INTERACTION OF RESTORATION, MANAGEMENT AND MONITORING OF THE CHESAPEAKE BAY, USA. THE BENTHIC BIOLOGICAL MONITORING PROGRAM

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The Chesapeake Bay is the largest estuary in the United States and historically has supported some of the world's most productive commercial fisheries. Environmental conditions in the Chesapeake Bay and its tributaries have deteriorated significantly over the past 50 years as indicated by declines in a variety of living resources including submerged aquatic vegetation, finfish and shellfish. Declines in living resources have been attributed primarily to increases in eutrophication and toxic substances.

The marked decline in the water quality and resources of the Chesapeake Bay stimulated the establishment of directives to better manage the bay and its associated river systems. State and federal agencies developed cooperative agreements to address the condition of the bay. The Chesapeake Bay Agreements of 1983 and 1987 were implemented between the U.S. Environmental Protection Agency (EPA), the State of Maryland, the Commonwealths of Pennsylvania and Virginia, and the District of Columbia to share the responsibilities for a comprehensive, long-term program to "revitalize" the bay. The monitoring of environmental conditions is considered vital to assessing the progress of the Best Management Practices being implemented throughout the bay and its tributaries.

In this presentation, the development, implementation and refinement of the benthic biological monitoring program is reviewed. The Chesapeake Bay Benthic Monitoring Program (CBBMP) was initiated in 1984 at a series of fixed-point stations and was recently modified to better meet the needs of the environmental management community. The present monitoring program design is the result of addressing the following questions (issues):

(1) What is the environmental condition of the system?
(2) Which regions of the system are in need of restoration?
(3) What restoration actions should be taken?
(4) Have the restoration actions been effective?

The first issue is a status issue (What is the environmental condition of the system?). Can we discriminate between degraded and undegraded conditions? For the CBBMP this question was addressed by the development of restoration goals for each major benthic habitat type in the bay. The restoration goals represent conditions at reference sites within the bay ecosystem that are minimally impacted by eutrophication and sediment contamination. The restoration goals include thresholds for several measures of benthic community structure, below which conditions are considered degraded. The evaluation of status is based upon a multi-metric index of biotic

integrity that ranges in value from 1 to 5; sites with values above 3 have met restoration goals. The index provides a simple, validated means for summarizing and communicating complex biological data to management and provides a means for comparing conditions across habitat types.

The second issue addresses how restoration efforts will be allocated. The spatial extent and level of degradation must be determined. The bay is a complex system consisting of many tributaries which differ in level of degradation and sources of degradation. Therefore, restoration efforts are now directed towards tributary-specific objectives. In order to identify which regions of the system are most in need of restoration, the CBBMP was modified to include a probability-based sampling design. The bay was divided into strata with benthic sampling sites randomly allocated within each stratum. Strata were determined primarily by management needs to develop and implement tributary-specific restoration efforts. A random-stratified allocation of sampling effort allows statements about the areal extent of degradation within each stratum. The extent of degradation is determined by applying the benthic restoration goals and index of biotic integrity to each sampling location within a stratum. The amount of degraded benthic habitat can then be estimated with a known level of statistical confidence. This approach allows comparisons between different regions of the bay and directs restoration efforts accordingly. In future monitoring efforts, strata may be redefined as management efforts are redirected.

The third issue concerns which types of restoration actions will be taken. For the Chesapeake Bay Program restoration initially involved a 40% reduction of nutrients entering the bay to reduce eutrophication and enforcement of federal and state regulations concerning contaminants entering the bay. Future restoration efforts will in part be based upon assessment of the fourth issue.

The fourth issue addresses the effectiveness of the restoration efforts and involves trend analyses of monitoring data and linkage of the trends to restoration actions. Long-term trends are analyzed by a series of powerful non-parametric trend tests.
Trend analyses include data from fixed-point stations that have been historically sampled for a over a decade and inter-annual changes in the areal extent of degradation within probability-based sampled strata.

The presentation will include recent analyses of status and trends in the benthic communities of the Chesapeake Bay and a discussion of the significance of the results relative to management actions.