13.8 Assessment of the Ecological Condition of the Delaware and Maryland Coastal Bays

13.8.1 Background

The coastal bays formed by the barrier islands of Maryland and Delaware are important ecological and economic resources whose physical characteristics and location make them particularly vulnerable to the effects of pollutants. A first step in developing management strategies for these systems is to characterize their present condition and how it has changed over time. This project was undertaken as a collaborative effort of the Coastal Bays Joint Assessment (CBJA), a group of state and federal agencies, to assess the ecological condition of this system and fill a data void identified in previous characterization studies.

Two hundred sites were sampled in the summer of 1993 using a probability-based sampling design that was stratified to allow assessments of the coastal bays as a whole, each of four major subsystems within coastal bays (Rehoboth Bay, Indian River Bay, Assawoman Bay, and Chincoteague Bay) and four target areas of special interest to resource managers (upper Indian River, St. Martin River, Trappe Creek, and artificial lagoons). Measures of biological response, sediment contaminants, and eutrophication were collected at each site using the same sampling methodologies and quality assurance/quality control procedures used by EMAP. The consistency of the sampling design and methodologies between this study and EMAP allows unbiased comparison of conditions in the coastal bays with that in other major estuarine systems in USEPA Region III that are sampled by EMAP. As an additional part of the study, trends in fish communities structure were assessed by collecting monthly beach seine and trawl measurements during the summer at about 70 sites where historic measurements of fish communities have been made.

13.8.2 Methods

Sampling sites were selected using a stratified random sampling design in which the coastal bays were stratified into several subsystems for which independent estimates of condition were desired:

- Upper Indian River;
- Trappe Creek/Newport Bay;
- St. Martin River;
- Artificial lagoons throughout the coastal bays;
- All remaining areas within Maryland's coastal bays; and
- All remaining areas within Delaware's coastal bays.

The upper Indian River, Trappe Creek, and St. Martin River were defined as sampling strata because resource managers expressed particular concern about these areas. Water quality data suggest that each of these tidal creeks is subject to excessive nutrient enrichment, algal blooms, and low concentrations of DO. These creeks are also believed to transmit large nutrient loads (from agricultural runoff) downstream contributing to eutrophication throughout the coastal bays (Boynton et al. 1993).

Artificial lagoons were defined as a stratum because of their high potential for impact based on their physical characteristics and their proximity to a variety of contaminant sources (Brenum 1976). These dredged canal systems can form the aquatic equivalent of streets in development parcels; they already encompass 105 linear miles and almost 4% of the surface area of Delaware's inland bays. In general, these systems are constructed as dead-end systems with little or no freshwater inflows for flushing. They are often dredged to a depth greater than the surrounding waters, leaving a ledge that further inhibits exchange with nearby waters and leads to stagnant water in the canals. The placement of these systems in relatively high density residential areas increases the potential contaminant input. Much of the modified land-use in dredged canal systems extends to the edge of the bulkheaded waters, providing a ready source of unfiltered runoff of lawn-care and pesticides. In many cases, the bulkhead and dock systems in these canal systems are built from treated lumber containing chromium, copper, and arsenic, providing another source of contaminants.

Four replicate bottom grabs were collected from each station with a 0.04-m^2 Young grab sampler. Of the two hundred sites sampled, 25 were in each of the first four sampling strata and 50 were in each of the last two. Sites were selected by simple random sampling in all strata except artificial lagoons. The randomly selected sites were chosen by enhancing the base EMAP grid (Overton et al. 1990). A different level of enhancement was applied to each stratum to obtain the required number of samples. Sites in the artificial lagoons were selected by developing a list frame (of all existing lagoons), randomly selecting 25 lagoons from that list, and then randomly selecting a site within each selected lagoon.

All sampling was conducted between July 12 and September 30, 1993. Sampling was limited to a single index period because available resources were insufficient to sample in all seasons. Late summer is the time during which environmental stress on estuarine systems in the mid-Atlantic region is expected to be greatest owing to high temperatures and low dilution flows (Holland 1990). The sampling period coincided with the period during which EMAP sampled estuaries of the mid-Atlantic region; therefore, data collected in the coastal bays annually for EMAP can be incorporated into estimates of ecological condition generated from Coastal Bays Joint Assessment (CBJA) data. That data can then contribute to continuing development and evaluation of EMAP indicators.

Measurements of physical characteristics provide basic information about the natural environment. Knowledge of the physical context in which biological and chemical data are collected is important for interpreting results accurately because physical characteristics of the environment determine the distribution and species composition of estuarine communities, particularly assemblages of benthic macroinvertebrates. Salinity, sediment type, and depth are all important influences on benthic assemblages (Snelgrove and Butman 1994, Holland et al. 1989). Sediment grain size also affects the accumulation of contaminants in sediments. Fine-grained sediments generally are more susceptible to contamination than sands because of the greater surface area of fine particles (Rhoads 1974, Plumb 1981).

Depth, silt-clay content of the sediment, bottom salinity, temperature, and pH were measured to describe the physical conditions at sites in the coastal bays.

Sediment type was defined according to silt-clay content (fraction less than 63-µ); classifications were the same as those used for EMAP. Biologically meaningful salinity classes were defined according to a modified Venice System (Symposium on the Classification of Brackish Waters 1958).

Healthy aquatic ecosystems require clear water, acceptable concentrations of dissolved oxygen, limited concentrations of phytoplankton, and appropriate concentrations of nutrients. Clear water is a critical requirement for submerged aquatic vegetation (SAV), which provides habitat for many other aquatic organisms (Dennison et al. 1993). As large concentrations of suspended sediment or algal blooms reduce water clarity, the amount of sunlight reaching SAV is diminished and the plants fail to thrive; consequently, critical habitat for crabs, fish, and other aquatic organisms is lost (Dennison et al. 1993). Nutrient enrichment causes excessive algal growth in the water column and on the surfaces of plants. As bacteria metabolize the excess algae, they deplete dissolved oxygen in the water column and sediments causing hypoxia and, in extreme cases, anoxia.

Water quality in the coastal bays of Delaware and Maryland was evaluated using classes of indicators: measures of algal productivity, dissolved oxygen (DO), water clarity, and nutrients. Measures of algal biomass included the concentrations of chlorophyll in the water column and sediment, and phaeophytin. Secchi depth, total suspended solids (TSS), and turbidity were measured to assess water clarity. Nutrient measures included dissolved inorganic nitrogen (DIN; nitrite, nitrate, and ammonium), dissolved inorganic phosphorus (DIP), total dissolved nitrogen (TDN), total dissolved phosphorus (TDP), and particulate nitrogen and phosphorus. Table 13-18 lists the core environmental parameters sampled at the various sites.

Estimating the percent of eutrophied area in the coastal bays requires identifying threshold levels for selected indicators that define eutrophication. While no such levels have been established for the coastal bays, the Chesapeake Bay Program has established thresholds for five water quality parameters to define critical habitat requirements for supporting SAV in a polyhaline environment (Dennison et al. 1993); these thresholds were used for our assessment (Table 13-19). All but one of the SAV restoration goal attributes were measured directly. The light attenuation coefficient was calculated from Secchi depth measurements.

Threshold values of sediment contaminants developed by Long and Morgan (1990) and updated by Long et al. (1995) were used to interpret concentrations of sediment contaminants measured in the coastal bays. Two values were identified for each contaminant: an effects range-low (ER-L) value corresponding to contaminant concentrations above which biological effects begin to appear, and an effects-range median (ER-M) concentration, above which biological effects are probable. Only a subset of the contaminant samples collected for the CBJA were processed because of cost constraints; consequently, comparisons were limited to the artificial lagoons and the coastal bays as a whole.

Sediment samples for analysis of benthic macroinvertebrates, silt-clay content, benthic chlorophyll, and chemical contaminants were collected using a 0.044-m^2, stainless steel, Young-modified VanVeen grab. Four measures of

Table 13-18. Environmental parameters for the Maryland/Delaware Coastal Bays.

Physical Parameters

Depth
% Silt/Clay content
Salinity
Temperature
pH

Water Quality Parameters

Chlorophyll *a*
Phaeophytin
Benthic chlorophyll
DO (Dissolved Oxygen)
NO_2 (Nitrite)
NO_3 (Nitrate)
Ammonium
TDN (Total Dissolved Nitrogen)
Orthophosphate
TDP (Total Dissolved Phosphorus)
TPN (Total Particulate Nitrogen)
TPP (Total Particulate Phosphorus)
TPC (Total Particulate Carbon)
Secchi Depth
TSS (Total Suspended Solids)
Turbidity

Benthic Parameters

Abundance
Biomass
Number of Species
Shannon-Wiener Index
EMAP Index

Table 13-19. Chesapeake Bay submerged aquatic vegetation habitat requirements for a polyhaline environment (Dennison et al. 1993).

Parameter	Critical Value
Light attenuation coefficient (k_d; m^{-1})	1.5
Total suspended solids (mgL^{-1})	15
Chlorophyll *a* (µg/l)	15
Dissolved inorganic nitrogen (µM)	10
Dissolved inorganic phosphorus (µM)	0.67

biological response were used to evaluate the condition of benthic assemblages in the coastal bays of Delaware and Maryland: abundance, biomass, diversity, and the EMAP benthic index. Abundance and biomass are measures of total biological activity at a location. The diversity of benthic organisms supported by the habitat at a location often is considered a measure of the relative "health" of the environment. Diversity was evaluated using the number of species; i.e., species richness, at a location and the Shannon-Wiener diversity index, which incorporates both species richness and evenness components. The EMAP benthic index integrates measures of species diversity, composition, biomass, and abundance into a single value that distinguishes between sites of good or poor ecological condition (Schimmel et al. 1994). A value of 0 or less denotes a degraded site at which the structure of the benthic community is poor, and the number of species, abundance of selected indicator species, and mean biomass are small.

13.8.3 Results/Conclusions

Major portions of the coastal bays have degraded environmental quality. EMAP's benthic index measured 28% of the area in the coastal bays had degraded benthic communities. At least one sediment contaminant exceeding the Long et al. (1995) ER-L concentration (threshold of initial biological concern) were found in 68% of the area in the coastal bays. More than 75% of the area in the coastal bays failed the Chesapeake Bay Program's Submerged Aquatic Vegetation (SAV) restoration goals, which are a combination of measures that integrate nutrient, chlorophyll, and water clarity parameters.

The tributaries to the coastal bays are in poorer condition than the mainstems of the major subsystems. Previous studies have suggested that the major tributaries to the system: upper Indian River, St. Martin River, and Trappe Creek are in poorer condition than the mainstem water bodies. This study confirmed that finding. The percentage of area containing degraded benthos was generally two to three times greater in the tributaries compared to the rest of the coastal bays. The percent of area with DO less than the state standard of 5-ppm was three to seven times greater in the tributaries. More than 70% of the area in upper Indian River and St. Martin River and in the artificial lagoons had chlorophyll *a* concentrations exceeding the SAV restoration goals.

Among these systems, Trappe Creek contained the sites in the worst condition. Two sites in the upper portion of Trappe Creek had concentrations of chlorophyll *a* exceeding 350 μgL^{-1}; algal blooms were evident at each site. In addition, daytime DO levels exceeding 14-ppm were measured at both sites. Although, supersaturated DO often occurs in hypereutrophic waterbodies on warm, sunny days. However, it appears that degraded conditions in the Trappe Creek system are spatially limited to Trappe Creek and have not spread to Newport Bay. Undoubtedly, this results from the low freshwater flow from this tributary compared to the other tributaries.

Moreover, the coastal bays are in as poor or worse condition than either the Chesapeake or Delaware Bays with respect to sediment contaminant levels, water quality, and benthic macroinvertebrate community condition. Based on comparison to EMAP data collected between 1990-1993, the coastal bays were found to have 68% chemical contamination in the sediments, a higher prevalence than either Chesapeake Bay or Delaware Bay. The total area in the coastal bays that had at least one sediment contaminant exceeding the Long et al. (1995) ER-L concentration was 50% higher than the spatial extent EMAP estimated for Chesapeake Bay using identical methods, and 40% higher, though not statistically distinguishable, from what EMAP estimated for Delaware Bay.

Twenty-eight percent of the area in the coastal bays had degraded benthic communities as measured by EMAP's benthic index. This was significantly greater than the 16% EMAP estimated for Delaware Bay using the same methods and same index, and statistically indistinguishable from the 26% estimated for the Chesapeake Bay.

Nutrients were not measured by EMAP and statistically unbiased estimates of average concentrations are unavailable for either Chesapeake or Delaware Bays. The Chesapeake Bay Program though, recently estimated that about 75% of the area in Chesapeake Bay meets SAV Restoration Goals. This is more than three times the percent of area meeting SAV Restoration Goals in the coastal bays. Even when the turbidity and TSS components of the SAV Restoration Goals (which are naturally high in shallow systems), are ignored, almost half of the area in the coastal bays still fails the SAV Restoration Goal estimates for nutrients and chlorophyll.

The fish community structure in Maryland's coastal bays has remained relatively unchanged during the past twenty years while that of similar systems in Delaware have changed substantially. Fish communities of the Maryland coastal bays are dominated by Atlantic silversides, bay anchovy, Atlantic menhaden, and spot. This community structure is similar to that of the Delaware coastal bays 35 years ago. The fish fauna in Delaware's coastal bays has shifted toward species of the Family Cyprinodontidae (e.g., killifish and sheepshead minnow) which are more tolerant to low oxygen stress, and extremes of salinity and temperature.

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