MARYLAND COASTAL BAYS PROGRAM

Eutrophication Monitoring Plan

APPENDIX A OF THE MARYLAND COASTAL BAYS
COMPREHENSIVE CONSERVATION MANAGEMENT PLAN

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Introduction

BACKGROUND:

This monitoring plan was developed to help determine the effectiveness of management actions taken as part of the Maryland Coastal Bays National Estuary Program's Comprehensive Conservation Management Plan, CCMP. Actions in the coastal bays management plan address five priority problems: degraded water quality, loss of habitats, changes in living resources, unsustainable growth and development and poorly planned recreational use of the bays. Degraded water quality, due to nutrient and sediment enrichment, was identified as the most pressing environmental problem facing Maryland's coastal bays. Due to priority and practical limitations the monitoring plan has focused initially on a detailed eutrophication monitoring plan. It is recognized that emerging issues (harmful algal blooms, blue crab parasite, wasting disease) and technologies (remote sensing) may bring about a reprioritization of monitoring efforts. A more complete monitoring strategy has been outlined that touches on additional monitoring needs (supplement C). This strategy will be further developed to meet the needs of the CCMP during the initial implementation phase. The 'Eutrophication Monitoring Plan' is designed to track the implementation of management actions and monitor changes in nutrient/sediment loading and subsequent responses to the ecosystem (e.g. impacts to general water quality, habitat and living resources).

GOALS:

The general goals of the Maryland Coastal Bays Comprehensive Monitoring Strategy are:

- To measure the effectiveness of implementing the management actions identified in the Comprehensive Conservation Management Plan (CCMP), and

- To provide information that can be used to redirect and refocus the CCMP over time.

- To provide information that will assist in predicting future trends related to implementation of management actions.

The monitoring plan addresses the eutrophication goals of the CCMP, but the CCMP does not have specific numeric goals such as the Chesapeake Bay Program 40% reduction. General monitoring topics were identified based upon recommended management actions in early drafts of the CCMP that are expected to improve environmental conditions or living resources. In addition, an outline of general monitoring issues was provided by the Scientific and Technical Advisory Committee (STAC). These were used to develop the following broad monitoring themes:

➢ characterize status and assess trends in nutrient inputs from surface water runoff (including ditches in the headwaters of streams), groundwater (direct discharge and base flow), atmospheric deposition, point sources, and the oceanic inputs to the coastal bays;

- characterize status and assess trends in sediment inputs from surface water runoff, shoreline erosion and the ocean (via shoaling and overwash) to the coastal bays;

- characterize status and assess trends in ambient water quality in the coastal bays;

- characterize status and assess trends in ambient sediment quality (sediment type and chemical contaminant concentrations) in the coastal bays;

- characterize status and assess trends in the areal extent and quality of habitats such as seagrasses, macroalgae, bottom type, coastal marshes, natural shoreline, bay islands, bay beaches and forests; evaluate the quality of disjointed habitats due to growth and development;

- characterize status and assess trends in the relative abundance and condition of plankton, benthic macroinvertebrates (including crabs and shellfish), fish, waterbird and birds (neotropical migrant and songbirds in the coastal bays.

COMPREHENSIVE MONITORING STRATEGY:
The current eutrophication monitoring plan focuses on the core elements related to the loading and impacts of nutrients and sediments in the coastal bays. A comprehensive monitoring *strategy* has also been prepared which outlines the goals, related management actions, existing programs etc., for a much larger, all-encompassing monitoring program. The comprehensive monitoring strategy is intended to serve as a working document to guide the development of the monitoring program over the long term as resources allow. This comprehensive monitoring strategy appears as an supplement to this document (supplement C).

In order to develop the comprehensive monitoring strategy, each monitoring theme was broken down into specific goals and objectives. From these monitoring components, a coordinated and comprehensive *plan* can be assembled as proposed for eutrophication in this document. A specific monitoring plan involves integrating a number of monitoring components and considering additional details such as compatibility and consistency with efforts of existing monitoring programs, identifying classes of indicators that may be measured, sample design (spatial and temporal bounds, methods and sample station location), performance criteria, statistical analyses and cost. Methods need to be chosen that incorporate quality assurance/quality control procedures to ensure that sampling, processing, and analysis techniques are applied consistently and correctly, and to minimize the number of lost, damaged and uncollected samples.

Information required to develop an effective monitoring program that would meet the needs of the MCBP was obtained from several sources. A compendium of over 70 existing or highly relevant monitoring programs within the coastal bays and its watershed was reviewed to identify historic and ongoing monitoring information available, as well as monitoring plan elements and monitoring parameters that should be considered. To find out more about monitoring programs in the coastal bays refer to 'A Compendium of Monitoring Programs in the Coastal Bays.'

All themes are covered in part in the eutrophication monitoring plan. Remaining categories of monitoring themes will be evaluated as part of the comprehensive monitoring strategy.

CONCEPTUAL FRAMEWORK OF THE EUTROPHICATION MONITORING PLAN:
Eutrophication and its impacts to living resources was identified in the MCBP Characterization Report, 'Today's Treasures for Tomorrow' as the most pressing environmental issue facing the coastal bays (MCBP 98-01). As a result, the STAC recommended that the initial focus of the monitoring plan be on nutrient and sediment inputs to the coastal bays and their impacts on living resources. The attached draft focuses on those aspects of the monitoring themes that are directly related to eutrophication. Five general categories of monitoring activities were identified:

1) track management actions.
2) nutrient and sediment inputs from the watershed and airshed,
3) ambient water quality,
4) eutrophication impacts to habitat,
5) eutrophication impacts to living resources.

Structure: Actions in the monitoring plan have been organized into three levels: Landscape Monitoring (Level I), Stressor Monitoring (Level II), and Response Monitoring (Level III). The lower the level, the more directly the monitoring is related to management actions. Inherent within all three levels is the for baseline and long-term monitoring data.

Baseline monitoring determines the current status of important indicators of the coastal bays environmental health against which to measure change. Data resulting from baseline monitoring are critical in being able to determine if management actions have had an impact. Sufficient baseline data are not currently available for all components of the monitoring plan, yet is necessary in order to evaluate future conditions (e.g. - have management actions had an impact?) and should be collected as part of the monitoring plan to establish existing conditions prior to full implementation of management actions.

Landscape monitoring (Level I) tracks the actual activities going on in the watershed (e.g. nutrient and chemical application rates, implementation of best management practices and landcover). This can often be directly related to implementation of management actions and may not need intense field monitoring. Depending upon the final management plan and its goals, this type of monitoring information may need to be reviewed in the future to evaluate the adequacy of current programs to track important aspects of landscape conditions and activities.

Stressor monitoring (Level II) determines the amount of pollutants (nutrient, sediment or chemical contaminants) entering the bays or extent of habitat alteration or loss occurring in the watershed. This may be very difficult to do in a comprehensive fashion but it was the decision of the STAC to initiate some of the high priority monitoring elements in this category that relates to nutrient inputs.

Response monitoring (Level III) uses indicators to show how the system is responding to management actions (changes in stressors) over time. This monitoring information is very important to the public (e.g. - Is the water degraded? What is the condition of the fish?). This draft of the plan focuses most attention on this aspect of the monitoring program.

Evaluation of status and trends: The monitoring plan has been designed to allow for evaluation of environmental status and trends. Trends in most parameters are best measured by sampling fixed stations at representative locations on a regular basis. Status may also be measured by fixed stations, but to provide comprehensive spatial coverage requires periodic, intensive random surveys. To accommodate both these needs, the monitoring plan is primarily a fixed station design with intensive random surveys of certain parameters on a rotating basis throughout the segments.

Segmentation: In order to provide a spatial framework by which to compare different areas and assign stations, the bays were divided into six segments based on the 7 digit watershed codes. In general, the segments are sections of the bays that are geographically or ecologically distinct and, for the most part, have similar environmental conditions. These divisions will allow comparison of specific environmental conditions and living resource responses between segments, as well as for the entire estuary.

Use of existing programs: Several existing, long-term eutrophication related monitoring programs are presently operating in the coastal bays. Unfortunately, most of these programs were implemented and designed to address a specific need, and alone are not comprehensive enough to meet the goals of this monitoring plan. Nonetheless, practicality dictates that these existing programs be utilized to as large a degree as possible. This may result in a less than ideal design, but every effort has been made to fill gaps and insure integration among the initially disparate elements.

IMPLEMENTATION:

Implementation of the monitoring plan will involve multiple partners including local governments, volunteers, academic institutions, State and federal agencies, and will be coordinated by DNR, Resource Assessment Service through a Monitoring Subcommittee of the STAC. Coordination of the program through DNR, which conducts other state-wide aquatic and wildlife monitoring programs, will insure consistent methodologies and analyses, rigorous quality assurance, integration with state-wide monitoring data bases and other aspects of the program.

Data will be analyzed by the respective group collecting the monitoring data and compiled into a comprehensive review, on a bi-annual basis, and presented to STAC for review. Data and results will be made available using a distributed Internet system. A geographic information system and other methods of public presentation (e.g. periodic “state of the bays” reports) will be used to display data and analyses.

Implementation of the plan described here will depend on the continuance of a number of existing programs as well as additional resources that have not been identified to date.

Eutrophication Monitoring Summary

I. Landscape/ Management Action Tracking (Level 1)

Landscape monitoring tracks the actual activities going on in the watershed (e.g. - nutrient application rates, implementation of sediment best management practices, and landcover). This can often be directly related to implementation of management actions and does not normally require intense field monitoring. Instead, existing tracking of management implementation efforts can often be sufficient. The effectiveness of existing tracking programs can be reassessed when the coastal bays management plan is finalized and the recommended management measures required are more clearly defined.

State of the Bays:

Some info collected by NRCS and MDA for agriculture applications (only for those farms with management plans). Nutrient and sediment best management practices are tracked through management plans but no analysis has been done except for manure sheds.

Gaps in Response to Management Questions:

Contributions to nutrient concentrations in the groundwater and to the coastal bays from septic tanks, land application of manure, and fertilizer applications in agricultural and suburban lands is uncertain. Significant work is needed to estimate the inputs from the major nutrient sources. Aggregate nutrient application data for agricultural fields and private land greater than 3 acres will be available from MDA beginning in 2005 which is when the 1998 Water Quality Improvement Act is fully implemented. Reporting of fertilizer application by homeowners is currently lacking. Availability of nutrient application data by watershed from all sources is limited.

Goals:

Provide data on nutrient inputs to the landscape in order to assess over time the effectiveness of management measures taken to reduce nutrient inputs to the coastal bays.

Provide data on sediment inputs to the stream system to assess over time the effectiveness of management actions taken to reduce sediment inputs to the coastal bays.

Implementation:

Data Collection -

The first goal will be met by tracking management actions related to nutrient application to agricultural land, residential/developed lands and upgrades to septic tanks. Nutrient application on agriculture land will be available from MDA as part of the nutrient management planning process, which will be strengthened under the Water Quality Improvement Act of 1998. Tracking application of nutrients on residential lands will need to use the best available information (for example, sales in the county). Upgrades to septic system will be tracked using a septic tracking program. This goal includes tracking nutrient exports, such as septage and crop yields, over time in order to determine net gains/losses. Exports of nutrients will be tracked as exports of agricultural products, while tracking septage export may be best tracked through a regulatory change that requires septage haulers to report data.

The second goal will be to track sediment inputs as the number and location of best management practices implemented. This information is currently collected by MDA and NRCS for agricultural land. The county and/or state has information on sediment controls for residential areas.

Issues for Consideration -
Will these data (nutrient application rates, exports) be available by watershed? Best management practices need to be inspected over time to ensure they maintain their function. Relationship of septic system upgrades to nutrient inputs may need to be further studied in the watershed.

Data Management, Analysis and Reporting -
These data could ultimately be used if a comprehensive nutrient or sediment loading model is developed for the coastal bays watershed.

II. WATERSHED/AIRSHED INPUTS (Level 2 - Stressor Monitoring)

This section includes monitoring nutrient and sediment loading in the coastal bays. Stressor monitoring looks at the actual pollutant loads (nutrient or sediment) to the bays from the watershed, the air and the ocean. Currently, nutrient loading data in the bays is limited to point sources and estimates of surface runoff nutrient loads "modeled" using runoff coefficients and land use. Projects are currently underway to get better information on groundwater nutrient loading and limited sediment loading due to shoreline erosion. Therefore, baseline data will need to be collected to achieve a better quantification of nutrient and sediment loads.

State of the Bays:

Ninety-six percent of the nutrients entering the bays from non-point sources (MCBP 9801). Current estimates of nutrient loading from surface runoff are primarily based on empirical models that use runoff coefficients and landuse to determine loads. These models suggest that agricultural runoff contributes 51% nitrogen loads, urban runoff contributes 1% of nitrogen loads, forest runoff contributes 3% nitrogen loads and groundwater contributes 9% of nitrogen loads (MCBP 9801). Atmospheric deposition is estimated to contribute 32% of the nitrogen but is not currently monitored in the coastal bays watershed (MCBP 9801). Groundwater estimates are believed to be underestimates since the risk of groundwater contamination by nutrients is high due to the watershed's sandy soils, high water table, and relatively unconfined layers of groundwater that provide easy access for contaminants. Projects are currently underway to get better information on groundwater nutrient loading. Drainage ditches also may serve as a direct source of nutrients to the coastal bays (including ditches in the headwaters of streams and those that discharge to the bays) and an indirect source (when the ditches are in contact with shallow groundwater). Additionally, there are also seven point source discharges that discharge to either groundwater or surface water in the bays, including four wastewater treatment facilities and three industrial facilities Combined, these seven point sources are estimated to contribute about four percent of total nitrogen and phosphorus inputs to the coastal bays.

Sediment loads have also been based on simple models using land runoff coefficients. The results indicate that total suspended solids surface runoff loads to the bays are predominantly due to agriculture, followed by development. Sediment loading from the ocean (via inlet and overwash) has recently been monitored by the Army Corps of Engineers and Maryland Geologic Survey by tracking the size of the flood and ebb shoals using aerial photography.

Gaps in Response to Management Questions:

Existing estimates of nutrient flows to the coastal bays are preliminary. The relative significance of groundwater and surface water as pathways for nutrient delivery to the bays is especially uncertain. Considerable work will be needed to estimate the major pathways of nutrient transport into the coastal bays. No programs are presently in place to monitor nutrient and sediment loads over time (except for point sources). Current estimates of non-point inputs are based on simple models using runoff coefficients and need to be refined. To determine surface runoff loads we need flow data. Atmospheric data needs to be collected in the watershed.

Goals:

Characterize status and assess trends in nutrient inputs from surface water runoff (including ditches in the headwaters of streams), point sources, ground-water (direct discharge and base flow), atmospheric deposition, and oceanic inputs to the coastal bays;

Characterize status and assess trends in sediment inputs from surface water runoff, erosion, shoaling and overwash to the coastal bays;

Implementation:

It is recognized from the outset that the proposed monitoring plan will only directly assess a portion of the total nutrient and sediment inputs to the coastal bays. The STAC decided to estimate inputs at key sites to begin to clarify the magnitude and assess trends in nutrient and sediment inputs. Data from these sites could later serve as a nucleus of information leading to the development of a more comprehensive nutrient budget

A. *Nutrient Loading Data Collection* -

Nutrient loading data from surface runoff and groundwater will be collected using automated flow driven sampling devices at stream gage stations to capture event (surface runoff) and baseflow (groundwater) inputs as well as non-tidal ambient monitoring stations. Currently, there are no stream gages in the coastal bays and one or more stations are critically needed. Two to three sites are proposed in areas of high nutrient loadings and relatively large flow sites, tentatively in the St. Martins and Trappe Creek watersheds (see Draft Loading Station Map for suggested stream gage stations). Furthermore, a loading station should be considered in Little Assawoman Bay, Delaware since preliminary data suggest that system may serve as a nutrient source to Assawoman Bay (this will require a partnership with Delaware). Parameters will include a full suite of nutrients (nitrogen and phosphorus) and sediments in addition to flow. A number of baseline sampling sites to estimate groundwater loads will also be monitored as part of a USGS/ASIS study.

Point source monitoring will continue to be collected through self monitoring of NPDES permits and MDE spot checks. Parameters are listed in supplement B.

Funding will be sought for the addition of an atmospheric deposition monitoring site in the coastal bays watershed for nutrients. In addition, new techniques that could monitor local deposition of ammonium (may be particularly important in this region) are being investigated to account for local variability.

B. *Sediment Loading* -

See nutrient loading section for stormwater sediment loading framework. Sediment loading from the ocean (via inlet and overwash) has recently been monitored by the ACOE and MGS by tracking the size of the flood and ebb shoals (size and volume) using aerial photography. Continued tracking of these shoals is recommended. Additional sediment loading may be monitored by estimating inputs due to erosion (this process includes shoreline interpretation and delineation using aerial photography, erosion rates determination, sediment volume, grain size, and mass calculations based on the character of the shoreline).

Issues for Consideration -
There are additional known sources of nutrient and sediment loading including stormwater runoff from Ocean City, ditches (agriculture, road and residential) that are in direct contact with the groundwater or downstream from headwaters, and oceanic (inlet for nutrients, overwash for sediment) that could be monitored. These sources are not being targeted for this initial monitoring plan. They may need to be considered in the future if complete and comprehensive nutrient and sediment budgets are required.

Data Management, Analysis and Reporting -
Data will be analyzed by the respective group collecting the monitoring data and compiled into a comprehensive review on a bi-annual basis and presented to STAC for review. Data and results will be made available using a distributed Internet system. A geographic information system and other methods of public presentation (e.g. periodic "state of the bays" reports) will be used to display data and analyses.

III. Eutrophication Response Monitoring (Level 3)

Response monitoring uses indicators to evaluate the overall health of a system and demonstrate how the system changes to balance/absorb the stressors it receives. This monitoring information is very important to the public (e.g. - Is the water degraded? What is the condition of the fish?). However, it is sometimes difficult to directly relate specific management actions to changes in the ecosystem and requires long term data sets to determine trends. Furthermore, there are various and often poorly understood, lag times between management actions and ecosystem responses.

A. AMBIENT WATER QUALITY

State of the Bays:

Over-enrichment with nitrogen (dissolved inorganic nitrogen >10M) occurs during the summer in 13% of the area of the coastal bays as a whole, and is especially prevalent in Assawoman Bay (1993 EPA Joint Assessment). Over enrichment with phosphorus (dissolved inorganic phosphorus >0.67M) occurs less often (in 9% of the area of the bays), but is more widespread in the tributaries and in the 'dead-end' canals (1993 EPA Joint Assessment). Additional nutrient status data was collected in the St. Martin River and Newport Bay/ Trappe Creek systems during 1998 as part of the State *Pfiesteria*-response monitoring but has not been analyzed. Data have also been collected by ASIS but has not been analyzed for trends.

An excess of phytoplankton as measured by the amount of chlorophyll a in the water (chlorophyll a >15 g/L) occurs in an estimated 16% of the area of Maryland's coastal bays. However, excess chlorophyll a concentrations occurred in 30% of the area of Assawoman Bay, 40% of Trappe Creek/Newport Bay, and 80% of the St. Martin River (1993 EPA Joint Assessment). Additional status data was collected in the St. Martin River and Newport Bay/ Trappe Creek systems during 1998 as part of the State *Pfiesteria*-response monitoring but has not been analyzed. Data have also been collected by ASIS but have not been analyzed for trends. The 'Status and Trends Report on Maryland's Coastal Bays' reports existing data are insufficient to support the idea that substantial long-term trends in water quality in the southern bays have occurred over the past 30 years (MCBP 9802). Although some small declines in summertime DO and chlorophyll levels in the southern bays were suggested.

Dissolved oxygen levels low enough to be cause for concern (DO <5mg/l) have been found in 7% of the coastal bays during summer daylight hours (1993 EPA Joint Assessment). Only in the 'dead-end' canals and St. Martin River are daytime low dissolved oxygen conditions frequent (occurring in 48% and 24% of these areas respectively). However, daylight measures of low dissolved oxygen conditions give a limited picture of oxygen dynamics since the lowest dissolved oxygen levels are observed in the early morning. In addition, data have been collected in the St. Martin River and Newport Bay/ Trappe Creek systems as part of the State Pfiesteria-response monitoring but have not been analyze. ASIS profile and fixed station data have been collected by ASIS but have not been analyzed for trends.

Furthermore, whole sections of the bays, including Trappe Creek, Newport Bay, St. Martin River and Assawoman Bay have water clarity insufficient (light attenuation coefficient, K

>1.5/m) to meet the SAV restoration goals used in the Chesapeake Bay. Overall only 22% of the coastal bays have water clarity that satisfies this target, which is primarily in Chincoteague Bay. Water clarity data has been collected by ASIS but has not been analyzed for trends.

Gaps in Response to Management Questions:

Presently, no one ongoing monitoring program addresses system-wide differences in status or trends in water quality parameters. Information is lacking regarding the temporal variability of water quality parameters including the frequency and extent of early morning low-dissolved conditions; therefore the monitoring plan needs to determine temporal resolution in addition to other 'event' monitoring. The usefulness of innovative technologies, such as remote sensing, should be explored to determine if they could be used in the coastal bays.

Goal(s):

Characterize status and assess trends in ambient water quality in the coastal bays; parameters will be measured that relate to important living resources, management control measures or that are important to the analyses of ecological relationships.

Implementation:

Water quality will be measured every month at fixed stations for evaluation of localized status and the determination of trends. Every 5 years, a more comprehensive evaluation of status in each segment of the coastal bays will be conducted using a random spatial design to objectively characterize the entire region. Technologies that involve remote sensing or flow through devices may be employed to achieve the broader spatial characterization.

A1. *Stations, Sampling Frequency and Parameters for Trend and Localized Status -*

Fixed stations will be used to monitor trends and to determine status in localized areas for key water quality parameters (see table). These stations will ideally be measured at least once a month throughout the year, and possibly twice a month at selected locations during the warmer growing season. There are three major programs that were incorporated into this monitoring scheme including ASIS water quality monitoring program, DNR *Pfiesteria* monitoring and MCBP Volunteer Monitoring Program. These programs each monitor specific regions in the bays and currently monitor a total of 73 stations in Maryland (see draft water quality monitoring stations map in supplement A).

ASIS and DNR programs sample the following water quality parameters (nutrients -N, P, C, Si species, total suspended solids, chlorophyll, dissolved oxygen, pH, water temp, salinity, and depth) once a month. The major differences between these programs operating procedures include months sampled (all year vs. April - Oct.), filtering method (positive vs. negative pressure), light attenuation (light meter vs. secchi) and lab where samples are analyzed (CBL vs. HPL).

The volunteer program samples year round, twice monthly March - Nov. and once monthly Dec.- Feb. This program focuses on the near-shore environment and is thus a complement to the more centrally-located stations sampled through other programs. Many of the same water quality parameters are tested at the 30 sites although only 15 test for nutrients and chlorophyll and these only include dissolved fractions of N and P (NH_4, NO_3/NO_2, PO_4). Since secchi disc is not an effective at several stations because of shallow depths, it is recommended that a Li-Cor meter be purchased and added to the sampling by having one volunteer take measurements at multiple shallow water stations in conjunction with other sampling. Samples are chemically analyzed by the University of Delaware. This program is currently funded by the National Estuaries Program and needs a secure source of long-term funding.

A total of seventeen additional open water stations were determined to be needed in Assawoman, Isle of Wight and Chincoteague Bays to provide sufficient coverage in each of the six segments. Water quality sample locations were coordinated to overlap with submerged aquatic vegetation, macroaglae, benthos and fish sampling sites as well as historic sampling stations to the extent possible. Stations are distributed among the six segments. Additionally, a photosynthetically active radiation, PAR, sensor should be set up for daily irradiance measurements.

A2 *Issues for Consideration* -

It is not currently recommended to move any ASIS stations in Chincoteague Bay due to the long-term data set already in place. Monitoring of DNR *Pfiesteria* sites (or at least a subsample in the St. Martins River) should be expanded to include at least March through November to obtain water quality data during the SAV growing season. Light attenuation should be measured with a light meter at least at stations where the secchi disc cannot be used due to the shallow depth (e.g. disc sits on the bottom). It is recommended that routine split sample analysis between the University of Delaware and the University of Maryland be conducted (especially for volunteer program). Research should be conducted to determine if light attenuation measurements should measure both downwelling and upwelling. Additionally, it is unknown if water quality sites are needed in SAV beds to help monitor changes in habitat criteria of existing beds. More research is also needed on the distribution, variability and responses of benthic microalgae before incorporating this component into the routine monitoring program.

A3 *Data Management Analysis and Reporting* -

To account for seasons and nonnormally distributed data, the Seasonal Kendall tau test, a nonparametric test based on ranks, will be used as one statistical technique to determine if there is a trend. This test assigns each data point a rank based on magnitude (smallest values get the lowest ranks, etc.). The ranks are then compared within a season and across years. The seasonal Kendall test is more robust than parametric tests to skewness, seasonality, and serial correlation but, it is not an exact test in the presence of serial correlation. This test is applicable for trends tests with data sets containing seasonality, missing values and censored data (e.g. incorporation of below detection limit samples by dividing the detection limit in half). Other statistical tests may also be performed to analyze data. Localized status information will be displayed at station locations or through aggregation of data by segment. Data will be managed using Microsoft Access based system. Geographic information systems and other methods of public presentation (e.g. 'state of the bays' report) will be used to display data and analyses.

B1. Stations, Sampling Frequency and Parameters for Spatial Analysis -
Characterization of Chlorophyll Distributions

Chlorophyll distributions are known to be spatially heterogeneous. In order to obtain more precise estimates of phytoplankton biomass, it is therefore necessary to sample with more complete spatial coverage at periods throughout the year. Remote sensing of chlorophyll levels is suggested to be done at least 8 times, monthly March through November, to evaluate spatial variability. Several options for better chlorophyll coverage include flow through fluorometry, aerial overflights and satellites. Studies should be done to compare these appropriateness of these methods in the coastal bays (currently waiting on results from Del. aerial overflight study - this may also be able to detect macroaglae and SAV distribution and from NOAA). Use of a flow-through sampling device could also obtain spatial variability of dissolved oxygen, pH, temperature.

Diel Oxygen Measurements -

Dissolved oxygen is known to be highly variable over diel cycles in eutrophied systems. There are several areas in the coastal bays that are believed to be subject to low dissolved oxygen stress in the early morning hours during warm weather periods. To examine the seriousness of these potential problems, continuous monitoring devices will be placed in the bays and tributaries for several weeks at a time to record diel oxygen measurements (& possibly other water quality parameters - DIN, TSS, etc.) in order to help better understand the severity of the problem and temporal variability. Stations will be placed in the St. Martin River and Trappe/Ayres Creek systems and will be rotated to obtain additional spatial coverage. Additional fixed stations could be set up in the main bays (e.g. tide gauges). Station locations will attempt to overlap with fish and benthos stations.

C1. *Stations, Sampling Frequency and Parameters for Temporal Analysis -*

Continuous monitoring sensors will be placed on ASIS tide gages to better understand temporal changes.

B. HABITAT IMPACTS RELATED TO EUTROPHICATION

State of the Bays:

The total area of SAV beds in Maryland's coastal bays has more than doubled in the last decade from approximately 2,100 hectares in 1986 to 5,598.37 hectares in 1997 (13,827 ac). Acreage by segment in 1996 was 178.15 hectares for Assawoman Bay, 46.34 hectares for Isle of Wight Bay, 0 for St. Martin River, 343.73 hectares in Sinepuxent Bay, 0 for Newport Bay, and 3,987.80 hectares for Chincoteague Bay. The dominant SAV species include eelgrass (*Zostera marina*) and widgeon grass *(Ruppia maritima*). 1997 was the first report of eelgrass in the northern bays. In 1996, a majority of the SAV (61%) was in the dense class, 12% moderate, 22% sparse and 4% very sparse. Modified Chesapeake Bay SAV habitat criteria have been developed for the coastal bays.

Benthic macroalgae communities were sampled in 1998 in the Maryland coastal bays. A random stratified sampling approach was taken, with seven strata designated based on chlorophyll status and dominant sediment type. Macroalgae were found throughout the bays; however, no relationship with sediment type or nutrient enrichment was evident. Results showed that baywide species richness was greatest in September, and abundance highest in October. The following seventeen genera were represented (in order of abundance from greatest to least). *Enteromorpha , Ecotcarpus , Agarhdiella , Chaetomorpha , Ulva , Gracilaria , Polysiphonia , Ceramium , Spyridia , Codium , Champia, Hypnea, Chondrus, Cladophora , Ulothrix,* and *Eudesme*. Of these, the five most frequently captured include *Enteromorpha, Gracilaria, Agarhdiella , Ulva* and *Ceramium*.

Gaps in Response to Management Questions:

Historic abundance of SAV is unknown. It's distribution and abundance needs to be related water quality criteria. Collection of SAV species abundance within large beds needs to be expanded. Use of macroalgae as a eutrophication indicator is still unclear and additional data is needed to document the extent in the MD coastal bays and relationship with water quality parameters.

Goal(s):

Characterize status and assess trends in the areal extent and quality of seagrasses and macroalgae habitats in relation to eutrophication.

Implementation:

A1.*Submerged Aquatic Vegetation, SAV, Data Collection* -

Abundance of SAV will be monitored using aerial photography. Since photos are typically flown in the early spring, widgeon grass populations may be underestimated due to their small size. It may therefore be advantageous to conduct two sets of flights each year (spring and early fall). Ground-truthing of photos for extent and species diversity will continue to be done and should be expanded to include more sites (possibly systematic transect sampling) using global positioning systems, GPS, within large beds and macoaglae data (at least presence absence or minimal ID training of common species). Percent cover of beds is also estimated from aerial photos.

A2.*Issues for Consideration* -
Water quality stations (some stations are in close proximity of/within beds as a control) will help evaluate areas that do not meet water quality goals for SAV. SAV habitat criteria developed for the Chesapeake Bay and modified for the coastal bays by the University of Delaware need to be applied. Furthermore sediment data collected by MGS need to be associated with sediment criteria developed by the Univ. of Md./ NRCS. Consider using epiphytic chlorophyll monitoring to help track SAV condition.

A3.*Data Management Analysis and Reporting* -
Data management and data analysis will be done by using GIS to digitize the extent of the beds. Reporting of SAV status and trends will be done annually and published in a technical report and on the internet.

B1.*Benthic Algae Data Collection* -
Baseline data on macroalgae species, abundance and general distribution are currently being collected using a stratified (based on sediment type and chlorophyll levels) random design (with a fixed station in each segment for trends). This study should also help to develop relationship with water quality parameters. Techniques are still being worked out for initial biomass estimates (first year used qualitative estimate based on trawl; other macroaglae sampling used quadrants).

B2.*Issues for Consideration* -
Remote sensing of macroaglae levels may be used to evaluate spatial variability in conjunction with chlorophyll characterization (waiting on results from Del. study). Additionally, see expanded groundtruthing recommendations under SAV.

B3.*Data Management Analysis and Reporting* -
Data management and data analysis for macroaglae will be done by using GIS to digitize the general distribution and number of species found. Reporting of macroaglae status will be done by May 2000 and published in a technical report and placed on the internet.

C. LIVING RESOURCES IMPACTS RELATED TO EUTROPHICATION

State of the Bays:

Harmful algal blooms pose a threat to the coastal bays. In 1998, the presence of *Pfiesteria* and *Aureococcus* (Brown Tide) were confirmed in the northern bays (Turville Creek and Assawoman Bay respectively). Although the presence of these organisms does not yet cause problems related to health risks or impaired uses, it further stresses the need to control nutrient inputs to these highly susceptible bays. Overall, little is known about the phytoplankton communities in the coastal bays. Recent data collected by DNR in 1998 and the ASIS pigment data needs to be summarized and analyzed data to better understand the phytoplankton community.

Approximately 40% of the area of Maryland's coastal bays has bottom communities that suggest degraded conditions (1993 EPA Joint Assessment). Degraded conditions are most common in dead-end canals (100%) and in the St. Martin River and least abundant in Chincoteague Bay (approximately 25% area). DNR Fisheries survey of shellfish between 1993 - 1996 showed distinct geographic differences among the molluscan communities within the coastal bays (63 mollusc species were collected). They were highly diverse with a strong relationship with habitat type (sediment, vegetation, shell cover and other biogenic structures); however, overall molluscan abundance appears to be no more than average as compared to other coastal embayments. Clam abundances were 25% less than estimates from the 1960's and early 1970's and it was confirmed that the Chincoteague oyster no longer inhabited the area (except in a few intertidal areas). The ribbed mussel, *Geukensia demissa*, is the ecologically dominant species (both structurally and functionally) in the intertidal zone. Additional benthic macroinvertebrate data from MDE's routine biological monitoring program showed the community and water quality in St Martin River (Birch Branch, Bishopville Prong and South Branch) and Trappe Creek (Bottle Branch and Trappe Creek) are in the poor to fair range with generally positive trend results in St. Martin River (except in Birch Branch) and no improvements in Trappe Creek. Benthic macroinvertebrate show no significant trend no change in the fair water quality at Birch Branch. Bishopville Prong showed improvement in both biotic and diversity indices from very poor values to poor values and the macroinvertebrate community showed a strong improvement in the water quality from the very poor range to the poor range. South Branch (also known as Church Branch) has shown taxa number increased from poor to fair numbers, Biotic and Diversity indices improve from poor to fair values and a strong improvement in the water quality from the very poor/poor range to the fair range. Bottle Branch showed no improvement with the benthic community or water quality which is in the poor range. Trappe Creek also showed no apparent change in the poor water quality.

The Maryland DNR Fishery Service has been monitoring fish abundance and diversity in the Maryland Coastal Bays since 1972. The bays are sampled by trawl and seine from April through October, and all species collected are recorded. This data is used to track the abundance of many recreational and commercial fisheries, as well as for monitoring the community structure of the coastal bays. While the fish community of the bays has fluctuated over the past two decades, the observed changes provide little evidence for systematic declines in environmental quality. An Index of Biotic Integrity developed by

Linder et. al. 1995 detected no trends in fish health over the last twenty years (species richness --the total number of species collected-- has actually increased). However, the data has shown an unexplained decline in a forage fish index (abundance index of spot, bay anchovy, Atlantic silverside and juvenile menhaden). Many possible factors can impact the forage species abundance including natural cycles, poor water quality, land use practices, over-harvesting, lack of food, predation, or decrease of suitable habitat.

Gaps in Response to Management Questions:

Few studies have identified phytoplankton species. With the threat of harmful algal blooms this data will be needed to respond to management actions. No system-wide benthic monitoring program is currently ongoing (MDE program has some stations in the major tributaries of the St. Martin River and Newport Bay). The spatial and temporal variability due to physical and biological factors can confound attempts at detecting anthropogenic disturbances in the molluscan community over time. Indicator development and analysis of fish data as it relates to eutrophication needs more study.

Goal(s):

Characterize status and assess trends in the relative abundance and condition of fish and benthos (including shellfish) populations in the coastal bays in relation to eutrophication;

Implementation:

A1.*Phytoplankton Data Collection -*

Preliminary phytoplankton community identifications will be done as part of the *Pfiesteria*-response monitoring. In addition, brown tide, *Aureococcus*, will be sampled for baseline information in the summer of 1999.

A2.*Data Management/ Reporting -*

Data will be managed by individual agencies collecting the data. Reporting will be determined as needed.

A3.*Issues for Consideration -*

Addition of phytoplankton monitoring in all segments at other ambient water quality monitoring stations.

B1.*Benthos/ Shellfish Data Collection -*

Benthic community structure and abundance will continue to be monitored at four non-tidal sites in St. Martin River and Trappe Creek to determine population trends related to eutrophication. These sites are the same as or very near to non-tidal water quality monitoring stations.

B2.*Data Management/ Reporting -*

Benthos data will continue to be managed by DNR and analyzed for trends in number of taxa and community structure.

B3. *Issues for Consideration* -
Additional sites may need to be monitored to relate to fish (forage base and cover a variety of habitats - sediment type and presence/absence of SAV or hardbottom) and chemical impacts (sediment triad). Sites can be chosen to overlap with water quality and fish sites to look at relationships with water quality and fish. On a periodic basis, a comprehensive survey, such as the one conducted in 1993, could be considered. These program can utilize the EMAP and Chesapeake Bay Program methodologies and benthic index to evaluate impacts and trends.

C1. *Finfish Data Collection* -
Fish species and abundance data at long term fixed stations will continue to be collected by DNR. Fish community structure (number of species and individuals), length and external condition (health) will be monitored monthly (from April - Oct) using trawl and seines. UMES will compare fish data from random and fixed stations to determine if there are statistically significant differences among the two sampling approaches. The historic DNR data will be used to further develop a fish 'eutrophication indicator.' The abundance of forage species may be used as a long term indicator for monitoring the fish community structure and overall health of the coastal bays.

C2. *Issues for Consideration* -
Ambient water quality stations have been co-located with most trawl stations and a subsample of beach seining stations because of the influence of dissolved oxygen and possibly phytoplankton have on the abundance and distribution of fish. Inadequate dissolved oxygen levels can cause extirpation of oxygen sensitive fish species as well as cause physiological changes that can influence swimming speed and feeding efficiency. Chlorophyll a concentrations have shown a positive relation with fish abundance in certain settings.

C3. *Data Management/ Analysis/ Reporting* -
Fish data will continue to be managed as SAS datasets. Data analysis will include examining trends in the index scores over time and relationships with water quality.

Supplement A

Sample Station Maps

Supplement B

Parameters and Standard Methods

Variables measured in the laboratory, current detection limits, method and preservation techniques.(n/a=not analyzed for and not calculated)			
Variable (units)	**Detection Limits**	**Method/Reference**	**Holding Time and Conditions**
Silica, Filtered (mg/l as Si)	0.01 mg/l	Technicon Industrial Systems, 1986	28 days at 4 ^oC
Total Organic Carbon (mg/l as C)	calculated	PC + DOC	calculated
Dissolved Organic Carbon (mg/L as C)	0.24 mg/l	Menzel and Vaccaro, 1964	28 days at -20 ^oC
Particulate Carbon (mg/l as C)	0.063 mg/l	Leeman Labs, Inc., 1988	28 days at -20 ^oC
Total Suspended Solids (mg/l)	1.5 mg/l	APHA, 1981 (sect. 209D p. 94., Gravimetric)	14 days at -20 ^oC
Total Dissolved Nitrogen, filtered (mg/l as N)	0.02 mg/l	D'Elia et. al, 1977, Valderma, 1981; EPA, 1979. (Method 353.2)	28 days at -20 ^oC
Particulate Nitrogen (mg/l as N)	0.0105 mg/l	Leeman Labs, Inc., 1988	28 days at -20 ^oC
Ammonium, filtered (mg/l as N)	0.003 mg/l	EPA, 1979. (Method 350.1; colorimetric automated phenate)	24 hrs. at 4 ^oC, unacidified; 28 days at 20 ^oC, pH <2 with H_2SO_4
Nitrate & Nitrite, filtered (mg/l as N)	0.0002 mg/l	EPA 1979. (Method 353.2; colrimetric, automated cadmium reduction; diazotation)	28 days at -20 ^oC
Nitrite, filtered (mg/l as N)	0.0002 mg/l	EPA 1979. (Method 353.2; colrimetric; diazotation)	28 days at -20 ^oC
Total Phosphorus (mg/l as P)	calculated	TDP + PP	calculated
Total Dissolved Phosphorus, filtered (mg/l as P)	0.001 mg/l	EPA 1979. (Method 365.4; colorimetric; automated ascorbic acid)	24 hrs at 4^oC; 28 days at 4^oC, pH <2 with H_2SO_4
Orthophosphate, filtered (mg/l as P)	0.0006 mg/l	EPA 1979. (Method 365.1; colorimetric; automated ascorbic acid)	Filter immediately, 28 days at -20 ^oC
Particulate Phosphorus (mg/l as P)	0.0012 mg/l	Aspilla et al., 1976	28 days at -20 ^oC
Chlorophyll/Phaeophytin (µg/L)	n/a	Std. Methods 1985. (Method 1002)	30 days at -20 ^oC