13.6 Ocean City, MD — Bethany Beach, DE — A Preliminary Study of the Use of Marine Biocriteria Survey Techniques to Evaluate the Effects of Ocean Sewage Outfalls in the Mid-Atlantic Bight

13.6.1 Study Objectives

This project investigates the practical, low cost application of marine biological community measurements and the near field/far field survey technique for use by coastal States as a water resource quality management tool. The methods applied here are derived from work reported by Pearson and Rosenberg (1978) and Mearns and Word (1982) with modifications.

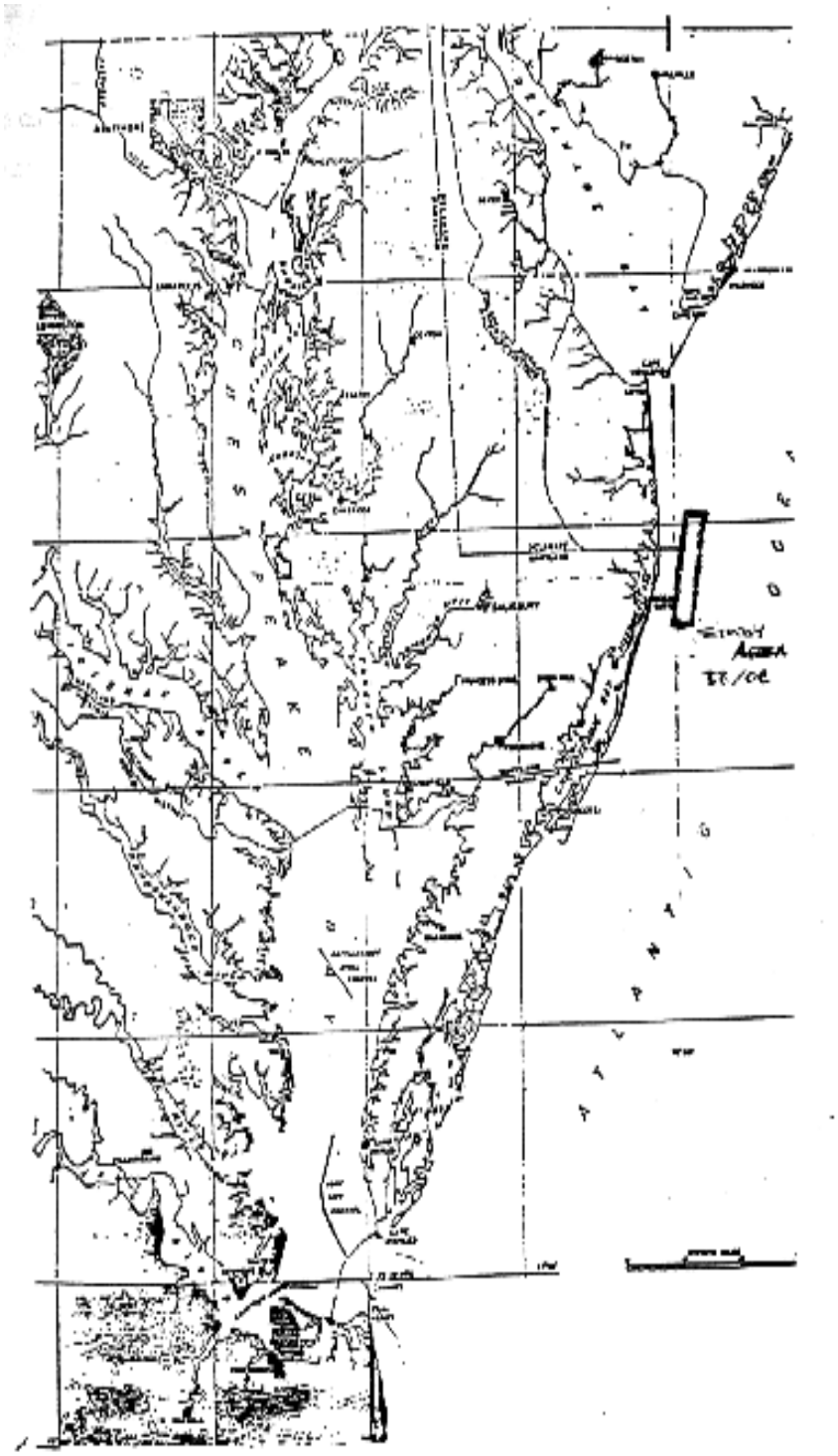
13.6.2 Study Methods

The study area is a 16-km coastal reach between Bethany Beach, Delaware and Ocean City, Maryland (Figure 13-1, 13-6). These are nearly adjacent resort communities on the Mid-Atlantic seaboard between Delaware Bay and Chesapeake Bay. Each has a secondary treatment municipal sewage discharge site about 2.8-km offshore. Discharge is in both cases through a diffuser at a water depth of approximately 12-m. The Bethany Beach sewage treatment plant average discharges about 0.61-m^3s^{-1}(14-mgd) and Ocean City about 1.4-m^3s^{-1} (32-mgd).

A series of nine north-south trending stations were installed parallel to the coast at intervals of about 2-km, each in about 12-m depth of water and over medium to fine sandy bottoms to obtain a similarity of habitat as much as possible. The stations are labeled "A" through "I", with station "C" at the Bethany Beach outfall and station "G" at the Ocean City outfall (Figure 13-7). This structure provides a set of control or reference stations for comparison to the test stations at "C" and "G". Each station is located with differential GPS with an estimated precision for the receiver of +/- 5-m.

The variables measured are benthic fish and macroinvertebrate communities as reflected in indexes and metrics incorporating number of taxa and number of individuals per taxa. Fish surveys are made with a 6-m (5-m effective opening), 2.5-cm mesh otter trawl. Tows are made parallel to the shoreline at 1-ms^{-1} over 0.9-km with the station coordinates located at the mid-point of the tow. Trawl scope used is six to one. Benthic macroinvertebrate samples are collected with a 0.1-m^2 Smith-McIntyre grab or with a 0.1-m^2 Young grab, and three replicates are taken for each sample at each station site as indicated by DGPS coordinates. Ferraro et al. (1994) reviewed their extensive data base and concluded that five replicates with a 0.02-m^2 petite ponar grab, each sub-sampled with four 8-cm diameter cores is optimal for waters of the Southern California Bight. We elected to use the 0.1-m^2 grab with three replicates, but to count the entire grab. This was judged to be a reasonable compromise between more replicates and the uncertainty of sub-sampling a site for which there was inadequate preliminary information. From this data base we hope to make further sampling refinements in the future. Identifications of collected organisms are to species whenever possible. All survey work was conducted from the USEPA Ocean Survey Vessel Peter W. Anderson. The Anderson is a 50-m research ship, but all equipment used and methods employed are appropriate for deployment from a 15-m vessel typically used by most coastal States. Incidental to this project,

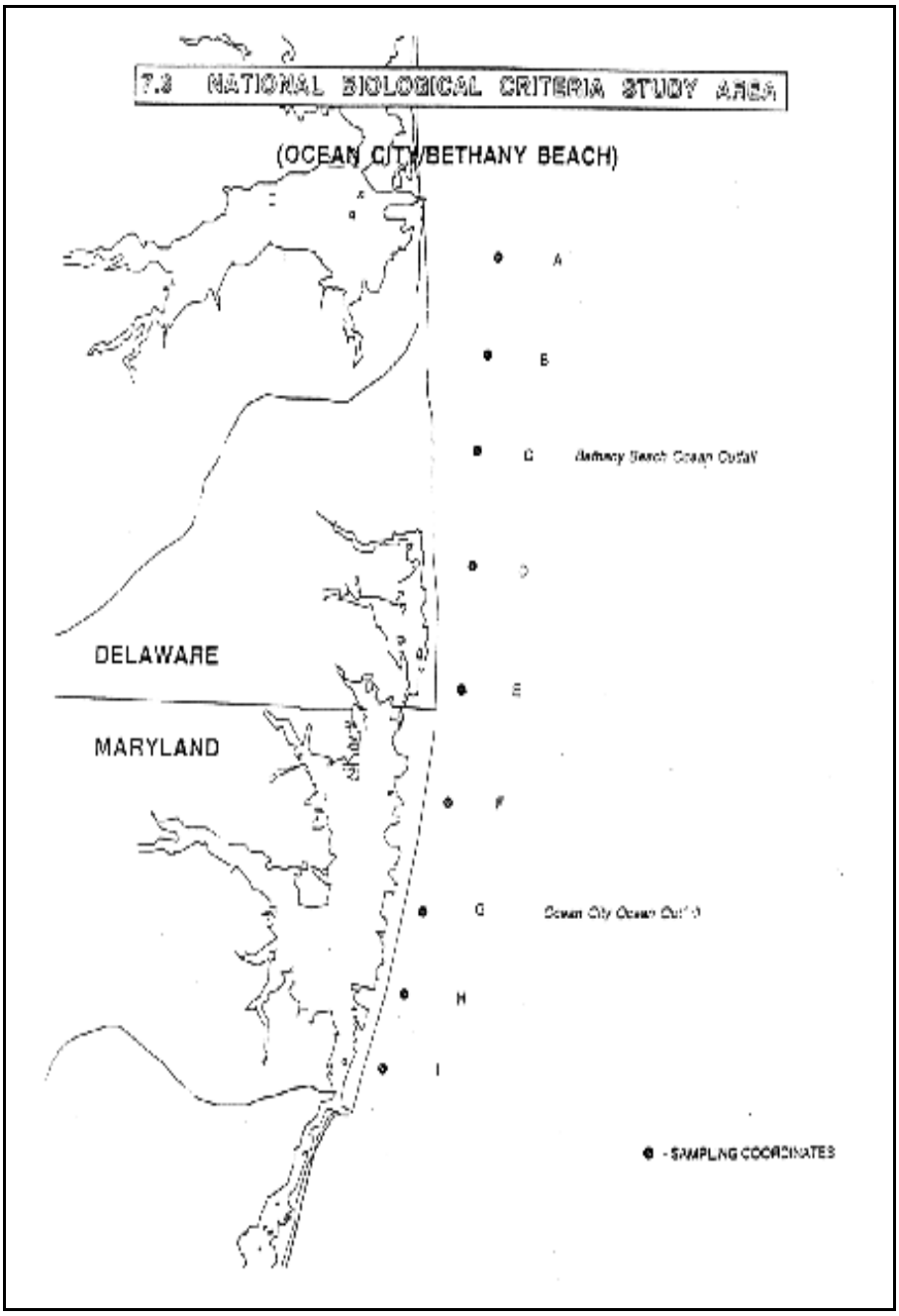
Figure 13-6
Bethany Beach - Ocean City study area.



a comparison of the Smith-McIntyre and Young grabs was made. Six replicate drops with each grab were made at three sites characterized by: hard packed fine sand; medium grain sand; and coarse sand and gravel. Either gear was judged acceptable, but the Young grab was less inclined to wash.

Sampling surveys have been conducted twice a year in July-September and January-February since 1993 to determine if multiple season indexing is necessary or appropriate. While the Mid-Atlantic area is considered to have four discrete seasons, benthic communities are expected to be in flux

Figure 13-7
Bethany Beach - Ocean City sampling locations.



during Spring and Fall and to be most stable in Summer and Winter (Ranasinghe et al. 1994).

Fish sample processing is conducted on board with all individuals identified to genus and usually to species. Length measurements (TL) are made and any gross anomalies recorded. The fish are returned to the water as soon as measurements are completed. Benthic invertebrate sediment samples are sieved on board using a 0.5-mm mesh screen after recording a physical description of the sample and taking a 2.5-cm diameter subcore for grain size analysis. The retained material is fixed in 10% buffered formaldehyde with Rose Bengal dye added. Taxonomic identifications and counts are made later at laboratory facilities ashore with most identifications carried to the species level.

To make comparisons between the sample sites, habitat control in the survey design was maintained as well as possible by attention to three major variables:

1) Grain size of bottom sediments. This also reflected a habitat impact of the discharges when fine sediments were deposited in bottom depressions near the outfalls. At the beginning of the project, sediment samples were collected from all nine stations and analyzed for heavy metals and a for a standard array of toxicants. All results were insignificant, suggesting no other sources of biotoxicity or impairment indigenous to the immediate area.

2) Water depth. Water depth over stations "A" through "E" ranges from 11-m to 14-m with the variation accounted for by a general ridge and swale bathymetry off Bethany Beach. From "E" through "I", the variation is from 14- to 16-m, accounted for by an east-west ledge with about a 3-m drop just south of the Ocean City outfall. Subsequent data analyses suggest that these variations in water depth do not restrict fish or invertebrate distributions over the area.

3) Water quality. At the outset of the study, and each time biosurveys are conducted, multiple depth and standard water quality measurements are made using a Sea-Bird SBE-9 "CTD" probe. Conductivity, temperature, depth, dissolved oxygen, pH, transmissivity, and chlorinity/salinity are measured and recorded throughout the water column.

To date, these variables have been consistent over the length of the transect for each cruise.

In keeping with the objective of low cost, practical applications of biological community measurements for resource impact detection; standard, basic but robust taxonomic indexes were applied to the data. The underlying premise for the indexes is that once the raw data for species and numbers of individuals per species are compiled, the investigator's primary question is whether or not there is a detectible impact. More refined indexes and indicators can later be applied or developed as needed. In this regard, the treatments selected for this project were: total number of individuals, total number of taxa (species), evenness index, Simpson's dominance index, Margalef's taxa richness index, and Shannon-Wiener index of general diversity. The appropriate equations were taken from Odum (1971).

13.6.3 Study Results

Fish Survey Data

Analysis of the fish data showed no significant differences in trawl data between the stations in either summer or winter collections for either number of taxa or numbers of individuals. These results are based on single tows at each station twice a year (summer and winter) for three years. Concern that this response results from too little data led to a trial in summer 1995, with three replicate trawl surveys over the nine stations, i.e., sequential tows of stations "A" through "I" conducted three times in one day. The results were still insignificant. Better results might be possible by replicating each station

individually. Eaton (1994) reported that for West Coast fish surveys in a Washington estuary, four replicate tows per station are necessary to obtain meaningful data within a fairly confined waterway. Qualitatively, taxa and number of individuals overall shifted considerably between summer and winter surveys at the nine stations. Greater numbers of both species and individuals (excepting winter runs of striped anchovy, *Anchoa hepsetus*) occur in the summer surveys.

Benthic Macroinvertebrate Data

Benthic macroinvertebrate results have been much more promising, but the same seasonal trend observed for fish for number of taxa and number of individuals has prevailed. Summer measurements are much more indicative of the condition of the benthic macroinvertebrate assemblages (some of the winter data is incomplete). The data in this instance is for three replicates at each station twice a year for three years. Significant differences are evident between each of the outfall sites and the other stations in the summer data (Figure 13-8a,b). The graphic data for number of individuals is intriguing in that it suggests enhanced and or enriched conditions at station "A", perhaps from the Delaware Bay discharge, and at the Ocean City outfall site.

When numbers of species are compared, a more negative trend in outfall impact is evident, especially for the Bethany Beach outfall station (Figure 13-9a). A similar pattern occurs at Ocean City, but is not as strong (Figure 13-9b). Ludwig and Reynolds (1988) state that a simple count of the number of species present, for samples of equal size, avoids some of the problems of using indexes which combine and may confound a number of variables that characterize community structure.

However, in this instance, it appears that at least some indexes enhance the measurement of outfall perturbations. Box plots of Simpson's dominance index (Figure 13-10a, b), the Shannon-Wiener index of general diversity (Figure 13-11a, b), and particularly Margalef's richness index (Figure 13-12a, b) (Odum 1971), over the three years of summer data provide strong indications of the negative effect of both discharges on the benthic macroinvertebrate community.

13.6.4 Discussion and Conclusions

The nearfield/farfield survey design for biological surveys, together with basic indexes of community structure, appears to work equally well on the West coast and in Mid-Atlantic coast open water environments (Santangelo, pers. comm. 1996). If the investigator is careful to control for habitat characteristics, the ends of the transect can serve as a reference condition, the outfall stations as test sites, and the intermediate stations provide an indication of the gradation of impact(s). The nine station design of this study made it possible to treat the data as a combination of two impact sites on the ambient environment, or as two individual studies in tandem.

Summer benthic macroinvertebrate data from stations "A" and "C" were significantly different in either case, lending confidence to the conclusion that the wastewater discharges were having a measurable impact on the coastal marine environment. This is of particular interest because routine water quality and sediment investigations at the sites failed to consistently detect change between the outfalls and the surrounding stations. The biocriteria technique employed appears to be not

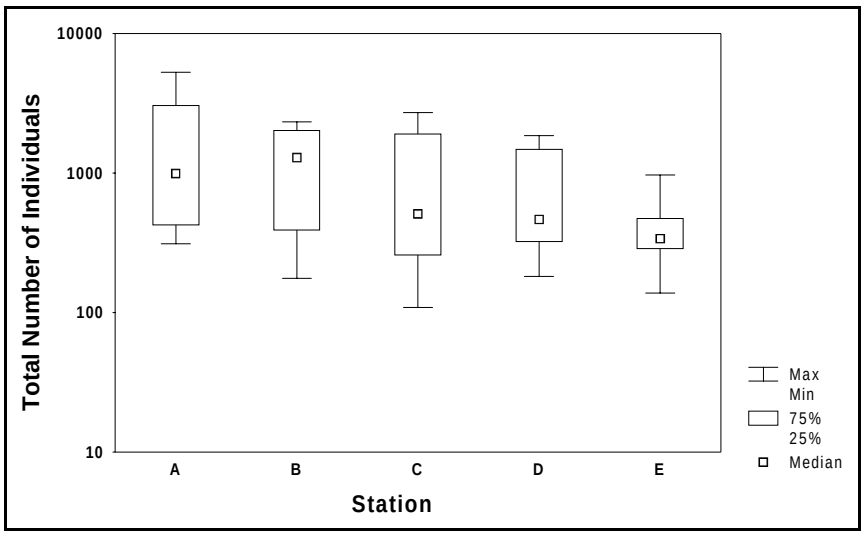


Figure 13-8a

Total number of macro-invertebrate individuals at Bethany Beach sites; summer data, n=9.

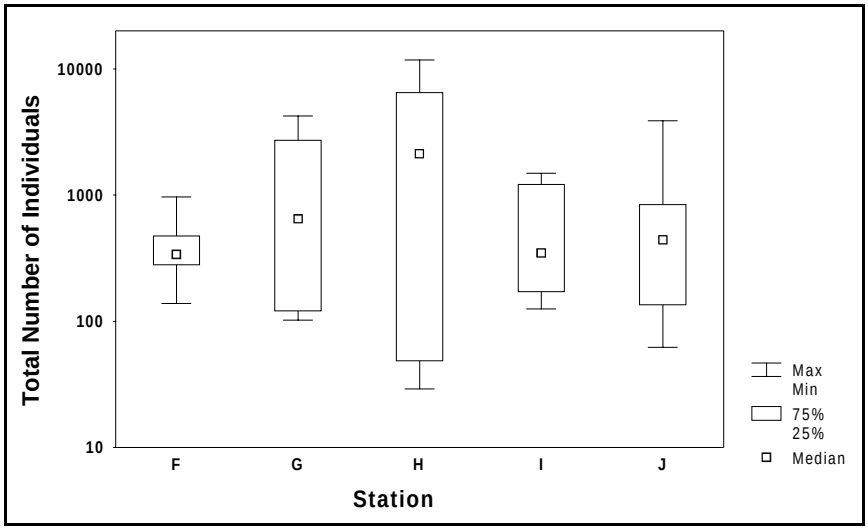


Figure 13-8b

Total number of macro-invertebrate individuals at Ocean City sites; summer data, n=9.

Figure 13-9a

Total number of macro-invertebrate taxa at Bethany Beach sites; summer data, n=9.

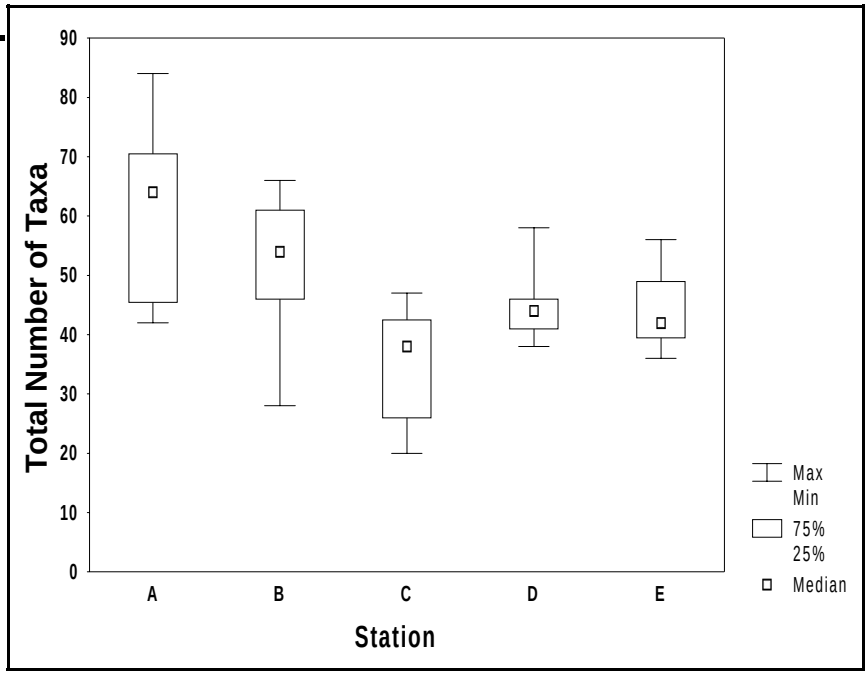
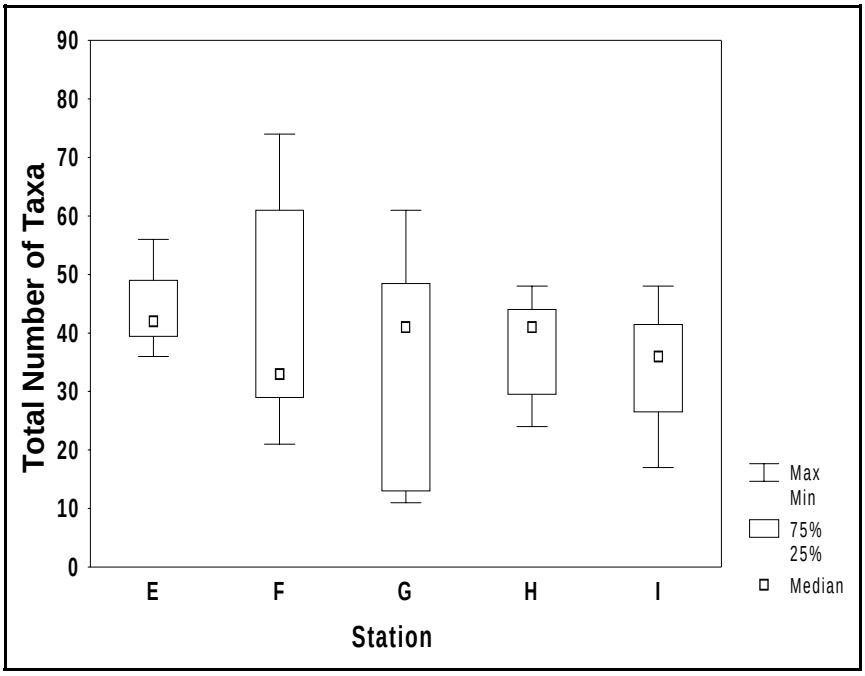


Figure 13-9b

Total number of macro-invertebrate taxa at Ocean City sites; summer data, n=9.



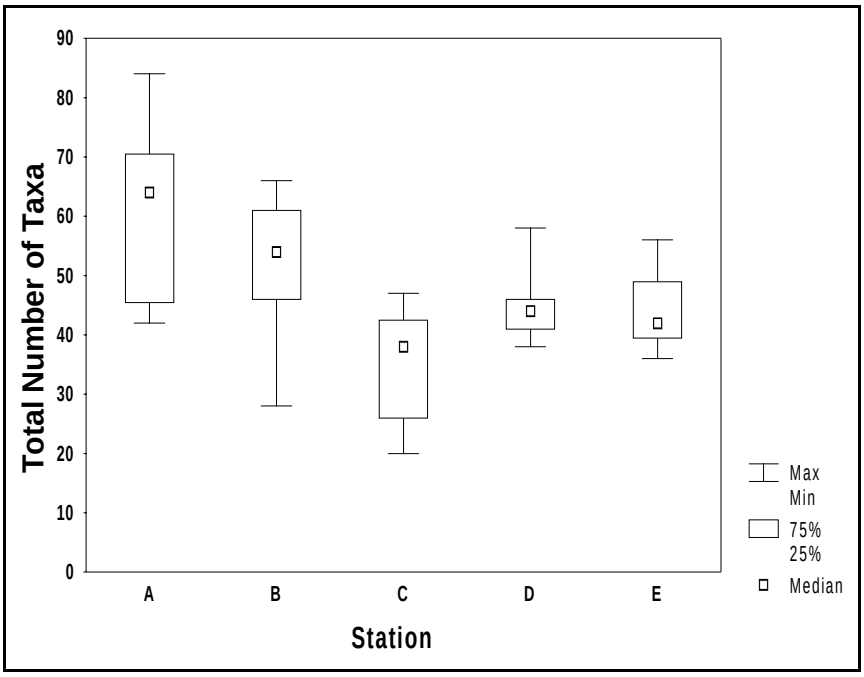


Figure 13-10a

Simpson's dominance index for macroinvertebrates at Bethany Beach sites; summer data, n=9.

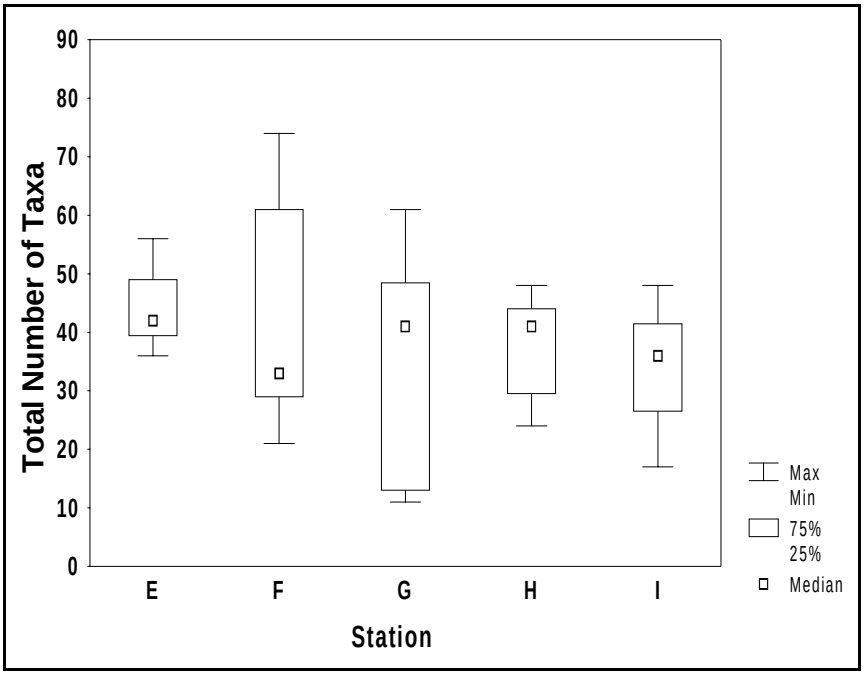


Figure 13-10b

Simpson's dominance index for macroinvertebrates at Ocean City sites; summer data, n=9.

Figure 13-11a

Shannon-Wiener diversity index for macro-invertebrates at Bethany Beach sites; summer data, n=9.

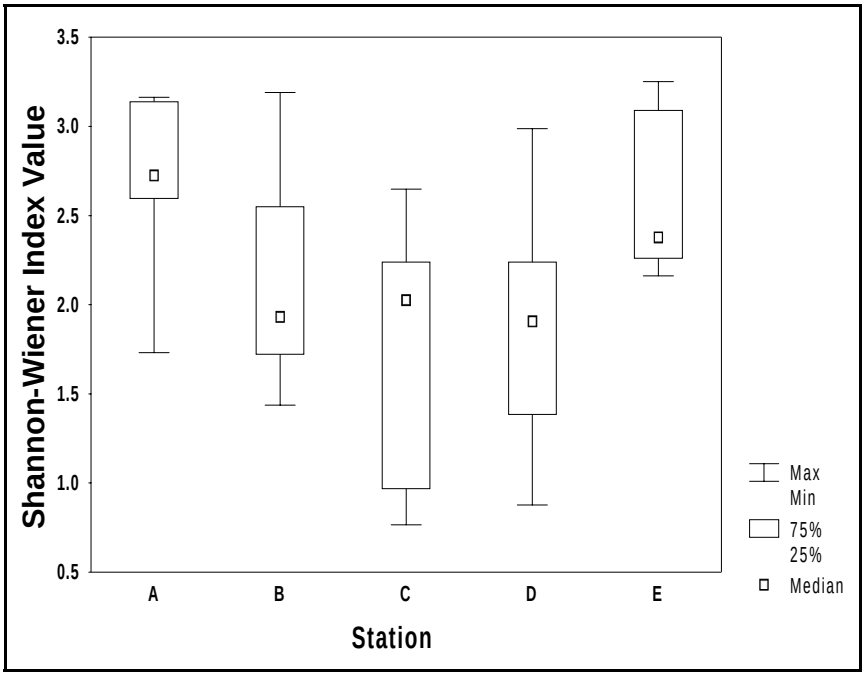
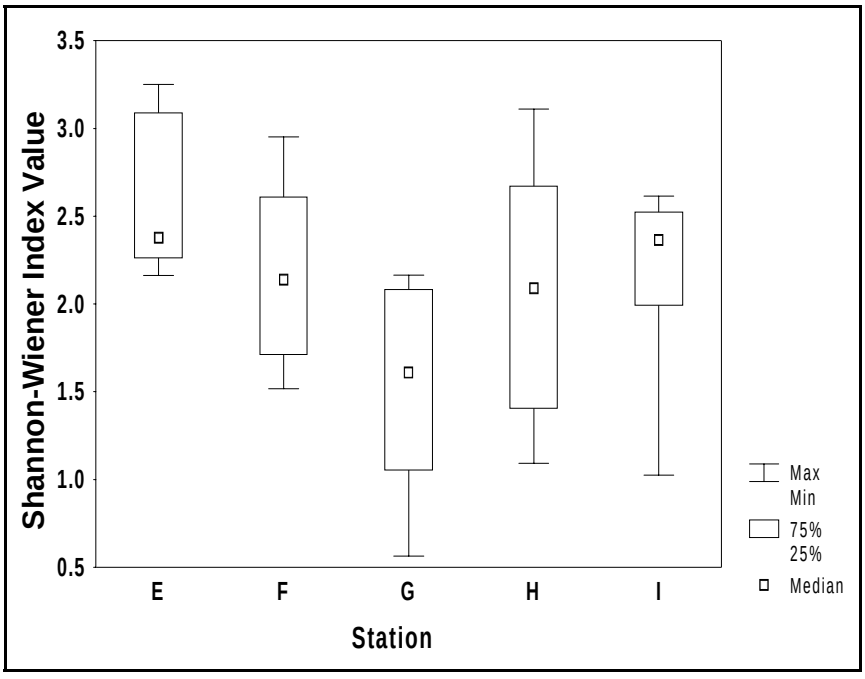


Figure 13-11b

Shannon-Wiener diversity index for macro-invertebrates at Ocean City sites; summer data, n=9.



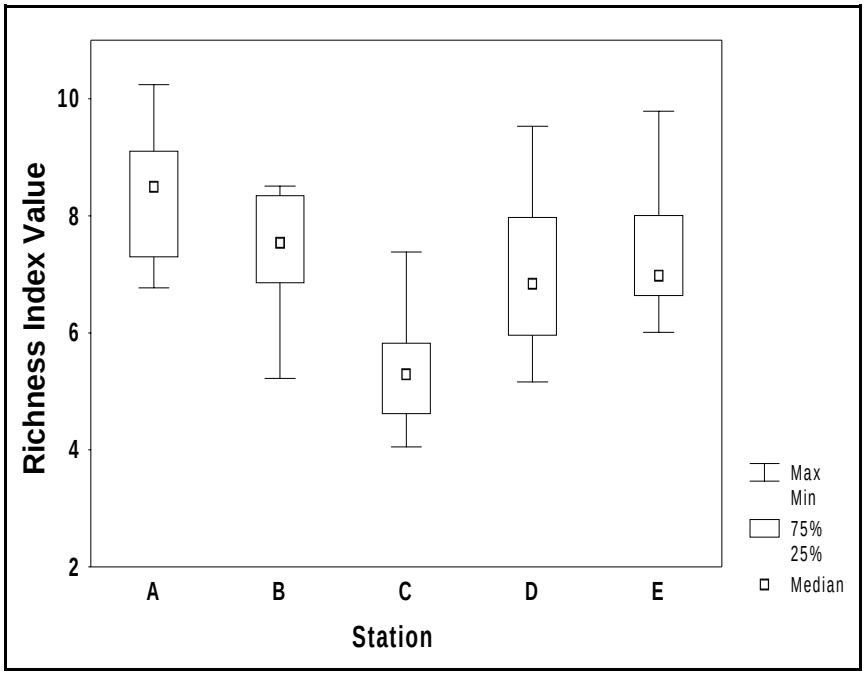


Figure 13-12a

Richness index for macro-invertebrates at Bethany Beach sites; summer data, n=9.

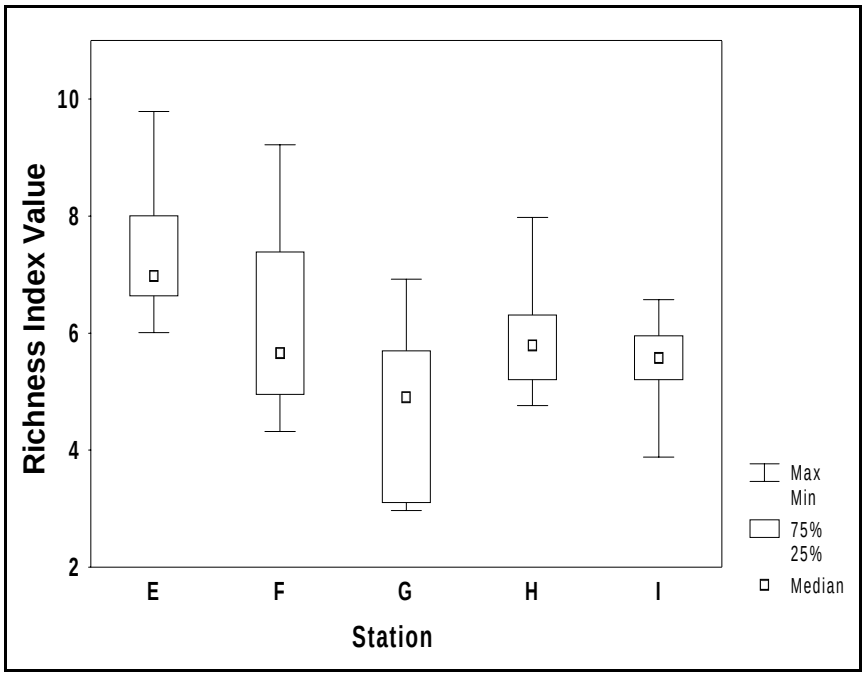


Figure 13-12b

Richness index for macro-invertebrates at Ocean City sites; summer data, n=9.

only practical, but sensitive as well, detecting impacts that might not always be observed with routine chemical testing. Standard indexes such as Margalef's Richness Index, Simpson's Dominance Index and Shannon-Wiener's Diversity Index are robust and were entirely appropriate for this survey.

The Smith-McIntyre and Young grabs were both entirely adequate, but the Young was more efficient and safer to work with, while the Smith-McIntyre was more accessible through the top for sub-sampling. Three replicate grabs were sufficient to generate meaningful data, but it may be possible to reduce the costs of the taxonomic operation by sub-sampling the grabs. An attempt was made to do this by mechanically splitting the intact samples in half with a sheet metal partition. It failed because the surficial organisms were unequally distributed as the sample drained and the ship rolled. Subcores of 5-cm diameter might be a better alternative requiring far less analytical effort. Similarly, sieving and counting only the top 5-cm of the sample as a variation of the technique reported by Diaz in Gibson et al. (1993) might be a more cost-effective approach. Another alternative to reduce the number of organisms dealt with is to double the sieve size to 1.0-mm, as practiced by many investigators. Any of these options could be explored and adopted as a cost-effective way to accomplish the benthic macroinvertebrate counts as long as the investigator ascertains that they produce reliable results consistent with those derived from the larger grab samples.

The 6-m otter trawl used in the fish surveys performed well and is believed to be appropriate for both coastal and estuarine biosurveys. However, the fish community does not appear to be very responsive to sewage discharge effects in this coastal area. This is probably because of the mobility of the fish in these open coastal waters, their seasonal migrations, and the potential sport and commercial fishing pressure confounding the survey effort; but the sampling replication factor was not adequately investigated in this study.

For biocriteria development and site monitoring, it is important to account for seasonality. For the Mid-Atlantic Bight, late June to early September appears to be a time of relatively high, stable community productivity and an optimal index period if once a year sampling is preferred. According to the Delaware and Maryland chambers of commerce, since Bethany Beach and Ocean City are summer resort communities, their populations increase at least ten-fold in warm weather (pers. comm. 1990). Their lower winter discharge rates, together with a natural cyclic depletion of the marine community, may account for the failure of our data to reveal sewage impacts in this season. This may not be the case with a year-round municipality of fairly large size. In any case, if the responsible agency can afford to sample at least occasionally in winter, that baseline biological data may prove invaluable in the event of oil spills or other marine accidents.

After the assessment of results from an initial set of 1.6-km interval station transects, the investigator may choose to delete some of the intermediate reference stations and replace them with a more diagnostic set of near discharge monitoring stations. It will then be possible to assess the relative expansion or contraction of the area of impact over time and in response to

plant operation declines or improvements. The initial and subsequent reference site data become part of the biocriteria which can be used as a benchmark to assess operational efficiencies, management initiatives, and the adequacy of NPDES permits.

Additional investigations for which results are pending

1. Because vertical splitting of each grab sample was determined to be an unsatisfactory approach to reducing sample volume and cost, we are attempting to test a horizontal approach at approximately the 5-cm depth level because most of the organisms observed are predominantly surficial sediment dwellers. In September 1996, the stations were sampled with three replicate grabs as before, but approximately the top 5-cm of sediment was scraped off of each sample and sieved through a 0.5-mm mesh screen. The remainder of the sample was similarly processed. We will count both fractions, combine the results and evaluate as usual.

This information will then be compared to a similar assessment using just the top 5-cm fraction. If the same impact information results, it may be possible to monitor the stations using just the surface fractions as long as these results are periodically calibrated against full grab counts.

2. On the January, 1997 survey, all of the stations sampled for benthic macroinvertebrates were sieved first through a 1.0-mm screen and then through the 0.5-mm screen. These separate fractions can be combined to produce a comprehensive result. The 1.0-mm fraction can then be compared to this control to assess the relative efficacy of this technique as a cost saving approach for these waters. The process was repeated during the summer of 1997 and the results of both trials will be evaluated when taxonomic studies, which were delayed (for this and the above study) are completed.

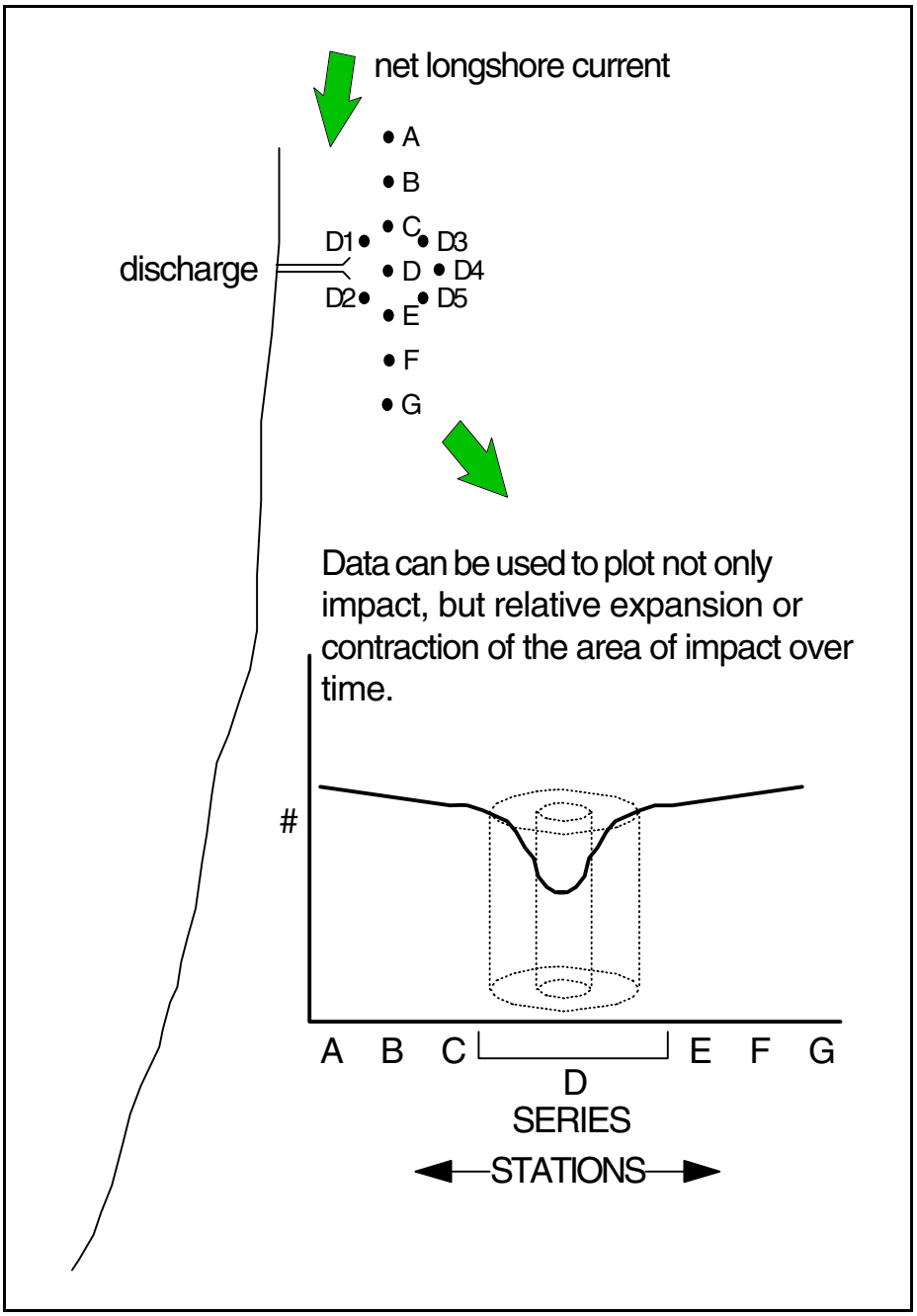
3. Because of the promising results of this project so far, three additional stations have been added around each outfall station, e.g., "C" at Bethany Beach and "G" at Ocean City. The pattern creates a roughly equilateral triangle with approximately 0.46-km legs and a station at each apex with the original station in the middle of the triangle. The intent here is to see if it is possible to refine the spatial assessment of the zone of impact for each outfall analogous to the concept illustrated in Figure 13-13.

13.6.5 Use of the Bethany Beach-Ocean City Data to Illustrate Biocriteria Development

An example of biocriteria development using this pilot project is as follows.

Classification and Reference Site Selection: A review of the data as presented in Figures 13-7 through 13-12 suggests that stations A, E, and I are appropriate reference sites being at the center and extreme ends of the transect and equidistant from the defined locales of effluent discharges being evaluated. General water quality conditions, including salinity and depth, are consistent for all stations. Grain size, although shifting from sand and gravel in the north at station A to sand at station I in the south represents the general benthic habitat condition of the area with an

Figure 13-13
Proposed diagnostic nearfield station array.



acceptable variation for the region. Thus, the stations (or sites) are considered to all be of comparable habitat characteristics, and because of the spatial arrangement, sites A, E, and I are selected as references.

Reference Condition: The reference condition may be derived from the interquartile range of scores of the values of the biotic condition measured at the reference sites. Table 13-13 presents the range of those values for the summer parameters measured at each of the three reference sites and the mean range of those scores. The range was selected over mean or median values to accommodate the variability of the biological data. This mean range is the reference condition or minimally impacted (by human activities, e.g. sewage discharge, all other factors being considered equal) condition for

Table 13-13. Establishment of reference condition using the mean of the interquartile range of scores for three reference sites.

	Inter-quartile Range of Values				
Station	**Individuals**	**Taxa**	**Simpson's Index**	**Shannon-Wiener**	**Richness**
A	427-3049	46-71	0.075-0.161	2.597-3.137	7.3-9.1
E	281-474	40-49	0.076-0.224	2.262-3.889	6.6-8.0
I	136-841	27-42	0.129-0.260	1.993-2.524	5.3-6.0
Mean Score	281-1455	38-54	0.093-0.215	2.284-3.183	6.4-7.7

this Maryland-Delaware reach of the Mid-Atlantic Bight.

Biocriteria: The elements of a biocriterion are: (1) historical information about the area; (2) present reference condition information; (3) empirical modeling of data if needed; and (4) an assessment of this preceding information by a locally familiar panel of specialists.

(1) There is insufficient local historical information or data to establish a trend against which the reference condition data can be compared.

(2) The present reference condition data is presented above.

(3) The indexes used to compile the raw data constitute the only modeling element since this is a site specific assessment.

(4) The authors of this manual are surrogates for a panel of local specialists which would likely consist of USEPA, US Fish and Wildlife Service, NOAA, and State biologists and water resource managers.

Consequently, the reference site data and index scores presented here essentially comprise by default, the candidate biocriteria for the purposes of this study. However, it is important to note that the other elements of development of a biocriterion should not be casually dismissed. While the reference condition is essential, with a large available historical database these present values might well be adjusted either up or down to accommodate the historical trend for the area.

Assessment Comparing Biocriteria to the Test Sites: The test sites at "C" (Bethany Beach, DE outfall) and at "G" (Ocean City, MD outfall) are then compared to the biocriteria as illustrated in Table 13-14.

Neither outfall site completely meets the range of criteria derived from the reference condition for any of the metrics applied, although the Bethany Beach outfall approximates the criterion for number of taxa present. It should be noted that the outlier at reference station "A" (perhaps caused by Delaware Bay enrichment) raises this criterion range at the expense of the Bethany Beach outfall. The Ocean City outfall nearly fits the diversity index criterion. However the outfall far exceeds the number of individuals category by more than three times the criterion. This reflects several instances when the benthic grab was overwhelmed by polychaete worms, a condition usually indicative of sewage pollution.

Table 13-14. Comparison of the reference condition derived biocriteria to the interquartile range of scores at the Bethany Beach and Ocean City outfalls.

Variable	Biocriteria	Bethany Beach Outfall	Ocean City Outfall
No. Indiv.	281-1455	260-1988	49-6,492
No. Taxa	=/>38-54	28-43	13-49
Simps. Dom.	=/<0.093-0.215	0.171-0.642	0.179-0.643
Shan.-Wien. DI	=/>2.284-3.183	0.970-2.648	1.855-2.883
Richness	=/>6.4-7.7	4.6-5.8	3.1-5.7

This instance of near exceedance of one of the criteria in each case illustrates the importance of using several biological metrics to establish a reference condition which best represents a diverse and healthy community, and which contributes to more robust and sensitive biocriteria.

Conclusion: For a formal criteria development program, more data are required, but the indexes applied appear to ably translate the data into workable criteria. Ironically, the number of individuals and number of taxa metrics individually do not reflect apparent conditions as well as the indexes which combine these primary variables.

Recommendations: The stations should continue to be monitored by USEPA Region III biologists and the data set further developed. The long term areal impact of the discharges should be better assessed using the additional near-discharge stations described above. Changes in sieve size and use of grab fractions, if justified, will help reduce the cost of the monitoring.

Eventually, as a further cost reduction measure, it may be possible to monitor just stations "A", "C", "E", "G", and "I". However, periodically the outfall stations should be intensively monitored to determine if the zones of impact are expanding or contracting. The combined information of criteria comparisons and impact zone measurements should provide valuable information for NPDES permit evaluations at Bethany Beach and Ocean City.

This technique and evaluation approach may prove particularly helpful as Eastern Seaboard development continues to increase and more coastal communities seek ocean discharge permits for their municipal effluents.

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