attention has been paid to this group in a monitoring context, they are important primary producers in portions of the Bay. Some are very abundant, and may have great significance both as food resources for higher organisms and as physical habitat. Decomposition of accumulated biomass may affect dissolved oxygen and nutrient concentrations significantly in some areas, especially during the summer.

Existing Monitoring Programs

There are no existing monitoring programs targeting benthic algae and macroalgae, although some research has been applied to the considerations raised above.

Program Deficiencies

There is no monitoring data collection program at present.

Recommendations

No recommendations for new data collection programs should be made unless research results suggest that monitoring this group would contribute important information useful in understanding and managing the Bay and its habitats.

TIDAL WETLANDS

Tidal wetlands are semi-aquatic habitats, covered periodically by tidal waters or washed by waves. These zones include marshes, sandy beaches, mudflats, and shoreline structures such as revetments and bulkheads.

Tidal wetlands provide habitat for marsh grasses, shore birds, waterfowl, muskrats, otters, many benthic species, and larval or juvenile stages of finfish and crabs. Marshes have high rates of primary production, some of which indirectly supports aquatic detrital food chains. Marshes can buffer wave energy, thereby stabilizing shorelines, and preventing erosion. Marshes also can buffer sediment and nutrient runoff.

Existing Monitoring Programs

Federal Programs

Long-term mid-Atlantic wetlands trends were analyzed from aerial photographs of *randomly-selected four-square-mile plots taken in the mid-1950's* and late *1970's* by the U.S. Fish and Wildlife Service and U.S. Environmental Protection Agency (Tiner, 1987). Changes over the intervening period in the areal coverage of several wetland classifications were estimated.

State Programs

Both Maryland and Virginia maintain databases of all permits and permit applications for wetland activities (filling, dredging, development).

Program Deficiencies

1. There are no ongoing, consistent monitoring programs for the regular mapping of the areal extent and distribution of tidal wetlands in Maryland and Virginia.

Recommendations

The recommendations below are provisional until final monitoring recommendations are developed by the Chesapeake Bay Wetlands Policy Task Force.

1. Design and implement a Baywide monitoring program for the periodic acquisition and storage of baseline data on the areal extent and distribution of tidal wetlands. A biennial aerial or satellite imagery acquisition and interpretation program is recommended.

2. Maintain jurisdictional databases of permit activities which can be linked with remotely sensed baseline data. Comparable approaches should be developed Baywide.

Program Integration

Wetlands information should be analyzed and reported on a Baywide basis in concert with other living resources monitoring programs. Baseline data collection (aerial photography or satellite scanning) for tidal wetlands might be compatible with data collection for non-tidal wetlands and SAV.

Bay segment and tributary water quality data (especially nutrients and turbidity) should be related to wetlands information on a regular basis. Monitoring of waterfowl, juvenile finfish and crabs, and other wildlife should also be related to tidal wetlands status and trends to the extent possible; first, at the level of data collection and second, at the level of information exchange.

Important Habitat Quality Variables

Air and water temperature, salinity, light flux, fresh water runoff, sea level trends, herbicides, and insecticides (because of their heavy use in marshes and potential impact on living resources), precipitation, land use.

NON-TIDAL WETLANDS

"Non-tidal wetlands are semi-aquatic lands, not influenced by tidal waters, that are flooded for varying periods of time during the growing season. When not flooded, wetland soils are often saturated near the land surface. Non-tidal wetlands include areas commonly called . . . swamps, and bogs as well as the shallow water zones of rivers, lakes, and ponds. The presence of water in these areas creates environmental conditions that affect the types of plants and animals living there. In general, wetlands are defined by the predominance of 'hydrophytes' (plants adapted for life in wet soils) and the presence of 'hydric soils' (saturated or periodically flooded soils)" (Tiner, 1987).

Non-tidal wetlands are important habitats for many plants and animals, including threatened and endangered species. Freshwater fish depend upon wetlands for food and nursery areas. Waterfowl, other birds, and several species of mammals use these wetlands extensively for food and shelter. Plants, soils, and ponds in non-tidal wetlands absorb and retain nutrients, water, and sediments, thereby reducing nutrient enrichment, runoff, turbidity, and sedimentation in Chesapeake Bay.

Existing Monitoring Programs

National Wetlands Inventory

Non-tidal wetlands in areas surrounding the Bay have been mapped on 1:24,000 quads as a part of the National Wetlands Inventory.

Other Federal Programs

Long-term mid-Atlantic wetlands trends were analyzed from aerial photographs of randomly-selected four square mile plots taken in the mid-1950s and late 1970s by the U.S. Fish and Wildlife Service and the U.S. Environmental Protection Agency (Tiner, 1987). Changes over the intervening period in the areal coverage of several wetland classifications were estimated.

Program Deficiencies

1. There are no ongoing, consistent monitoring programs for the regular mapping of the areal extent and distribution of non-tidal wetlands in Pennsylvania, Maryland, the District of Columbia and Virginia. Low-frequency baseline assessments (the study cited above) can be only retrospective in nature. Pressures to develop and alter non-tidal wetlands appear to be such that much more frequent data are necessary to monitor trends in such a way that serious losses of these valuable lands can be prevented.

Recommendations

The recommendation below is provisional until final monitoring recommendations are developed by the Chesapeake Bay Wetlands Policy Task Force.

1. Design and implement a Baywide monitoring program for the periodic acquisition and storage of baseline data on the areal extent and distribution of non-tidal wetlands in Pennsylvania, Maryland, the District of Columbia, and Virginia. A biennial aerial or satellite imagery acquisition and interpretation program along with appropriate ground-truthing is recommended. The random quadrant scheme used previously appears to be a sound approach. Because several states, a wide geographic area, and broad regional interests are involved, a federally-sponsored program is warranted.

2. Each jurisdiction should maintain a database of development, restoration and mitigation activities which affect the quantity and quality of non-tidal wetlands. The databases should be linked easily with remotely-sensed baseline data and should be comparable Baywide.

Program integration

For non-tidal wetlands above the fall line, ambient in-stream and fall line water quality monitoring data (especially nutrients and suspended solids) are the most important correlates. Below the fall line, Bay segment and tributary water quality data are most relevant. Regular comparisons of data and monitoring results between these programs should be performed. Monitoring of waterfowl and other wildlife should also be related to non-tidal wetlands status and trends.

Important habitat quality variables

Rainfall, vegetative cover, land use patterns.

BENTHIC FAUNAL COMMUNITIES

Benthic fauna are organisms that live in the sediments (benthic infauna), and those that live on the sediments, or are attached to other solid surfaces below the water's surface (benthic epifauna). Benthic fauna are further categorized as macrofauna or meiofauna, depending upon their size. Macrofauna generally are organisms that are retained on a 500 m mesh; meiofauna are retained on a 50 m mesh.

Benthic organisms, because they are immobile for the most part, are important indicators of water quality, especially for dissolved oxygen. Benthic communities respond in rather predictable ways to nutrient enrichment and other types of contamination.

BENTHIC INFAUNA

The most numerous components of the larger (macro-) benthic infauna in Chesapeake Bay are clams, worms, and amphipods, with species distributions depending largely on salinity and bottom type. Meiofaunal communities are generally dominated by nematodes (roundworms), but include many other forms (e.g., copepods, ciliates).

In reference primarily to benthic infauna, Holland (1987) indicated that "Much of the particulate carbon and detritus added to the Bay [by algal production and] the surrounding watershed . . . settles to the bottom and is used by the benthos. The burrowing activities of benthic organisms contribute significantly to the recycling of nutrients back into the overlying water. [Also,] many commercially and recreationally important fish . . . feed on the benthos".

Existing Monitoring Programs

Maryland Chesapeake Bay Benthic Monitoring Program

Spatial coverage:

Thirty-two mainstem stations characterizing CBP segments CB2 (2 stations), CB3 (3 stations), CB4 (21 stations) and CB5 (6 stations); twenty-six tributary stations characterizing tidal fresh, riverine estuarine transition, and lower estuarine zones of the Potomac (TF2 - 1 station; RET2 - 7 stations; and LE2 - 8 stations) and Patuxent (TF1 - 8 stations; RET1 - 1 station; and LE1 - 1 station) rivers, respectively; one station each in the Elk (ET2), and Nanticoke (ET6) rivers; two stations in the Patapsco (WT5) and Chester (ET4) rivers; four stations characterizing the upper (ET5) and lower (EE2) reaches of the Choptank River; and two stations characterizing Tangier Sound (EE3).

Sampling frequency:

Ten times per year at all 70 stations.

Measurements and collection procedures:

Five replicate samples are collected with a Ponar grab, a hand box-corer or a hydraulically closing van Veen grab depending on sediment type. Benthic samples are field-sieved through a 0.5 mm screen; retained organisms and detritus preserved with formalin. Benthic invertebrates in three of the samples are identified and counted, biomass of the 20 numerically dominant species are determined and length frequency measurements are made for dominant clam species. The two unprocessed replicates are archived.

Sediment median diameter, sorting coefficient, and carbonate content are measured annually at all stations. The silt-clay, carbon and moisture content as a percentage of sediment dry weight, and interstitial salinity are recorded at each station during each sampling event.

Surface to bottom profiles of temperature, salinity and dissolved oxygen at 3 m depth intervals are recorded at each station. Surface pH is also recorded.

Hart and Miller Islands Benthic Monitoring Program

Spatial Coverage:

Eighteen stations characterizing CBP segment CB3.

Sampling Frequency:

All 18 stations are sampled twice a year.

Measurements and collection procedures:

At each station, three replicate samples are obtained with a van Veen sampler. Benthic organisms are separated out onto a 1 mm screen and preserved prior to identification and enumeration. Sediment grab samples are analyzed for percent silt, sand and clay.

Virginia Chesapeake Bay Benthic Monitoring Program

Spatial Coverage:

Five mainstem stations characterize CBP segments CB5 (1 station), CB6 (2 stations), CB7 (1 station) and CB8 (1 station); eleven tributary stations characterize the tidal fresh, riverine-estuarine transition and lower estuarine zones of the Rappahannock (TF3 - 1 station; RET3 - 1 station; and LE3 - 1 station), York (TF4 - 1 station; RET4 - 1 station; and LE4 - 2 stations), and James (TF5 - 1 station; RET5 - 1 station; and LE5 - 2 stations) rivers.

Sampling Frequency:

All 16 stations are sampled quarterly.

Measurements and Collection Procedures:

Four replicate box-core samples are collected to a minimum depth of 25 cm below the sediment-water interface at each station. One sample is archived and the remaining three are frozen until analyzed. Benthic organisms in the remaining three samples are retained on a 0.5 mm sieve screen and preserved with formalin. They are then identified and counted, and ash-free weight or biomass is determined for the 20 numerically dominant species. One of the samples is analyzed for depth distribution (0-2 cm, 2-5 cm, and 5 cm classes at greater depths). Species, numbers and biomass (ash-free dry weight) are recorded. Sediment particle size distributions and total volatile solids (equivalent to ash-free dry weight) are measured quarterly. During the summer quarter, replicate sediment samples are partitioned into three depths for each analysis. At each station, bottom temperature, dissolved oxygen and salinity are recorded.

District of Columbia Aquatic Benthic Macroinvertebrate Monitoring Program

Spatial Coverage:
Thirty stations on the Potomac (TF1) and Anacostia (TF1) rivers, Rock Creek and their respective tributaries.

Sampling Frequency:
Annual.

Measurement and Collection Procedures:
Samples are collected with a box sampler or an Ekman dredge sampler. At each station, two samples are collected, sieved and sorted in the field. Species diversity, species richness, and individuals per unit area are recorded.

Program Deficiencies

1. Existing benthic infauna programs are not fully compatible among jurisdictions:

   a. Biomass measurements are based on dry weight in the Maryland program and ash-free dry weight in Virginia's program.
   b. The District of Columbia's program does not include biomass determinations.
   c. Sediment organic matter is measured as carbon in Maryland and ash-free weight in Virginia.
   d. The Maryland program's sampling gear varies, depending on sediment type; only a box core is used in the Virginia program.
   e. Virginia's protocol includes identification and enumeration by depth distribution down to 25 cm; Maryland's protocol does not include identification and enumeration by depth.

2. Existing sample collection techniques employed by both programs do not characterize benthic meiofauna, however the state of knowledge of the taxonomy of the major groups of meiofauna is poor. The identifications that result produce data with little or no utility in terms of the plan objectives. No recommendations for monitoring benthic meiofauna are warranted.

3. The existing Virginia benthic monitoring program has insufficient spatial (there is no replication of stations within regions) and temporal (no replication within seasons) resolution to achieve its stated objectives.

Recommendations

1. Continue the existing benthic infauna monitoring programs.

2. Review the sample collection, identification and enumeration protocols used in the existing benthic monitoring programs and develop a set of Baywide consensus protocols and a plan for implementing them.

3. Review the Virginia benthic monitoring program and recommend specific enhancements required to meet the program's objectives.

Program Integration

Ongoing macro-infauna monitoring is well-integrated with existing water quality and plankton monitoring programs. Integration needs to be established with finfish monitoring. Initiation of a Baywide trawl survey will provide finfish data at appropriate times and locations for correlation of data with benthic infauna monitoring. It will be necessary for these programs to maintain communication and to compare results.

Important Habitat Quality Variables

Water column profiles of temperature, salinity, and dissolved oxygen; sediment grain size, organic carbon content, silt-clay content, moisture content; phytoplankton biomass, size distribution and species composition (for suspension-feeders).

BENTHIC EPIFAUNA

Benthic epifaunal communities in Chesapeake Bay are largely dependent on hard surfaces for attachment. Because of the general lack of natural rock outcrops in Chesapeake Bay, oyster shells and man-made structures (bulkheads, pilings, revetments) provide the bulk of this habitat. Oyster reefs, in particular, are habitats for a diverse assemblage of epifauna, including mussels, barnacles, anemones, worms, small crabs, sponges and tunicates.

Epifaunal communities, especially those on oyster reefs can contain high densities of suspension-feeders, which filter great quantities of water and produce large amounts of sediment. This process can play an important role in the distribution and recycling of organic matter, nutrients, and contaminants.

Existing Monitoring Programs

Epifauna are collected and recorded during ongoing spat surveys of oyster bars (see below).

Maryland Fall Oyster Survey

Spatial Coverage:
Fifty-five key oyster bars equally distributed throughout the major oyster-producing river systems: Chester River (ET4), Eastern Bay (EE1), Choptank River (EE2), Tangier and Pocomoke Sounds (EE3), Wicomico (ET7), Manokin River (ET8) and lower Potomac River (LE2); and the mainstem of the Maryland portion of Chesapeake Bay (CB3, CB4, CB5).

Sampling Frequency:
Annually in October.

Measurements and Collection Procedures:

A random sample of oysters is taken from each location with either patent tongs or a dredge. Observations are made on the fouling community (barnacles, mussels, anemones, tunicates, etc.) that inhabit the collected oyster shells.

Maryland Choptank River Intensive Oyster Habitat Monitoring Program

Spatial Coverage:

Four oyster bars in the lower Choptank River (EE2, ET5).

Sampling Frequency:

Weekly from June through September, monthly from October through May.

Measurements and Collection Procedures:

A sample of 60 oysters is obtained with a small dredge at each bar. Relative abundance and viability of fouling organisms (barnacles, mussels, tunicates, anemones) are recorded from a subsample of ten live oysters.

Hart and Miller Islands Benthic Monitoring Program

Spatial Coverage:

Four stations (on pilings) at the Hart and Miller Islands facility (CB3).

Sampling Frequency:

Three times per year at all 4 stations.

Measurements and Collection Procedures:

Epifaunal abundance and species composition are recorded from scrapings of 10 cm^2 areas at selected depths on pilings at the Hart and Miller Islands facility. Scraping is done by a diver.

Virginia Spring and Fall Oyster Bar Survey

Spatial coverage:

Twenty-six stations at oyster bars located in the James (LE5), York (LE4), Rappahannock (LE3), Great Wicomico (CB5), and Potomac (LE2) rivers, Mobjack Bay (WE4), and Pocomoke Sound (EE3).

Sampling Frequency:

Weekly in May and October of each year at all 26 stations.

Measurements and Collection Procedures:

Sampling is performed by one-hour dredge hauls at each station. The presence of predators (oyster drills, starfish, flatworms, mud crabs, blue crabs, others) is recorded.

Program Deficiencies

1. Epifaunal communities are generally not targeted in ongoing benthic and oyster monitoring programs.

2. Epifaunal monitoring is inadequate and lacks integration with water quality, plankton and infauna monitoring.

3. Epifaunal data collected during oyster spat surveys often are not computerized and reported.

Recommendations

1. Continue to monitor benthic epifauna as part of the planned and ongoing oyster bar surveys.

2. Record, computerize, analyze and report observations of benthic epifauna along with other related living resources monitoring data.

3. Review the existing sample collection, identification and enumeration protocols used in the existing oyster bar surveys to monitor benthic epifauna and develop a set of Baywide consensus protocols and a plan for implementing the compatible protocols.

4. Design and implement a benthic epifauna monitoring program (complementary to the existing oyster bar survey epifauna component) to cover all representative salinity zones. Artificial substrates should be placed and retrieved periodically to target larval recruitment of epifaunal organisms. Link the program design to existing water quality, plankton, and benthic monitoring programs.

Program Integration

The oyster bar component of epifaunal monitoring is directly integrated with oyster monitoring. Artificial substrate monitoring should be integrated with water quality, plankton, and benthic infauna monitoring. Recruitment of some epifaunal organisms may be found to be closely related (either positively or negatively) to recruitment of oysters and clams, because both groups have planktonic larvae and must settle on hard substrates. Environmental factors should act similarly to influence early survival and recruitment of both epifauna and bivalve shellfish.

Important Habitat Quality Variables

Water column profiles of temperature, salinity, and dissolved oxygen; phytoplankton biomass, size distribution, and species composition (for suspension-feeders). Availability of hard substrate, especially oyster shell, currents.

PLANKTONIC COMMUNITIES

PICOPLANKTON

Picoplankton (or ultraplankton) are swimming or floating organisms less than 2 μm in diameter. Picoplankton that depend on outside sources of organic matter for energy (heterotrophic) are largely bacteria, whereas picoplankton that use solar energy to produce organic matter (autotrophic) are largely spherical blue-green algae (coccoid cyanobacteria). This group also includes some very small nonbacterial (eukaryotic) algae and bacteria that use chemical energy to produce organic matter (chemoautotrophs).

Bacteria provide food for single-celled animals (protozoa), especially flagellates and possibly ciliates (microzooplankton). Cycling of important biological elements including carbon, nitrogen, phosphorus and sulfur is largely controlled by bacteria. Sulfate reduction, catalyzed by bacteria in anoxic water and sediments, is an important process which yields dissolved oxygen-depleting and extremely toxic sulfides.

Studies in central Chesapeake Bay have shown that bacteria comprise a large percentage of the standing stock of carbon in summer. Investigators have associated these high bacterial densities with high water column oxygen consumption rates. When coupled with sediment oxygen demand, observed water column respiration rates are sufficient to maintain hypoxic and anoxic conditions in the deep trough areas of the mid-Chesapeake Bay during the summer months.

Through monitoring picoplankton populations, correlations between water column respiration and bacterial populations can be established and further linked to phytoplankton and zooplankton abundances. Picoplankton complete the link between nutrient loadings, phytoplankton blooms, zooplankton grazing, die-off of unconsumed plankton and the consumption of oxygen through decomposition of detrital material.

There is growing evidence that overenrichment by nutrients may be causing changes in the plankton which negatively affect the supply of food to fish and shellfish. Tracking picoplankton over time will assist managers and scientists in characterizing the impacts of nutrient reductions on living resources.

Existing Monitoring Programs

There are no ongoing programs for routine identification and enumeration of picoplankton. Past and present short-term research studies are the only sources of data on Chesapeake Bay picoplankton populations. Some of the autotrophic picoplankton are enumerated in the nanoplankton and microphytoplankton cell counts, but special preservation methods and the use of epifluorescent microscopy are required for quantitative enumeration of this group. Measurements of chlorophyll *a* and primary production conducted as part of the ongoing phytoplankton monitoring programs include contributions by the autotrophic picoplankton.

Program deficiencies

1. No systematic monitoring of picoplankton populations is conducted as a part of the ongoing plankton monitoring programs.

Recommendations

1. Initiate a pilot monitoring study to determine the relative densities and distributions of picoplankton at selected stations among those currently included in the ongoing plankton monitoring programs in the mainstem Bay and tidal tributaries. The objectives of the pilot study will be to: (1) determine the temporal and spatial requirements for incorporating a picoplankton component into the existing plankton monitoring program; and (2) evaluate the application of epifluorescence identification and enumeration techniques within Chesapeake Bay.

2. Based on the findings of the pilot study and related research studies to date, implement picoplankton monitoring as an integral component of the existing Maryland and Virginia plankton monitoring programs. Placement of a sampling station in the upper reaches of the tidal fresh Potomac River should ensure characterization of the District of Columbia's tidal waters. This station should be incorporated into Maryland's plankton monitoring program to ensure program comparability and cost efficiency even if the station is located in District waters.

3. Routine measurement of water column respiration rates at selected stations is recommended in concert with ongoing plankton monitoring programs. A standard biochemical oxygen demand (BOD) test or a adaptation thereof should suffice. These measurements should be made at the same stations and times as picoplankton sampling.

4. Monitor dissolved sulfides in the below pycnocline grab samples as a routine component of ongoing tidal tributary and mainstem water quality monitoring programs in Maryland and Virginia at stations which experience periodic hypoxic or anoxic conditions.

Program Integration

All four recommendations should be implemented as a part of the ongoing Baywide water quality and plankton monitoring programs. Picoplankton sample collection should be directly coordinated with phytoplankton monitoring (in time and space) because of the importance of carbon flow between these groups at the base of the food chain. Samples for hydrogen sulfide analysis should be subsampled from water column grab samples collected below the pycnocline as part of the existing water quality monitoring programs.

Important Habitat Quality Variables

Water column profiles of dissolved oxygen, temperature, salinity, conductivity and pH; selected nutrient species (particulate nitrogen, dissolved organic nitrogen, ammonia, nitrate, nitrate, particulate phosphorus, dissolved inorganic phosphorus, dissolved organic phosphorus, particulate carbon, dissolved organic carbon); chlorophyll *a*, pheophytin, TSS, hydrogen sulfide; phytoplankton and microzooplankton species composition and distribution.

NANOPLANKTON AND PHYTOPLANKTON

Nanoplankton are swimming or floating organisms between 2 and 20 μm in diameter. Phytoplankton are defined here as planktonic autotrophs greater than 20 μm in size. Both functional groups are considered together here as they are sampled and enumerated by similar methods. The nanoplankton include a wide range of phytoplankton taxa, as well as heterotrophic flagellates and several small ciliated protozoans. Phytoplankton are dominated by diatoms and dinoflagellates in meso- and polyhaline portions of the Bay. In oligohaline areas, cyanobacteria also make up a major portion of the nanophytoplankton assemblage.

Phytoplankton are at the base of the Chesapeake Bay food web in their role as the major primary producers. They are food for zooplankton, suspension feeders such as clams and oysters, and herbivorous finfish. Phytoplankton numbers, species composition and production are critical to higher organisms in the Bay.

Characterization of phytoplankton taxonomic abundance and distribution, and primary productivity provide excellent biological indications of water quality conditions. Monitoring changes in phytoplankton population composition and densities are critical for the interpretation and evaluation of long-term trends in water and habitat quality. Further understanding of the causes of excessive water column and sediment oxygen demand requires tracking photosynthetic activity and metabolic rates over time.

Existing Monitoring Programs

Maryland Chesapeake Bay Phytoplankton Monitoring Program

Spatial coverage:

Five mainstem stations characterizing CBP segments CB1, CB2, CB3, CB4 and CB5; nine tributary stations characterizing tidal fresh, riverine-estuarine transition, and lower estuarine zones of the Potomac (TF2, RET2 and LE2) and Patuxent (TF1, RET1, and LE1) Rivers, respectively; and the upper and lower reaches of the Choptank River (ET5 and EE2), and the lower Patapsco River (WT5).

Sampling frequency:

Once monthly in November, December and March and either January or February; twice monthly from April to September at all 14 stations.

Measurements and Collection Procedures:

Water column samples are collected from five depths above and five depths below the pycnocline. Above and below pycnocline samples are subsampled to determine cell densities and species identification. Grab water column samples collected at the surface, 1.0 meter above and 1.0 meter below the pycnocline (1/3 and 2/3 the total water column depth in the absence of a pycnocline), and 1.0 meter above the bottom are analyzed for chlorophyll *a*. Vertical whole-water *in vivo* fluorescence profiles are measured while on station. Horizontal whole-water *in vivo* fluorescence profiles are measured while the sample collection vessel is underway between stations in the Bay mainstem and the Patuxent and Potomac rivers. Phytoplankton productivity is estimated in euphotic zones by ^{14}C analysis of the surface mixed-layer composite samples at all 14 stations.

Maryland Phytoplankton Monitoring Program

Spatial Coverage:

Three mainstem stations characterizing CBP segments CB2, CB3 and CB5; seventeen tributary stations characterizing tidal fresh, riverine-estuarine transition, and lower estuarine zones of the Potomac (TF2 - 6 stations, RET2 - 1 station, and LE2 - 3 stations) and Patuxent (TF1 - 1 station, RET1 - 1 station, and LE1 - 2 stations) respectively, and the Choptank (ET5), Chester (ET4) and Patapsco (WT5) rivers.

Sampling Frequency:

Monthly from October through March and twice monthly from April through September.

Measurements and Collection Procedures:

Species identifications and cell densities are determined from surface water column grab samples.

Virginia Chesapeake Bay Phytoplankton Monitoring Program

Spatial Coverage:

Four mainstem stations characterizing CBP segments CB6 (2 stations) and CB7 (2 stations); nine tributary stations characterizing the tidal fresh, riverine-estuarine transition and lower estuarine zones of the Rappahannock (TF3, RET3, and LE3), York (TF4, RET4, and LE4), and James (TF5, RET5, and LE5) rivers, respectively.

Sampling Frequency:

Monthly from November to February; twice monthly from March to October.

Measurements and Collection Procedures:

Composite water column samples are collected from five depths above and five depths below the pycnocline. Above and below-pycnocline samples are subsampled to determine cell densities and species identification. Grab water column samples collected at 1.0 meter below the surface, 1.0 m above and 1.0 meter below the pycnocline (or 1/3 and 2/3 the total water column depth in the absence of a pycnocline), at selected mainstem stations, and 1.0 meter above the bottom are analyzed for chlorophyll *a*.

District of Columbia Phytoplankton Monitoring Program

Spatial Coverage:

A total of nine stations characterizing CBP segment TF2 are sampled in the Potomac (5 stations) and Anacostia (4 stations) rivers.

Sampling Frequency:

Monthly samples are collected at all eight stations.

Measurements and Collection Procedures:

Samples are collected as whole-water surface grab samples. Species identification and density are determined from subsamples. Surface grab samples are analyzed for chlorophyll *a* and pheophytin.

Program Deficiencies

1. The Virginia and District of Columbia programs do not include measurements of primary productivity rates.

2. The Virginia and District of Columbia programs do not measure vertical or horizontal *in vivo* chlorophyll *a* fluorescence profiles.

3. None of the existing phytoplankton monitoring programs size-fractionate measurements of chlorophyll *a* or primary productivity (phytoplankton size classes respond in different ways to environmental factors such as nutrient enrichment and toxicants, and differ in their nutritional value to higher trophic levels.)

4. The preservation and enumeration methods currently used by all three jurisdictions underestimate abundances of picoplankton populations.

5. Existing programs do not discriminate heterotrophic from autotrophic flagellates or obtain good data for ciliates smaller than 80 μm (District of Columbia) or 44 μm (Maryland).

6. Existing temporal and spatial coverage of phytoplankton monitoring programs do not characterize adequately conditions relevant to the critical life stages of living resources at higher trophic levels.

Recommendations

1. Continue the existing phytoplankton monitoring programs.

2. Review the sample collection, identification and enumeration protocols used in the existing phytoplankton monitoring programs (placing emphasis on the smaller organisms) and develop a set of Baywide consensus protocols and a plan for implementing them.

3. Initiate measurements of primary production as part of Virginia's ongoing phytoplankton monitoring program.

4. Evaluate the utility and feasibility of size fractionation of chlorophyll *a* and primary production measurements to allow attribution of primary production to various size groups of phytoplankton. Resultant recommendations should include temporal and spatial sampling requirements to achieve the objective of size fractionation.

5. Implement more intensive (in time and space) monitoring of phytoplankton (chlorophyll *a*, species composition, density and size distribution) in specific habitats, as a component of second tier monitoring for anadromous fish and oysters. (More specific implementation recommendations are found in the FINFISH and SHELLFISH sections.)

6. Initiate measurements of vertical and horizontal *in vivo* chlorophyll *a* fluorescence profiles as part of Virginia's ongoing phytoplankton monitoring program.

Program Integration

Existing phytoplankton programs are directly integrated with ongoing water quality and micro- and mesozooplankton monitoring. Comparability of sample collection, identification and enumeration techniques across jurisdictions should be documented. Better integration is needed with programs that monitor filter-feeding biota, including oysters, clams, and planktivorous fish. Specific recommendations for integration are contained in the FINFISH and SHELLFISH Sections.

Important Habitat Quality Variables

Water column profiles of dissolved oxygen, temperature, salinity, and pH; selected nutrient species (particulate nitrogen, dissolved organic nitrogen, ammonia, nitrate, nitrite, particulate phosphorus, dissolved inorganic phosphorus, particulate carbon, dissolved organic carbon); chlorophyll *a*, pheophytin, TSS, Secchi depth; picoplankton, microzooplankton, mesozooplankton, and gelatinous zooplankton and composition and distribution.

MICROZOOPLANKTON

Microzooplankton are swimming or floating animals in the size range of 20-200 μm. This group includes single-celled animals or protozoa, rotifers, and early life stages of larger zooplankton such as copepods, molluscan and polychaete larvae, and barnacle nauplii.

Microzooplankton are food for larger mesozooplankton, fish and crustacean larvae, and gelatinous zooplankton, or jellyfish. Early life stages of important commercial species such as oyster larvae are members of this functional group. Microzooplankton are important consumers of nanoplankton and picoplankton. Zooplankton abundance and distribution are affected both by changes in phytoplankton and changes in predator populations. Therefore, this functional group can manifest symptoms of water quality problems, fishing pressure, and other habitat problems for predator species.

Existing Monitoring Programs

Maryland Chesapeake Bay Microzooplankton Monitoring Program

Spatial Coverage:

Five mainstem stations characterizing CBP segments CB1, CB2, CB3, CB4 and CB5; nine tributary stations characterizing tidal fresh, riverine-estuarine transition, and lower estuarine zones of the Potomac (TF2, RET2 and LE2) and Patuxent (TF1, RET1, and LE1) Rivers, respectively; the upper and lower reaches of the Choptank River (ET5 and EE2) and the lower Patapsco River (WT5).

Sampling Frequency:

Monthly March through December; once in January or February.

Measurements and Collection Procedures:

Composite samples are collected from five depths above and five depths below the pycnocline. A 44 μm mesh net is used to retain zooplankton. Microzooplankton are counted and identified to the lowest possible taxonomic group.

Program Deficiencies

1. The size range of 20-44 μm is not well-represented in Maryland's microzooplankton monitoring program. Organisms in this size range are an important food source for first-feeding fish larvae and the primary consumers of phytoplankton.

2. The District of Columbia's zooplankton monitoring program does not allow for enumeration and identification of zooplankton species less than 80 μm in size (see MESOZOOPLANKTON).

3. There is no microzooplankton monitoring program in Virginia.

4. Current microzooplankton sampling frequencies are not adequate to relate to nutritional requirements of larval fish in a given year or habitat.

Recommendations

1. Continue the existing microzooplankton monitoring program.

2. Review the sample collection, identification and enumeration protocols used in the existing microzooplankton monitoring program and develop a set of Baywide consensus protocols and a plan for implementing them. Reconsider the importance of the 20-44 μm size range of zooplankton being missed by the current collection protocol in the Maryland microzooplankton program and consider targeting the collection of the 20-44 μm size range at selected stations. Reconsider the importance of the 20-80 μm size range of zooplankton being missed by the current collection protocol in the District of Columbia zooplankton program and consider targeting the collection of the 20-80 μm size range at selected stations through the enumeration of microzooplankton in whole samples taken for phytoplankton analysis.

3. Implement a microzooplankton monitoring component as part of the ongoing Virginia plankton monitoring program. Whole water samples should be collected with a 44 μm net.

4. Implement more intensive (in time and space) monitoring of microzooplankton in selected spawning areas during appropriate times of the year in concert with early life stage monitoring of anadromous fish (see FINFISH).

Program Integration

Maryland's microzooplankton program is fully integrated with the State's ongoing mainstem and tidal tributary water quality, mesozooplankton, and phytoplankton monitoring programs. Initiation of microzooplankton programs in the District of Columbia and Virginia should be integrated with ongoing plankton and water quality monitoring programs.

Important Habitat Quality Variables

Water column profiles of dissolved oxygen, temperature, salinity and pH; selected nutrient species (particulate nitrogen, dissolved organic nitrogen, ammonia, nitrate, nitrite, particulate phosphorus, dissolved inorganic phosphorus, particulate carbon, dissolved organic carbon); Secchi depth, total suspended solids, chlorophyll *a*, pheophytin; picoplankton, phytoplankton, mesozooplankton, gelatinous zooplankton and ichthyoplankton composition and distribution.

MESOZOOPLANKTON

Mesozooplankton are swimming or floating animals larger than 200 μm, excluding gelatinous predators, fish, and other large swimming forms. This group is dominated by copepods and cladocerans (small crustaceans). Mysids, shrimp and crab larvae, barnacle, polychaete, molluscan and tunicate larvae, chaetognaths, and fish eggs are also caught in abundance in mesozooplankton samples.

Mesozooplankton are important food sources for larval fish, as well as later developmental stages of fish such as anchovies and menhaden. Other consumers of mesozooplankton include gelatinous zooplankton, shrimp and crab larvae, mysids, and chaetognaths. They are major consumers of phytoplankton and microzooplankton, and thus are a pathway from primary producers to higher trophic levels. Shifts in phytoplankton species composition, (e.g., towards very small forms and cyanophytes) may have deleterious effects on the growth and production of mesozooplankton.

Existing Monitoring Programs

Maryland Chesapeake Bay Mesozooplankton Monitoring Program

Spatial Coverage:

Five mainstem stations characterizing CBP segments CB1, CB2, CB3, CB4 and CB5; nine tributary stations characterizing tidal fresh, riverine-estuarine transition, and lower estuarine zones of the Potomac (TF2, RET2 and LE2) and Patuxent (TF1, RET1, and LE1) rivers, respectively, the upper and lower reaches of the Choptank River (ET5 and EE2) and the lower Patapsco River (WT5).

Sampling Frequency:

Monthly March through December; once in January or February.

Measurements and Collection Procedures:

Replicate oblique 5-10 minute tows are made in five discrete steps with metered 20 cm diameter 202 μm mesh bongo nets. By these means, sample collection is integrated through the water column from a few meters above the bottom to just below the surface. Of two replicate samples, one is preserved in formalin for counts of density by species; the other is frozen for biomass (dry weight and ash-free dry weight) determinations. Ctenophores are removed from both replicate samples before processing (see GELATINOUS ZOOPLANKTON).

Virginia Chesapeake Bay Zooplankton Monitoring Program

Spatial Coverage:

Four mainstem stations characterizing CBP segments CB6 (2 stations) and CB7 (2 stations); nine tributary stations characterizing the tidal fresh, riverine-estuarine transition and lower estuarine zones of the Rappahannock (TF3, RET3, and LE3), York (TF4, RET4, and LE4), and James (TF5, RET5, and LE5) rivers, respectively.

Sampling Frequency:

Monthly throughout the year at all stations.

Measurements and Collection Procedures:

Single oblique 5-10 minute tows with twin 50-cm diameter 202 μm mesh bongo nets are used to integrate sample collection through the water column from one meter above the bottom to the surface. Densities and species composition are recorded according to a method which stabilizes the coefficient of variation of multiple subsample counts.

District of Columbia Zooplankton Monitoring Program

Spatial Coverage:

A total of three stations characterizing CBP and TF2 are located in the Potomac (2 stations) and Anacostia (1 station) rivers.

Sampling Frequency:

Monthly throughout the year at all three stations.

Measurements and Collection Procedures:
Single horizontal five-minute surface tows with a metered 80 μm mesh net are used to collect zooplankton.

Program Deficiencies

1. Programs are not fully comparable among jurisdictions:
   a. Virginia and Maryland use different net diameters;
   b. The District of Columbia uses a smaller mesh size; Virginia and the District do not measure biomass;
   c. Subsampling procedures appear to differ between jurisdictions.

2. The District of Columbia's zooplankton sample collection protocol appears to be missing the important near-bottom zooplankton communities in its surface tow procedure.

3. Existing sample collection protocols in Maryland and Virginia appear not to be fully characterizing the important near-bottom mesozooplankton populations.

4. Sampling frequencies are inadequate to address short-term linkages between zooplankton and larval fish during critical spawning periods.

Recommendations

1. Continue existing mesozooplankton monitoring programs.

2. Review the sample collection, identification and enumeration protocols used in the existing mesozooplankton monitoring programs. Develop a set of Baywide consensus protocols and a plan for their implementation. Analyze existing plankton data to assess the ability of existing sample collection methods to fully characterize the near-bottom mesozooplankton populations and achieve the program's objectives.

3. Implement more intensive (in time and space) monitoring of mesozooplankton in selected spawning areas during appropriate times of the year in concert with early life stage surveys.

Program Integration

All of the jurisdictional mesozooplankton monitoring is integrated with water quality monitoring and monitoring of other plankton groups. Better integration with early life stage and other fisheries monitoring is required. Monthly zooplankton data can be compared to early life stage data on a multi-year basis. More frequent zooplankton data collected within spawning areas can be compared with early life stage data annually.

Important Habitat Quality Variables

Water column profiles of dissolved oxygen, temperature, salinity and pH; selected nutrient species (particulate nitrogen, dissolved organic nitrogen, ammonia, nitrate, nitrite, particulate phosphorus, dissolved inorganic phosphorus, particulate carbon, dissolved organic carbon); Secchi depth, total suspended solids, chlorophyll *a*, pheophytin, hydrogen sulfide; phytoplankton and microzooplankton composition and distribution; composition and distribution of gelatinous zooplankton.

GELATINOUS ZOOPLANKTON

This group includes the ctenophores or comb jellies; scyphozoans or jellyfish (including the infamous sea nettle, the lion's mane jellyfish, and the moon jelly); and the inconspicuous hydromedusae.

The abundant ctenophores and sea nettles are major consumers of zooplankton and early life stages of finfish. Sea nettles and one species of ctenophore prey heavily on *Mnemiopsis*, the most abundant ctenophore. The jellies are not major prey items for fish or other living resources, although some are eaten by water birds, sea turtles, and a few species of fish. Because most are not consumed directly and they are so abundant, jellies are important in shunting planktonic production to benthic detrital food chains.

It has been suggested that nutrient enrichment has caused shifts in phytoplankton towards smaller pico- and nanoplankton. These shifts have altered the structure of the pelagic food chain, and may have stimulated production of ctenophores and sea nettles at the expense of finfish.

Existing Monitoring Programs

Maryland Chesapeake Bay Mesozooplankton Monitoring Program, Gelatinous Zooplankton Component

Spatial Coverage:
Five mainstem stations characterizing CBP segments CB1, CB2, CB3, CB4 and CB5; nine tributary stations characterizing tidal fresh, riverine-estuarine transition, and lower estuarine zones of the Potomac (TF2, RET2 and LE2) and Patuxent (TF1, RET1, and LE1) rivers, respectively, the upper and lower reaches of the Choptank River (ET5 and EE2) and the lower Patapsco River (WT5).

Sampling Frequency:
Monthly throughout the year.

Measurements and collection procedures:
Replicate oblique 5-10 minute tows are taken in five discrete steps with metered 20 cm diameter 202 μm mesh bongo nets. By these means, samples are integrated through the water column from a few meters above the bottom to just below the surface. Ctenophores are removed from both replicate samples before processing; density and biomass are recorded in the field.

Maryland Long-term Sea Nettle Population Survey Program

Spatial Coverage:
One station characterizing CBP segment LE1 in the lower Patuxent River.

Sampling Frequency:
Daily from May to September at the one station.

Measurements and Collection Procedures:
Long-term monitoring of sea nettle abundance has been maintained at one site, the pier at Chesapeake Biological Laboratory in Solomons, Maryland. Visual counts are made by experienced observers along one side of the Laboratory's pier over a determined surface area.

Virginia Chesapeake Bay Zooplankton Monitoring Program, Gelatinous Zooplankton Component

Spatial Coverage:
Four mainstem stations characterizing CBP segments CB6 (2 stations) and CB7 (2 stations); nine tributary stations characterizing the tidal fresh, riverine-estuarine transition and lower estuarine zones of the Rappahannock (TF3, RET3, and LE3), York (TF4, RET4, and LE4), and James (TF5, RET5, and LE5) rivers, respectively.

Sampling Frequency:
Monthly throughout the year at all 13 stations.

Measurements and Collection Procedures:
Oblique 5-10 minute tows with twin 50-cm diameter 202 μm mesh bongo nets are used to integrate sample collection through the water column from one meter above the bottom to the surface. Ctenophores are removed from the samples prior to processing; settled volume is measured in the field.

Program Deficiencies

1. The Virginia mesozooplankton monitoring program does not record the biomass of the collected ctenophores.

2. Existing monitoring programs do not target sea nettles.

Recommendations

1. Continue existing gelatinous zooplankton monitoring programs.

2. Review the sample collection, identification and enumeration protocols used in the existing gelatinous zooplankton monitoring programs and develop a set of Baywide consensus protocols and a plan for implementing compatible protocols.

3. Initiate measurements of ctenophore biomass as part the ongoing Virginia mesozooplankton monitoring program through development and application of regression formulas of biomass to settled volume.

4. Enhance the capabilities of the Maryland and Virginia's mesozooplankton monitoring programs to characterize sea nettle populations. Twice monthly from May through September at all plankton monitoring stations within the salinity range from 4 to 32 ppt, surface tows of larger plankton nets (50 cm minimum diameter) should be used to collect sea nettles. Total counts, settled volume, and biomass measurements should be made on the collected gelatinous zooplankters.

5. Develop volume:dry weight and volume:carbon regression models to calculate dry weight and carbon biomass for gelatinous predators (this is important information for

ecological models). These models will require that volume, dry weight, and total carbon measurements are made on representative samples of gelatinous predators. Once accurate regression equations are developed, it will be necessary only to measure volume.

Program Integration

As a component of mesozooplankton monitoring, monitoring of gelatinous predators will be integrated with water quality and plankton monitoring programs. Integration of data with finfish early life stage monitoring information should be required. This can be accomplished through correlation of early life stage and gelatinous predator abundances when stations and sampling times are adequately coordinated.

Important Habitat Quality Variables

Water column profiles of temperature and salinity. Composition and distribution of picoplankton, phytoplankton, microzooplankton, and mesozooplankton.

OTHER LIVING RESOURCES MONITORING

The recommended core program, implemented so as to be fully integrated with water quality monitoring, will go far towards meeting the need for comprehensive, long-term information on the relationships between living resources and habitats in Chesapeake Bay. It will track the progress of Bay restoration efforts toward achieving the goal of a more productive and balanced estuarine ecosystem. However, there are important kinds of long-term biological monitoring that are planned or extant that are not specifically represented in the core program:

- monitoring of body burdens of toxic substances in edible finfish and shellfish for the protection of human health;

- monitoring of ambient water and sediment toxicity to aquatic life for the protection of living resources (bioassays or biomonitoring).

- monitoring that will document, on narrowly defined spatial scales, how mesohaline and polyhaline (medium and high salinity) Bay ecosystems respond to specific changes in land use, pollutant loadings and controls, habitat degradation or habitat restoration.

Each of these forms of monitoring clearly is closely related to the living resources monitoring objectives.

TOXICANT BODY BURDEN MONITORING

Because of the expense and technical complexity of body burden monitoring, it was considered impractical to include a specific toxicity component for each functional group in the core monitoring program. There are well-established state and federal programs for monitoring tissue concentrations of toxic substances in edible fish and shellfish, and wildlife species, both for protection of human health and as indicators for tracking environmental toxicant burdens. In the case of a few wildlife species, body burdens can be related directly to health impacts for individual animals or populations.

Descriptions of these programs have not been included in the plan (see USEPA 1988). Because programs of this type generally undergo extensive technical review, it is assumed at present that they are meeting their objectives. However, better communication with the overall living resources monitoring effort is required. Also, the spatial coverage, species selection and frequency of these programs should be reviewed from the perspective of better coordination and integration with water quality and living resources monitoring.

Recommendation

1. Review existing state and federal toxicant body burden monitoring programs for their consistency with living resources monitoring objectives, interjurisdictional comparability, and integration with water quality monitoring.

BIOLOGICAL TOXICITY MONITORING OF AMBIENT WATER AND SEDIMENT

This topic refers to the use of responses in organisms to assess toxicity, or its absence, in the medium to which the organisms are exposed, or biomonitoring. Common test organisms range from bacteria to fish, birds and mammals. Responses to toxicity that are measured include biochemical reactions, physiological changes, behavior, reproductive success, and death.

Maryland and Virginia have established programs for assessing the toxicity of effluents, and requirements for biomonitoring are included in some discharge permits. These effluent programs can track potential degradation of local water bodies by point sources of toxic substances. But studies of the effects of diffuse, usually trace amounts, of toxicants on the health, reproduction and survival of aquatic organisms native to Chesapeake Bay remain largely a topic for laboratory research.

Biomonitoring techniques as applied to the natural waters, sediments, and important native species of estuaries are still largely in an exploratory phase of development. The use of organism responses to monitor habitat toxicity is considerably less expensive on a site-by-site basis than extensive chemical sampling and analysis. Also, biological responses are more relevant to the problems of living resources in nature than chemical sampling or body burden analysis, because they directly reflect impacts to organisms.

Recommendations

1. Based on current pilot programs, identify indicator species, biomonitoring techniques, and specific assays suitable for long-term monitoring of ambient habitat toxicity to Chesapeake Bay living resources; recommend specific geographic areas, media (water, sediment), and monitoring frequency.

2. Implement ambient habitat biomonitoring based on pilot program recommendations.

3. Improve integration and information exchange between ambient, effluent and body burden monitoring programs.

TRIBUTARY ECOSYSTEM MONITORING

This concept reflects a second tier monitoring program that is generic to the estuarine ecosystem, rather than targeted at an individual species or group of species. There is a solid understanding of how many freshwater ecosystems (lakes, ponds, flowing streams) respond to eutrophication, acidification, sediment loading and other impacts related to human activities in watersheds. But for estuaries, particularly the extensive mesohaline and polyhaline segments unique to Chesapeake Bay, there is no clear understanding of these relationships. Particularly problematic are the relationships of higher trophic levels (e.g., finfish) to changes in planktonic and benthic communities. Long-term measurements of key biological and water quality variables in carefully selected embayments or small tributaries of the Bay could illuminate food chain associations and their responses to changes in local watersheds. Appropriate tributaries would serve as natural, mesoscale counterparts of the Bay proper. The selected tributaries should be small enough to permit comprehensive monitoring, and large enough to contain species assemblages representative of the larger Bay ecosystem.

Monitoring will include regular (weekly to monthly) sampling of planktonic and benthic communities, trawling and seining for finfish and crabs, dredge hauls for oysters and benthic epifauna, sea nettle counts, water quality measurements (temperature, *salinity, dissolved oxygen, pH, chlorophyll a, particulate and dissolved* nitrogen and phosphorus, and total suspended solids), and estimates of SAV abundance. Some of these measurements would be quite adaptable to volunteer (citizen) monitoring. Estuarine Research Reserves might be ideal "reference" sites, with developed or developing areas as sites where long-term changes could be documented.

Recommendation

1. Design and implement a small-tributary ecosystem monitoring program, including selection of reference and impacted mesohaline or polyhaline sites in Maryland and Virginia.

TIDAL POTOMAC RIVER LIVING RESOURCES MONITORING PLAN

An integrated biological and water quality monitoring plan for the tidal Potomac River has been drafted by the Interstate Commission on the Potomac River Basin (Appendix A). The first of the Potomac River Plan documents existing programs, identifies additional data needs, indicates possible overlaps and redundancies in data collection, and presents recommendations and funding estimates.

The Potomac River Plan is an initial step towards establishing an integrated Chesapeake Bay water quality and living resources monitoring plan, as opposed to two separate monitoring plans. The Potomac River Plan represents a large step in this direction, by identifying key water quality variables for each biological group, by documenting existing biological monitoring programs, and by making recommendations for an integrated living resources monitoring program responsive to clear objectives.

It should be recognized that the Potomac River Plan describes a number of programs established with a variety of objectives. The structure of the Potomac River Plan is based on relating existing water quality programs with living resources to ascertain status and trends.

Prior to completing a final draft of the Potomac River Living Resources Monitoring Plan, a task force will be established to review the structure and recommendations contained in the draft Plan.

Recommendation

Establish a task force to review the structure and recommendations contained in the Draft Tidal Potomac River Living Resources Monitoring Plan. The task force should include representatives from all agencies, committees, and current monitoring programs concerned with the tidal Potomac River. The task force should develop a final plan with the primary objectives of improving and integrating living resources and water quality monitoring in the tidal Potomac River.

CHAPTER 3
DATA MANAGEMENT AND REPORTING

"Continuous long-term records (i.e., 10-40 years) of biological data are rare for estuarine and coastal systems, and especially so for those time series where uniform sampling strategies and measurement methods have been used together." (Wolfe et al. 1987; page 181).

The Living Resources Monitoring Plan lays out a framework designed for long-term tracking of the abundance and distribution of Chesapeake Bay living resources and habitat quality. The most important product of living resources monitoring will be a large quantity of consistent data of known quality. This data must be managed so that it can be used to meet all monitoring objectives. In addition, long time series will serve as foundations for research, generating hypotheses testable by analysis of the monitoring record and by experimental studies. It will be critical to ensure that data will be readily available, and provide the information necessary to achieve the monitoring objectives.

It must be stressed that data management will be an integral element of the long-term living resources monitoring program. If data are inaccessible, poorly managed, inadequately documented, or not analyzed or reported in a timely manner, monitoring cannot achieve its goals of providing information to the Bay community and serving the restoration and management of the Bay.

DATA ENTRY, STORAGE AND SECURITY

The large quantities of data that are generated by monitoring must be consistent and of known quality. It also is critical that the data be thoroughly documented and easily accessible for analytical and reporting purposes. The key to achieving these goals is to build a data base with common data attributes, in identical or easily translatable formats. The Chesapeake Bay Program's Data Management Plan for Biological Monitoring (USEPA 1987) describes procedures for data documentation, submission, storage, and retrieval of data from the Chesapeake Bay Program Computer Center data base. The Living Resources Monitoring Program will rely initially on the existing Data Management Plan for the technical details of data entry, data storage, and data security. There must be a commitment to update this plan as additional experience is gained with the management of large quantities of biological data.

It may not be appropriate or necessary to store all detailed data records "on line" (i.e., on interactive disk storage). At a minimum, however, all documentation, file access information, and summary data must be on line. Data base management software systems should be evaluated for their ability to provide accessibility and efficient management of the kinds of data generated by living resources monitoring.

DATA ANALYSIS AND REPORTING

The kinds of data analysis done and the ways in which information is presented will be determined by the monitoring objectives (Section I) and by specific information needs (Section II). A brief discussion of suggested analytical procedures and recommended reports follows.

The current status of living resources will be expressed by means (averages) and ranges (minimums and maximums) of true or relative abundance or biomass. These estimates can be compared to target or warning levels, or to long-term means. Trends can be displayed graphically on simple time series plots; where a long enough time series is available, trend lines can be generated by appropriate statistical procedures (see Figure 1). Trends also may be compared to target or warning levels where multiple-year criteria have been established. Caution must be applied in calculating these statistics. Valid comparisons of means and analysis of trends may require transformations of data (e.g., the use of logarithms or square roots rather than raw numbers).

There are many techniques available for investigating associations between variables; a detailed discussion of these methods is not appropriate here. However, much can be learned from the judicious employment of correlational analysis in its many forms (see Figure 2). Water quality trends can be compared to trends in populations of living resources, and trends in the abundance of one species or group can be compared to changes in another species or group. An uncomplicated, but important way of integrating habitat quality and living resources information will entail comparing ranges of habitat (especially water quality) data with critical habitat requirements for target species (Chesapeake Executive Council 1987). Conditions that do not meet habitat requirements at specific seasons and locations will indicate unfavorable environments for the survival and well-being of target species of living resources. Living resources monitoring data will allow tests of this principle and help to refine knowledge of habitat requirements.

To meet short-term (status) objectives, monitoring data will need to be summarized on an annual basis. These summaries should be contained in a brief report showing graphically how the Bay and its living resources are doing. More frequent status reports on selected resources might be generated (*Bay Barometer*). Also for the short term, each program element of the Baywide monitoring program should have complete access to the data base to produce individual program reports.

A user interface to the Chesapeake Bay Computer Center and the associated data base should be developed that will allow any user with a compatible computer terminal to obtain printed data summaries or view standard graphic outputs with a few simple commands or queries. Summary data should include a level of detail that will at least allow characterization of important living resources within each Bay and tributary segment by season (for example, means and ranges of finfish juvenile indices by tributary, chlorophyll *a* by month and segment, etc.). Certain standard statistics should be published promptly after the data are collected (e.g., seasonal or annual indices of abundance).

Long-term monitoring data will be used to meet the objectives of tracking trends and determining associations between living resources and changes in habitat quality. These analyses will give a good picture of progress in the Bay restoration, along with pointing out present or potential problems. As with the short term analyses, information will be generated about how well habitat objectives (e.g., water quality requirements) are met. These longer views will also provide a good vehicle for in-depth review and analysis of living resources monitoring.

There will be many other uses of long-term monitoring data. For example, ecological and economic analyses will benefit greatly from long-term records of resource abundance, improving our understanding of the complex Chesapeake Bay ecosystem and its human benefits. Redundancies and deficiencies in the monitoring program will be uncovered, allowing fine-tuning of the program. Cost efficiencies can be achieved by providing accessible, low- cost, data to researchers. This will reduce redundancies in data collection and eliminate start-up costs for short term data collection efforts. However, priority always must be given to meeting the primary objectives of the monitoring program.

Baywide integration of reporting and analysis will be achieved through a system whereby each data generator performs elements of analysis according to an overall, coordinated work plan. This work plan will be developed and updated annually by the Data Analysis Work Group of the Monitoring Subcommittee.

COMPUTER AND STAFF RESOURCES

It is reiterated that data management will be the most important element of a long-term living resources monitoring program. Data collection, in a sense, is secondary, in that methods can be modified, components added or dropped, and a certain amount of missing data can be tolerated without fatally compromising the program. But if data are inaccessible, poorly managed, or not analyzed or reported in a timely way, *monitoring cannot achieve its goals of providing information* to the Bay community and serving the restoration and management of the Bay. The success of this program will depend upon a commitment to dedicate adequate computer and staff resources to the continuing tasks of data management, analysis and reporting.

The Chesapeake Bay Program is fortunate to have adequate computer resources available to meet the near-term needs of a living resources monitoring program, given that other priorities do not usurp these resources. The VAX 8600 computer that serves the Bay Program apparently has sufficient processing capacity to fulfill living resources monitoring data management needs for at least the first two to three years of the program. Processing and storage upgrades may be needed during this period, but as the computer is shared among several programs, specific hardware recommendations will not be made here.

Current State agency staff cannot meet the data management, analysis, and reporting requirements of the recommended living resources monitoring program. Existing programs are understaffed in this critical area. It is recommended that at a minimum, one staff person should be dedicated full time to each major element of the living resources monitoring program (FINFISH, SHELLFISH, SAV, etc.). These staff will be assigned to appropriate state agencies, but will work closely with the Chesapeake Bay Computer Center staff to ensure that all requirements for data management, analysis and reporting are met.

RECOMMENDATIONS

1. Each element of the living resources monitoring program must routinely submit all data collected as a part of the program to the Chesapeake Bay Computer Center, within deadlines to be established by the Chesapeake Bay Program's Data Management Subcommittee.

2. Living resources and supporting habitat and water quality data previously collected as part of the existing monitoring programs or key historical monitoring

programs will submit these data to the Chesapeake Bay Computer Center within deadlines to be established by the Data Management Subcommittee.

3. The Data Management Plan for Biological Data (USEPA 1987) is adopted by reference as the initial technical plan for data entry, storage and security of living resources monitoring data. All program elements should conform to the Data Management Plan in the submission of data. The Data Management Plan will be updated and expanded to address all forms of living resources data to be collected through the recommended core monitoring program.

4. The Chesapeake Bay Computer Center should strive to improve data accessibility, both to agency users and to a broader community of scientists and citizens. A data base management system, with a user-friendly interface that can produce summary statistics (in more detail than presently available) and graphics, should be developed.

5. A three-tiered reporting system is recommended:

a. annual reports of individual program elements, including key statistics such as annual SAV abundance, juvenile finfish indices, etc. These key statistics should be available through the Chesapeake Bay Program computer as well as in print.

b. annual or biennial integrated reports, built on the example of the *State of the Chesapeake Bay.*

c. occasional synthesis reports (biennial or less frequent), describing trends, correlations, and other results of long-term monitoring.

6. Develop and implement a plan for Baywide integration of reporting and analysis, resulting in a system where each data generator performs elements of the overall, coordinated plan.

7. A professional staff of at least six programmer-statisticians should be dedicated to managing living resources data. Recommended allocations are as follows: three to Virginia (Virginia Marine Resources Commission, Virginia Institute of Marine Sciences, or State Water Control Board, as determined by Virginia participants; two to the Maryland Department of Natural Resources (finfish, shellfish, SAV and second tier monitoring); and one to the Department of the Environment (plankton and benthos). This staff should be assigned to the Chesapeake Bay Liaison Office, in keeping with the Bay Agreement Commitment to strengthen the Liaison Office with staff from state agencies.

CHAPTER 4
IMPLEMENTATION

IMPLEMENTATION STRATEGY

If comprehensive living resources monitoring for Chesapeake Bay is to succeed, the monitoring plan must be both more and less than a list of recommended data collection projects. The plan must reflect a strategic approach to meeting objectives which are very large in ecological, temporal and spatial scope. It also must reflect reasonable assumptions about human, physical, and financial resources. These considerations imply that a carefully defined set of priorities should govern the plan's final recommendations.

In discussions during the development of this plan, it was argued that priorities should be set by identifying a small group of indicator species. Monitoring would focus on collecting abundance and habitat quality data for these target species. Carefully chosen, this small set of species would provide reasonably good information on the status of Bay habitats and trends in the Bay's ability to support important and valuable living resources. This approach offers the attractions of simplicity and low cost.

If the monitoring plan were being developed as the design for a completely new program, the indicator species approach might have been adopted. However, the plan has been developed in an environment where a multitude of biological data collection efforts, touching virtually all components of the Chesapeake Bay ecosystem, are in existence. To a large extent, these efforts, while worthy in themselves, and designed to meet specific information needs, are fragmented and not integrated with water quality monitoring (plankton and benthic monitoring excepted). Therefore, it was considered imperative to establish consistent monitoring methods, coordination, and program integration for a broad spectrum of species and groups of species. Thus, the monitoring plan will serve, in part, as a program guide and methods manual for all those who participate in or design projects for Chesapeake Bay biological data collection.

Monitoring of target species in the past has produced valuable data for many non-target species that are collected incidentally (e.g., juvenile finfish seine and trawl surveys). Also, several existing monitoring programs are designed to collect information on functional groups rather than individual species (e.g., plankton, benthic and SAV monitoring). These considerations have suggested a structural approach to the monitoring plan that combines the concept of ecological relationships (or functional groups) with the practicality of multi-species collection methods. We are led naturally, then, to recommend a *core* monitoring program which will depend, for the most part, upon multi-species collection methods to obtain long-term status and trends information for most of the major components of the Bay ecosystem. There will be many information needs that will not be met by the core program (for example, specific data on life histories and population dynamics required for stock assessments, research projects, or crisis responses), but that are not directly applicable to the major monitoring objectives. However, the core program will provide both a background and a framework for these additional (generally short-term) data collection efforts. In a practical sense, additional data collection can be adapted to the core program on an as-needed basis (e.g., sharing of boat time and biological specimens). Also, to the extent that auxiliary data collection projects adhere to core program methods, compatibility and comparability of data with the core program will be assured.

A CORE LIVING RESOURCES MONITORING PROGRAM

A brief summary of the key elements of the core monitoring program follows. A detailed list of recommendations (extracted from Chapter 2), budget estimates, timelines, personnel needs, administrative and coordinating entities can be found in Table 1. A two-tiered approach to living resources monitoring is recommended, with tier 1 designed primarily to meet monitoring objectives I and II, over broad spatial (the whole Bay) and temporal (monthly to biennial) scales. The second tier addresses objective III at higher resolution in time (daily to monthly) and space (critical habitat areas of selected tributaries) resolution.

FINFISH
- A. Trawl Surveys
    - 1. Baywide survey (pilot program at present)
    - 2. Supplementary trawls (tributaries, shallow waters)
- B. Seine Surveys
- C. Early Life Stage (Egg and Larval) Surveys
    - 1. Bay anchovy & other pelagic estuarine species (first tier)
    - 2. Anadromous fish (second tier)

SHELLFISH
- A. Oysters
    - 1. Dredged shell surveys
    - 2. Habitat monitoring (second tier)
- B. Blue crabs
    - 1. Trawl surveys (see FINFISH)
- C. Hard Clams
    - 1. Virginia recruitment index
- D. Soft Clams
    - 1. Benthic data review (see BENTHIC FAUNAL COMMUNITIES)

WILDLIFE
- A. Waterfowl
    - 1. Annual aerial counts
- B. Other birds
    - 1. Annual counts

PLANT COMMUNITIES
- A. Submerged Aquatic Vegetation
    - 1. Annual overflight program
    - 2. Annual ground survey program
    - 3. Habitat monitoring (second tier)
- B. Tidal Wetlands
    - 1. Biennial baseline monitoring (aerial or satellite)
    - 2. Permit database
- C. Non-tidal Wetlands
    - 1. Biennial baseline monitoring (aerial or satellite)

BENTHIC FAUNAL COMMUNITIES
- A. Benthic infauna
    - 1. Existing Baywide program
- B. Benthic epifauna
    - 1. Oyster dredged-shell surveys (see SHELLFISH)
    - 2. Artificial substrates

PLANKTONIC COMMUNITIES
- A. Picoplankton
    - 1. Pilot monitoring study
- B. Nanoplankton and phytoplankton
    - 1. Existing Baywide program with improvements
- C. Microzooplankton
    - 1. Existing Baywide program with improvements
- D. Mesozooplankton
    - 1. Existing Baywide program with improvements
- E. Gelatinous Zooplankton
    - 1. Existing Baywide program with improvements

TOXICITY AND TOXICANT BODY BURDENS
- A. Existing body burden monitoring with improvements
- B. Develop ambient toxicity biomonitoring program

ECOSYSTEM MONITORING
- A. Initiate program in selected tributaries

Table 1. Monitoring Recommendations, Coordinating Committees, Implementing Agencies, Personnel Needs, and Estimated Costs.

Key

Responsible Coordinating Committees

LRS	Chesapeake Bay Program Living Resources Subcommittee
CBSAC	Chesapeake Bay Stock Assessment Committee
MSC	Chesapeake Bay Program Monitoring Subcommittee
STAC	Chesapeake Bay Program Scientific and Technical Advisory Committee
DMS	Chesapeake Bay Program Data Management Subcommittee

Implementing Agencies and Institutions

DNR	Maryland Department of Natural Resources
VIMS	Virginia Institute of Marine Resources
DCRA	District of Columbia Department of Consumer and Regulatory Affairs
MDE	Maryland Department of the Environment
VWCB	Virginia Water Control Board
FWS	U.S. Fish and Wildlife Service
VDGIF	Virginia Department of Game and Inland Fisheries
NOAA	National Oceanic and Atmospheric Administration
VA COE	Virginia Council on the Environment
EPA	U.S. Environmental Protection Agency
VMRC	Virginia Marine Resources Commission

Abbreviation

TBD	To be determined

Assumptions used in Table 1:

1. Costs for full-time employees (FTEs) were estimated at $30,000 per year, plus 30% for fringe benefits and accessories, a total of $39,000.

2. Costs include estimated amounts for contractual services, vessel costs, minor equipment, supplies, travel, etc.

3. The Living Resources Subcommittee (LRS) has the responsibility to oversee all living resources monitoring elements. Therefore, LRS is shown in Table 1 as the "Responsible Coordinating Committee" only when it has the major or sole responsibility for a monitoring recommendation.

RECOMMENDATION	RESPONSIBLE COORDINATING COMMITTEE	IMPLEMENTING AGENCIES AND INSTITUTIONS	TARGET DATE FOR IMPLEMENTATION OR REVIEW COMPLETION	ADDITIONAL PERSONNEL REQUIREMENTS
FINFISH				
A. Seine surveys				
1. continue existing seine surveys	CBSAC	DNR/VIMS/DCRA	current	
2. target additional species	CBSAC	DNR/VIMS/VMRC/DCRA	7/90	1
3. analytical review of seine data	CBSAC	DNR/VIMS/VMRC/DCRA	7/89	
B. Trawl surveys				
1. continue tributary trawl surveys in VA & DC	CBSAC	VIMS/DCRA	current	
2. initiate small gear trawls in MD & VA	CBSAC	DNR	7/90	2
3. implement standard Bay-wide trawl survey	CBSAC	DNR/VIMS/VMRC/DCRA	workshops-2/89; implement-7/89	
C. Early life stage monitoring				
1. continue existing programs	MSC/CBSAC	DNR/VIMS	current	
2. enhance existing programs	MSC/CBSAC	DNR/VIMS	2/90	4
3. high frequency plankton monitoring	MSC	DNR/VIMS	2/90	
4. bay anchovy sampling	MSC/CBSAC	DNR/VIMS or MDE/VWCB	7/90	
5. program review workshop	MSC/CBSAC		7/89	
SHELLFISH				
A. Oysters				
1. continue dredged shell surveys	CBSAC	DNR/VIMS	current	
2. Maryland spring survey	CBSAC	DNR	4/90	
3. calibrate dredge sampling	CBSAC	DNR/VIMS	12/89	
4. enhance 2nd tier monitoring	CBSAC	DNR/VIMS	1/90	2
B. Blue Crabs (see FINFISH, B.1. and B.2.)				
C. Hard Clams				
1. Virginia recruitment index	CBSAC	VMRC/VIMS	7/90	1
D. Soft Shell Clams				
1. continue Maryland Soft Clam survey	CBSAC	DNR	current	
2. review benthic data	MSC/CBSAC/LRS	DNR/MDE	7/89	
3. improve soft clam reporting	CBSAC	DNR	7/89	
WILDLIFE				
A. Waterfowl				
1. continue annual aerial counts	MSC	FWS/DNR/VDGIF	current	
2. improve information exchange	MSC	FWS/DNR/VDGIF	7/89	
3. historical correlations	MSC	FWS/DNR/VDGIF	12/89	
4. improve program integration	MSC	FWS/DNR/VDGIF	12/89	2
5. design second tier monitoring program	MSC	FWS/DNR/VDGIF	7/89	
B. Colonial Birds				
1. continue existing surveys	MSC	FWS/VDGIF	current	
3. improve information exchange	MSC	FWS/DNR/VDGIF		
4. improve MD-VA program integration	MSC	FWS/DNR/VDGIF		
C. Shore and Seabirds				
1. continue existing surveys	MSC	FWS/DNR/VDGIF	current	
2. improve information exchange	MSC	FWS/DNR		
D. Raptors				
1. continue existing eagle and osprey surveys	MSC	FWS/DNR/VDGIF	current	
2. improve information exchange	MSC	FWS/DNR/VDGIF		
E. Reptiles and Amphibians				
1. continue VA sea turtle survey	MSC	NOAA/FWS/VDGIF	current	
F. Mammals				
no recommendations				
PLANT COMMUNITIES				
A. Submerged Aquatic Vegetation				
1. continue overflight program	MSC	FWS/DNR/VIMS/EPA/ USGS/NOAA/VA COE	current	
2. continue ground surveys	MSC	DNR/VIMS/USGS	current	
3. evaluate MD ground survey program	MSC	DNR	12/88	
4. evaluate satellite scanners	STAC/MSC	FWS/DNR/VIMS/EPA	7/89	
5. enhance 2nd tier monitoring	MSC	DNR/VIMS	7/90	

ESTIMATED COST INCLUDING PERSONNEL	EXISTING PROGRAM COST	ADDITIONAL COST FOR IMPLEMENTATION	COMMENTS
$80,000.00	$80,000.00		
$80,000.00		$80,000.00	Pending Review
staff review		staff review	
$128,000.00	$128,000.00		
$88,000.00		$88,000.00	
$658,000.00	$658,000.00		
$400,000.00	$400,000.00		
$200,000.00		$200,000.00	
$50,000.00		$50,000.00	
$30,000.00		$30,000.00	
staff		staff	
$40,000.00	$40,000.00		
$20,000.00		$20,000.00	
$20,000.00		$20,000.00	
$123,000.00	$40,000.00	$83,000.00	
$45,000.00		$45,000.00	
$10,000.00	$10,000.00		
staff review		staff review	
$10,000.00	$10,000.00		
$78,000.00		$78,000.00	
staff		staff	
$28,730.00	$73,730.00	($45,000.00)	current MD program is intensive; long-term annual cost lower
$10,000.00	$10,000.00		
$36,000.00	$36,000.00		
TBD	TBD		
$160,000.00		$160,000.00	no permanent funding; stable funding badly needed
$50,000.00	$50,000.00		
staff review		staff review	
staff review		staff review	
$50,000.00		$50,000.00	

RECOMMENDATION	RESPONSIBLE COORDINATING COMMITTEE	IMPLEMENTING AGENCIES AND INSTITUTIONS	TARGET DATE FOR IMPLEMENTATION OR REVIEW COMPLETION	ADDITIONAL PERSONNEL REQUIREMENTS
B. Benthic Algae and Macroalgae				
No recommendations				
C. Tidal Wetlands				
1. baseline monitoring program	LRS	DNR/VIMS	7/90	
2. maintain permit data base	LRS	DNR/VIMS	current	
D. Non-Tidal Wetlands				
1. baseline monitoring program	LRS	DNR/VIMS	7/90	
2. maintain activities data base	LRS	DNR/VIMS	current	
BENTHIC FAUNAL COMMUNITIES				
A. Benthic Infauna				
1. continue existing programs	MSC	DNR/MDE/DCRA/ VWCB/VIMS	current	
2. review existing programs for Baywide consistency	MSC	DNR/MDE/DCRA/ VWCB/VIMS	7/89	
3. review VA benthic monitoring	MSC	VWCB	7/89	
B. Benthic Epifauna				
1. continue monitoring as component of oyster dredge surveys	CBSAC/MSC		current	
2. improve data management/reporting	MSC/DMS	DNR/VIMS		
3. review existing surveys for Baywide consistency	MSC	DNR/VIMS	7/89	
4. design artificial substrate program	MSC	MDE/VWCB or DNR/VIMS	12/89	
PLANKTONIC COMMUNITIES				
A. Picoplankton				
1. implement pilot study	MSC	MDE/VWCB	7/90	
2. implement monitoring program	MSC	MDE/VWCB	1/91	
3. monitor water column respiration	MSC	MDE/VWCB	7/89	
4. measure sulfides	MSC	MDE/VWCB	7/89	
B. Nanoplankton & Phytoplankton				
1. continue existing programs	MSC	MDE/VWCB/DCRA	current	
2. review existing programs for Baywide consistency	MSC	MDE/VWCB/DCRA	7/89	
3. Virginia primary production	MSC	VWCB	7/89	
4. evaluate size fractionation	MSC	MDE/VWCB/DCRA	7/89	
5. intensive monitoring in specific habitats	see FINFISH, OYSTERS, SAV			
C. Microzooplankton				
1. continue existing program	MSC	MDE	current	
2. review existing programs for Baywide consistency	MSC	MDE/VWCB/DCRA	12/89	
3. initiate monitoring in VA	MSC	VWCB	7/90	
4. high frequency sampling	see FINFISH, OYSTERS, SAV			
D. Mesozooplankton				
1. continue existing programs	MSC	MDE/VWCB/DCRA	current	
2. review existing programs for Baywide consistency	MSC	MDE/VWCB/DCRA	12/89	
3. high frequency sampling	see FINFISH			
E. Gelatinous Zooplankton				
1. continue existing programs	MSC	MDE/VWCB	current	
2. review existing programs for Baywide consistency	MSC	MDE/VWCB	12/89	
3. initiate measurements of ctenophore biomass in VA	MSC	VWCB	1/89	
4. sea nettle monitoring	MSC	MDE/VWCB	1/89	
5. develop dry wgt. & carbon biomass regressions	MSC	MDE/VWCB	1/89	
ADDITIONAL MONITORING				
A. Toxics body burden monitoring				
1. review existing programs for Baywide consistency	MSC	EPA/FWS/DCRA/NOAA/ DNR/VIMS/VWCB/MDE	7/89	
B. Biological toxicity monitoring				
1. identify toxicity assays	MSC/STAC	EPA/FWS/DCRA/ DNR/VIMS/VWCB/MDE	7/89	
2. implement habitat toxicity monitoring	MSC	EPA/FWS/DCRA/ DNR/VIMS/VWCB/MDE	7/89	2
3. integrate toxicity monitoring	MSC/STAC	DNR/VIMS/VWCB/MDE	7/89	1
C. Ecosystem Monitoring				
1. initiate program	MSC	DNR/VWCB/MDE/VIMS	7/90	4

ESTIMATED COST INCLUDING PERSONNEL	EXISTING PROGRAM COST	ADDITIONAL COST FOR IMPLEMENTATION	COMMENTS
$50,000.00		$50,000.00	annualized cost for biennial program
$50,000.00	$50,000.00		
$50,000.00		$50,000.00	annualized cost for biennial program
$50,000.00	$50,000.00		
$500,000.00	$500,000.00		
staff review		staff review	
staff review		staff review	
see OYSTERS	see OYSTERS		
see DATA MANAGEMENT			
staff review		staff review	
staff review		staff review	
$30,000.00		$30,000.00	
$30,000.00		$30,000.00	
$20,000.00		$20,000.00	
$5,000.00		$5,000.00	
staff review		staff review	
$22,000.00		$22,000.00	
staff review		staff review	
staff review		staff review	
$51,500.00		$51,500.00	
staff review		staff review	
see MESOZOOPLANKTON		see MESOZOOPLANKTON	
staff review		staff review	
no add. cost		no add. cost	
$4,000.00		$4,000.00	
no add. cost		no add. cost	
staff review		staff review	
$180,000.00	$120,000.00	$60,000.00	
$100,000.00		$100,000.00	
$40,000.00		$40,000.00	
$200,000.00		$200,000.00	

RECOMMENDATION	RESPONSIBLE COORDINATING COMMITTEE	IMPLEMENTING AGENCIES AND INSTITUTIONS	TARGET DATE FOR IMPLEMENTATION OR REVIEW COMPLETION	ADDITIONAL PERSONNEL REQUIREMENTS
DRAFT TIDAL POTOMAC RIVER LIVING RESOURCES MONITORING PLAN				
1. establish review task force	LRS/MSC	TBD	10/88	
DATA MANAGEMENT				
1. submission of living resources data	DMS	MDE/DNR/VMRC/VWCB VIMS/DCRA/FWS/EPA	12/88	
2. historical data submission				
3. Data Management Plan revision	DMS	MDE/DNR/VMRC/VWCB MDE/DNR/VMRC/VWCB VIMS/DCRA/FWS/EPA	12/88	
4. improve data accessibility	DMS	MDE/DNR/VMRC/VWCB VIMS/DCRA/FWS/EPA	12/89	
5. integrate reporting system	MSC/DMS	MDE/DNR/VMRC/VWCB VIMS/DCRA/FWS/EPA	7/89	
6. develop data analysis and reporting work plan	MSC	MDE/DNR/VMRC/VWCB VIMS/DCRA/FWS/EPA	7/89	
7. data management staff	DMS	DNR/MDE/VWCB/VMRC	12/88	6
TOTALS				25

ESTIMATED COST INCLUDING PERSONNEL	EXISTING PROGRAM COST	ADDITIONAL COST FOR IMPLEMENTATION	COMMENTS
staff		staff	
staff		staff	
staff		staff	
staff		staff	
staff		staff	
$234,000.00		$234,000.00	
$4,011,230.00	$2,255,730.00	$1,755,500.00	

Full implementation of the plan recommendations will require approximately two years. During this period, there will be variations in funding as new elements are implemented and cost reductions occur in other elements. Year-by-year funding estimates are summarized in Table 2.

Table 2. Estimated Costs of Living Resources Monitoring by Federal Fiscal Year (October-September). The increment is the amount required above current costs.

Year	Increment	Total Cost
1989	$ 645,000	$2,900,730
1990	$1,080,500	$3,981,230
1991	$ 30,000	$4,011,230

Target species, critical habitats, and sensitive life stages of Chesapeake Bay living resources were identified by a task force for initial attention in the compilation of information on their habitat requirements (Chesapeake Executive Council 1987). Table 3 shows how the recommended monitoring elements apply to these target species and to key ecological groups.

Table 3
Target and Prey Living Resources Monitored through the Core Living Resources Monitoring Program

TARGET SPECIES * (Striped bass – Redhead grass); PREY SPECIES * (Emergent vegetation – Gelatinous zooplankton)

CORE PROGRAMS	Striped bass	Blueback herring	Alewife	American shad	Hickory shad	Yellow perch	White perch	Menhaden	Spot	Anchovy	American oyster	Blue crab	Hard clam	Softshell clam	Redhead duck	Black duck	Canvasback	Wood duck	Great blue heron	Little blue heron	Green-backed heron	American egret	Snowy egret	Osprey	Bald eagle	Widgeongrass	Eelgrass	Wild celery	Sago pondweed	Redhead grass	Emergent vegetation	Benthic infauna	Benthic epifauna	Picoplankton	Nannoplankton	Phytoplankton	Microzooplankton	Mesoplankton	Gelatinous zooplankton
Seine Surveys	■	■	■	■	■		■	■	■	■																													
Baywide Trawl Surveys	■	■	■				■	■	■	■		■																											
Upper Tributary Trawl Surveys	■	■	■	■	■	■	■			■		■																											
Early Life Stage Surveys	■	■	■	■	■	■	■			■																													
Oyster Bar Surveys											■																						■						
Oyster Habitat Monitoring											■																						■						
Hard Clam Monitoring													■																										
Softshell Clam Monitoring														■																									
Waterfowl Surveys															■	■	■																						
Colonial Bird Surveys																			■	■	■	■	■																
Shore Bird Surveys																																							
Raptors Surveys																								■	■														
SAV Surveys																										■	■	■	■	■									
Tidal Wetlands Surveys																															■								
Non-tidal Wetlands Surveys																															■								
Benthic Infauna Monitoring														■																		■							
Benthic Epifauna Monitoring											■																						■						
Picoplankton Monitoring																																		■					
Phytoplankton Monitoring																																			■	■			
Microzooplankton Monitoring																																					■		
Mesozooplankton Monitoring																																						■	■

* From Habitat Requirements for Chesapeake Bay Living Resources (U.S. EPA 1988)

INSTITUTIONAL AND FISCAL CONSIDERATIONS

Governance

The implementation, continuation and further development of living resources monitoring will be overseen at the technical level by three interstate, interagency groups: (1) The Chesapeake Bay Living Resources Subcommittee (all monitoring components); (2) The Chesapeake Bay Stock Assessment Committee (finfish and shellfish); and (3) The Chesapeake Bay Monitoring Subcommittee (plankton, benthos, wildlife, SAV). Overall program coordination will be the responsibility of the Living Resources Subcommittee. At least until the recommendations of this plan are fully implemented, the Living Resources Monitoring Work Group, with direction from the technical groups, should continue its role in assisting with planning and development. The Work Group should include representatives from each of the three technical committees and subcommittees and members with technical knowledge of each of the major ecosystem components (plankton, benthos, etc.). Management oversight, to ensure that this plan is implemented and that monitoring programs are consistently conducted and properly integrated, will be maintained by the Chesapeake Bay Implementation Committee.

Funding

Current biological monitoring programs are financed by a complex of state and federal agencies and initiatives. This is one of the reasons for the present lack of coordination and integration. It can be anticipated that no agency will eagerly give up programs or funding so that long-term monitoring can enjoy a single funding source. However, a dedicated, stable, consistently managed funding base will be required to support living resources monitoring. There are several possible ways to resolve this issue.

Alternatives for Funding

a. Establish a new, joint Federal-State initiative package to fund the core living resources monitoring program. The advantages are "new" money and central administration (e.g. by the Implementation Committee). This alternative offers the best chance of success. Several existing programs with direct living resources monitoring commitments could be incorporated with little additional cost or programmatic impact. This option might be funded by new fees, licenses, taxes, or endowed by capital bond issues. An equitable approach, with insignificant financial impact on individual citizens, would be a surtax placed on state income taxes, with proceeds put into special funds dedicated to the monitoring program. The cost per taxpayer (Maryland, Virginia, and District of Columbia) could be as little as $0.25 per year. A surtax does not increase tax *rates*, and is directly accountable because of its visibility both to taxpayers and legislators.

b. Pool existing budgets through interagency agreements, with enhancements as necessary to implement the core program. This would permit central administration, although less certainly than (a), and would require less new money than (a), but might require diversion of funds to monitoring from other activities. From a pragmatic point of view, this option probably would encounter insurmountable bureaucratic resistance.

c. Continue current funding arrangements, with enhancements as necessary. The advantage is minimum impact upon existing programs. The major disadvantages would be (1) the difficulty of achieving the integration and coordination critical to the success of the core monitoring program, and (2) the likelihood that non-dedicated funds eventually will be diverted from long-term monitoring to meet other immediate priorities. For this reason, this alternative probably has the least chance of success.

Initial implementation of the plan will depend upon funding alternative c. for funding. This will permit immediate action on a number of the plan recommendations. However, the responsible committees and agencies (Tables 1 and 2) should continue to seek a stable, dedicated source of funds. Success in this endeavor will ensure the availability of comprehensive, long-term living resources information for Chesapeake Bay.

Priorities for Implementation

It is recommended strongly that this plan be implemented as a whole, according to the target dates shown in Tables 1 and 2. However, it is possible to rank generic elements of the plan according to their importance in meeting the monitoring objectives.

1. **Existing living resources monitoring programs**
   Only those elements of current programs that well serve long-term monitoring objectives have been documented in the plan. Recommended new or enhanced monitoring elements should not be implemented with funds released by termination or reduction of existing programs.

2. **Data management staff**
   People to manage, analyze and report living resources monitoring data are a critical element of the plan. The presently poor flow of information from existing programs will be improved greatly by dedicating staff to these tasks. No additional program elements should be implemented before sufficient data management staff are available.

3. **Program review elements**
   Several detailed reviews of existing programs are recommended. Most of these reviews can be performed by existing staff, at little or no additional cost. The purposes of the reviews are to improve the quality of information gathered by existing monitoring programs, to explore more efficient methods and sampling designs, and to consolidate and integrate separate programs where possible.

4. **New and enhanced programs**
   Most of the projected cost increments for implementation of the plan are associated with new or enhanced data collection efforts. These elements were recommended because they will generate important, long-term information on target species that are poorly represented by current sampling (e.g., bay anchovy), or on critical living resources problems (e.g., toxicity in Bay habitats). It is a better stategy to implement these new monitoring elements under the guidance of a comprehensive Baywide plan, rather than

allow them to be developed in piecemeal fashion as the information becomes immediately necessary.

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APPENDIX A
DRAFT LIVING RESOURCES MONITORING PLAN
FOR THE TIDAL POTOMAC RIVER

INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN

8/11/88
Revised

DRAFT

TIDAL POTOMAC RIVER LIVING RESOURCES MONITORING PLAN

The Potomac River is a major spawning and nursery area for anadromous and estuarine fish, including striped bass, river herring, American shad, white perch and Bay anchovy. The living resources of the Potomac River have experienced in recent years the same patterns of degradation shown in the entire Chesapeake Bay: declines in stocks of anadromous fish, oysters, and submerged aquatic vegetation (SAV), algal blooms, and depletion of dissolved oxygen. The Potomac River also shares with the Bay some early signs of recovery of living resources, particularly the reestablishment of SAV in some areas. The Potomac River is clearly an integral part of monitoring and research on its living resources. The river can thus function as an important model of the Bay as a whole to explore strategies for monitoring and restoration of the Bay's living resources.

The recommendations made here for the Potomac River are intended to be compatible with the Baywide monitoring plan. The recommendations are made in the context of existing monitoring programs in the Potomac River, which are more comprehensive than those currently operating in some other areas of the Bay. This plan has been developed to monitor large-scale and long-term trends in living resources in the Potomac River; it does not address aspects of present monitoring programs designed to detect local impacts of point sources of pollutants or other disturbances, such as benthic monitoring conducted for the Maryland Power Plant Research Program.

I. Plankton and Benthos Monitoring:

Coordinated monitoring of water quality, plankton, and benthos is recommended at a fixed set of stations in the tidal Potomac River. All of these stations are at or near existing water quality stations in the Coordinated Potomac Regional Monitoring Program (CPRMP), and some biological monitoring is presently conducted at all of these stations by either the State of Maryland, the District of Columbia, or George Mason University. The recommended stations, ordered by program and from upstream to downstream are:

District of Columbia:
- Key Bridge (Water quality station PMS-10)
- Anacostia River at Pennsylvania Ave. (ANA-14)
- Naval Research Laboratory (PMS-37)

George Mason University:
- Four stations in Gunston Cove, Dogue Creek, and the adjacent Potomac River mainstem (POH-232 and XFB-1433)

Maryland:
- Indian Head (XEA-6596)
- Maryland Point (XDA-1177)
- Ragged Point (XBE-9541)

These stations provide good coverage of the tidal Potomac River. D.C.'s programs follow input into the tidal river from the free-flowing Potomac and Anacostia Rivers. George Mason University and Maryland's Indian Head station monitor the freshwater tidal river, while Maryland's downstream stations cover the transition and mesohaline zones.

Phytoplankton monitoring:

Sample frequency: Monthly Oct.-Mar., twice monthly Apr.-Sept.
Sample variables: Phytoplankton cell counts, chlorophyll a, primary productivity, water column respiration (BOD or other).

Zooplankton and Ichthyoplankton monitoring:

Sample frequency: Monthly
Sample variables: >44 um microzooplankton, >202 um mesozooplankton, >333 um ichthyoplankton (fish eggs and larvae). All samples should be integrated vertical samples of water column.

Benthos monitoring:

Sample frequency: Quarterly
Sample variables: Benthos enumeration and biomass, associated sediment variables: silt-clay, carbon and moisture content as a percentage of sediment dry weight, interstitial salinity. Also annual measurements of sediment median diameter, sorting coefficient, and carbonate content. At each station in the mainstem river, samples should be taken in mid-channel and shallow water near-shore habitats. This sample design is sufficient to measure effects of seasonal development of anoxia in mid-channel.

II. Intensive monitoring of egg and larval stages of anadromous fish

A new program is recommended for high-frequency monitoring of spawning and nursery habitats to examine relationships of critical larval stages of commercially important anadromous fish with water and habitat quality. The absence of declines in stocks of marine spawning fish in the Chesapeake Bay suggest that unfavorable conditions during portions of the life cycle spent in freshwater tributaries are responsible for decreases in stocks of anadromous fishes. The coordination of spring gill net surveys of spawning stocks, summer juvenile index surveys, and this ichthyoplankton monitoring program will permit estimates of relative rates of reproduction, growth, and survivorship during all freshwater phases of the life cycles of these fish.

Station Locations (water quality station number):

Smith Point (XDA 4238).
Possum Point (XEA 1840).
Piscataway Creek (XFB 1986).
Broad Creek (--).

Smith and Possum Points represent prime spawning and nursery areas for striped bass and white perch, while Piscataway and Broad Creeks are major spawning sites for anadromous Clupeids and white perch. An alternative site on the Virginia site of the river would be Gunston Cove (POH 232), which is also a major spawning site for Clupeids and white perch. See Figure 1 for map locations of stations.

Sample Frequency:

Weekly, 1 April through 30 June. Extra sampling following major storm events.

Minimal Biological Monitoring Parameters:

Fish eggs and larvae
Mesozooplankton
Microzooplankton
Phytoplankton

Minimal Water Quality Parameters:

Temperature
Dissolved oxygen
Conductivity
pH
Secchi depth
Total suspended solids
Chlorophyll-a
Heavy metals

III. Finfish Monitoring

Continuation of several existing fishery monitoring programs is recommended:

Maryland Spawning Striped Bass Assessment:

Sample frequency: Daily, early April-late May.
Stations: Drift gill nets placed between Maryland Point (XDA-1177) and Indian Head (XEA-6596).

Maryland Juvenile Index Survey:

Sample frequency: Monthly, July-Sept.
Stations: Beach haul seine samples at 18 stations in tidal Potomac River.

D.C. Fisheries Monitoring:

a. Gill net sampling of anadromous fish, Feb.-late summer.
b. Shore haul seine, monthly March-December.

George Mason University Fisheries Monitoring:

Gunston Cove area, Monthly March-November
a. Bottom trawl - 5 stations
b. Beach haul seine - 4 stations

Potomac River Fisheries Commission:

Annual compilation of commercial finfish and shellfish landings.

New Anadromous Clupeids Survey:

Maryland's spring gill net and summer juvenile index haul seine surveys, which are directed primarily at striped bass, do not provide good estimates of relative abundance of anadromous Clupeids because they differ in habitat use and gear vulnerability. A separate program is necessary, directed at the anadromous Clupeids.

Pound nets or gill nets targeted at Clupeids could be used to obtain estimates of relative abundance of adult spawners. Sampling should be conducted in the upper freshwater tidal Potomac, which is the major spawning area for anadromous Clupeids. Four stations are recommended, to be sampled at least three times weekly during April-May: Mattawoman Creek, Gunston Cove, Piscataway Creek, and Broad Creek.

Juvenile Clupeids largely occur in mid-channel and recent growth of SAV in the upper freshwater tidal Potomac has restricted opportunities for seining (Jones et al. 1987; Dale Weinrich and Steve Early, personal communication), so relative abundances of juvenile Clupeids should be estimated by biweekly sampling between July and September using a midwater trawl. The same four stations as used for adult spawners should be sampled for juveniles. Clupeids become able to effectively avoid midwater trawls by the time they reach a size of 100-120 mm (Dale Weinrich, personal communication). Some young-of-the-year Clupeids may reach this size range by fall (Lippson et al. undated), but midwater trawls should produce accurate estimates of relative abundance through late summer.

IV. Oyster Monitoring

Present annual surveys of oyster populations are insufficient to adequately assess population status and trends and relationships with water quality. Three key oyster bars are selected for intensive monitoring while Maryland and PRFC continue less intensive monitoring of other key bars for management purposes. The three key bars recommended for intensive monitoring are Cedar Point, Ragged Point, and Cornfield Harbour Bars (See Figure 1). These three bars are approximately equally spaced along the zone of the estuary that supports producing oyster bars, and all are adjacent to existing water quality stations (XDC 1706, XBE 9541, and MLE 2.3, respectively). The Ragged Point bar is also adjacent to a recommended plankton and benthos monitoring station.

Currently, spring bar surveys and shellstring surveys of spatfall are conducted only in Virginia tributaries of the

Chesapeake Bay. Since planktonic larvae drift for long distances before settling, to accurately assess oyster reproduction and recruitment it is necessary to conduct comparable monitoring programs in both Virginia and Maryland waters.

At each station, spring and fall dredge surveys should be conducted, measuring oyster abundance, size structure, condition, disease prevalence, mortality, contaminant burden, predators, fouling, and spat count. The objectives of the additional spring survey are to determine bushel counts, size distribution, and condition of market and seed oysters on selected bars prior to fall harvest. These measurements will provide estimates of relative population sizes, health, growth rates, and reproduction that may be related to water quality variables monitored at the same site. Spring condition will provide an index of health and spawning condition which may be related to later spatfall. The dredge surveys should be conducted with sufficient replication to ensure accurate and precise measurements of oyster populations.

From June through early October, weekly surveys of spatfall on shellstrings should be conducted on at least the Cornfield Harbour, Great Neck, and Ragged Point Bars. Generally, spatfall on Potomac River oyster bars is poor, except for near the mouth of the River. Cornfield Harbour and Great Neck regularly receive a moderate to heavy set (Whitcomb 1987). Ragged Point rarely receives spatfall, but its proximity to water quality and plankton monitoring stations will be useful in analyzing the causes of poor set in much of the oyster producing area of the river.

Spatfall on shellstrings is correlated with that on bottom cultch, although recruitment on bottom cultch may be reduced due to prevention of settlement by fouling or due to post-settlement mortality (Whitcomb 1987). Thus, spatfall on shellstrings indicates the availability of oyster larvae for recruitment. If recruitment is not noted in the subsequent fall bar survey, then settlement and post-settlement processes must be studied further to understand the causes for recruitment failure. Monitoring data on fouling, predators, and water quality will help in determining these causes.

Although the selected oyster bars are near water quality monitoring stations, water quality at the shallow bars may differ from that at the mid-channel monitoring stations. Therefore, CPRMP water quality variables should be measured on the oyster bars in coordination with both the dredge and shellstring surveys.

V. Aquatic Vegetation Monitoring

The current aerial submerged aquatic vegetation (SAV) survey should be continued to provide data on distribution and percent cover. Priority should be placed on maintaining annual aerial surveys of SAV in order to maintain an archive of data for analysis of long-term trends, even if digitization and interpretation of data is conducted only periodically. Ambient water quality standards for SAV are currently under development (SAV Workgroup). These standards are being formulated in part based on monitoring of water quality and SAV distribution in the Potomac River. Continued monitoring of trends in water quality and SAV distribution will contribute towards verification of these standards.

A biennial aerial survey of tidal wetlands should be instituted in conjunction with the current aerial SAV survey.

VI. Data Management

Currently, there are limited centralized data management facilities for living resources monitoring data collected on the Potomac River. Most monitoring programs produce summary data reports, although sometimes at irregular intervals. However, availability of the data reports is extremely limited, and they can usually be obtained only by contacting the individuals or programs conducting the work. The Metropolitan Washington Council of Governments (COG) has been collecting biological data from various programs monitoring the Potomac River since 1984. However, this biological data has not been entered into a usable computerized database by COG, as has been done for water quality data. There is need for a centralized data bank in which living resources data is entered in a standardized format and made available to researchers, managers, and the public. The data bank should be part of a proposed central data management facility for Bay-wide living resources monitoring data, to be located at the CBLO Computer Center in Annapolis, Maryland. The feasibility of maintaining a separate database for Potomac River living resources data should be explored. COG would be a logical location for a Potomac living resources database, since they already maintain the Potomac water quality database, and have been collecting biological data. If a separate computerized living resources database is developed for the Potomac River, it should be compatible with the CBLO Bay-wide database.

VII. Data Analysis

Statistical techniques need to be established for interpreting the long-term, multivariate data sets to be produced by the monitoring program. Two types of analysis must be applied to the data for judging the effectiveness of management actions in improving biotic resources in the Potomac River. First, the data needs to be analyzed for temporal trends. Most commonly, linear regression analyses are applied to analyses of temporal trends in water quality variables. However, a number of assumptions of such parametric analyses may be violated in water quality and living resources data sets. An alternative test for trend, the Seasonal Kendall Tau test, has been developed for detection of trends in water quality time series (Hirsch et al. 1982), and has been used in analysis of trends in water quality in the Potomac River (ICPRB 1987). These techniques (linear regression and Kendall Tau) are useful for detecting linear, or at least consistent, temporal trends. For other types of nonlinear trends, such as cyclic behavior, spectral analysis or some type of curvilinear regression analysis would have to be employed.

The second type of analysis to be applied to monitoring data is analysis of relationships among variables. Analyses of varying complexity can be applied. The simplest would be parametric or nonparametric correlations between two variables, such as relating a single living resources to a single water quality variable. Multiple and partial correlations, or multivariate analyses such as principal components analysis, can be used to relate one living resources variable to a set of other variables. Finally, two sets of independent variables, such as water quality and living resources variables, may be related through multivariate techniques, such as canonical correlation analysis.

The results of data analysis will assist in development of research programs addressing causal relationships among variables. When the causal relationships among living resources, habitat quality, and water quality are firmly established through a combination of monitoring and research, this knowledge can be used in improved modeling efforts to predict the consequences of management actions for living resources in the Potomac River and the Chesapeake Bay. Thus, monitoring, research, and modeling efforts will jointly contribute to management of the Chesapeake Bay restoration.

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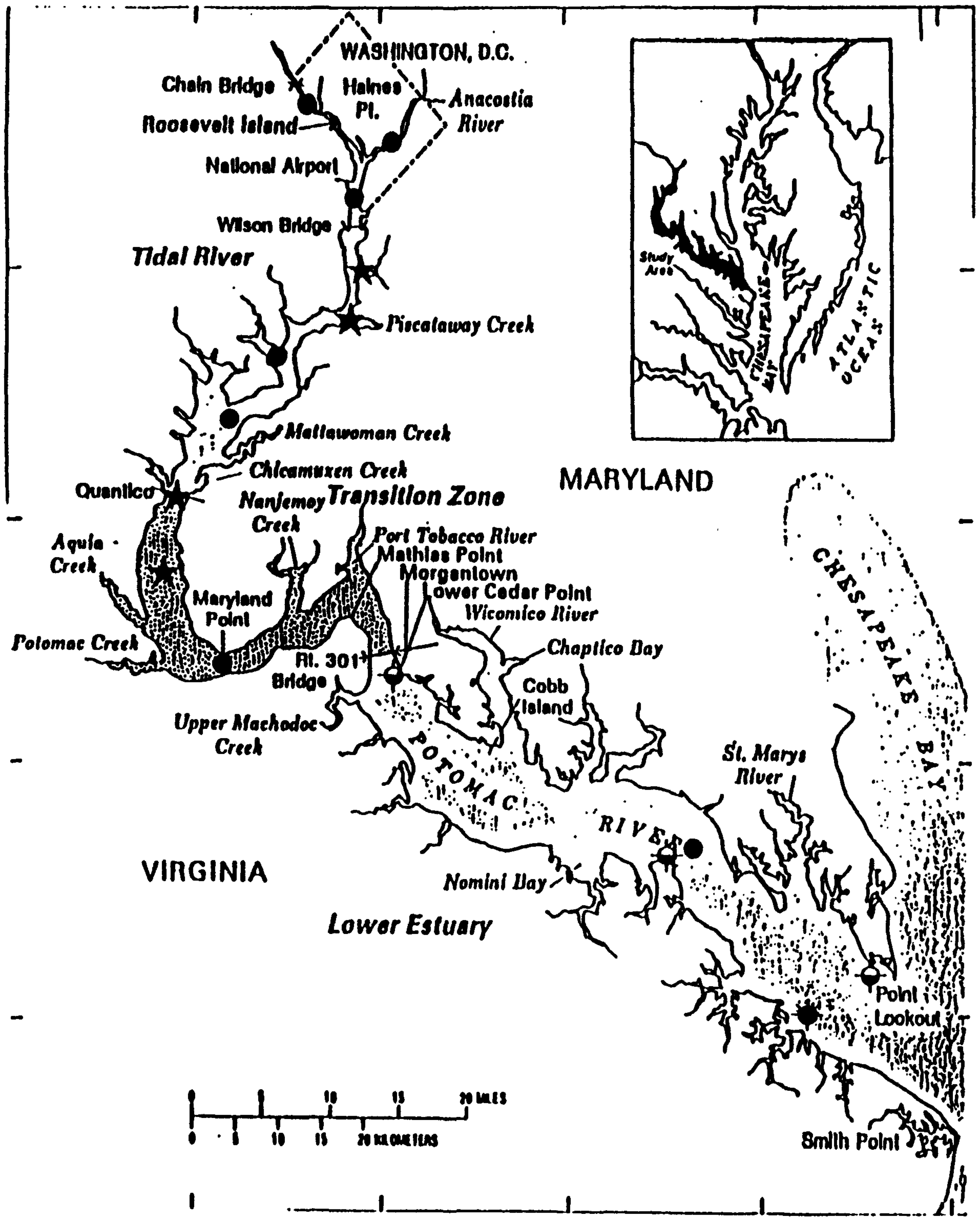

FIGURE 1

Recommended monitoring stations.

● - Plankton and benthic monitoring stations.

★ - High-frequency ichthyoplankton monitoring stations.

⊕ - Selected key oyster bar stations.

✹ - Great Neck bar (spatfall monitoring station).

INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN

RECOMMENDED BIOLOGICAL MONITORING PROGRAMS ON THE TIDAL POTOMAC RIVER

	STATIONS	RESPONSIBLE AGENCY	SAMPLE VARIABLES	SAMPLE FREQUENCY	ESTIMATED COST
Plankton and Benthos Monitoring	Indian Head (XEA 6596) Maryland Point (XDA 1177) Ragged Point (XBE 9541)	Maryland " "	Plankton -cell counts -chlorophyll-a -primary productivity	Twice monthly Apr-Sept. Monthly Oct.-Mar.	Plankton Maryland $115,000 GMU $ 29,600 D.C. $ 50,000
	4 stations in Gunston Cove, Dogue Creek, Potomac River (near POH 232 & XFB 1433)	George Mason University	-water column respiration -integrated water column measurements		
	Key Bridge (PMS 10) Naval Research Lab (PMS 32) Anacostia River at Pennsylvania Avenue (ANA 14)	D. of Columbia " "	Zooplankton ->44um microzooplankton ->202um mesozooplankton ->333um ichthyoplankton -integrated water column measurements	Monthly	
			Benthos ->500um macrobenthos -associated sediment variables -collected in shallow & mid-channel sites at each station	Quarterly	Benthos Maryland $ 59,500 GMU $ 20,300 D.C. $ 30,000
Intensive Monitoring of Anadromous Fish Larval Stages	Smith Point (XDA 4238) Possum Point (XEA 1840) Piscataway Creek (XFB 1986) Broad Creek (--) or Gunston Cove (POH 232)	Maryland (or GMU for POH 232)	Fish eggs and larvae mesozooplankton microzooplankton phytoplankton water quality variables, including heavy metals	Weekly, Apr-Jun.	$108,400

INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN

RECOMMENDED BIOLOGICAL MONITORING PROGRAMS ON THE TIDAL POTOMAC RIVER

	STATIONS	RESPONSIBLE AGENCY	SAMPLE VARIABLES	SAMPLE FREQUENCY	ESTIMATED COST
Maryland Striped Bass Assessment	Drift gill nets placed between Maryland Point (XDA 1177) and Indian Head (XEA 6596)	Mary,and	Spawning stocks of striped bass and other anadromous fish	Daily, early Apr.-late May	$ 65,200
Maryland Juvenile Index Survey	13 stations in tidal Potomac River	Maryland	Juvenile abundances in beach haul seine samples	Monthly, July-Sept.	$ 9,630
George Mason University Fish Monitoring	Gunston Cove area	GMU	Bottom trawl-5 stations Beach haul seine-4 stations	Monthly, Mar.-Nov.	$ 19,400
District of Columbia Fish Monitoring	Several stations on Potomac and Anacostia River within D.C. boundaries	D.C.	1. Gill net samples of anadromous fish 2. Shore haul seine	1. Feb.-late summer, 2-3 times weekly in spring 2. Monthly Mar.-Dec.	$100,000
Commercial Fisheries Landings		Potomac R. Fisheries Commission	Compilation of finfish & shellfish landings	Annually	
New Anadromous Clupeid Surveys	Mattawoman Creek Gunston Cove Piscataway Creek Broad Creek	Maryland	1. Pound or gill net samples of spawning adults 2. Midwater trawl samples of of juveniles	1. 3 times weekly, Apr.-May 2. 2 times monthly, July-Sept.	1. $ 65,200 2. $ 31,100

8/8/88

INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN

RECOMMENDED BIOLOGICAL MONITORING PROGRAMS ON THE TIDAL POTOMAC RIVER

	STATIONS	RESPONSIBLE AGENCY	SAMPLE VARIABLES	SAMPLE FREQUENCY	ESTIMATED COST
Oyster Monitoring	1. Cedar Point Bar Ragged Point Bar Cornfield Harbour Bar	Maryland-PRFC	1. Dredge Sampling - oyster size, condition, disease prevalence, mortality, spatfall, contaminant burden, bushel counts	1. Twice annually, spring and fall	$ 4,400
	2. Cedar Point Bar Great Neck Bar Cornfield Harbour Bar		2. Shell-string spatfall survey	2. Weekly, June-early Oct.	$ 6,000
Aquatic Vegetation Monitoring	Tidal River	Chesapeake Bay Aerial SAV Survey	Aerial SAV survey Aerial tidal wetland survey	Annually Biennially	$ 56,000
Data Management		CBLO Computer Center	Establish centralized living resoures data bank, at CBLO, Annapolis, MD		$ 43,800