OLD DOMINION UNIVERSITY

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DEVELOPMENT OF DIAGNOSTIC APPROACHES TO DETERMINE SOURCES OF ANTHROPOGENIC STRESS AFFECTING BENTHIC COMMUNITY CONDITION IN THE CHESAPEAKE BAY

Final Report

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Submitted to:

U.S. EPA Chesapeake Bay Program Office
410 Severn Avenue, Suite 109
Annapolis, Maryland 21403

Attn: Ms. Kelly Shenk

April 30, 2002

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I. Introduction

Benthic macrofauna are an important component of estuarine ecosystems. These organisms are a food source for higher trophic levels including fishes and crabs (Virnstein 1977, 1979; Holland et al. 1980; Dauer et al. 1982) and birds (Botton 1984; Quammen 1984). Benthic macrofauna affect both the physical and chemical properties of the sediment and the overlying water column (e.g., Rhoads and Young 1970; Rhoads 1973; Aller 1978, 1980), influence nutrient cycling (Rowe et al 1975; Zeiteschel 1980; Flint and Kamykowski 1984), and are capable of directly controlling phytoplankton biomass in the water column (Cleorn 1982; Officer et al 1982; Cohen et al. 1984; Nichols 1985). Because of these characteristics, monitoring of the benthos provides important information for making management decisions in marine systems (Bilyard 1987). Also, the relatively long life span and sedentary nature of these organisms make them good indicators of water quality and the effects of man-made disturbances on aquatic systems (Reish 1973; Pearson and Rosenberg 1978; Bilyard 1987).

Numerous studies have documented the effects of pollution and other anthropogenic activities on macrofaunal communities within estuaries (e.g., Boesch 1972; Brown et al. 1987; Beukema 1991; Gaston and Young 1992; Dauer et al. 1992, 1993; Dauer 1993, 1997; Dauer and Alden 1995). Investigators attempting to describe the effects of pollution on benthic macrofaunal communities have often experienced the problem of distinguishing the natural variation in these communities due to habitat type (i.e., salinity regime, sediment type, depth, etc.) from the effects caused by pollution. These problems have resulted in the development of multi-metric indices that allow for the characterization of benthic biological condition within and between habitat types. This approach has been used primarily in freshwater ecosystems and is typically referred to as the index of biotic integrity (IBI) approach (see reviews by Davis and Simon 1995; Karr and Chu 1999). Recently, a benthic index of biotic integrity (B-IBI) was developed for the Chesapeake Bay and its major tributaries (Weisberg et al. 1997). This index compares the deviation of community metrics from values at reference sites that are assumed to be minimally impacted by anthropogenic activities. This index has been successfully used to describe the status of and long-term trends in benthic community conditions within the Chesapeake Bay and its tributaries in relation to water quality characteristics (Dauer et al. 1998; 1999) and is correlated to measures of land use and nutrient loads within the Chesapeake Bay watershed (Dauer et al. 2000). However, one of the major limitations of this index is its inability to directly identify the source of stress that is the cause of degraded benthic community condition.

The objective of this study was to develop analytical tools that are capable of classifying regions in Chesapeake Bay identified as having degraded benthic communities into categories distinguished by the type of stress experienced by those communities. Sediment contaminants and bottom low dissolved oxygen concentrations were identified as the primary sources of anthropogenic stress on benthic communities and an attempt was made to develop multivariate statistical tools that could distinguish between these sources of stress. Ultimately, environmental managers could use these tools to make recommendations for analytical chemistry studies to confirm the sources and levels of contaminants in predetermined regions of concern and to develop management plans for controlling contaminant effects.

II. Methods

A. Overview

The objective of this study was to develop statistical diagnostic tools that would allow environmental managers to identify potential sources of anthropogenic stress to benthic communities within Chesapeake Bay. To accomplish this task, data characterizing benthic community condition were aggregated at different spatial scales and with a variety of defined stress groups (Table 1). Three spatial scales of aggregation were identified: (1) a Within Habitat scale as defined by Weisberg et al.(1997), (2) a Within Salinity Regimes scale, and (3) on a Baywide scale. At each spatial scale, stress categories were defined. Four types of stress groups were defined: 1) a Contaminant stress group, 2) a low dissolved oxygen (Low DO) stress group, 3) a combined contaminant and low dissolved oxygen (Combined) stress group, and 4) an Unknown stress group. For some scenarios, the Low DO stress group was excluded for two reasons: (1) regions affected by low dissolved oxygen stress, particularly associated with a stratified water column, are fairly well known; and (2) benthic community condition due to contaminant stress might be less unique and, therefore, less distinguishable from other sources of stress when including benthic community data affected by low DO stress. For each spatial scale and stress groups combination tested, three Contaminant stress groups criteria and two levels of benthic community degradation were applied to each data set (Table 1).

Linear discriminant analysis was used to develop diagnostic tools to differentiate between stress groups as defined for each scenario (Kachigan 1991; Huberty1994). Linear discriminant analysis is a procedure that uses a set of predictor variables from a calibration data set to create a multivariate discriminant function for assigning observations into one of two or more mutually exclusive qualitative groups. Once developed, the discriminant function can be used to assign new observations into the groups defined in the calibration data set (Kachigan 1991; Huberty 1994). Classification of new observations into the groups is accomplished by one of two methods. The discriminant scores calculated for each observation can be compared to a predetermined cutoff value or values that determine group membership or posterior probabilities of group membership calculated during the analysis are examined and new observations are assigned to the group with the highest probability of group membership. For this study, linear discriminant functions for stress group classification were developed using bioindicators calculated from a subset of data compiled from existing and historical monitoring programs conducted within Chesapeake Bay. A second subset of this data set was used to validate the discriminant functions developed. A similar approach has been used to differentiate between degraded and reference benthic communities in the Gulf of Mexico (Engle et al. 1994; Engle and Summers 1999; Paul et al. 2001) and more recently to identify stress source within a specific habitat type in Chesapeake Bay (Christman and Dauer, 2002)

B. Database

The analytical tools were calibrated and validated using data collected within Chesapeake Bay that were used previously to develop the Chesapeake Bay Program's Benthic Index of Biotic Integrity

(B-IBI) and USEPA's Mid-Atlantic Integrated Assessment (MAIA) Program's Benthic Index data (Weisberg et al. 1997; Llansó, In Review). Additional data from sites monitored as part of probability-based sampling regime for the Chesapeake Bay Program's Benthic Monitoring Program (Dauer 1999; Dauer and Rodi 1999, 2001;Versar Inc. 2001) and for the Chesapeake Bay Program's Ambient Toxicity Program (McGee et al. 2001) were also included. Data used in these analyses met the following criteria: (1) all samples were collected within the geographic boundaries of Chesapeake Bay and its tributaries, (2) all benthic biological samples were collected using a Young grab with a sampling area of 0.0440 m^2, (3) all benthic biological samples were collected during the period of July 15 through September 30, (4) measurements of dissolved oxygen were collected concurrently with the biological data, and (5) sediment contaminant data were collected during the same year as the biological samples. Finally, only sites classified as either degraded (B-IBI < 2.6 but > 2.0) or severely degraded (B-IBI $\leq$2.0) were retained for subsequent analysis.

C. Candidate Metrics

Table 2 provides the list of candidate metrics used for the analyses that included measures of abundance, richness, proportional abundance, species diversity and dominance of species in various taxonomic, life history, and trophic categories. Additional metrics included total community biomass, the ratio of epifaunal species abundance to infaunal abundance and the ratio of total biomass to total abundance. Abundance metrics were calculated as the total count of individuals for each metric category per replicate. Richness metrics were calculated as the number of taxa for each metric category per replicate. Proportional abundance metrics were calculated as the value of the total count of individuals per replicate for each metric category divided by the total count of infaunal individuals per replicate. Species diversity metrics were estimated using the Shannon-Wiener diversity index (H') which is calculated as follows:

$$H' = -\sum_{i=1}^{s} p_i \log_2 p_i$$

where p_i is the proportion of the ith species and S is the number of species. Dominance metrics were estimated using Pielou's evenness index (J) which is calculated as follows:

$$J = \frac{H'}{\log_2 S}$$

where H' is the diversity index and S is the total number of species collected. Diversity and dominance metrics were calculated only for the total infaunal and epifaunal life history categories. The assignment of species to life history and feeding categories was based on designations used for the development of the B-IBI for Chesapeake Bay (Weisberg et al. 1997). Appendix A provides a list of species designated as epifaunal while Appendices B-E provide lists of species belonging to each feeding group used. Taxonomic category metrics were calculated using only infaunal species.

D. Data Aggregation

1. Spatial Scales

Three spatial scales of aggregation were identified: (1) a Within Habitat scale, (2) a Within Salinity Regimes scale, and (3) on a Baywide scale. Since estuarine macrobenthic community structure varies in relation to salinity and sediment type, all sites were first classified into the seven habitat types defined for the Chesapeake Bay by Weisberg et al. (1997)(Table 3) for the Within Habitat scale for spatial aggregation. Our *a priori* expectation was that benthic community indicators allowing discrimination between stress groups would be more effective if they were developed separately for each major habitat type. For example, the tidal freshwater and polyhaline regions have no species in common and higher level metrics based upon community characteristics might also have better discriminatory abilities at the habitat spatial scale. The other two spatial aggregation scales increased the number of samples available for developing any discriminant function.

2. Stress Categories

Sites were classified into stress groups using four aggregation schemes (Table 1). The maximum number of stress groups was four : (1) a contaminant effect stress group (Contaminant), (2) a low dissolved oxygen effect stress group (Low DO), (3) a combined contaminant and low dissolved oxygen effect stress group (Combined), and 4) and a stress group of unknown source(s) (Unknown). The criteria for inclusion in the Contaminant stress group was based on sediment quality guidelines established for a suite of organic and metal contaminants known to adversely affect benthic invertebrates. Three different criteria, presented below, were used and separately analyzed for discriminant function development. A site was classified into Low DO stress group if dissolved oxygen concentration at the time of collection was ≤ 2 ppm. A site was classified into the Combined stress group if it met both the Low DO criterion and the Contaminant criterion. Sites not classified into either the Contaminant, Low DO or Combined stress groups were assigned to the Unknown group.

3. Contaminant Stress Category Criteria

Three different sediment quality guideline (SQG) schemes were used. Each of the classification schemes was based on sediment quality guidelines established for a suite of organic and metal contaminants known to adversely affect benthic invertebrates. The first contaminant stress group criterion used the Effects Range Median (ERM) values developed to represent concentrations at or above which adverse toxic effects occur frequently (Long and Morgan 1990; Long et al. 1995). In the first classification scheme, referred to as the ERM Exceedance classification scheme, a site was assigned to the contaminant stress group if any of a suite of 24 sediment contaminants (Table 4) detected at the site exceeded the ERM concentration for the contaminant as specified by Long et al. (1995). Several of the analytes originally listed by Long et al. (1995) were not used in this study because they were not measured at a large number of sites.

The second and third classification schemes were based on mean sediment quality guideline (SQG) quotients. This approach involves the calculation of the mean of ratios of individual contaminant concentrations relative to their corresponding ERM values. The mean SQG quotients are then compared to thresholds established for specific geographic regions (Hyland et al. in preparation). For this study, two mean SQG quotients were used.

One SQG quotient value (SQV) was developed for the EMAP Virginian province which includes all estuarine locations from Chesapeake Bay to Cape Cod. We used the median SGV value derived from a frequency distribution plot. The plot included all sites where the benthic community condition was declared degraded and at which no low dissolved oxygen effects occurred. The Virginian Province median SQV value was 0.098. This threshold represents median SQG quotient at or above which there is a high risk that benthic communities will be degraded within the Virginian province (Hyland et al. in preparation).

The second SQG quotient value (SQV) was developed for the region encompassing the EMAP Lousianian, Carolinian, and Virginian provinces combined and has a value of 0.044. The region includes samples from the Gulf of Mexico and the eastern U.S. estuaries from north Florida through Cape Cod. This threshold represents the median SQV value at or above which there is a high risk that benthic communities will be degraded within all three provinces combined (Hyland et al., in preparation) and was used to assign sites into the contaminant stress group for the classification scheme referred to as All Province.

4. Level of Benthic Community Degradation

Only sites classified as either degraded (B-IBI < 2.6 but > 2.0) or severely degraded (B-IBI $\leq$2.0) were retained for subsequent analysis. Our *a priori* expectation was that the most severely degraded benthic community conditions might allow better discrimination between stress groups. Consequently for each spatial scale and stress group combination discriminant functions were developed for data using only the severely degraded sites and also using both severely degraded and degraded sites. The latter data aggregation increased the number of samples available for developing any discriminant function.

E. Spatial Scales and Analytical Scenarios

1. Within Habitat Scale

The first set of analytical scenarios, referred to as Within Habitat Type scenarios, were intended to develop discriminant functions for six of the seven separate habitat types as defined by Weisberg et al. (1997). For each habitat type, functions were created to discriminate between the Four Stress Groups combination and for the Two Stress Groups combination of a Contaminant stress group and all other stress groups combined. No attempt was made to develop functions for the polyhaline sand habitat type because no sites within this habitat type were classified into the Contaminant stress group regardless of the stress group classification scheme used.

2. Within Salinity Regime Scale

The second set of analytical scenarios, referred to as Within Salinity Regime scenarios, were intended to develop discriminant functions for three salinity regimes: (1) polyhaline (> 18 ppt), (2) mesohaline (5-18 ppt), and (3) tidal freshwater/oligohaline combined (< 5 ppt). For the polyhaline and mesohaline salinity regimes functions were created to discriminate: (1) between the Four Stress Groups combination, (2) between the Three Stress Groups combination (Contaminant, Combined and Unknown stress groups), (3) between the Two Stress Groups combination with a Contaminant stress group and all other stress groups combined, and 4) between the Two Stress Groups combination but without the Low DO stress group. For the tidal freshwater/oligohaline regime discriminant functions were created only for Two Stress Group combination between the Contaminant stress group and all other stress groups combined. Other scenarios for the tidal freshwater/oligohaline salinity regime were not conducted because most sites were classified into either the Contaminant or Unknown stress groups regardless of the classification scheme used.

3. Baywide Scale

The final group of scenarios were attempts to develop discriminant functions that were applicable to any habitat within Chesapeake Bay regardless of salinity regime or sediment type. Discriminant functions for these scenarios were developed to discriminate between: all four possible stress groups; the Contaminant, Unknown, and Combined stress groups; and, the Contaminant stress group and all other stress groups combined both with and without the Low DO stress group.

When conducting a discriminant analysis if the number of variables approaches or exceeds a value of n-1, where n is the total number of observations, the pooled sample variance-covariance matrix will be singular and the resulting functions developed may not reliable (Khattree and Naik 2000). For a number of the scenarios attempted, the number of variables relative to the total number of samples in the calibration data set surpassed this theoretical limitation. Despite this problem, all scenarios except those listed above were conducted in order to identify scenarios that could be potentially useful if future studies generate sufficient data to produce more reliable discriminant functions.

F. Discriminant Function Calibration and Validation

Linear discriminant function development and calibration procedures were conducted on a randomly selected subset of each classified data set comprising two thirds of the total number of observations for a given scenario. The number of discriminant functions required for the classification of observations into stress groups was dependant upon the number of stress groups being classified for each of the analytical scenarios. All discriminant analyses were conducted assuming proportional prior probabilities of group membership. If the total percentage of correctly classified observations was less than 75% for the calibration data set the discriminant functions developed were considered inapplicable for the scenario. If the percentage of correctly classified observations for any of the individual stress groups within the calibration data set was less than 70%, the discriminant function was considered inapplicable for the scenario.

Validity of the linear discriminant functions were tested by classifying the remaining third of the data set into stress groups. Percentages of observations classified into each stress group using the functions were compared with the known percentages in each stress category of the validation data set. If the total percentage of correctly classified observations was less than 75% for a given scenario then the discriminant function was considered inapplicable for the scenario. If the percentage of correctly classified observations for any of the individual stress groups was less than 70%, the discriminant function was considered inapplicable for the scenario. If the validation data set lacked data for one or more of the stress groups, the discriminant functions developed were considered inapplicable for the scenario under consideration.

G.. Salinity Correction

Salinity is an important environmental stressor that affects the composition and distribution of benthic communities in estuaries. In an attempt to improve classification efficiency of the discriminant functions, two additional runs of the Baywide scenarios were conducted using indicator values from which the effect of natural variation due to salinity was removed. Pearson's correlation coefficient was used to identify significant relationships between salinity and all of the indicators. If a significant correlation between salinity and a given indicator was indicated ($p \leq 0.01$) and the absolute value of the Pearson correlation coefficient was ≥ 0.50 (Paul et al. 2001), a linear regression analysis was employed to remove variance in the indicator due to salinity. For each of these indicators, a linear regression equation was developed and predicted values for each indicator were estimated based on the observed salinity. These predicted indicator values were subtracted from the observed indicator values to obtain salinity corrected residuals. These residuals were then substituted for the original values in the indicators data set and the discriminant function analysis for the Baywide scenarios were rerun.

Significant relationships with r values ≥ 0.50 were found for polychaete species richness, proportional abundance of polychaetes, oligochaete species richness, proportional abundance of oligochaetes, tubificid species richness, proportional abundance of tubificids, and species richness of deep deposit feeders (Appendix G). Regression relationships developed for salinity correction of these parameters are presented in Appendix H. Plots of residuals for two of these parameters, oligochaete species richness and tubificid species richness, indicated a potential polynomial relationship with salinity. Polynomial relationships for these two parameters are also provided in Appendix H.

H. Variable Reduction Approaches

Classification efficiencies of discriminant functions can be adversely affected if the number of variables is large relative to the number of observations in the data set used (Huberty 1994; Khattree and Naik 2000). For those scenarios considered applicable to a given management scenario, an attempt was made to simplify the function and improve classification efficiencies by reducing the number of variables used. A variety of techniques are typically employed to select variables for linear discriminant function analysis; however, there is little agreement in the literature as to the validity and relative efficacy of different approaches (McLachlan1992; Huberty 1994; Khattree and Naik 2000).

For this study, two separate variable selection approaches were attempted. The first approach involved the use of a stepwise discriminant analysis using a stepwise selection method with an F-test selection criterion of 0.15 (Khattree and Naik 2000). Applicable scenarios were conducted again using this reduced variable set. The second approach involved testing for variables that were significantly different between stress groups using an ANOVA. Applicable scenarios were conducted again using only those variables which were significantly different between stress groups at $p \leq 0.05$. Similar approaches have been effectively used as a variable reduction technique (Huberty 1994).

All statistical analyses were conducted using SAS/Base® and SAS/Stat® v. 8.1 statistical software. Correlation, linear discriminant function and regression analyses were conducted using the CORR, DISCRIM, and GLM procedures, respectively (SAS Institute 1990a,b). Stepwise discriminant analyses and ANOVA's were conducted using the STEPDISC and ANOVA procedures (SAS Institute 1990a,b).

III. Results

A. Description of Database

A total of 608 sampling event/location combinations were compiled from 1,450 replicate biologicalsamples collected throughout Chesapeake Bay and its tributaries. Most of these data were generated by the EPA's EMAP and MAIA Programs (Table 5). Thirteen of these sampling event/location combinations were repeat visits to the same location. A total of 268 (44%) observations were classified as either degraded or severely degraded based on the mean B-IBI values. Approximately 45% were classified as meeting benthic restoration goals and approximately 11% were classified as marginal. The mean B-IBI value across all sites was 2.76 and ranged from 1.58 at severely degraded sites to 3.61 at sites that met benthic restoration goals (Table 6). Of the observations classified as degraded or severely degraded, 12 were eliminated due to a lack of sufficient dissolved oxygen and/or contaminant concentration data leaving a reduced database of 256 observations for all subsequent analyses (Table 5).

More than 30% of the sites in the reduced database were found in high mesohaline muds while polyhaline sands had the fewest number (≅4%) of sites . The polyhaline mud, oligohaline and tidal freshwater habitat types had approximately equal numbers of sites. For most habitat types, the number of severely degraded sites was greater than the number of degraded sites (Table 7).

The number of contaminants exceeding the ERM concentration across all sites was 0.19 ± 0.68 (mean ± standard deviation) with a maximum of six contaminants exceeding ERM concentrations at a single site. The two contaminants with the highest number of observations exceeding the ERM were zinc and total DDTs which were higher than the ERM concentration at twelve and nine sites, respectively. A total of 13 contaminants including arsenic, copper, acenaphthene, acenaphthylene, anthracene, benzo[a]anthracene, benzo[a]pyrene, chrysene, dibenz[a,h]anthracene, fluoranthene, 2-methylnaphthalene, naphthalene, phenanthrene, did not exceed ERM concentrations at any of the severely degraded and degraded sites. The mean SQV quotient for severely degraded and degraded sites ranged from 0.002 to 2.87 with an average mean SQV quotient of 0.111 ± 0.204 (mean ± standard deviation). Appendix F provides a listing of number of contaminants exceeding the ERM concentration, the mean SQG quotient, and the number missing analytes for each station date combination in the reduced database.

Based on the ERM classification scheme, nearly 75% of sites were classified into the Unknown stress group. Most of the remaining sites were classified into either Contaminant or Low D.O. effect sites (Table 8). The majority of sites in each habitat type was classified into the Unknown stress group (Table 9). The highest number of Contaminant stress group sites was found in the oligohaline habitat type while the highest number of Low D.O. stress group sites occurred in high mesohaline muds. The maximum number of Combined stress group sites was found in the low mesohaline habitat type. No sites in the high mesohaline and polyhaline sand habitat types were classified into the Contaminant or Combined stress groups. No Low D.O. sites were identified in the oligohaline and tidal freshwater habitat types.

Using the Virginian Province SQV, nearly 59% of sites were classified into the Unknown stress group (Table 8). Most of the remaining sites were classified into the contaminant stress group. The majority of sites in each habitat type was classified into the Unknown stress group except for the low mesohaline and oligohaline habitat types (Table 9). The maximum number of Contaminant stress group sites was found in the oligohaline habitat type while no Contaminant stress group sites were found in the polyhaline sand and high mesohaline sand habitat types. The maximum number of Low DO stress group sites was found in the high mesohaline mud habitat type while the oligohaline and tidal freshwater had no Low DO stress group sites. The maximum number of Combined stress group sites was found in the low mesohaline habitat type while no Combined stress group sites were found in the polyhaline sand, high mesohaline sand and oligohaline habitat types. The high mesohaline mud habitat type had the highest number of Unknown stress group sites.

Using the All Province SQV resulted in an increase in the number of Contaminant and Combined effect sites, primarily as a result of a decrease in Unknown effects sites (Table 8). The majority of sites in each habitat type was classified as Contaminant effect sites except for the high mesohaline sand and polyhaline sand habitat type where the majority of sites were classified as Unknown effect sites (Table 9). The maximum number of Contaminant effect sites was found in the high mesohaline mud habitat type while no Contaminant effect sites were found in the polyhaline sand habitat type. The maximum number of Low DO sites across habitat types was three, and three habitat types (low mesohaline, oligohaline, and tidal freshwater) had no Low DO effect sites. The maximum number of Combined effect sites was found in the low mesohaline habitat type while the polyhaline sand, high mesohaline sand and oligohaline habitats had no Combined effect sites. The high mesohaline sand habitat type had the most Unknown effect sites.

B. Within Habitat Type Scale

None of the Within Habitat Type scenarios had a sufficient sample size for discriminant function development. The High Mesohaline Mud habitat type, when using both degraded and severely degraded sites, had the highest number of samples available for the calibration data set - 57 sites; however, 63 sites were necessary. The next highest sample number was the Low Mesohaline habitat type with 31 samples. Correct classification rates are presented below even though the sample size was inadequate.

1. All Four Stress Groups

None of these scenarios met criteria for applicability based upon correct classification rates (Table 10) due to low classification efficiencies in the validation data sets and missing values in individual stress groups. No attempts were made to reduce variable sets for these scenarios. Use of the discriminant functions developed for these scenarios is not recommended.

2. Contaminant vs All Other Stress Groups

Overall classification efficiencies for the calibration data sets for these scenarios were 100%. Overall classification efficiencies for the validation data sets exceeded 75% for several scenarios (Table 11) but only two had high ($\geq$75%) stress group specific classification efficiencies and had more than one observation in the Contaminant stress group for the validation data sets. These two scenarios included the All Province Polyhaline Mud scenario for severely degraded and degraded sites; and the All Province High Mesohaline Mud scenario for severely degraded sites (Table 11) However, the number of variables relative to sample size exceeded the theoretical limitation for discriminant analysis and as a result the classification efficiencies obtained may be unrealistic and these discriminant function may not accurately classify new observations. Variable reduction procedures were attempted for these scenarios but resulted in lower overall classifications efficiencies for validation data sets (Table 23). Although the use of the discriminant functions for these scenarios is not recommended at present, the high classification efficiencies for the calibration data obtained for some of these scenarios suggest that the use of additional data could result in discriminant functions that might be applicable.

C. Within Salinity Regime Scale

Only the Mesohaline salinity regime had a sufficient sample size for discriminant function development. For the Polyhaline and combined Tidal Freshwater and Oligohaline regimes the maximum number of available sites for the calibration data set were 34 and 49, respectively when using both degraded and severely degraded sites. The minimum number of sites was 63. Correct classification rates are presented below even when the sample size was inadequate.

1. Polyhaline

a. All Four Stress Groups

None of these scenarios met criteria for applicability due to low classification efficiencies or missing values in some of the stress groups in the validation data set (Table 12). No attempts were made to reduce variable sets for these scenarios. Use of the discriminant functions developed for these scenarios is not recommended.

b. Three Stress Groups with no Low DO sites - Contaminant, Combined and Unknown

None of these scenarios met criteria for applicability due to low classification efficiencies or missing values in some of the stress groups in the validation data set (Table 13). No attempts were made to reduce variable sets for these scenarios. Use of the discriminant functions developed for these scenarios is not recommended.

c. Contaminant vs All Other Stress Groups

Although overall classification efficiencies for the calibration data sets were 100% and overall classification efficiencies for the validation data sets exceeded 75% for 7 out of 12 of these scenarios, classifications for individual stress groups were generally low with one exception: the All Province scenario with the Low D.O. stress group for severely degraded and degraded sites which had classification efficiencies of 80% for both stress groups (Table 14). The number of variables relative to sample size exceeded the theoretical limitation for discriminant analysis and as a result the classification efficiencies obtained may be unrealistic and the discriminant function may not accurately classify new observations. Variable reduction approaches resulted in a decrease in classification efficiency for this scenario (Table 23). The use of this discriminant function is not recommended at present; however, the high classification efficiencies obtained suggest that the use of additional data could result in a discriminant function that might be applicable to this scenario.

2. Mesohaline

a. All Four Stress Groups

Overall classification efficiencies for the calibration data sets were high ranging from 92% to nearly 99% but none of the scenarios had overall classification efficiencies above 58% for the validation data sets. As a result, none of these scenarios met criteria for applicability (Table 15). No attempts were made to reduce variable sets for these scenarios. Use of the discriminant functions developed for these scenarios is not recommended.

b. Three Stress Groups with no Low DO sites - Contaminant, Combined and Unknown

Although overall classification efficiencies for the calibration data sets for these scenarios ranged from 93% to 100%, overall classification efficiencies for the validation data sets were low ranging from approximately 19% to a maximum of 66% (Table 16). Implementation of discriminant functions for these scenarios is not recommended.

c. Contaminant vs. All Other Stress Groups

Calibration data set overall classification efficiencies ranged from 93% to 100% for the scenarios with Low DO sites and from 96% to 100% for the scenarios without Low DO sites (Table 17). The discriminant function for the All Province SQV without Low DO sites scenario and for severely degraded sites had the highest overall classification efficiency for the validation data set (79%). Stress group specific classification efficiencies were 82% and 75% for the Contaminant and Other stress groups, respectively. Validation data set classification efficiencies within habitat type for this function were > 80% for the High Mesohaline Mud and Low Mesohaline habitat types but < 30% for the High Mesohaline Sand habitat type (Figure 1). Both variable reduction approaches for this scenario resulted in a decrease in overall and within stress group classification efficiencies (Table 23). The function for this scenario met the criteria for applicability and could be implemented.

3. Tidal Freshwater/Oligohaline

Although overall classification efficiencies for the calibration data sets for these scenarios were always at or above 90%, overall classification efficiencies or stress group specific classification efficiencies for the validation data sets were too low to meet the criteria for applicability (Table 18). Poor classification efficiencies of the validation data set were probably the result of low numbers of observations for these scenarios. Implementation of the discriminant functions developed for these scenarios is not recommended.

D. Baywide Scale

1. All Four Stress Groups

Although the calibration data set overall classification efficiency for these scenarios ranged from 78% to 96%, overall classification efficiencies for the validation data set did not meet criteria for applicability ranging from 39% to 66% (Table 19). Neither of the salinity correction approaches used resulted in classification efficiencies that met the criteria for applicability (Table 19). Implementation of discriminant functions developed for these scenarios is not recommended.

2. Three Stress Groups with no Low DO sites - Contaminant, Combined and Unknown

Overall classification efficiencies for the calibration data sets ranged from nearly 82% to nearly 98% (Table 20). However, the overall classification efficiencies for the validation data sets were less than 70% for all scenarios except two: (1) the ERM Exceedance scenario for degraded and severely degraded sites, and (2) the All Province SQV scenario for severely degraded and degraded sites. Although overall classification efficiencies were above 70% for these scenarios, classification efficiencies for some stress groups were less than or equal to 50%. Salinity correction procedures did not improve and generally reduced the classification efficiencies of the discriminant functions for these scenarios (Table 20). Implementation of the discriminant functions developed for these scenarios is not recommended.

3. Contaminant vs. All Other Stress Groups

a. With Low DO Sites

Overall classification efficiencies for the calibration data sets ranged from 78% to 100% while overall classification efficiencies for the validation data sets ranged from approximately 49% to just over 83% (Table 21). The All Province SQV scenario for severely degraded and degraded sites had an overall classification efficiency of 75% and the best classification efficiencies for individual stress groups (82% for the Contaminant stress group and 68% for the Other stress group). Classification efficiencies within habitat types for this scenario were > 75% for five of the seven habitat types (Figure 2). Salinity correction procedures did not improve overall classification efficiencies for the calibration or validation data sets for any of the scenarios (Tables 21). Neither of the variable reduction approaches improved the classification efficiencies of this function (Table 23). The All Province SQV scenario for severely degraded and degraded sites without salinity correction met the criteria for applicability. This discriminant function could be implemented to identify potentially contaminated sites.

b. Without Low DO Sites

Overall classification efficiencies for the calibration data sets ranged from 90% to 100% while within stress group classification efficiencies were > 75% (Table 22). Although overall classification efficiencies for the validation data sets for half the scenarios were above 70%, classification efficiencies for at least one stress group were always less than 70% (Table 22). Salinity correction procedures did not improve overall classification efficiencies for the calibration or validation data sets for any of the scenarios attempt.

IV. Discussion

A. Overview of Results

Regardless of the spatial scale under consideration, discriminant functions developed for more than two separate stress groups had very poor classification efficiencies for either the validation data sets or both the calibration and validation data sets. As a result, none of discriminant functions developed to discriminate between three or four potential stress groups should be implemented. Poor classification efficiencies for these scenarios were due primarily to low numbers of observations within individual stress groups.

The only Within Salinity Regime discriminant function that met criteria for applicability was for the

Mesohaline salinity regime, using two stress groups and severely degraded sites only (excluding Low DO sites) and using the All Province SQV contaminant classification scheme (Table 17). Implementation of this discriminant function is not recommended until functions for the other habitat type combinations can be successfully validated.

The discriminant function for one Baywide scenario met the criteria for use in identifying potential sources of stress: the Contaminant versus Others stress groups (with Low DO sites) using the All Province SQV contaminant criterion for severely degraded and degraded sites without a salinity correction. This particular function is capable of discriminating contaminated sites from sites affected by all other potential sources of stress in any of the seven habitat types.

B. Usage Constraints

The characteristics of the data sets used in this study and statistical techniques employed put certain constraints on how the tool should be used and how results of subsequent classification analyses should be interpreted. The diagnostic tool developed provides a means to assign new observations to one of two groups of potential sources of stress and assign a probability of group membership to each new observation. The discriminant function coefficients used to make these assignments were developed based on the distributional, variance-covariance and correlation structure of the predictor variables in calibration data set. In effect, new observations are assigned to stress groups based on their similarity to observations in the two stress categories in the calibration data set.

The calibration data set was taken from benthic biological data sets collected under a set of specific conditions which affects the underlying data structure of the predicator variables. As a result, new observations can be classified into stress categories only if they meet these conditions. Since the functions were developed using samples collected within Chesapeake Bay and its tributaries, samples collected outside of these geographical boundaries should not be classified using these functions. Since the functions were developed using samples collected with a Young grab and different sampling gear have inherent properties that affect estimates of various biological variables (Word 1975,1976; Ewing et al. 1988), samples collected using any gear type other than a Young grab cannot be classified using these functions. All observations used in this study were collected during the B-IBI index period (July 15 through September 30). No attempt should be made to classify into stress groups new observations that are not collected during the index period. The calibration data set contained only observations that had been previously classified as either degraded or severely degraded using the Chesapeake Bay Program Index of Biotic Integrity. No attempt should be made to classify into stress groups new observations that have not been previously classified as degraded or severely degraded by the B-IBI.

It is possible that characteristics of Contaminant stress group in the calibration data do not reflect the characteristics of all of the potentially contaminated sedimentary environments found in Chesapeake Bay. The number of contaminants used in contaminant classification schemes was limited to a total of 8 metals and 16 organic compounds. As a result, the Contaminant stress group for the calibration data sets may not include some samples that were, in fact, affected by anthropogenic contaminants not included in the list used by this study. Therefore, it is possible that a new observation could be classified into the Other category despite the presence of anthropogenic sediment contaminants. Assigning group membership to new observations using discriminant function is always accompanied by the risk of mis-classifying the new observations. For the case of the diagnostic tools developed for this study, the classification efficiencies of the validation data sets can be used to estimate the risk of mis-classifying new observations. For the Baywide diagnostic tool, the risk of mis-classifying a new observation would be approximately 25%. Because of these limitations the diagnostic tool developed cannot be used to definitively assign new observations to the contaminant stress group or not without independent and direct measurement of sediment contaminant concentrations. The tool developed should be used exclusively as a screening tool to identify sites or regions with a high probability of sediment contamination that should be targeted for further study. Posterior probabilities of group membership could be used to prioritize sites with respect to the need for conducting additional studies to identify and quantify sediment contaminants. Sites with the highest posterior probability of group membership in the Contaminant stress group would warrant the highest priority for additional investigations.

C. Technical Approaches to Implementation

From a technical standpoint, discriminant functions could be implemented using a variety of techniques. The simplest method would be to create a spreadsheet containing formulae to multiply the linear discriminant coefficients with values for each of the bioindicators for each observation being classified. The resulting transformed values would be summed together to produce the discriminant score for each observation. These discriminant scores would then be compared to the cutoff value for the function. The primary advantage to this approach is that users would not be required to have specialized computer programming skills to use the functions. The disadvantage is that entry of formulae and bioindicators into spreadsheets would be tedious, labor intensive and prone to data entry errors. In addition, this approach does not provide posterior probabilities of stress group membership for new observations. Table 24 provides the linear discriminant coefficients for the function recommended for implementation along with the cutoff values used to determine stress group membership. Values below the cutoff values are classified into the Contaminant stress group while values above the cutoff are classified into the Other stress group for the Baywide function.

The use of SAS statistical programming language would appear to be the most efficient means to implement the diagnostic tool provided the user is familiar with this application. To classify new sites into stress groups using SAS would require the user to: (1) have access to copies of the original calibration data sets used for this study, (2) create a SAS format data set containing the new observations with the same format as that of the calibration data sets, and (3) be familiar with and able to interpret output from the SAS DISCRIM procedure. A copy of the calibration data set along with SAS programs for conducting a discriminant analysis are provided on the diskette attached to this report to assist users in implementing the diagnostic tools. Using SAS programs would combine relative ease of use in combination with the detailed output provided by this statistical package.

Other programming languages such as Visual Basic or C^{++} could be used to create programs for calculating discriminant scores and comparing them to the cutoff values and for calculating posterior probabilities. Such programs could be written to perform the same operations as SAS programs but the user would be required to have not only computer programming language skills but would need an extensive knowledge of multivariate statistics. A typical user would find this approach time consuming and difficult to implement.

D. Recommendations

Prior to implementation, it is recommended that operational effectiveness of the diagnostic tools be further tested using additional validation data sets. A variety of benthic community data sets exist that do not include sediment contaminant data and, therefore, could not be included in our calibration and validation data sets. For example, since 1996, the entire tidal Chesapeake Bay has been sampled using a stratified random procedure (Llansó et al. 2002). The Bay is divided into ten strata and within each stratum 25 random locations are sampled for a total of 250 random locations each year. Sites with degraded benthic community condition could be putatively placed into stress categories for further validation. In addition, this large random data set could be reviewed to generate additional data to (1) attempt to develop discriminant functions including additional stress groups, e.g., a Low DO stress group and (2) possibly provide an adequate sample size for discriminant function development for some of the spatial scales below the Baywide scale. Other data sets from areas known to have sediment contaminant problems but not meeting our data inclusion criteria could provide additional validation data sets. For example, Dauer and Llansó (2002) present data from 125 randomly selected locations sampled for benthic community condition in 1999 in the Elizabeth River watershed.

All diagnostic tools implemented should be periodically "re-calibrated" as new benthic biological data sets with associated contaminants data become available. Two of the Within Habitat Type and two of the Within Salinity Regime functions showed promise and efforts to update and validate these functions should be attempted if additional data become available. If and when the diagnostic tools described are implemented for regular use by the Chesapeake Bay management community, they should be employed with all usage constraints as described above.

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Figures

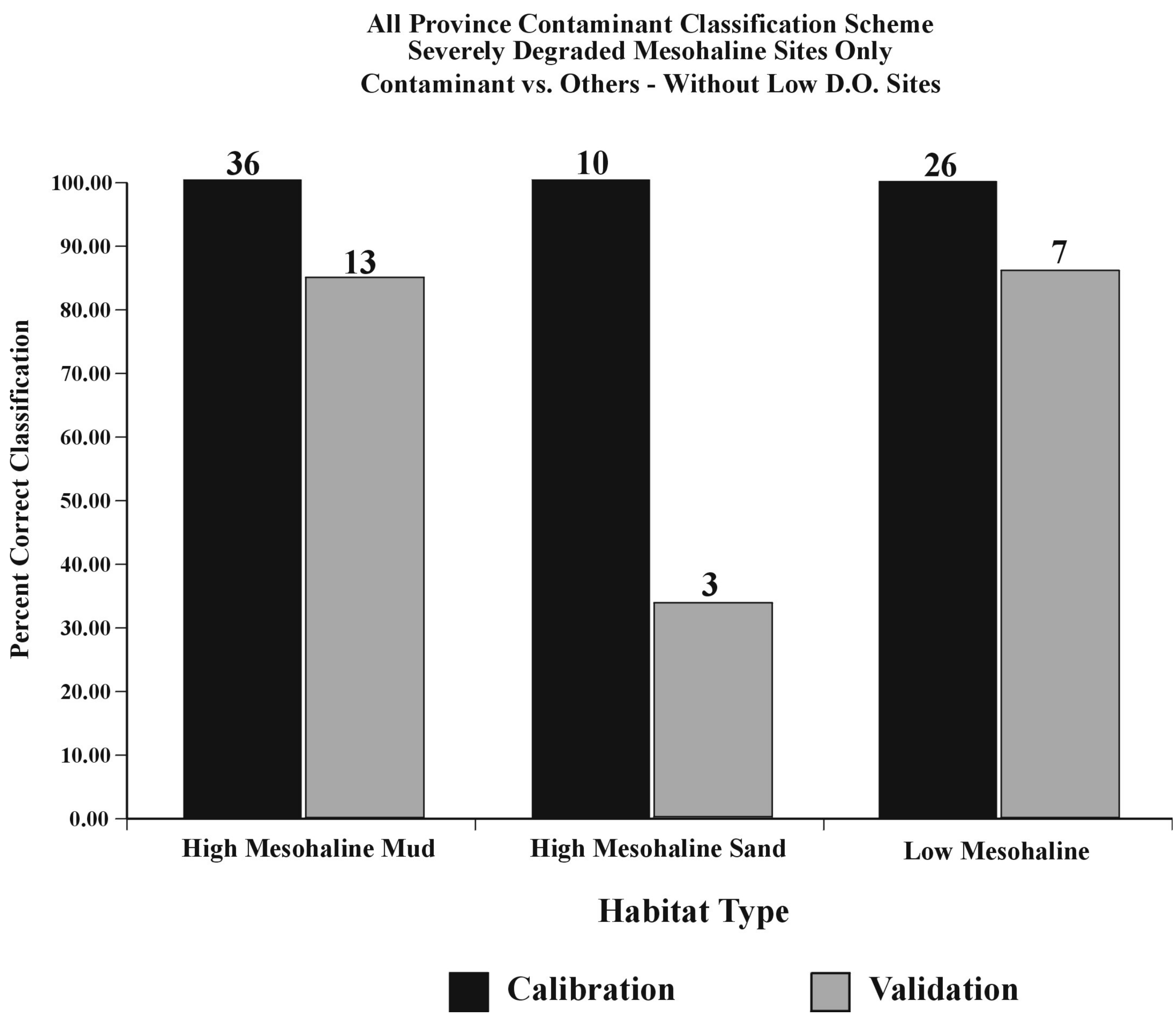

Figure 1. Discriminant function classification efficiencies for individual habitat types for classifying Mesohaline severely degraded sites (excluding Low D.O. sites) into the Contaminant and Other stress groups. Numbers above the bars indicate the number of observations within each habitat type.

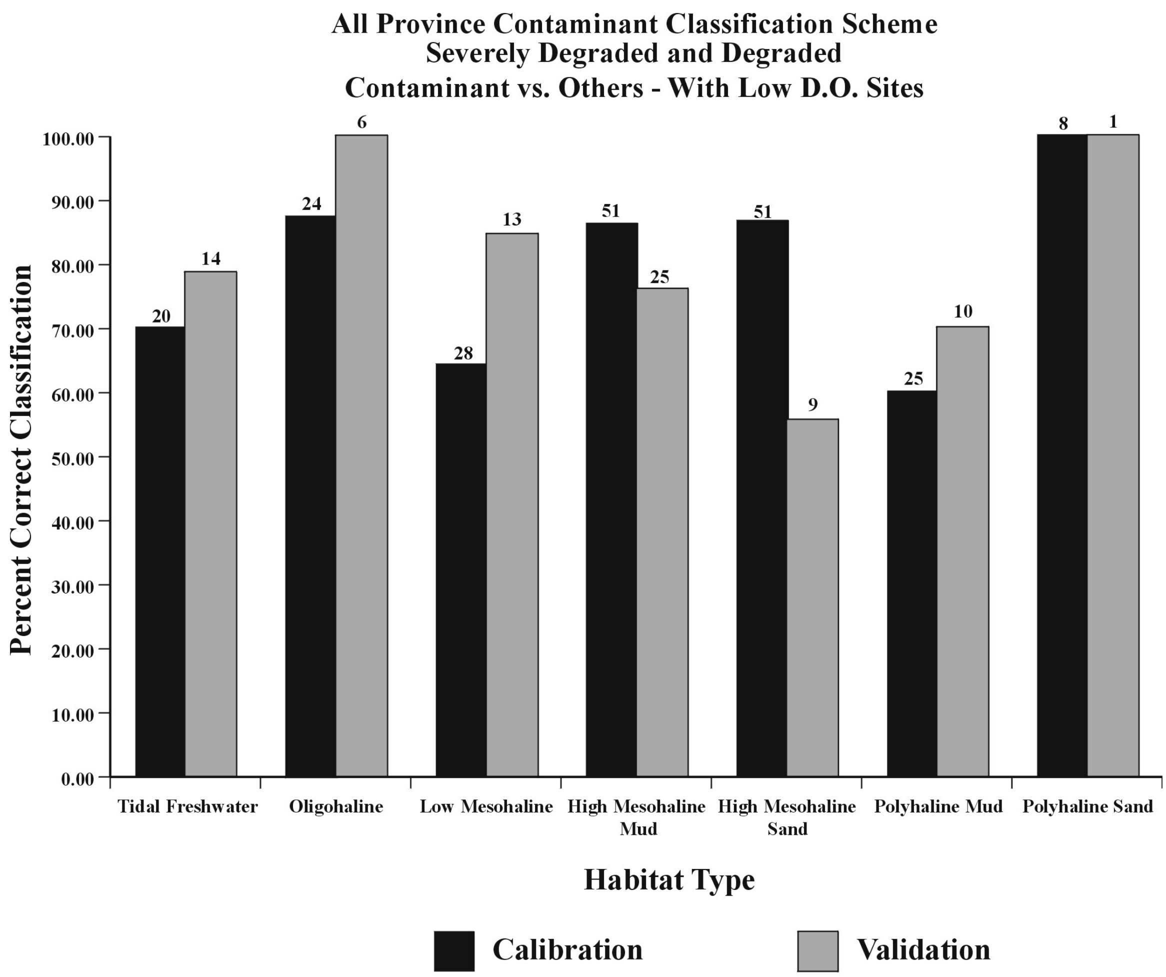

Figure 2. Discriminant function classification efficiencies for individual habitat types for the Baywide discriminant function for classifying severely degraded and degraded sites (including Low D.O. sites) into the Contaminant and Other stress groups. Numbers above the bars indicate the number of observations within each habitat type.

Tables

Table 1 Data Aggregation schemes used in analyses. For definition of habitat types see Table 2. Stress categories are defined in the text.

A. Spatial Scale
- Within Habitat
  - Tidal Freshwater
  - Oligohaline
  - Low Mesohaline
  - High Mesohaline Sand
  - High Mesohaline Mud
  - Polyhaline Sand
  - Polyhaline Mud
- Within Salinity Regime
  - Tidal Freshwater/Oligohaline
  - Mesohaline
  - Polyhaline
- Baywide

B. Stress Categories
- Four Stress Groups
  - Contaminant
  - Low DO
  - Combined
  - Unknown
- Three Stress Groups
  - Contaminant
  - Combined
  - Unknown
- Two Stress Groups
  - Contaminant
  - Others

C. Contaminant Stress Group Criterion
- ERM Exceedance
- Virginian Province ERM quotient
- All Province ERM quotient

D. Level of Benthic Community Degradation

Severely degraded and degraded	B-IBI < 2.6
Severely degraded	B-IBI ≤ 2.0

Table 2. Candidate metrics used for analytical tool development. An asterisk indicates that a given metric for the category listed was included in the analytical tools.

Metric Categories	Abundance	Richness	Relative Abundance	Species Diversity	Dominance	Biomass
Taxonomic Categories						
Isopoda	*	*	*	-	-	-
Amphipoda	*	*	*	-	-	-
Haustoriidae	*	*	*	-	-	-
Ampeliscidae	*	*	*	-	-	-
Corophiidae	*	*	*	-	-	-
Mollusca	*	*	*	-	-	-
Bivalvia	*	*	*	-	-	-
Gastropoda	*	*	*	-	-	-
Polychaeta	*	*	*	-	-	-
Spionidae	*	*	*	-	-	-
Capitellidae	*	*	*	-	-	-
Nereidae	*	*	*	-	-	-
Oligochaeta	*	*	*	-	-	-
Tubificidae	*	*	*	-	-	-
Life History Categories						
Infaunal species	*	*	-	*	*	-
Epifaunal species	*	*	*	*	*	-
Infaunal and epifaunal species	-	-	-	-	-	*
Trophic Categories						
Deep Deposit feeder	*	*	*	-	-	-
Suspension feeder	*	*	*	-	-	-
Interface feeder	*	*	*	-	-	-
Carnivore/Omnivore	*	*	*	-	-	-

Table 3. Habitat types for the Chesapeake Bay B-IBI as defined by Weisberg et al. (1997). (N/A: Not applicable)

Habitat	Bottom Salinity (ppt)	Silt/Clay (<63μ) Content by Weight (%)
Tidal Freshwater	0-0.5	N/A
Oligohaline	0.5-5	N/A
Low Mesohaline	5-12	N/A
High Mesohaline Sand	12-18	0-40
High Mesohaline Mud	12-18	> 40
Polyhaline Sand	> 18	0-40
Polyhaline Mud	> 18	> 40

Table 4. ERM guidelines for 24 trace metals (ppm dry wt) and organic compounds (ppb, dry wt) as defined from Long et al. (1995).

	Effects Range Median Concentration
Trace Metals	
Arsenic	70
Cadmium	9.6
Chromium	370
Copper	270
Lead	218
Mercury	0.71
Silver	3.7
Zinc	410
Organic Compounds	
Acenaphthene	500
Acenaphthylene	640
Anthracene	1100
Benzo[a]anthracene	1600
Benzo[a]pyrene	1600
Chrysene	2800
Dibenz[a,h]anthracene	260
Fluoranthene	5100
Fluorene	540
2-Methylnaphthalene	670
Naphthalene	2100
Phenanthrene	1500
Pyrene	2600
Total PCBs	180
4,4'-DDE	27
Total DDTs	46.1

Table 5. Number of sampling location/date combinations for each monitoring program within Chesapeake Bay and the number of location date combinations retained for discriminant analysis. An asterisk indicates that contaminants data were collected separately as part of the Ambient Toxicity Program.

Monitoring Program	Years of Collection	Sampling Locations	Samples
EMAP Virginian Province	1990-93	290	109
Mid-Atlantic Integrated Assessment Program	1997-98	121	67
CBP Long-term Benthic Monitoring Program (Maryland)*	1997	48	17
Tidal Freshwater Goals Program	1996	47	22
CBP Long-term Benthic Monitoring Program (Virginia)*	1997	46	17
Ambient Toxicity Program (Maryland)	1999	36	11
Ambient Toxicity Program (Virginia)	1999	20	13
		Total=608	Total=256

Table 6. Frequency and percentage of sites and mean B-IBI for sites within each status classification category. Values in parentheses represent one standard deviation in the B-IBI within each classification category.

Status	Number of Sites	% of Sites	Mean B-IBI
Meets Goals	272	44.66	3.6(0.5)
Marginal	69	11.33	2.8(0.1)
Degraded	110	18.06	2.4(0.1)
Severely Degraded	158	25.94	1.6(0.4)
Overall	609		2.8(1.0)

Table 7. Frequency of sites classified as severely degraded and degraded for each habitat type.

	Total		Severely Degraded		Degraded	
Habitat	Number	Percentage	Number	Percentage	Number	Percentage
Polyhaline Mud	35	13.67	19	7.42	16	6.25
Polyhaline Sand	9	3.52	2	0.78	7	2.73
High Mesohaline Mud	78	30.47	51	19.92	27	10.55
High Mesohaline Sand	26	10.16	16	6.25	10	3.91
Low Mesohaline	42	16.41	33	12.89	9	3.52
Oligohaline	32	12.50	15	5.86	17	6.64
Tidal Freshwater	34	13.28	17	6.64	17	6.64

Table 8. Frequency of sites classified as severely degraded and degraded for each stress group.

	ERM Sediment Contaminant Classification		VA Province Mean SQG Quotient Sediment Contaminant Classification		All Province Mean SQG Quotient Sediment Contaminant Classification	
Stress Group	Number	Percentage	Number	Percentage	Number	Percentage
Contaminant	23	8.98	63	24.61	140	54.69
Low D.O.	34	13.28	24	9.38	10	3.91
Combined	9	3.52	19	7.42	33	12.89
Unknown	190	74.22	150	58.59	73	28.52

Table 9. Frequency of sites classified as severely degraded and degraded within each habitat and effect type for each of the sediment contaminant classification schemes.

		ERM Sediment Contaminant Classification			VA Province Mean SQG Quotient Sediment Contaminant Classification			All Province Mean SQG Quotient Sediment Contaminant Classification		
Habitat	Stress Group	Total	Severely Degraded	Degraded	Total	Severely Degraded	Degraded	Total	Severely Degraded	Degraded
High Mesohaline Mud	Combined	2	2	0	4	3	1	12	11	1
High Mesohaline Mud	Contaminant	3	2	1	14	9	5	46	31	15
High Mesohaline Mud	Low D.O.	12	11	1	10	10	0	2	2	0
High Mesohaline Mud	Unknown	61	36	25	50	29	21	18	7	11
High Mesohaline Sand	Combined	0	0	0	0	0	0	0	0	0
High Mesohaline Sand	Contaminant	0	0	0	0	0	0	3	3	0
High Mesohaline Sand	Low D.O.	3	3	0	3	3	0	3	3	0
High Mesohaline Sand	Unknown	23	13	10	23	13	10	20	10	10
Low Mesohaline	Combined	6	5	1	14	13	1	15	14	1
Low Mesohaline	Contaminant	5	5	0	14	13	1	20	17	3
Low Mesohaline	Low D.O.	9	9	0	1	1	0	0	0	0
Low Mesohaline	Unknown	22	14	8	13	6	7	7	2	5
Oligohaline	Combined	0	0	0	0	0	0	0	0	0
Oligohaline	Contaminant	8	5	3	16	9	7	26	14	12
Oligohaline	Low D.O.	0	0	0	0	0	0	0	0	0
Oligohaline	Unknown	24	10	14	16	6	10	6	1	5
Polyhaline Mud	Combined	0	0	0	0	0	0	5	5	0
Polyhaline Mud	Contaminant	3	1	2	5	2	3	21	11	10
Polyhaline Mud	Low D.O.	7	7	0	7	7	0	2	2	0
Polyhaline Mud	Unknown	25	11	14	23	10	13	7	1	6
Polyhaline Sand	Combined	0	0	0	0	0	0	0	0	0
Polyhaline Sand	Contaminant	0	0	0	0	0	0	0	0	0
Polyhaline Sand	Low D.O.	3	2	1	3	2	1	3	2	1
Polyhaline Sand	Unknown	6	0	6	6	0	6	6	0	6
Tidal Freshwater	Combined	1	1	0	1	1	0	1	1	0
Tidal Freshwater	Contaminant	4	3	1	14	6	8	24	10	14
Tidal Freshwater	Low D.O.	0	0	0	0	0	0	0	0	0
Tidal Freshwater	Unknown	29	13	16	19	10	9	9	6	3

Table 10. Classification efficiencies of linear discriminant functions developed for the Within Habitat Type scenarios for all available stress groups. Shown are the percentages of correctly classified observations for each stress group and the total percentage of observations correctly classified by the discriminant function. Values in parentheses are the total number observations for each stress group.

Polyhaline Mud Calibration Data Set						
Classification Scheme	Data Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	-	100.00(2)	100.00(5)	100.00(21)	100.00
ERM Exceedance	Severely Degraded Only	-	100.00(1)	100.00(5)	100.00(9)	100.00
VA Province	Severely Degraded and Degraded	-	100.00(4)	100.00(5)	100.00(19)	100.00
VA Province	Severely Degraded Only	-	100.00(1)	100.00(5)	100.00(9)	100.00
All Province	Severely Degraded and Degraded	100.00(3)	100.00(18)	100.00(2)	100.00(5)	100.00
All Province	Severely Degraded Only	100.00(4)	100.00(9)	100.00(1)	100.00(1)	100.00
Polyhaline Mud Validation Data Set						
Classification Scheme	Data Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	-	0.00(1)	100.00(2)	25.00(4)	36.61
ERM Exceedance	Severely Degraded Only	-	-	100.00(2)	50.00(2)	67.86
VA Province	Severely Degraded and Degraded	-	0.00(1)	100.00(2)	0.00(4)	17.86
VA Province	Severely Degraded Only	-	0.00(1)	100.00(2)	100.00(1)	93.33
All Province	Severely Degraded and Degraded	-	66.67(3)	-	0.00(2)	57.69
All Province	Severely Degraded Only	0.00(1)	50.00(2)	100.00(1)	-	39.29
High Mesohaline Sand Calibration Data Set						
Classification Scheme	Data Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	-	-	100.00(3)	100.00(16)	100.00
ERM Exceedance	Severely Degraded Only	-	-	100.00(2)	100.00(12)	100.00
VA Province	Severely Degraded and Degraded	-	-	100.00(3)	100.00(16)	100.00
VA Province	Severely Degraded Only	-	-	100.00(2)	100.00(12)	100.00
All Province	Severely Degraded and Degraded	-	100.00(3)	100.00(3)	100.00(13)	100.00
All Province	Severely Degraded Only	-	100.00(3)	100.00(2)	100.00(9)	100.00
High Mesohaline Sand Validation Data Set						
Classification Scheme	Data Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	-	-	-	100.00(6)	100.00
ERM Exceedance	Severely Degraded Only	-	-	100.00(1)	100.00(1)	100.00
VA Province	Severely Degraded and Degraded	-	-	-	100.00(5)	100.00
VA Province	Severely Degraded Only	-	-	100.00(1)	100.00(1)	100.00
All Province	Severely Degraded and Degraded	-	-	-	100.00(5)	100.00
All Province	Severely Degraded Only	-	-	100.00(1)	100.00(1)	100.00

Table 10. Continued.

High Mesohaline Mud Calibration Data Set						
Classification Scheme	Data Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	100.00(1)	100.00(2)	62.50(8)	100.00(46)	94.74
ERM Exceedance	Severely Degraded Only	100.00(2)	100.00(2)	57.14(7)	100.00(28)	92.71
VA Province	Severely Degraded and Degraded	50.00(2)	100.00(12)	100.00(7)	100.00(36)	98.25
VA Province	Severely Degraded Only	33.33(3)	100.00(9)	100.00(6)	100.00(21)	94.87
All Province	Severely Degraded and Degraded	100.00(7)	100.00(37)	100.00(2)	100.00(11)	100.00
All Province	Severely Degraded Only	100.00(7)	100.00(23)	100.00(2)	100.00(7)	100.00
High Mesohaline Mud Validation Data Set						
Classification Scheme	Data Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	100.00(1)	0.00(1)	0.00(4)	46.15(13)	39.00
ERM Exceedance	Severely Degraded Only	-	-	25.00(4)	75.00(8)	65.00
VA Province	Severely Degraded and Degraded	0.00(2)	0.00(2)	66.67(3)	16.67(12)	18.71
VA Province	Severely Degraded Only	-	-	75.00(4)	75.00(8)	75.00
All Province	Severely Degraded and Degraded	60.00(5)	11.11(9)	-	0.00(5)	15.11
All Province	Severely Degraded Only	50.00(4)	75.00(8)	-	-	69.17
Low Mesohaline Calibration Data Set						
Classification Scheme	Data Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	80.00(5)	100.00(2)	100.00(8)	100.00(16)	96.77
ERM Exceedance	Severely Degraded Only	50.00(2)	100.00(3)	100.00(9)	100.00(12)	96.15
VA Province	Severely Degraded and Degraded	100.00(12)	100.00(9)	100.00(1)	100.00(9)	100.00
VA Province	Severely Degraded Only	100.00(10)	100.00(9)	100.00(1)	100.00(6)	100.00
All Province	Severely Degraded and Degraded	100.00(13)	100.00(13)	-	100.00(5)	100.00
All Province	Severely Degraded Only	100.00(11)	100.00(13)	-	100.00(2)	100.00
Low Mesohaline Validation Data Set						
Classification Scheme	Data Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	0.00(1)	0.00(3)	0.00(1)	20.00(5)	10.32
ERM Exceedance	Severely Degraded Only	0.00(3)	0.00(2)	-	50.00(2)	35.29
VA Province	Severely Degraded and Degraded	50.00(2)	0.00(5)	-	66.67(3)	40.00
VA Province	Severely Degraded Only	66.67(3)	0.00(4)	-	-	35.09
All Province	Severely Degraded and degraded	50.00(2)	42.86(7)	-	100.00(1)	55.07
All Province	Severely Degraded Only	66.67(3)	25.00(4)	-	-	44.10

Table 10. Continued.

Oligohaline Calibration Data Set						
Classification Scheme	Data Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	-	100.00(6)	-	100.00(19)	100.00
ERM Exceedance	Severely Degraded Only	-	100.00(4)	-	100.00(7)	100.00
VA Province	Severely Degraded and Degraded	-	100.00(10)	-	100.00(15)	100.00
VA Province	Severely Degraded Only	-	100.00(5)	-	100.00(6)	100.00
All Province	Severely Degraded and Degraded	-	100.00(19)	-	100.00(6)	100.00
All Province	Severely Degraded Only	-	100.00(10)	-	100.00(1)	100.00
Oligohaline Validation Data Set						
Classification Scheme	Data Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	-	100.00(2)	-	66.67(3)	74.67
ERM Exceedance	Severely Degraded Only	-	0.00(1)	-	0.00(1)	0.00
VA Province	Severely Degraded and Degraded	-	50.00(4)	-	100.00(1)	80.00
VA Province	Severely Degraded Only	-	50.00(2)	-	-	50.00
All Province	Severely Degraded and Degraded	-	100.00(5)	-	-	100.00
All Province	Severely Degraded Only	-	50.00(2)	-	-	50.00
Tidal Freshwater Calibration Data Set						
Classification Scheme	Data Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	100.00(1)	100.00(3)	-	100.00(23)	100.00
ERM Exceedance	Severely Degraded Only	100.00(1)	100.00(1)	-	100.00(12)	100.00
VA Province	Severely Degraded and Degraded	100.00(1)	100.00(10)	-	100.00(16)	100.00
VA Province	Severely Degraded Only	100.00(1)	100.00(5)	-	100.00(8)	100.00
All Province	Severely Degraded and Degraded	100.00(1)	100.00(19)	-	100.00(7)	100.00
All Province	Severely Degraded Only	100.00(1)	100.00(8)	-	100.00(5)	100.00
Tidal Freshwater Validation Data Set						
Classification Scheme	Data Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	-	0.00(1)	-	66.67(6)	58.97
ERM Exceedance	Severely Degraded Only	-	50.00(2)	-	100.00(1)	96.15
VA Province	Severely Degraded and Degraded	-	25.00(4)	-	33.33(3)	30.13
VA Province	Severely Degraded Only	-	0.00(1)	-	50.00(2)	30.77
All Province	Severely Degraded and Degraded	-	0.00(5)	-	0.00(2)	0.00
All Province	Severely Degraded Only	-	0.00(2)	-	0.00(1)	0.00

Table 11. Classification efficiencies of linear discriminant functions developed for Within Habitat Type scenarios for discriminating between the Contaminant and Other stress groups. Shown are the percentages of correctly classified observations for each stress group and the total percentage of observations correctly classified by the discriminant function. Values in parentheses are the total number observations for each stress group.

Classification Scheme	Data Set Used	Contaminant	Other	Total
Polyhaline Mud Calibration Data Set				
ERM Exceedance	Severely Degraded and Degraded	100.00(2)	100.00(26)	100.00
ERM Exceedance	Severely Degraded	100.00(1)	100.00(14)	100.00
VA Province	Severely Degraded and Degraded	100.00(4)	100.00(24)	100.00
VA Province	Severely Degraded	100.00(1)	100.00(14)	100.00
All Province	Severely Degraded and Degraded	100.00(18)	100.00(10)	100.00
All Province	Severely Degraded	100.00(9)	100.00(6)	100.00
Polyhaline Mud Validation Data Set				
ERM Exceedance	Severely Degraded and Degraded	0.00(1)	66.67(6)	61.90
ERM Exceedance	Severely Degraded	-	100.00(4)	100.00
VA Province	Severely Degraded and Degraded	0.00(1)	66.67(6)	57.14
VA Province	Severely Degraded	0.00(1)	100.00(3)	93.33
All Province	Severely Degraded and Degraded	100.00(3)	75.00(4)	91.07
All Province	Severely Degraded	50.00(2)	100.00(2)	70.00
High Mesohaline Sand Calibration Data Set				
All Province	Severely Degraded and Degraded	100.00(3)	100.00(16)	100.00
All Province	Severely Degraded	100.00(3)	100.00(11)	100.00
High Mesohaline Sand Validation Data Set				
All Province	Severely Degraded and Degraded	-	100.00(5)	100.00
All province	Severely Degraded	-	100.00(2)	100.00
High Mesohaline Mud Calibration Data Set				
ERM Exceedance	Severely Degraded and Degraded	100.00(2)	100.00(55)	100.00
ERM Exceedance	Severely Degraded	100.00(2)	100.00(37)	100.00
VA Province	Severely Degraded and Degraded	100.00(12)	100.00(45)	100.00
VA Province	Severely Degraded	100.00(9)	100.00(30)	100.00
All Province	Severely Degraded and Degraded	100.00(37)	100.00(20)	100.00
All Province	Severely Degraded	100.00(23)	100.00(16)	100.00
High Mesohaline Mud Validation Data Set				
ERM Exceedance	Severely Degraded and Degraded	0.00(1)	83.33(18)	80.41
ERM Exceedance	Severely Degraded	-	83.33(12)	83.33
VA Province	Severely Degraded and Degraded	0.00(2)	70.59(17)	55.73
VA Province	Severely Degraded	-	91.67(12)	100.00
All Province	Severely Degraded and Degraded	44.44(9)	60.00(10)	49.90
All Province	Severely Degraded	75.00(8)	100.00(4)	85.26

Table 11. Continued.

Low Mesohaline Calibration Data Set				
Classification Scheme	Data Set Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	100.00(2)	100.00(29)	100.00
ERM Exceedance	Severely Degraded	100.00(3)	100.00(23)	100.00
VA Province	Severely Degraded and Degraded	100.00(9)	100.00(22)	100.00
VA Province	Severely Degraded	100.00(9)	100.00(17)	100.00
ALL Province	Severely Degraded and Degraded	100.00(13)	100.00(18)	100.00
ALL Province	Severely Degraded	100.00(13)	100.00(13)	100.00
Low Mesohaline Validation Data Set				
Classification Scheme	Data Set Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	0.00(3)	57.14(7)	53.46
ERM Exceedance	Severely Degraded	0.00(2)	80.00(5)	70.77
VA Province	Severely Degraded and Degraded	40.00(5)	80.00(5)	68.39
VA Province	Severely Degraded	25.00(4)	66.67(3)	52.24
ALL Province	Severely Degraded and Degraded	42.86(7)	66.67(3)	56.68
ALL Province	Severely Degraded	25.00(4)	66.67(3)	45.83
Oligohaline Calibration Data Set				
Classification Scheme	Data Set Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	100.00(6)	100.00(19)	100.00
ERM Exceedance	Severely Degraded	100.00(4)	100.00(7)	100.00
VA Province	Severely Degraded and Degraded	100.00(10)	100.00(15)	100.00
VA Province	Severely Degraded	100.00(5)	100.00(6)	100.00
ALL Province	Severely Degraded and Degraded	100.00(19)	100.00(6)	100.00
ALL Province	Severely Degraded	100.00(10)	100.00(1)	100.00
Oligohaline Validation Data Set				
Classification Scheme	Data Set Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	100.00(2)	66.67(3)	74.67
ERM Exceedance	Severely Degraded	0.00(1)	0.00(1)	0.00
VA Province	Severely Degraded and Degraded	50.00(4)	100.00(1)	80.00
VA Province	Severely Degraded	50.00(2)	-	50.00
ALL Province	Severely Degraded and Degraded	100.00(5)	-	100.00
ALL Province	Severely Degraded	50.00(2)	-	50.00

Table 11. Continued.

Tidal Freshwater Calibration Data Set				
Classification Scheme	Data Set Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	100.00(3)	100.00(24)	100.00
ERM Exceedance	Severely Degraded	100.00(1)	100.00(13)	100.00
VA Province	Severely Degraded and Degraded	100.00(10)	100.00(17)	100.00
VA Province	Severely Degraded	100.00(5)	100.00(9)	100.00
ALL Province	Severely Degraded and Degraded	100.00(19)	100.00(8)	100.00
ALL Province	Severely Degraded	100.00(8)	100.00(6)	100.00
Tidal Freshwater Validation Data Set				
Classification Scheme	Data Set Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	100.00(1)	83.33(6)	85.19
ERM Exceedance	Severely Degraded	50.00(2)	100.00(1)	96.43
VA Province	Severely Degraded and Degraded	50.00(4)	33.33(3)	39.51
VA Province	Severely Degraded	50.00(1)	50.00(2)	67.86
ALL Province	Severely Degraded and Degraded	40.00(5)	0.00(2)	28.15
ALL Province	Severely Degraded	50.00(2)	0.00(1)	28.57

Table 12. Classification efficiencies of linear discriminant functions developed for classifying Polyhaline sites into one of the four stress groups. Shown are the percentages of correctly classified observations for each stress group and the total percentage of observations correctly classified by the discriminant function. Values in parentheses are the total number observations for each stress group.

		Calibration Data Set				
Classification Scheme	Sites Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	-	100.00(2)	100.00(8)	100.00(24)	100.00
ERM Exceedance	Severely Degraded Only	-	100.00(1)	100.00(7)	100.00(9)	100.00
VA Province	Severely Degraded and Degraded	-	100.00(4)	100.00(8)	100.00(22)	100.00
VA Province	Severely Degraded Only	-	100.00(1)	100.00(7)	100.00(9)	100.00
All Province	Severely Degraded and Degraded	100.00(4)	100.00(16)	100.00(4)	100.00(10)	100.00
All Province	Severely Degraded Only	100.00(5)	100.00(9)	100.00(2)	100.00(1)	100.00

		Validation Data Set				
Classification Scheme	Sites Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	-	0.00(1)	50.00(2)	57.14(7)	52.10
ERM Exceedance	Severely Degraded Only	-	-	100.00(2)	100.00(2)	100.00
VA Province	Severely Degraded and Degraded	-	100.00(1)	50.00(2)	57.14(7)	60.50
VA Province	Severely Degraded Only	-	0.00(1)	100.00(2)	100.00(1)	94.12
All Province	Severely Degraded and Degraded	100.00(1)	100.00(5)	100.00(1)	0.00(3)	70.59
All Province	Severely Degraded Only	50.00(2)	-	100.00(2)	-	59.09

Table 13. Classification efficiencies of linear discriminant functions developed for classifying Polyhaline sites into the Contaminant, Combined and Unknown stress groups. Shown are the percentages of correctly classified observations for each stress group and the total percentage of observations correctly classified by the discriminant function. Values in parentheses are the total number observations for each stress group.

		Calibration Data Set			
Classification Scheme	Sites Used	Combined	Contaminant	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	-	100.00(3)	100.00(24)	100.00
ERM Exceedance	Severely Degraded Only	-	100.00(1)	100.00(10)	100.00
VA Province	Severely Degraded and Degraded	-	100.00(5)	100.00(22)	100.00
VA Province	Severely Degraded Only	-	100.00(2)	100.00(9)	100.00
All Province	Severely Degraded and Degraded	100.00(4)	100.00(15)	100.00(12)	100.00
All Province	Severely Degraded Only	100.00(4)	100.00(9)	100.00(1)	100.00

		Validation Data Set			
Classification Scheme	Sites Used	Combined	Contaminant	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	-	-	85.71(7)	85.71
ERM Exceedance	Severely Degraded Only	-	-	100.00(1)	100.00
VA Province	Severely Degraded and Degraded	-	-	71.43(7)	71.43
VA Province	Severely Degraded Only	-	-	100.00(1)	100.00
All Province	Severely Degraded and Degraded	0.00(1)	66.67(6)	0.00(1)	32.26
All Province	Severely Degraded Only	0.00(1)	50.00(2)	-	34.62

Table 14. Classification efficiencies of linear discriminant functions developed for classifying Polyhaline sites

into the Contaminant and all Other stress groups with and without Low D.O. sites. Shown are the percentages of correctly classified observations for each stress group and the total percentage of observations correctly classified by the discriminant function. Values in parentheses are the total number observations for each stress group.

With Low DO stress group

		Calibration Data Set		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	100.00(2)	100.00(32)	100.00
ERM Exceedance	Severely Degraded Only	100.00(1)	100.00(16)	100.00
VA Province	Severely Degraded and Degraded	100.00(4)	100.00(30)	100.00
VA Province	Severely Degraded Only	100.00(1)	100.00(16)	100.00
All Province	Severely Degraded and Degraded	100.00(16)	100.00(18)	100.00
All Province	Severely Degraded Only	100.00(9)	100.00(8)	100.00

		Validation Data Set		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	0.00(1)	77.78(9)	73.20
ERM Exceedance	Severely Degraded Only	-	100.00(4)	100.00
VA Province	Severely Degraded and Degraded	100.00(1)	66.67(9)	70.59
VA Province	Severely Degraded Only	0.00(1)	100.00(3)	94.12
All Province	Severely Degraded and Degraded	80.00(5)	80.00(5)	80.00
All Province	Severely Degraded Only	100.00(2)	50.00(2)	76.47

Without Low DO stress group

		Calibration Data Set		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	100.00(3)	100.00(24)	100.00
ERM Exceedance	Severely Degraded Only	100.00(1)	100.00(10)	100.00
VA Province	Severely Degraded and Degraded	100.00(5)	100.00(22)	100.00
VA Province	Severely Degraded Only	100.00(2)	100.00(9)	100.00
All Province	Severely Degraded and Degraded	100.00(15)	100.00(16)	100.00
All Province	Severely Degraded Only	100.00(9)	100.00(5)	100.00

		Validation Data Set		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	-	85.71(7)	85.71
ERM Exceedance	Severely Degraded Only	-	100.00(1)	100.00
VA Province	Severely Degraded and Degraded	-	71.43(7)	71.43
VA Province	Severely Degraded Only	-	100.00(1)	100.00
All Province	Severely Degraded and Degraded	66.67(6)	50.00(2)	58.06
All Province	Severely Degraded Only	100.00(2)	0.00(1)	64.29

Table 15. Classification efficiencies of linear discriminant functions developed for classifying Mesohaline sites into one of the four stress groups. Shown are the percentages of correctly classified observations for each stress group and the total percentage of observations correctly classified by the discriminant function. Values in parentheses are the total number observations for each stress group.

		Calibration Data Set				
Classification Scheme	Sites Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	57.14(7)	100.00(6)	94.74(19)	96.92(65)	93.81
ERM Exceedance	Severely Degraded Only	50.00(6)	100.00(4)	100.00(19)	97.83(46)	94.67
VA Province	Severely Degraded and Degraded	100.00(15)	100.00(22)	63.64(11)	95.92(49)	93.81
VA Province	Severely Degraded Only	100.00(12)	100.00(16)	69.23(13)	94.12(34)	92.00
All Province	Severely Degraded and Degraded	95.45(22)	97.87(47)	75.00(4)	91.67(24)	94.85
All Province	Severely Degraded Only	100.00(20)	97.22(36)	100.00(5)	100.00(14)	98.67

		Validation Data Set				
Classification Scheme	Sites Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	100.00(1)	0.00(2)	40.00(5)	61.11(36)	56.00
ERM Exceedance	Severely Degraded Only	0.00(1)	0.00(3)	75.00(4)	17.65(17)	29.82
VA Province	Severely Degraded and Degraded	66.67(3)	66.67(6)	0.00(3)	40.63(32)	45.95
VA Province	Severely Degraded Only	75.00(4)	33.33(6)	0.00(1)	57.14(14)	45.02
All Province	Severely Degraded and Degraded	100.00(5)	45.45(22)	0.00(1)	56.25(16)	58.62
All Province	Severely Degraded Only	60.00(5)	53.33(15)	-	0.00(5)	44.57

Table 16. Classification efficiencies of linear discriminant functions developed for classifying Mesohaline sites into the Contaminant, Combined and Unknown stress groups. Shown are the percentages of correctly classified observations for each stress group and the total percentage of observations correctly classified by the discriminant function. Values in parentheses are the total number observations for each stress group.

		Calibration Data Set			
Classification Scheme	Sites Used	Combined	Contaminant	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	100.00(6)	100.00(5)	97.33(75)	97.67
ERM Exceedance	Severely Degraded Only	100.00(6)	100.00(5)	100.00(47)	100.00
VA Province	Severely Degraded and Degraded	93.33(15)	91.30(23)	94.44(54)	93.48
VA Province	Severely Degraded Only	100.00(14)	100.00(17)	96.97(33)	98.44
All Province	Severely Degraded and Degraded	92.00(25)	100.00(47)	95.65(23)	96.84
All Province	Severely Degraded Only	100.00(17)	100.00(40)	93.33(15)	98.61

		Validation Data Set			
Classification Scheme	Sites Used	Combined	Contaminant	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	100.00(2)	33.33(3)	57.69(26)	59.23
ERM Exceedance	Severely Degraded Only	0.00(1)	100.00(2)	12.50(16)	18.75
VA Province	Severely Degraded and Degraded	66.67(3)	80.00(5)	59.26(27)	65.65
VA Province	Severely Degraded Only	100.00(2)	40.00(5)	0.00(15)	32.50
All Province	Severely Degraded and Degraded	100.00(2)	45.45(22)	58.82(17)	63.05
All Province	Severely Degraded Only	87.50(8)	63.64(11)	25.00(4)	61.22

Table 17. Classification efficiencies of linear discriminant functions developed for classifying Mesohaline sites into the Contaminant and all Other stress groups with and without Low D.O. sites. Shown are the percentages of correctly classified observations for each stress group and the total percentage of observations correctly classified by the discriminant function. Scenarios with the best overall and within stress group classification efficiencies are highlighted in bold. Values in parentheses are the total number observations for each stress group.

With Low DO stress group

		Calibration Data Set		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded Only	100.00(91)	100.00(6)	100.00
ERM Exceedance	Severely Degraded Only	100.00(4)	100.00(71)	100.00
VA Province	Severely Degraded and Degraded Only	95.45(22)	96.00(75)	95.88
VA Province	Severely Degraded Only	100.00(16)	0.00(59)	98.67
All Province	Severely Degraded and Degraded Only	89.36(47)	96.00(50)	92.78
All Province	Severely Degraded Only	97.22(36)	100.00(39)	98.67

		Validation Data Set		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded Only	0.00(2)	76.19(42)	71.48
ERM Exceedance	Severely Degraded Only	0.00(3)	72.73(22)	68.85
VA Province	Severely Degraded and Degraded Only	66.67(6)	73.68(38)	72.09
VA Province	Severely Degraded Only	33.33(6)	73.68(19)	65.08
All Province	Severely Degraded and Degraded Only	50.00(22)	81.82(22)	66.40
All Province	Severely Degraded Only	53.33(15)	70.00(10)	62.00

Without Low D.O. Stress Group

		Calibration Data Set		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded Only	100.00(5)	100.00(81)	100.00
ERM Exceedance	Severely Degraded Only	100.00(5)	100.00(53)	100.00
VA Province	Severely Degraded and Degraded Only	91.30(23)	97.10(69)	95.65
VA Province	Severely Degraded Only	100.00(17)	100.00(47)	100.00
All Province	Severely Degraded and Degraded Only	93.62(47)	97.92(48)	95.79
All Province	**Severely Degraded Only**	**100.00(40)**	**100.00(32)**	**100.00**

		Validation Data Set		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded Only	33.33(3)	78.57(28)	75.94
ERM Exceedance	Severely Degraded Only	100.00(2)	70.59(17)	73.12
VA Province	Severely Degraded and Degraded Only	80.00(5)	66.67(30)	70.00
VA Province	Severely Degraded Only	40.00(5)	76.47(17)	66.78
All Province	Severely Degraded and Degraded Only	40.91(22)	84.21919)	62.79
All Province	**Severely Degraded Only**	**81.82(11)**	**75.00(12)**	**78.79**

Table 18. Classification efficiencies of linear discriminant functions developed for classifying Tidal Freshwater and Oligohaline sites into the Contaminant and all Other stress groups. Shown are the percentages of correctly classified observations for each stress group and the total percentage of observations correctly classified by the discriminant function. Values in parentheses are the total number observations for each stress group.

		Calibration Data Set		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	100.00(7)	97.67(43)	98.00
ERM Exceedance	Severely Degraded Only	100.00(6)	100.00(19)	100.00
VA Province	Severely Degraded and Degraded	94.44(18)	100.00(32)	98.00
VA Province	Severely Degraded Only	100.00(10)	100.00(15)	100.00
All Province	Severely Degraded and Degraded	94.59(37)	76.92(13)	90.00
All Province	Severely Degraded Only	100.00(18)	100.00(7)	100.00

		Validation Data Set		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	40.00(5)	55.56(9)	53.38
ERM Exceedance	Severely Degraded Only	50.00(2)	100.00(3)	88.00
VA Province	Severely Degraded and Degraded	50.00(10)	0.00(4)	18.00
VA Province	Severely Degraded Only	33.33(3)	0.00(2)	13.33
All Province	Severely Degraded and Degraded	45.45(11)	33.33(3)	42.30
All Province	Severely Degraded Only	50.00(4)	0.00(1)	36.00

Table 19. Classification efficiencies of linear discriminant functions developed for Baywide scenarios to discriminate between four potential stress groups for both uncorrected and salinity corrected data. Shown are the stress group specific and total percentages of correctly classified observations for each discriminant function. Values in parentheses are the total number observations for each stress group.

Without Salinity Correction				Calibration Data Set		
Classification Scheme	Sites Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	57.14(7)	84.62(13)	70.83(24)	92.13(127)	87.23
ERM Exceedance	Severely Degraded Only	100.00(8)	100.00(12)	73.68(19)	96.83(63)	93.14
VA Province	Severely Degraded and Degraded	86.67(15)	58.33(36)	56.25(16)	87.50(104)	78.36
VA Province	Severely Degraded Only	100.00(15)	88.46(26)	83.33(12)	97.96(49)	96.12
All Province	Severely Degraded and Degraded	72.00(25)	88.64(88)	100.00(6)	67.31(52)	80.12
All Province	Severely Degraded Only	87.50(16)	95.16(62)	100.00(5)	84.21(19)	92.16
				Validation Data Set		
Classification Scheme	Sites Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	0.00(2)	60.00(10)	70.00(10)	69.64(56)	66.11
ERM Exceedance	Severely Degraded Only	-	23.08(4)	25.00(13)	36.73(32)	38.81
VA Province	Severely Degraded and Degraded	50.00(4)	40.00(25)	25.00(8)	63.41(41)	53.71
VA Province	Severely Degraded Only	100.00(2)	45.45(11)	18.18(11)	40.00(25)	45.69
All Province	Severely Degraded and Degraded	62.50(8)	78.00(50)	0.00(4)	43.75(16)	62.58
All Province	Severely Degraded Only	73.33(15)	59.09(22)	0.00(4)	50.00(8)	56.73
Linear Regression Salinity Correction				Calibration		
Classification Scheme	Sites Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	57.14(7)	92.31(13)	70.83(24)	92.37(118)	87.65
ERM Exceedance	Severely Degraded Only	100.00(8)	100.00(12)	73.68(19)	91.53(59)	89.80
VA Province	Severely Degraded and Degraded	93.33(15)	63.89(36)	62.50(16)	90.53(95)	82.10
Va Province	Severely Degraded Only	100.00(15)	88.46(26)	91.67(12)	91.11(45)	91.84
All Province	Severely Degraded and Degraded	72.00(25)	88.51(87)	83.33(6)	75.00(44)	82.10
All Province	Severely Degraded Only	95.45(22)	91.23(57)	60.00(5)	85.71(14)	89.80
				Validation		
Classification Scheme	Sites Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	0.00(2)	30.00(10)	70.00(10)	66.67(54)	61.34
ERM Exceedance	Severely Degraded Only	-	0.00(4)	15.38(13)	37.50(32)	34.50
VA Province	Severely Degraded and Degraded	50.00(4)	32.00(25)	62.50(8)	69.23(39)	58.51
VA Province	Severely Degraded Only	100.00(2)	45.45(11)	9.09(11)	40.00(25)	46.85
All Province	Severely Degraded and Degraded	62.50(8)	73.47(36)	0.00(4)	40.00(15)	59.97
All Province	Severely Degraded Only	77.78(9)	40.74(27)	0.00(4)	44.44(9)	45.71
Polynomial Regression Salinity Correction				Calibration		
Classification Scheme	Sites Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	42.86(7)	76.92(13)	70.83(24)	91.53(118)	85.19
ERM Exceedance	Severely Degraded Only	100.00(8)	91.67(12)	68.42(19)	93.22(59)	88.78
VA Province	Severely Degraded and Degraded	93.33(15)	66.67(36)	62.50(16)	88.42(95)	81.48
VA Province	Severely Degraded Only	100.00(15)	84.62(22)	75.00(12)	95.56(45)	90.82
All Province	Severely Degraded and Degraded	72.00(25)	88.51(87)	83.33(6)	79.55(44)	83.33
All Province	Severely Degraded Only	95.45(22)	91.23(57)	60.00(5)	85.71(14)	89.80
				Validation		
Classification Scheme	Sites Used	Combined	Contaminant	Low D.O.	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	0.00(2)	30.00(10)	60.00(10)	72.22(54)	63.90
ERM Exceedance	Severely Degraded Only	-	75.00(4)	15.38(13)	37.50(12)	37.83
VA Province	Severely Degraded and Degraded	50.00(4)	32.00(25)	37.50(8)	61.54(39)	51.53
VA Province	Severely Degraded Only	100.00(2)	45.45(11)	45.45(11)	44.00(25)	53.14
All Province	Severely Degraded and Degraded	62.50(8)	65.31(49)	0.00(4)	40.00(15)	55.58
All Province	Severely Degraded Only	77.78(9)	37.04(27)	25.00(4)	44.44(9)	46.63

Table 20. Classification efficiencies of linear discriminant functions developed for Baywide scenarios to discriminate between the Contaminant, Combined and Unknown stress groups for both uncorrected and salinity corrected data. Shown are the stress group specific and total percentages of correctly classified observations for each discriminant function. Values in parentheses are the total number observations for each stress group.

Without Salinity Correction		Calibration Data Set			
Classification Scheme	Sites Used	Combined	Contaminant	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	75.00(4)	91.67(12)	96.88(128)	95.83
ERM Exceedance	Severely Degraded Only	100.00(8)	100.00(9)	97.18(69)	97.73
VA Province	Severely Degraded and Degraded	84.62(13)	82.05(39)	89.11(101)	86.93
VA Province	Severely Degraded Only	100.00(13)	91.67(24)	92.86(56)	93.55
All Province	Severely Degraded and Degraded	77.27(22)	89.01(91)	70.00(50)	81.60
All Province	Severely Degraded Only	78.95(19)	94.83(58)	90.00(20)	90.72
		Validation Data Set			
Classification Scheme	Sites Used	Combined	Contaminant	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	40.00(5)	9.09(11)	87.27(55)	78.96
ERM Exceedance	Severely Degraded Only	-	28.57(7)	62.50(24)	58.68
VA Province	Severely Degraded and Degraded	50.00(6)	27.27(22)	63.64(44)	53.21
VA Province	Severely Degraded Only	100.00(4)	38.46(13)	33.33(18)	43.98
All Province	Severely Degraded and Degraded	54.55(11)	85.11(47)	50.00(18)	70.21
All Province	Severely Degraded Only	83.33(12)	61.54(26)	57.14(7)	64.90
Linear Regression Salinity Correction		Calibration			
Classification Scheme	Sites Used	Combined	Contaminant	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	75.00(4)	91.67(12)	98.33(120)	97.06
ERM Exceedance	Severely Degraded Only	100.00(8)	100.00(9)	97.06(68)	97.65
VA Province	Severely Degraded and Degraded	84.62(13)	84.62(39)	90.11(91)	88.11
VA Province	Severely Degraded Only	100.00(13)	91.67(24)	90.57(53)	92.22
All Province	Severely Degraded and Degraded	81.82(22)	93.33(90)	73.81(42)	86.36
All Province	Severely Degraded Only	91.67(24)	96.23(53)	81.25(16)	92.47
		Validation			
Classification Scheme	Sites Used	Combined	Contaminant	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	40.00(5)	9.09(11)	84.62(52)	76.64
ERM Exceedance	Severely Degraded Only	-	14.29(7)	60.87(23)	55.42
VA Province	Severely Degraded and Degraded	66.67(6)	22.73(22)	48.84(43)	43.34
VA Province	Severely Degraded Only	100.00(4)	23.08(13)	23.53(17)	34.45
All Province	Severely Degraded and Degraded	54.55(11)	82.61(46)	58.82(17)	72.11
All Province	Severely Degraded Only	57.14(7)	64.52(31)	71.43(7)	63.80
Polynomial Regression Salinity Correction		Calibration			
Classification Scheme	Sites Used	Combined	Contaminant	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	75.00(4)	83.33(12)	98.33(120)	96.32
ERM Exceedance	Severely Degraded Only	100.00(8)	100.00(9)	97.06(68)	97.65
VA Province	Severely Degraded and Degraded	84.62(13)	76.92(39)	90.11(91)	86.01
VA Province	Severely Degraded Only	100.00(13)	91.67(24)	92.45(53)	93.33
All Province	Severely Degraded and Degraded	81.82(22)	93.33(90)	73.81(42)	86.36
All Province	Severely Degraded Only	91.67(24)	96.23(53)	81.25(16)	92.47
		Validation			
Classification Scheme	Sites Used	Combined	Contaminant	Unknown	Total
ERM Exceedance	Severely Degraded and Degraded	40.00(5)	18.18(11)	80.77(52)	74.05
ERM Exceedance	Severely Degraded Only	-	14.29(7)	65.22(23)	59.26
VA Province	Severely Degraded and Degraded	50.00(6)	22.73(22)	58.14(43)	47.74
VA Province	Severely Degraded Only	100.00(4)	15.38(13)	23.53(17)	32.40
All Province	Severely Degraded and Degraded	54.55(11)	80.43(46)	58.82(17)	70.84
All Province	Severely Degraded Only	57.14(7)	58.06(31)	71.43(7)	60.13

Table 21. Classification efficiencies of linear discriminant functions developed for Baywide scenarios to discriminate between the Contaminant and all Other stress groups with Low D.O. sites for both uncorrected and salinity corrected data. Shown are the stress group specific and total percentages of correctly classified observations for each discriminant function. Values in parentheses are the total number observations for each stress group.

Without Salinity Correction		Calibration Data Set		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	84.62(158)	96.20(13)	95.32
ERM Exceedance	Severely Degraded Only	100.00(12)	100.00(90)	100.00
VA Province	Severely Degraded and Degraded	50.00(36)	94.81(135)	85.38
VA Province	Severely Degraded Only	84.62(26)	98.68(76)	95.1
All Province	**Severely Degraded and Degraded**	**81.82(88)**	**73.49(83)**	**77.78**
All Province	Severely Degraded Only	91.23(57)	93.33(45)	92.16
		Validation Data Set		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	40.00(10)	86.76(68)	83.21
ERM Exceedance	Severely Degraded Only	25.00(4)	73.33(45)	67.65
VA Province	Severely Degraded and Degraded	48.00(25)	79.25(53)	72.67
VA Province	Severely Degraded Only	45.45(11)	71.05(38)	64.53
All Province	**Severely Degraded and Degraded**	**82.00(50)**	**67.86(28)**	**75.14**
All Province	Severely Degraded Only	40.74(27)	59.09(22)	48.84
Linear Regression Salinity Correction		Calibration		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	84.62(13)	95.97(149)	95.06
ERM Exceedance	Severely Degraded Only	100.00(12)	98.84(86)	98.98
VA Province	Severely Degraded and Degraded	61.11(36)	93.65(126)	86.42
VA Province	Severely Degraded Only	80.77(26)	97.22(70)	92.86
All Province	Severely Degraded and Degraded	86.21(87)	77.33(75)	82.10
All Province	Severely Degraded Only	92.98(57)	90.24(41)	91.84
		Validation		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	30.00(10)	84.85(66)	80.45
ERM Exceedance	Severely Degraded Only	50.00(4)	71.11(45)	68.53
VA Province	Severely Degraded and Degraded	40.00(25)	76.47(51)	68.37
VA Province	Severely Degraded Only	45.45(11)	11.05(38)	64.26
All Province	Severely Degraded and Degraded	81.63(49)	66.67(18)	74.70
All Province	Severely Degraded Only	51.85(27)	59.09(22)	54.88
Polynomial Regression Salinity Correction		Calibration		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	76.92(13)	95.97(149)	94.44
ERM Exceedance	Severely Degraded Only	91.67(12)	100.00(86)	98.98
VA Province	Severely Degraded and Degraded	58.33(36)	93.65(126)	85.80
VA Province	Severely Degraded Only	80.77(26)	98.61(72)	93.88
All Province	Severely Degraded and Degraded	87.36(87)	77.33(75)	82.72
All Province	Severely Degraded Only	92.98(57)	90.24(41)	91.84
		Validation		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	30.00(10)	89.39(66)	84.63
ERM Exceedance	Severely Degraded Only	75.00(4)	66.67(45)	67.69
VA Province	Severely Degraded and Degraded	32.00(25)	76.47(51)	66.59
VA Province	Severely Degraded Only	45.45(11)	73.68(38)	66.19
All Province	Severely Degraded and Degraded	67.35(49)	66.67(27)	67.03
All Province	Severely Degraded Only	51.85(27)	59.09(22)	54.88

Table 22. Classification efficiencies of linear discriminant functions developed for Baywide scenarios to discriminate between the Contaminant and all Other groups without Low D.O. sites for both uncorrected and salinity corrected data. Shown are the stress group specific and total percentages of correctly classified observations for each discriminant function. Values in parentheses are the total number observations for each stress group.

Without Salinity Correction		Calibration Data Set		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	91.67(12)	98.48(132)	97.92
ERM Exceedance	Severely Degraded Only	100.00(9)	100.00(79)	100.00
VA Province	Severely Degraded and Degraded	79.49(39)	93.86(114)	90.20
VA Province	Severely Degraded Only	87.50(24)	95.65(69)	93.55
All Province	Severely Degraded and Degraded	84.62(91)	75.00(72)	80.37
All Province	Severely Degraded Only	92.45(53)	88.64(44)	90.72
		Validation Data Set		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	9.09(11)	91.67(60)	84.79
ERM Exceedance	Severely Degraded Only	28.57(7)	83.33(24)	77.73
VA Province	Severely Degraded and Degraded	22.73(22)	68.00(50)	56.46
VA Province	Severely Degraded Only	38.46(13)	45.45(22)	43.65
All Province	Severely Degraded and Degraded	87.23(47)	55.17(29)	73.07
All Province	Severely Degraded Only	58.06(31)	50.00(14)	54.41
Linear Regression Salinity Correction		Calibration		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	91.67(12)	100.00(124)	99.26
ERM Exceedance	Severely Degraded Only	100.00(9)	100.00(76)	100
VA Province	Severely Degraded and Degraded	82.05(39)	95.19(104)	91.61
VA Province	Severely Degraded Only	91.67(24)	93.94(66)	93.33
All Province	Severely Degraded and Degraded	88.89(90)	71.88(64)	81.82
All Province	Severely Degraded Only	92.45(53)	85.00(40)	89.25
		Validation		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	9.09(11)	89.47(57)	82.38
ERM Exceedance	Severely Degraded Only	14.29(6)	82.61(19)	75.37
VA Province	Severely Degraded and Degraded	27.27(22)	59.18(49)	50.48
VA Province	Severely Degraded Only	23.08(13)	33.33(21)	30.60
All Province	Severely Degraded and Degraded	84.78(46)	64.29(28)	76.26
All Province	Severely Degraded Only	58.06(31)	42.86(14)	51.52
Polynomial Regression Salinity Correction		Calibration		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	83.33(12)	100.00(124)	98.53
ERM Exceedance	Severely Degraded Only	100.00(9)	100.00(76)	100.00
VA Province	Severely Degraded and Degraded	82.05(39)	94.23(104)	90.91
VA Province	Severely Degraded Only	91.67(24)	96.97(66)	95.56
All Province	Severely Degraded and Degraded	88.89(90)	71.88(64)	81.82
All Province	Severely Degraded Only	94.34(53)	87.50(40)	91.40
		Validation		
Classification Scheme	Sites Used	Contaminant	Other	Total
ERM Exceedance	Severely Degraded and Degraded	18.18(11)	84.21(57)	78.38
ERM Exceedance	Severely Degraded Only	14.29(7)	73.91(23)	67.60
VA Province	Severely Degraded and Degraded	27.27(22)	61.22(49)	51.96
VA Province	Severely Degraded Only	23.08(13)	38.10(21)	34.09
All Province	Severely Degraded and Degraded	82.61(46)	64.29(28)	74.99
All Province	Severely Degraded Only	64.52(31)	57.14(14)	61.34

Table 23. Classification efficiencies of discriminant functions developed for selected scenarios after application of the stepwise discriminant and ANOVA variable reduction procedures.

Classification Scheme	Data Set	Contaminant	Other	Total
Across Habitat Severely Degraded and Degraded Stepwise Variable Reduction				
All Province	Validation	63.33(90)	70.93(86)	67.05
All Province	Validation	68.00(50)	66.67(30)	67.35
Across Habitat Severely Degraded and Degraded ANOVA Variable Reduction				
Classification Scheme	Data Set	Contaminant	Other	Total
All Province	Validation	71.11(90)	68.60(86)	30.11
All Province	Validation	68.00(50)	70.00(30)	31.02
Polyhaline Mud Severely Degraded and Degraded With Low D.O. Sites Stepwise Variable Reduction				
Classification Scheme	Data Set	Contaminant	Other	Total
All Province	Calibration	88.89	80.00	85.71
All Province	Validation	100.00	25.00	73.21
Polyhaline Mud Severely Degraded and Degraded With Low D.O. Sites ANOVA Variable Reduction				
Classification Scheme	Data Set	Contaminant	Other	Total
All Province	Calibration	100.00	100.00	100.00
All Province	Validation	66.67	50.00	60.61
High Mesohaline Mud Severely Degraded and Degraded With Low D.O. Sites Stepwise Variable Reduction				
Classification Scheme	Data Set	Contaminant	Other	Total
All Province	Calibration	89.19	71.43	82.76
All Province	Validation	44.44	54.55	48.10
High Mesohaline Mud Severely Degraded and Degraded With Low D.O. Sites ANOVA Variable Reduction				
Classification Scheme	Data Set	Contaminant	Other	Total
All Province	Calibration	86.47	75.00	82.46
All Province	Validation	77.78	60.00	71.54
Polyhaline Severely Degraded and Degraded With Low D.O. Sites Stepwise Variable Reduction				
Classification Scheme	Data Set	Contaminant	Other	Total
All Province	Calibration	93.75	83.33	88.24
All Province	Validation	100.00	40.00	68.24
Polyhaline Severely Degraded and Degraded With Low D.O. Sites ANOVA Variable Reduction				
Classification Scheme	Data Set	Contaminant	Other	Total
All Province	Calibration	87.50	100.00	94.12
All Province	Validation	100.00	40.00	68.24
Mesohaline Severely Degraded Only With Low D.O. Sites Stepwise Variable Reduction				
Classification Scheme	Data Set	Contaminant	Other	Total
All Province	Calibration	75.00	94.87	85.33
All Province	Validation	53.85	66.67	60.51
Mesohaline Severely Degraded Only With Low D.O. Sites ANOVA Variable Reduction				
Classification Scheme	Data Set	Contaminant	Other	Total
All Province	Calibration	86.11	88.10	87.18
All Province	Validation	46.15	53.85	50.30

Table 24. Coefficients and cutoff values for the Baywide linear discriminant function for classifying severely

degraded and degraded sites into the Contaminant and Other stress groups using “uncorrected” data.

See replacement table in addendum

Variable	Coefficient	Variable	Coefficient
Bivalvia Abundance	-5.7758	Mollusca Abundance	3.4078
Deep Deposit Feeder Species Richness	-4.9318	Deep Deposit Feeder Proportional Abundance	2.9854
Haustoriidae Abundance	-1.9847	Infaunal Species Richness	2.8957
Carnivore-Omnivore Species Richness	-1.9341	Haustoriidae Proportional Abundance	2.1790
Epifaunal Species Richness	-1.6869	Corophiidae Abundance	2.0845
Spionidae Species Richness	-1.6390	Tubificidae Species Richness	1.8683
Interface Feeder Species Richness	-1.5044	Oligochaeta Species Richness	1.7297
Polychaeta Proportional Abundance	-1.3688	Interface Feeder Proportional Abundance	1.4703
Suspension Feeder Species Richness	-1.2402	Interface Feeder Abundance	1.4380
Corophiidae Species Richness	-1.2291	Capitellidae Species Richness	1.3813
Deep Deposit Feeder Abundance	-1.1099	Epifaunal Species Richness	1.3278
Isopoda Species Richness	-0.9923	Suspension Feeder Abundance	1.2508
Gastropoda Abundance	-0.9463	Infaunal Species Diversity	1.2457
Oligochaeta Proportional Abundance	-0.9326	Isopoda Abundance	1.2194
Infaunal Species Evenness	-0.7874	Ratio of Epifaunal to Infaunal Abundance	1.1108
Amphipoda Proportional Abundance	-0.7706	Spionidae Proportional Abundance	0.9090
Ampeliscidae Abundance	-0.6400	Total Biomass	0.8661
Corophiidae Proportional Abundance	-0.6079	Oligochaeta Abundance	0.8107
Amphipoda Species Richness	-0.4602	Polychaeta Species Richness	0.7996
Gastropoda Proportional Abundance	-0.4197	Nereidae Proportional Abundance	0.6975
Nereidae Abundance	-0.4029	Bivalvia Species Richness	0.6930
Mollusca Proportional Abundance	-0.3791	Mollusca Species Richness	0.6648
Ampeliscidae Species Richness	-0.3257	Ampeliscidae Proportional Abundance	0.6035
Epifaunal Species Diversity	-0.2631	Suspension Feeder Proportional Abundance	0.5728
Haustoriidae Species Richness	-0.2470	Amphipoda Abundance	0.5295
Tubificidae Proportional Abundance	-0.2319	Carnivore-Omnivore Proportional Abundance	0.5292
Ratio of Biomass to Abundance	-0.1790	Carnivore-Omnivore Abundance	0.5151
Tubificidae Abundance	-0.1686	Gastropoda Abundance	0.2762
Bivalvia Proportional Abundance	-0.1372	Isopoda Proportional Abundance	0.2669
Spionidae Abundance	-0.1167	Polychaeta Abundance	0.1674
Nereidae Species Richness	-0.0909	Total Infaunal Abundance	0.1516
		Capitellidae Proportional Abundance	0.1383
		Capitellidae Abundance	0.1211

Cutoff Value=0.2411

Appendices

Appendix A. List of species classified as epifaunal.

Turbellaria
Stylochus ellipticus
Turbellaria spp.

Polychaeta
Dipolydora commensalis
Filograninae sp. A Morris
Harmothoe extenuata
Harmothoe spp.
Hydroides dianthus
Hydroides protulicola
Hydroides spp.
Lepidonotus sublevis
Lepidonotus variabilis
Polydora websteri
Polynoidae spp.
Sabellaria vulgaris
Serpulidae spp.

Hirudinea
Hirudinea spp.
Batracobdella phalera
Helobdella spp.

Gastropoda
Amnicola limosa
Anachis lafresnayi
Anachis obesa
Anachis spp.
Astyris lunata
Bittium alternatum
Boonea bisuturalis
Boonea impressa
Boonea seminuda
Cincinnatia winkleyi
Columbella spp.
Columbellidae spp.
Crassispira ostrearum
Cratena pilata
Crepidula convexa-fornicata
Crepidula maculosa
Crepidula plana
Crepidula spp.
Cylichnella bidentata
Doridella obscura
Epitonium greenlandicum
Epitonium humphreysi
Epitonium rupicola
Epitonium spp.
Eupleura caudata
Fargoa bushiana
Ferrissia rivularis
Gastropoda spp.

Gastropoda
Goniobasis virginica
Gyraulus spp.
Hydrobia spp.
Hydrobiidae spp.
Hydrobiidae sp. Y Morris
Hydrobiidae sp. Z Morris
Kurtziella atrostyla
Littoridinops tenuipes
Melanella spp.
Nudibranchia
Odostomia engonia
Odostomia spp.
Physidae spp.
Planorbidae spp.
Pleurocera spp.
Pyramidella candida
Pyramidellidae spp.
Sayella chesapeakea
Turbonilla spp.
Turridae sp. A Mountford
Urosalpinx cinerea
Valvata sincera
Vitrinellidae spp.
Viviparidae spp.

Bivalvia
Anomia simplex
Anomia spp.
Crassostrea virginica
Geukensia demissa
Ischadium recurvum
Modiolus spp.
Mytilidae spp.
Mytilopsis leucophaeata
Mytilus edulis

Chelicerata
Limulus polyphemus

Cladocera
Cladocera spp.

Cirripedia
Balanus improvisus
Balanus spp.

Mysidae
Americamysis almyra
Americamysis bigelowi
Americamysis spp.
Heteromysis formosa
Mysidae spp.

Mysidae
Neomysis americana

Isopoda
Edotea triloba
Erichsonella attenuata
Erichsonella filiformis
Paracereis caudata
Sphaeroma quadridentatum
Cassidinidea ovalis

Amphipoda
Ampithoe longimanna
Apocorophium lacustre
Apocorophium simile
Batea catharinensis
Caprella andreae
Caprella penantis
Caprella spp.
Caprellidae spp.
Cerapus tubularis
Corophium spp.
Cymadusa compta
Dulichiella appendiculata
Elasmopus laevis
Ericthonius brasiliensis
Gammaropsis sutherlandi
Gammarus daiberi
Gammarus fasciatus
Gammarus spp.
Gitanopsis spp.
Melita nitida
Microprotopus raneyi
Monocorophium acherusicum
Monocorophium insidiosum
Monocorophium tuberculatum
Mucrogammarus mucronatus
Paracaprella tenuis
Parametopella cypris
Photis pugnator
Stenothoe minuta
Stenothoe spp.

Decapoda
Callinectes sapidus
Crangon septemspinosa
Decapoda spp.
Dissodactylus mellitae
Eurypanopeus depressus
Hexapanopeus angustifrons
Pagurus longicarpus
Pagurus spp.
Palaemonetes pugio

Decapoda
Panopeus herbstii
Penaeidae spp.
Pinnotheres ostreum
Processa vicina
Rhithropanopeus harrisii
Trachypenaeus constrictus
Xanthidae

Insecta
Brachycercus spp.
Caenis spp.
Coenagrionidae
Odonata spp.
Curculionidae
Dubiraphia spp.
Elmidae
Gyrinidae
Stenelmis spp.
Cyrnellus fraternus
Hydroptilidae
Oecetis spp.
Trichoptera

Bryozoa
Alcyonidium spp.
Anguinella palmata
Callopora craticula
Membranipora tenuis

Ascidiacea
Ascidiacea spp.
Molgula arenata
Molgula manhattensis
Perophora viridis

Appendix B. List of species classified as deep deposit feeders.

Polychaeta

Amastigos caperatus
Capitella capitata complex
Capitellidae spp.
Clymenella torquata
Heteromastus filiformis
Leitoscoloplos fragilis
Leitoscoloplos robustus
Leitoscoloplos spp.
Macroclymene zonalis
Maldanidae spp.
Mediomastus ambiseta
Notomastus sp. A Ewing
Notomastus spp.
Orbinia riseri
Orbiniidae spp.
Pectinaria gouldii
Sabaco elongatus
Scalibregma inflatum
Scoloplos rubra
Travisia sp. A Morris

Oligochaeta

Aulodrilus limnobius
Aulodrilus paucichaeta
Aulodrilus pigueti
Aulodrilus pluriseta
Branchiura sowerbyi
Bratislavia unidentata
Dero digitata
Dero spp.
Haber cf. speciosus
Homochaeta naidina
Ilyodrilus templetoni
Isochaetides freyi
Limnodrilus cervix
Limnodrilus claparedianus
Limnodrilus hoffmeisteri
Limnodrilus spp.
Limnodrilus udekemianus
Naididae spp.
Nais pardalis
Nais pseudobtusa
Nais variabilis
Oligochaeta spp.
Piguetiella michiganensis
Pristinella jenkinae
Pristinella osborni
Quistadrilus multisetosus
Specaria josinae

Oligochaeta

Stephensoniana spp.
Stephensoniana tandyi
Stephensoniana trivandrana
Telmatodrilus vejdovskyi
Tubificidae with capiliform chaetae
Tubificidae without capiliform chaetae
Tubificoides heterochaetus
Tubificoides spp.

Bivalvia

Nucula annulata
Nucula proxima
Nucula spp.
Solemya velum
Yoldia limatula

Enteropneusta

Enteropneusta spp.

Appendix C. List of species classified as suspension feeders.

Polychaeta

Chaetopterus variopedatus
Demonax microphthalmus
Sabellidae spp.

Bivalvia

Aligena elevata
Anadara ovalis
Anadara transversa
Anodonta spp.
Barnea truncata
Corbicula fluminea
Donax variabilis
Ensis directus
Gemma gemma
Lyonsia hyalina
Lyonsia spp.
Mactridae spp.
Mercenaria mercenaria
Mulinia lateralis
Musculium spp.
Mya arenaria
Mysella planulata
Pandora spp.
Parvilucina multilineata
Periploma margaritaceum
Petricola pholadiformis
Pisidium spp.
Pitar morrhuanus
Rangia cuneata
Sphaeridae spp.
Spisula solidissima
Tagelus divisus
Tagelus plebeius
Tagelus spp.
Unionidae spp.

Amphipoda

Ampelisca abdita-vadorum complex
Ampelisca spp.
Ampelisca verrilli

Phoronida

Phoronis spp.

Cephalochordata

Branchiostoma caribaeum

Appendix D. List of species classified as interface feeders.

Polychaeta
- Ampharetidae spp.
- *Amphitrite ornata*
- *Apoprionospio pygmaea*
- *Aricidea catherinae*
- *Aricidea wassi*
- *Asabellides oculata*
- *Boccardiella hamata*
- *Boccardiella ligerica*
- *Carazziella hobsonae*
- *Caulleriella* sp. B (Blake)
- Cirratulidae spp.
- *Cirriformia grandis*
- Cirrophorus spp.
- *Dipolydora socialis*
- *Dispio uncinata*
- *Enoplobranchus sanguineus*
- *Hobsonia florida*
- *Levinsenia gracilis*
- *Loimia medusa*
- *Magelona* spp.
- *Manayunkia aestuarina*
- *Marenzelleria viridis*
- *Melinna maculata*
- *Monticellina baptisteae-dorsobranchialis*
- *Monticellina* spp.
- *Owenia fusiformis*
- Oweniidae spp.
- *Paraonis fulgens*
- *Paraprionospio pinnata*
- *Pista cristata*
- *Pista* spp.
- *Polycirrus* spp.
- *Polydora cornuta*
- *Polydora* spp.
- *Polydora/Boccardiella* spp.
- Polygordius spp.
- *Prionospio heterobranchia*
- *Prionospio perkinsi*
- *Prionospio* spp.
- *Pseudopolydora* spp.
- *Scolelepis bousfieldi*
- *Scolelepis* spp.
- *Scolelepis squamata*
- *Scolelepis texana*
- *Spio setosa*
- *Spiochaetopterus costarum*
- Spionidae spp.
- *Spiophanes bombyx*
- *Streblospio benedicti*
- Terebellidae spp.
- *Tharyx* sp. A Morris

Bivalvia
- *Macoma balthica*
- *Macoma mitchelli*
- *Macoma tenta*
- *Tellina agilis*
- Tellinidae spp.

Cumacea
- *Almyracuma proximoculi*
- *Bodotria* sp. A Morris
- *Cyclaspis varians*
- *Leucon americanus*
- *Mancocuma stellifera*
- *Oxyurostylis smithi*

Tanaidacea
- *Hargeria rapax*
- Tanaidacea spp.
- *Tanaissus psammophilus*

Amphipoda
- *Acanthohaustorius millsi*
- *Acanthohaustorius similis*
- *Americhelidium americanum*
- *Ameroculodes* species complex
- Amphipoda spp.
- *Bathyporeia parkeri*
- *Corophium lacustre*
- *Eobrolgus spinosus*
- Haustoriidae spp.
- *Lepidactylus dytiscus*
- *Leptocheirus plumulosus*
- *Listriella barnardi*
- *Listriella clymenellae*
- *Listriella smithi*
- *Listriella* spp.
- *Monoculodes edwardsi*
- *Parahaustorius longimerus*
- Phoxocephalidae spp.
- *Protohaustorius cf. deichmannae*
- *Protohaustorius wigleyi*
- *Rhepoxynius hudsoni*
- *Unciola dissimilis*
- *Unciola irrorata*
- *Unciola serrata*
- *Unciola* spp.

Insecta
- *Stictochironomous* spp.

Sipuncula
- *Microphiopholis atra*

Ophiuroidea
- Ophiuroidea spp.

Holothuridea
- *Havelockia scabra*
- Holothuroidea spp.
- *Leptosynapta tenuis*
- *Pentamera pulcherrima*

Enteropneusta
- *Saccoglossus kowalevskii*

Appendix E. List of species classified into the carnivore/omnivore feeding group category.

Anthozoa
Anthozoa spp.
Edwardsia elegans

Nemertea
Amphiporus bioculatus
Carinoma tremaphoros
Micrura leidyi
Nemertinea

Nematoda
Nematoda spp.

Polychaeta
Aglaophamus verrilli
Ancistrosyllis hartmanae
Ancistrosyllis jonesi
Arabella iricolor-multidentata
Arabellidae spp.
Autolytus spp.
Bhawania heteroseta
Brania clavata-swedmarki
Brania spp.
Brania wellfleetensis
Cabira incerta
Diopatra cuprea
Drilonereis longa
Eteone foliosa
Eteone heteropoda
Eteone spp.
Eumida sanguinea
Exogone dispar
Exogone spp.
Glycera americana
Glycera dibranchiata
*Glycer*a spp.
Glyceridae spp.
Glycinde solitaria
Goniadidae
Gyptis crypta
Hesionidae
Laeonereis culveri
Lepidametria commensalis
Lumbrineridae spp.
Malmgreniella taylori
Marphysa sanguinea
Microphthalmus aberrans
Microphthalmus sczelkowii
Microphthalmus similis
Microphthalmus spp.

Polychaeta
Neanthes arenaceodentata
Neanthes succinea
Nephtyidae
Nephtys bucera
Nephtys cryptomma
Nephtys incisa
Nephtys picta
Nephtys spp.
Nereididae
Nereis grayi
Onuphidae
Onuphis eremita
Parahesione luteola
Paranaitis speciosa
Parapionosyllis longicirrata
Parougia caeca
Phyllodoce arenae
Phyllodoce spp.
Phyllodocidae
Pilargidae
Pionosyllis spp.
Podarke obscura
Podarkeopsis levifuscina
Protodriloides chaetifer
Pseudeurythoe paucibranchiata
Scoletoma tenuis
Sigambra bassi
Sigambra spp.
Sigambra tentaculata
Sphaerosyllis aciculata
Sphaerosyllis taylori
Sthenelais boa
Sthenelais spp.
Streptosyllis arenae
Streptosyllis pettiboneae
Syllidae spp.
Syllides spp.
Syllides verrilli

Oligochaeta
Chaetogaster spp.

Gastropoda
Acteocina canaliculata
Bithynia tentaculata
Busycon spp.
Caecidae spp.
Caecum regulare
Caecum sp. A Mountford

Gastropoda
Gastropoda sp. A Mountford
Haminoea solitaria
Ilyanassa obsoleta
Lymnaeidae spp.
Nassarius spp.
Nassarius trivittatus
Nassarius vibex
Natica pusilla
Naticidae
Rictaxis punctostriatus

Copepoda
Argulus spp.

Stomatopoda
Squilla empusa

Isopoda
Amakusanthura magnifica
Ancinus depressus
Chiridotea almyra
Chiridotea coeca
Cyathura burbancki
Cyathura polita
Cyathura spp.
Ptilanthura tenuis

Decapoda
Alpheus heterochaelis
Automate sp. A Williams
Callianassa setimanus
Euceramus praelongus
Libinia spp.
Ogyrides alphaerostris
Ovalipes ocellatus
Pinnixa chaetopterana
Pinnixa retinens
Pinnixa spp.
Polyonyx gibbesi
Thalassinidea
Upogebia affinis

Insecta
Ephemeridae
Hexagenia limbata
Hexagenia spp.
Bezzia spp.
Ceratopogonidae spp.
Chaoborus albatus

Insecta
Chaoborus punctipennis
Chaoborus spp.
Diptera spp.
Ablabesmyia annulata
Axarus spp.
Chironomidae spp.
Chironomini spp.
Chironomus spp.
Cladopelma spp.
Cladotanytarsus spp.
Clinotanypus pinguis
Clinotanypus spp.
Coelotanypus spp.
Cricotopus spp.
Cricotopus/Orthocladius spp
Cryptochironomus fulvus
Cryptochironomus spp.
Cryptotendipes spp.
Demicryptochironomus spp.
Dicrotendipes spp.
Endochironomus spp.
Epoicocladius spp.
Glyptotendipes spp.
Harnischia spp.
*Kiefferul*us spp.
Microchironomus spp.
Nanocladius spp.
Orthocladiinae
Parachironomus spp.
Paracladopelma spp.
Paralauterborniella spp.
Phaenopsectra spp.
Polypedilum halterale group
Polypedilum spp.
Procladius spp.
Procladius sublettei
Pseudochironomus spp.
Rheotanytarsus spp.
Tanypodinae
Tanypus spp.
Tanytarsini
Tanytarsus spp.

Echinoidea
Echinoidea spp.
Mellita quinquiesperforata

Appendix F. Number of contaminants exceeding the Effects Range Median concentration (ERM Conc.), the mean Sediment QualityGuidelines (SQG) quotient, the number of missing analytes, and a listing of missing analytes for each station date combination classified as severely degraded or degraded.Habitat type is based on Weisberg et al. (1997).

Station	Date	Estuary	Habitat	Number of Contaminants Exceeding ERM Conc.	Mean SQG quotient	Number of Missing Analytes	Missing Analytes
CP94084	07/12/94	Albemarle-Chesapeake Canal	Low Mesohaline	0	0.018	0	
AR4	08/26/98	Anacostia River	Tidal Freshwater	4	0.405	3	AG, Total PCBs, 2-Methylnaphthalene
VA90-088	07/08/90	Anacostia River	Tidal Freshwater	1	0.237	1	
VA90-088	08/26/90	Anacostia River	Tidal Freshwater	1	0.237	1	AS
VA92-494	07/29/92	Aquia Creek	Oligohaline	0	0.100	0	
VA90-090	07/08/90	Back River	Oligohaline	3	0.449	1	
VA90-090	07/26/90	Back River	Oligohaline	3	0.449	1	AS
VA90-090	09/05/90	Back River	Oligohaline	3	0.449	1	
VA90-140	08/15/90	Back River	Oligohaline	6	0.723	1	AS
VA91-090	09/05/91	Back River	Low Mesohaline	3	0.451	1	p,pDDE
VA90-081	08/27/90	Bear Creek	Low Mesohaline	3	0.578	1	AS
VA92-483	08/15/92	Big Annemessex River	High Mesohaline Mud	0	0.035	0	
MET06424	09/09/99	Bohemia River	Oligohaline	2	0.437	5	Acenaphthene,Acenaphthylene,Dibenz(a,h)anthracene,2Methylnaphthalene,Naphthalene,
MET06425	09/09/99	Bohemia River	Oligohaline	0	0.034	5	Acenaphthene,Acenaphthylene,Dibenz(a,h)anthracene,2Methylnaphthalene,Naphthalene,
VA90-089	08/07/90	Bohemia River	Oligohaline	0	0.068	1	AS
VA92-521	08/28/92	Bohemia River	Oligohaline	2	2.867	0	
VA91-306	07/28/91	Breton Bay	High Mesohaline Sand	0	0.036	0	
VA91-312	07/28/91	Breton Bay	High Mesohaline Mud	0	0.065	0	
VA92-452	08/09/92	Broad/Linkhorn Bay	Polyhaline Mud	0	0.091	0	
VA90-091	08/14/90	Bush River	Tidal Freshwater	0	0.109	1	AS
VA92-519	08/05/92	Bush River	Oligohaline	0	0.231	0	
VA90-050	07/20/90	Chesapeake Bay	High Mesohaline Sand	0	0.022	1	AS
VA90-056	08/19/90	Chesapeake Bay	Polyhaline Mud	0	0.038	1	AS
VA90-059	07/22/90	Chesapeake Bay	Polyhaline Mud	0	0.029	1	AS

Appendix F. Continued.

Station	Date	Estuary	Habitat Type	Number of Contaminants Exceeding ERM Conc.	Mean SQG quotient	Number of Missing Analytes	Missing Analytes
VA90-062	07/05/90	Chesapeake Bay	High Mesohaline Mud	0	0.054	1	
VA90-062	08/24/90	Chesapeake Bay	Polyhaline Mud	0	0.054	1	AS
VA90-062	09/07/90	Chesapeake Bay	Polyhaline Mud	0	0.054	1	
VA90-065	09/07/90	Chesapeake Bay	High Mesohaline Sand	0	0.002	1	
VA90-066	08/24/90	Chesapeake Bay	High Mesohaline Mud	0	0.082	1	AS
VA90-080	08/16/90	Chesapeake Bay	Polyhaline Mud	0	0.073	1	AS
VA91-050	07/11/91	Chesapeake Bay	High Mesohaline Mud	0	0.049	1	p,pDDE
VA91-282	08/12/91	Chesapeake Bay	Polyhaline Mud	0	0.049	1	p,pDDE
VA91-283	08/23/91	Chesapeake Bay	Polyhaline Mud	0	0.043	1	p,pDDE
VA91-303	08/27/91	Chesapeake Bay	High Mesohaline Mud	0	0.088	1	p,pDDE
VA91-325	08/15/91	Chesapeake Bay	High Mesohaline Mud	0	0.160	1	p,pDDE
VA91-426	07/10/91	Chesapeake Bay	High Mesohaline Mud	0	0.047	0	
VA92-050	08/03/92	Chesapeake Bay	High Mesohaline Mud	0	0.037	0	
VA92-058	08/30/92	Chesapeake Bay	Low Mesohaline	0	0.020	0	
VA92-455	08/08/92	Chesapeake Bay	Polyhaline Sand	0	0.006	0	
VA92-482	08/30/92	Chesapeake Bay	Polyhaline Mud	0	0.056	0	
VA92-497	08/14/92	Chesapeake Bay	Polyhaline Mud	0	0.083	0	
VA92-500	08/30/92	Chesapeake Bay	Polyhaline Sand	0	0.018	0	
VA93-050	07/29/93	Chesapeake Bay	High Mesohaline Sand	0	0.010	0	
VA93-050	08/26/93	Chesapeake Bay	High Mesohaline Mud	0	0.077	0	
VA93-617	08/22/93	Chesapeake Bay	High Mesohaline Mud	0	0.049	0	
VA93-622	08/07/93	Chesapeake Bay	High Mesohaline Sand	0	0.010	0	
VA93-626	09/03/93	Chesapeake Bay	Polyhaline Sand	0	0.013	0	
VA93-630	08/04/93	Chesapeake Bay	High Mesohaline Mud	0	0.052	0	
VA93-644	09/02/93	Chesapeake Bay	Polyhaline Mud	0	0.046	0	

Appendix F. Continued.

Station	Date	Estuary	Habitat Type	Number of Contaminants Exceeding ERM Conc.	Mean SQG quotient	Number of Missing Analytes	Missing Analytes
VA93-647	08/05/93	Chesapeake Bay	High Mesohaline Mud	0	0.094	0	
VA93-650	08/29/93	Chesapeake Bay	High Mesohaline Sand	0	0.006	0	
VA93-653	08/27/93	Chesapeake Bay	High Mesohaline Mud	0	0.135	0	
VA93-657	08/25/93	Chesapeake Bay	High Mesohaline Mud	0	0.137	0	
MMS-04508	09/17/97	Chesapeake Bay Mainstem	High Mesohaline Sand	0	0.007	3	Total PCBs, p,pDDE, Total DDTs
MMS-04512	09/16/97	Chesapeake Bay Mainstem	High Mesohaline Mud	0	0.075	2	Total PCBs, Total DDTs
MMS-04515	09/02/97	Chesapeake Bay Mainstem	High Mesohaline Mud	0	0.101	2	Total PCBs, Total DDTs
UPB-04613	09/03/97	Chesapeake Bay Mainstem	High Mesohaline Mud	0	0.138	0	
UPB-04621	08/26/97	Chesapeake Bay Mainstem	Tidal Freshwater	0	0.060	1	Total PCBs,
VBY-04M14	08/04/97	Chesapeake Bay Mainstem	Polyhaline Sand	0	0.003	2	Total PCBs, Total DDTs
VBY-04M16	08/11/97	Chesapeake Bay Mainstem	Polyhaline Mud	0	0.026	2	Total PCBs, Total DDTs
VBY-04M22	08/12/97	Chesapeake Bay Mainstem	Polyhaline Mud	0	0.029	2	Total PCBs, Total DDTs
VBY-04M24	08/12/97	Chesapeake Bay Mainstem	Polyhaline Mud	0	0.044	2	Total PCBs, Total DDTs
VBY-04M30	08/12/97	Chesapeake Bay Mainstem	Polyhaline Sand	0	0.026	2	Total PCBs, Total DDTs
CR59	09/10/98	Chester River	High Mesohaline Mud	0	0.035	3	AG,Total PCBs 2-Methylnaphthalene
CR61	09/10/98	Chester River	High Mesohaline Sand	0	0.015	3	AG,Total PCBs 2-Methylnaphthalene
VA93-661	08/05/93	Chester River	Low Mesohaline	0	0.135	0	
CH10	09/15/99	Choptank River	Oligohaline	0	0.022	4	AG, Total PCBs, Total DDTs, 2-Methylnaphthalene
CH9	09/15/99	Choptank River	Low Mesohaline	0	0.026	4	AG, Total PCBs, Total DDTs, 2-Methylnaphthalene
VA90-082	08/27/90	Colgate Cove	Low Mesohaline	2	0.236	1	AS
VA93-620	08/08/93	Corrotoman River	High Mesohaline Mud	0	0.069	0	
VA93-730	08/08/93	Corrotoman River	High Mesohaline Mud	0	0.054	0	
MA98-1021	08/27/98	Eastern Bay	High Mesohaline Sand	0	0.011	2	Total PCBs, Total DDTs
MA98-1022	08/29/98	Eastern Bay	High Mesohaline Mud	0	0.063	2	Total PCBs, Total DDTs
MA98-1023	08/27/98	Eastern Bay	High Mesohaline Sand	0	0.006	3	HG, Total PCBs, Total DDTs

Station	Date	Estuary	Habitat Type	Number of Contaminants Exceeding ERM Conc.	Mean SQG quotient	Number of Missing Analytes	Missing Analytes
MA98-1028	08/26/98	Eastern Bay	High Mesohaline Mud	0	0.056	2	Total PCBs, Total DDTs
MA98-1029	08/26/98	Eastern Bay	High Mesohaline Mud	0	0.040	2	Total PCBs, Total DDTs
MA98-1030	08/26/98	Eastern Bay	High Mesohaline Mud	0	0.038	2	Total PCBs, Total DDTs
VA90-086	08/01/90	Elizabeth River	Polyhaline Mud	1	0.342	1	AS
VA90-086	09/13/90	Elizabeth River	Polyhaline Mud	1	0.342	1	
VA91-308	08/29/91	Fishing Bay	High Mesohaline Mud	0	0.038	0	
VA91-286	08/11/91	Great Wicomico River	Polyhaline Mud	0	0.061	0	
VA91-290	08/11/91	Great Wicomico River	High Mesohaline Mud	0	0.085	0	
JAM-04J01	08/25/97	James River	Polyhaline Mud	0	0.129	1	Total PCBs
JAM-04J05	08/25/97	James River	Polyhaline Mud	0	0.050	2	Total PCBs, TotalDDTs
JAM-04J26	08/21/97	James River	Oligohaline	0	0.085	1	Total PCBs
JAM06J17	08/03/99	James River	Tidal Freshwater	0	0.244	5	Acenaphthene, Acenaphthylene, Dibenz[a,h]anthracene, 2-Methylnaphthalene, Naphthalene
JAM06J23	08/03/99	James River	Tidal Freshwater	0	0.120	5	Acenaphthene, Acenaphthylene, Dibenz[a,h]anthracene, 2-Methylnaphthalene, Naphthalene
VA90-208	08/22/90	James River	Tidal Freshwater	0	0.034	1	AS
VA90-210	07/23/90	James River	Tidal Freshwater	0	0.010	1	AS
VA91-273	08/04/91	James River	Tidal Freshwater	0	0.115	1	p,pDDE
VA91-275	08/05/91	James River	Tidal Freshwater	1	0.080	0	
VA92-464	08/17/92	James River	Tidal Freshwater	0	0.061	0	
VA93-602	08/13/93	James River	Polyhaline Mud	0	0.098	0	
VA93-609	08/15/93	James River	Tidal Freshwater	0	0.104	0	
VA93-610	08/16/93	James River	Tidal Freshwater	0	0.029	0	
VA93-728	08/15/93	James River	Oligohaline	0	0.110	0	
MMS-04514	09/02/97	Little Choptank River	High Mesohaline Sand	0	0.006	2	Total PCBs, Total DDTs
VA91-322	08/15/91	Little Choptank River	High Mesohaline Mud	0	0.025	1	p,pDDE
VA91-323	08/15/91	Little Choptank River	High Mesohaline Mud	0	0.037	1	p,pDDE

Appendix F. Continued.

Station	Date	Estuary	Habitat Type	Number of Contaminants Exceeding ERM Conc.	Mean SQG quotient	Number of Missing Analytes	Missing Analytes
MWT06309	09/08/99	Magothy River	Low Mesohaline	2	0.410	5	Acenaphthene, Acenaphthylene, Dibenz[a,h]anthracene, 2-Methylnaphthalene, Naphthalene
MWT06310	09/08/99	Magothy River	Low Mesohaline	0	0.034	5	Acenaphthene, Acenaphthylene, Dibenz[a,h]anthracene, 2-Methylnaphthalene, Naphthalene
VA92-136	08/04/92	Middle River	Oligohaline	0	0.077	0	
VA92-136	08/29/92	Middle River	Oligohaline	0	0.307	0	
VA93-136	08/03/93	Middle River	Oligohaline	2	0.268	0	
VA93-136	08/30/93	Middle River	Low Mesohaline	0	0.132	0	
VA91-330	08/17/91	Miles River	High Mesohaline Mud	0	0.051	1	p,pDDE
VA91-331	08/16/91	Miles River	High Mesohaline Mud	0	0.056	1	p,pDDE
VA92-466	08/21/92	Mobjack Bay	Polyhaline Mud	0	0.048	0	
VA92-451	08/10/92	Nansemond River	High Mesohaline Mud	0	0.081	0	
VA90-134	07/07/90	Patapsco River	Low Mesohaline	1	0.210	1	
VA90-134	08/15/90	Patapsco River	Low Mesohaline	1	0.210	1	AS
VA90-134	09/06/90	Patapsco River	High Mesohaline Mud	1	0.210	1	
PXR-04216	09/05/97	Patuxent River	High Mesohaline Mud	0	0.066	2	Total PCBs, Total DDTs
PXR-04223	09/12/97	Patuxent River	High Mesohaline Sand	0	0.046	2	Total PCBs, Total DDTs
PXR06207	08/31/99	Patuxent River	High Mesohaline Mud	3	0.617	5	Acenaphthene, Acenaphthylene, Dibenz[a,h]anthracene, 2-Methylnaphthalene, Naphthalene
VA91-280	08/09/91	Piankatank River	High Mesohaline Mud	0	0.052	0	
PMR-04101	09/15/97	Potomac River	High Mesohaline Mud	0	0.070	2	Total PCBs, Total DDTs
PMR-04102	09/15/97	Potomac River	High Mesohaline Sand	0	0.010	2	Total PCBs, Total DDTs
PMR-04104	09/15/97	Potomac River	High Mesohaline Mud	0	0.082	2	Total PCBs, Total DDTs
PMR-04108	09/15/97	Potomac River	High Mesohaline Mud	0	0.081	2	Total PCBs, Total DDTs
PMR-04110	09/16/97	Potomac River	High Mesohaline Sand	0	0.008	2	Total PCBs, Total DDTs
PMR-04111	09/16/97	Potomac River	High Mesohaline Mud	0	0.095	2	Total PCBs, Total DDTs
PMR-04112	09/16/97	Potomac River	High Mesohaline Mud	0	0.090	2	Total PCBs, Total DDTs
PMR-04115	09/16/97	Potomac River	High Mesohaline Mud	0	0.091	2	Total PCBs, Total DDTs

Appendix F. Continued.

Station	Date	Estuary	Habitat Type	Number of Contaminants Exceeding ERM Conc.	Mean SQG quotient	Number of Missing Analytes	Missing Analytes
PMR06106	09/20/99	Potomac River	High Mesohaline Mud	1	0.247	5	Acenaphthene, Acenaphthylene, Dibenz[a,h]anthracene, 2-Methylnaphthalene, Naphthalene
VA90-180	08/16/90	Potomac River	High Mesohaline Sand	0	0.016	1	AS
VA90-182	08/06/90	Potomac River	Low Mesohaline	0	0.046	1	AS
VA90-188	08/26/90	Potomac River	Tidal Freshwater	0	0.138	1	AS
VA91-302	07/28/91	Potomac River	High Mesohaline Sand	0	0.012	0	
VA92-188	07/27/92	Potomac River	Tidal Freshwater	0	0.118	0	
VA92-489	07/30/92	Potomac River	Low Mesohaline	0	0.086	0	
VA93-637	08/11/93	Potomac River	High Mesohaline Mud	0	0.080	0	
VA93-645	08/10/93	Potomac River	Oligohaline	0	0.125	0	
RAP-04R01	08/28/97	Rappahannock River	High Mesohaline Mud	0	0.053	2	Total PCBs, Total DDTs
RAP-04R05	08/28/97	Rappahannock River	High Mesohaline Mud	0	0.055	3	Total PCBs, p,pDDE, Total DDTs
RAP-04R12	08/28/97	Rappahannock River	High Mesohaline Mud	0	0.058	3	Total PCBs, p,pDDE, Total DDTs
RAP-04R15	08/28/97	Rappahannock River	High Mesohaline Mud	0	0.056	2	Total PCBs, TotalDDTs
RAP-04R17	08/28/97	Rappahannock River	High Mesohaline Mud	0	0.058	3	Total PCBs, p,pDDE, TotalDDTs
RAP-04R25	09/17/97	Rappahannock River	High Mesohaline Sand	0	0.049	2	Total PCBs, Total DDTs
RP1	08/11/99	Rappahannock River	High Mesohaline Mud	0	0.043	4	AG, Total PCBs, TotalDDTs, 2-Methylnaphthalene
RP2	08/11/99	Rappahannock River	High Mesohaline Mud	0	0.047	4	AG, Total PCBs, TotalDDTs, 2-Methylnaphthalene
RP3	08/11/99	Rappahannock River	High Mesohaline Mud	0	0.043	4	AG, Total PCBs, TotalDDTs, 2-Methylnaphthalene
RP4	08/11/99	Rappahannock River	High Mesohaline Mud	0	0.040	4	AG, Total PCBs, TotalDDTs, 2-Methylnaphthalene
RP5	08/11/99	Rappahannock River	High Mesohaline Mud	0	0.041	4	AG, Total PCBs, TotalDDTs, 2-Methylnaphthalene
RP6	08/11/99	Rappahannock River	High Mesohaline Mud	0	0.015	4	AG, Total PCBs, TotalDDTs, 2-Methylnaphthalene
RP8	08/10/99	Rappahannock River	High Mesohaline Mud	0	0.029	4	AG, Total PCBs, TotalDDTs, 2-Methylnaphthalene
RP9	08/10/99	Rappahannock River	Low Mesohaline	0	0.048	4	AG, Total PCBs, TotalDDTs, 2-Methylnaphthalene
VA90-084	08/14/90	Rappahannock River	High Mesohaline Mud	0	0.040	1	AS
VA90-190	08/15/90	Rappahannock River	High Mesohaline Mud	0	0.035	1	AS

Appendix F. Continued.

Station	Date	Estuary	Habitat Type	Number of Contaminants Exceeding ERM Conc.	Mean SQG quotient	Number of Missing Analytes	Missing Analytes
VA90-192	07/06/90	Rappahannock River	Oligohaline	0	0.050	1	
VA90-192	09/07/90	Rappahannock River	Oligohaline	0	0.050	1	
VA90-196	08/05/90	Rappahannock River	Tidal Freshwater	0	0.037	1	AS
VA91-294	07/30/91	Rappahannock River	Oligohaline	0	0.050	0	
VA91-298	07/30/91	Rappahannock River	Tidal Freshwater	0	0.062	0	
VA92-477	08/04/92	Rappahannock River	High Mesohaline Mud	1	0.228	0	
VA92-481	08/06/92	Rappahannock River	Oligohaline	0	0.061	0	
VA93-628	08/19/93	Rappahannock River	Oligohaline	0	0.067	0	
VA92-504	08/06/92	South River	Low Mesohaline	0	0.137	0	
VA91-304	07/24/91	St Clements Bay	High Mesohaline Mud	0	0.061	1	p,pDDE
VA92-486	08/28/92	St Marys River	High Mesohaline Mud	0	0.051	0	
VA91-351	07/30/91	Susquehanna River	Tidal Freshwater	0	0.085	0	
MMS-04511	09/17/97	Tangier Sound	High Mesohaline Sand	0	0.006	3	Total PCBs, p,pDDE, TotalDDTs
VA92-045	08/02/92	Tangier Sound	High Mesohaline Mud	0	0.015	0	
VA93-627	08/09/93	Tangier Sound	High Mesohaline Mud	0	0.038	0	
VA93-652	08/28/93	Tred Avon River	Low Mesohaline	0	0.055	0	
VA91-332	08/16/91	Wye River	High Mesohaline Mud	0	0.032	1	p,pDDE
VA93-729	08/28/93	York River	Low Mesohaline	0	0.031	0	
YRK-04Y02	08/26/97	York River	Polyhaline Mud	0	0.051	2	Total PCBs, Total DDTs
YRK-04Y14	08/26/97	York River	High Mesohaline Sand	0	0.036	2	Total PCBs, Total DDTs
YRK-04Y23	09/16/97	York River	High Mesohaline Sand	0	0.047	2	Total PCBs, Total DDTs
YRK06Y16	08/10/99	York River	Low Mesohaline	0	0.082	5	Acenaphthene, Acenaphthylene, Dibenz[a,h]anthracene, 2-Methylnaphthalene, Naphthalene
YRK06Y18	08/04/99	York River	Low Mesohaline	1	0.167	5	Acenaphthene, Acenaphthylene, Dibenz[a,h]anthracene, 2-Methylnaphthalene, Naphthalene
YRK06Y21	08/04/99	York River	Oligohaline	1	0.194	5	Acenaphthene, Acenaphthylene, Dibenz[a,h]anthracene, 2-Methylnaphthalene, Naphthalene
MA97-0061	07/27/97	Unknown	Polyhaline Sand	0	0.012	2	Total PCBs, Total DDTs

Appendix F. Continued.

Station	Date	Estuary	Habitat Type	Number of Contaminants Exceeding ERM Conc.	Mean SQG quotient	Number of Missing Analytes	Missing Analytes
MA97-0062	07/26/97	Unknown	Polyhaline Mud	0	0.043	2	Total PCBs, Total DDTs
MA97-0063	07/26/97	Unknown	Polyhaline Sand	0	0.008	2	Total PCBs, Total DDTs
MA97-0064	07/27/97	Unknown	Polyhaline Mud	0	0.047	2	Total PCBs, Total DDTs
MA97-0065	07/26/97	Unknown	Polyhaline Mud	0	0.053	2	Total PCBs, Total DDTs
MA97-0068	07/26/97	Unknown	Polyhaline Mud	0	0.055	2	Total PCBs, Total DDTs
MA97-0069	07/27/97	Unknown	Polyhaline Mud	0	0.043	2	Total PCBs, Total DDTs
MA97-0071	07/29/97	Unknown	Tidal Freshwater	0	0.059	2	Total PCBs, Total DDTs
MA97-0076	07/31/97	Unknown	Polyhaline Mud	0	0.049	2	Total PCBs, Total DDTs
MA97-0084	08/30/97	Unknown	Polyhaline Sand	0	0.005	2	Total PCBs, Total DDTs
MA97-0090	08/26/97	Unknown	High Mesohaline Mud	1	0.308	1	Total PCBs
MA97-0096	07/30/97	Unknown	High Mesohaline Mud	0	0.083	1	Total PCBs
MA97-0110	08/04/97	Unknown	Low Mesohaline	0	0.175	2	Total PCBs, Total DDTs
MA97-0112	08/05/97	Unknown	Low Mesohaline	0	0.107	2	Total PCBs, Total DDTs
MA97-0113	08/06/97	Unknown	Low Mesohaline	0	0.203	1	Total PCBs
MA97-0114	08/07/97	Unknown	Low Mesohaline	0	0.188	2	Total PCBs, Total DDTs
MA97-0116	08/06/97	Unknown	Low Mesohaline	0	0.182	2	Total PCBs, Total DDTs
MA97-0117	08/08/97	Unknown	Low Mesohaline	0	0.150	1	Total PCBs
MA97-0118	08/07/97	Unknown	Low Mesohaline	0	0.262	2	Total PCBs, Total DDTs
MA97-0119	08/09/97	Unknown	Low Mesohaline	0	0.076	2	Total PCBs, Total DDTs
MA97-0120	08/09/97	Unknown	Low Mesohaline	1	0.272	1	Total PCBs
MA97-0121	08/08/97	Unknown	Low Mesohaline	0	0.196	2	Total PCBs, Total DDTs
MA97-0122	08/08/97	Unknown	Low Mesohaline	0	0.015	2	Total PCBs, Total DDTs
MA97-0124	08/15/97	Unknown	Low Mesohaline	0	0.016	2	Total PCBs, Total DDTs
MA97-0125	08/09/97	Unknown	Low Mesohaline	0	0.154	2	Total PCBs, Total DDTs
MA97-0126	08/14/97	Unknown	High Mesohaline Mud	0	0.152	2	Total PCBs, Total DDTs

Appendix F. Continued.

Station	Date	Estuary	Habitat Type	Number of Contaminants Exceeding ERM Conc.	Mean SQG quotient	Number of Missing Analytes	Missing Analytes
MA97-0128	08/10/97	Unknown	Low Mesohaline	0	0.190	2	Total PCBs, Total DDTs
MA97-0129	08/12/97	Unknown	High Mesohaline Mud	0	0.146	2	Total PCBs, Total DDTs
MA97-0131	08/15/97	Unknown	Low Mesohaline	0	0.116	0	
MA97-0132	08/11/97	Unknown	High Mesohaline Mud	0	0.166	2	Total PCBs, Total DDTs
MA97-0134	08/11/97	Unknown	High Mesohaline Mud	0	0.182	2	Total PCBs, Total DDTs
MA97-0137	08/13/97	Unknown	High Mesohaline Mud	0	0.171	1	Total PCBs
MA97-0138	08/19/97	Unknown	Low Mesohaline	0	0.219	1	Total DDTs
MA97-0141	08/19/97	Unknown	Low Mesohaline	1	0.198	1	Total DDTs
MA97-0142	08/18/97	Unknown	Low Mesohaline	1	0.308	2	Total PCBs, Total DDTs
MA97-0144	08/19/97	Unknown	High Mesohaline Mud	0	0.159	2	Total PCBs, Total DDTs
MA97-0145	08/18/97	Unknown	Low Mesohaline	2	0.243	1	Total DDTs
MA97-0146	08/22/97	Unknown	Low Mesohaline	0	0.228	2	Total PCBs, Total DDTs
MA97-0147	08/16/97	Unknown	Low Mesohaline	0	0.068	2	Total PCBs, Total DDTs
MA97-0148	08/16/97	Unknown	Low Mesohaline	0	0.135	2	Total PCBs, Total DDTs
MA97-0152	08/23/97	Unknown	High Mesohaline Mud	0	0.148	2	Total PCBs, Total DDTs
MA97-0153	08/25/97	Unknown	High Mesohaline Mud	0	0.126	1	Total PCBs
MA97-0159	08/21/97	Unknown	High Mesohaline Sand	0	0.008	2	Total PCBs, Total DDTs
MA97-0163	08/21/97	Unknown	High Mesohaline Sand	0	0.019	3	Total PCBs, p,pDDE, Total DDTs
MA97-0177	07/28/97	Unknown	Oligohaline	0	0.078	2	Total PCBs, Total DDTs
MA97-0228	08/01/97	Unknown	Polyhaline Mud	0	0.069	1	Total PCBs
MA97-0229	08/01/97	Unknown	Polyhaline Mud	1	0.121	1	Total PCBs
MA97-0230	08/03/97	Unknown	Polyhaline Mud	0	0.051	1	Total PCBs
MA97-0231	08/01/97	Unknown	Polyhaline Mud	0	0.059	1	Total PCBs
MA97-0232	07/31/97	Unknown	Polyhaline Mud	0	0.049	2	Total PCBs, Total DDTs
MA97-0233	08/03/97	Unknown	Polyhaline Mud	0	0.057	1	Total PCBs

Appendix F. Continued.

Station	Date	Estuary	Habitat Type	Number of Contaminants Exceeding ERM Conc.	Mean SQG quotient	Number of Missing Analytes	Missing Analytes
MA97-0234	07/31/97	Unknown	Polyhaline Mud	0	0.051	2	Total PCBs, Total DDTs
MA97-0236	08/03/97	Unknown	Polyhaline Sand	0	0.005	2	Total PCBs, Total DDTs
MA97-0237	08/29/97	Unknown	High Mesohaline Mud	0	0.052	2	Total PCBs, Total DDTs
MA97-0238	08/27/97	Unknown	High Mesohaline Mud	0	0.054	2	Total PCBs, Total DDTs
MA97-0241	08/27/97	Unknown	High Mesohaline Sand	0	0.018	2	Total PCBs, Total DDTs
MA97-0242	08/29/97	Unknown	High Mesohaline Sand	0	0.022	1	Total PCBs
MA97-0243	08/28/97	Unknown	High Mesohaline Mud	0	0.049	2	Total PCBs, Total DDTs
MA97-0244	08/28/97	Unknown	High Mesohaline Sand	0	0.013	2	Total PCBs, Total DDTs
MA97-0245	08/28/97	Unknown	High Mesohaline Mud	0	0.069	2	Total PCBs, Total DDTs
MA97-0246	08/28/97	Unknown	High Mesohaline Sand	0	0.015	2	Total PCBs, Total DDTs
OL-01	08/27/96	Unknown	Oligohaline	0	0.047	2	Total PCBs, 2-Methylnaphthalene
OL-08	08/29/96	Unknown	Oligohaline	0	0.075	2	Total PCBs, 2-Methylnaphthalene
OL-09	08/29/96	Unknown	Oligohaline	0	0.076	2	Total PCBs, 2-Methylnaphthalene
OL-11	09/15/96	Unknown	Oligohaline	0	0.032	2	Total PCBs, 2-Methylnaphthalene
OL-12	09/12/96	Unknown	Oligohaline	0	0.137	2	Total PCBs, 2-Methylnaphthalene
OL-14	09/15/96	Unknown	Oligohaline	0	0.117	2	Total PCBs, 2-Methylnaphthalene
OL-15	09/12/96	Unknown	Oligohaline	0	0.035	2	Total PCBs, 2-Methylnaphthalene
OL-20	09/12/96	Unknown	Oligohaline	0	0.135	2	Total PCBs, 2-Methylnaphthalene
TF-03	09/19/96	Unknown	Tidal Freshwater	0	0.044	2	Total PCBs, 2-Methylnaphthalene
TF-04	09/19/96	Unknown	Tidal Freshwater	0	0.041	2	Total PCBs, 2-Methylnaphthalene
TF-06	09/19/96	Unknown	Tidal Freshwater	0	0.015	2	Total PCBs, 2-Methylnaphthalene
TF-08	09/19/96	Unknown	Tidal Freshwater	0	0.072	2	Total PCBs, 2-Methylnaphthalene
TF-16	09/05/96	Unknown	Tidal Freshwater	0	0.050	2	Total PCBs, 2-Methylnaphthalene
TF-18	09/15/96	Unknown	Tidal Freshwater	0	0.074	2	Total PCBs, 2-Methylnaphthalene
TF-19	09/18/96	Unknown	Tidal Freshwater	0	0.044	2	Total PCBs, 2-Methylnaphthalene

Appendix F. Continued.

Station	Date	Estuary	Habitat Type	Number of Contaminants Exceeding ERM Conc.	Mean SQG quotient	Number of Missing Analytes	Missing Analytes
TF-20	09/25/96	Unknown	Tidal Freshwater	0	0.115	2	Total PCBs, 2-Methylnaphthalene
TF-21	09/19/96	Unknown	Tidal Freshwater	0	0.115	2	Total PCBs, 2-Methylnaphthalene
TF-22	09/20/96	Unknown	Tidal Freshwater	0	0.034	2	Total PCBs, 2-Methylnaphthalene
TF-23	09/19/96	Unknown	Tidal Freshwater	0	0.121	2	Total PCBs, 2-Methylnaphthalene
TF-24	09/19/96	Unknown	Tidal Freshwater	0	0.081	2	Total PCBs, 2-Methylnaphthalene
TF-25	09/20/96	Unknown	Tidal Freshwater	0	0.167	2	Total PCBs, 2-Methylnaphthalene
TF-28	09/11/96	Unknown	Tidal Freshwater	1	0.174	2	Total PCBs, 2-Methylnaphthalene

Appendix G. Correlations between benthic bioindicators and salinity. Shown are the p values for the statistical test and Pearson's correlation coefficients r values for each bioindicator. Values in gray and bold face type are those selected for salinity correction.

	Abundance		Species Richness		Relative Abundance		Dominance		Diversity		Total Biomass*	
	p value	*r* value	p value	*r* value	p value	*r* value	p value	*r* value	p value	*r* value	p value	*r* value
Isopoda	0.0317	-0.14	<0.0001	-0.30	0.0183	-0.15	-		-		-	
Amphipoda	0.0309	-0.14	0.2538	0.07	0.0221	-0.15	-		-		-	
Haustoriidae	0.0976	0.11	0.0113	0.16	0.1107	0.10	-		-		-	
Ampeliscidae	0.0353	0.13	<0.0001	0.32	0.0062	0.17	-		-		-	
Corophiidae	0.7316	-0.02	0.3489	-0.06	0.4180	-0.05	-		-		-	
Mollusca	0.3157	0.06	0.0010	0.21	<0.0001	0.26	-		-		-	
Bivalvia	0.3628	0.06	0.7926	-0.02	0.1770	0.09	-		-		-	
Gastropoda	<0.0001	0.27	<0.0001	0.49	<0.0001	0.36	-		-		-	
Polychaeta	0.0011	0.21	**<0.0001**	**0.54**	**<0.0001**	**0.59**	-		-		-	
Spionidae	0.0855	0.11	<0.0001	0.37	<0.0001	0.33	-		-		-	
Capitellidae	0.0019	0.20	<0.0001	0.47	<0.0001	0.39	-		-		-	
Nereidae	0.0304	0.14	<0.0001	0.27	<0.0001	0.25	-		-		-	
Oligochaeta	<0.0001	-0.35	**<0.0001**	**-0.65**	**<0.0001**	**-0.65**	-		-		-	
Tubificidae	<0.0001	-0.41	**<0.0001**	**-0.68**	**<0.0001**	**-0.70**	-		-		-	
Deep Deposit Feeder	<0.0001	-0.31	**<0.0001**	**-0.51**	<0.0001	-0.43	-		-		-	
Suspension Feeder	0.3641	0.06	0.1119	0.10	0.9672	-0.002	-		-		-	
Interface Feeder	0.9589	0.003	<0.0001	0.27	<0.0001	0.37	-		-		-	
Carnivore/Omnivore	0.3583	-0.06	0.0002	0.23	0.7780	0.02	-		-		-	
Total Infauna	0.1205	-0.10	0.8057	-0.02	-		0.5168	0.04	0.3216	0.06	0.8757	-0.01
Epifauna	-		0.1134	0.10	0.0834	0.11	0.6067	0.03	0.2260	0.08	-	

*includes epifaunal species biomass

Appendix H. Regression relationships for salinity corrections of selected benthic bioindicators.

Polychaete Species Richness (Linear Relationship)

Source	D.F.	Sum of Squares	Mean Square	F Value	Prob. > F	R-Squared	Equation
Model	1	567.146	567.146	101.26	<0.0001	0.29	0.299+0.206*Salinity
Error	243	1361.076	5.601				
Corrected	244	1928.222					

Proportional Abundance of Polychaetes (Linear Relationship)

Source	D.F.	Sum of Squares	Mean Square	F Value	Prob. > F	R-Squared	Equation
Model	1	9.759	9.759	127.33	<0.0001	0.34	0.041+0.027*Salinity
Error	243	18.624	0.077				
Corrected	244	28.384					

Oligochaete Species Richness (Linear Relationship)

Source	D.F.	Sum of Squares	Mean Square	F Value	Prob. > F	R-Squared	Equation
Model	1	351.491	351.492	180.43	<0.0001	0.43	3.13-0.1623*Salinity
Error	243	473.374	1.948				
Corrected	244	824.866					

Oligochaete Species Richness(Polynomial Relationship)

Source	D.F.	Sum of Squares	Mean Square	F Value	Prob. > F	R-Squared	Equation
Model	3	476.414	158.805	109.83	<0.0001	0.58	$4.143-0.733*Sal+0.0463*Sal^2-0.001*Sal^3$
Error	241	348.452	1.446				
Corrected	244	824.866					

Proportional Abundance of Oligochaetes (Linear Relationship)

Source	D.F.	Sum of Squares	Mean Square	F Value	Prob. > F	R-Squared	Equation
Model	1	12.076	12.076	181.70	<0.0001	0.43	0.624-0.030*Salinity
Error	243	16.149	0.066				
Corrected	244	28.225					

Tubificid Species Richness (Linear Relationship)

Source	D.F.	Sum of Squares	Mean Square	F Value	Prob. > F	R-Squared	Equation
Model	1	364.483	364.48	204.01	<0.0001	0.45	2.865-0.165*Salinity
Error	243	434.132	1787				
Corrected	244	798.614					

Tubificid Species Richness (Polynomial Relationship)

Source	D.F.	Sum of Squares	Mean Square	F Value	Prob. > F	R-Squared	Equation
Model	3	511.690	170.563	143.26	<0.0001	0.64	$3.958-0.786*Sal+0.0497*Sal^2-0.001*Sal^3$
Error	241	286.924	1.191				
Corrected	244	798.614					

Proportional Abundance of Tubificids (Linear Relationship)

Source	D.F.	Sum of Squares	Mean Square	F Value	Prob. > F	R-Squared	Equation
Model	1	13.539	13.539	239.19	<0.0001	0.50	0.561-0.0319*Salinity
Error	243	13.755	0.057				
Corrected	244	27.294					

Richness of Deep Deposit Feeders (Linear Relationship)

Source	D.F.	Sum of Squares	Mean Square	F Value	Prob. > F	R-Squared	Equation
Model	1	146.72	146.722	53.59	<0.0001	0.18	3.061-0.104*Salinity
Error	243	665.266	2.738				
Corrected	244	811.99					

Richness of Deep Deposit Feeders (Polynomial Relationship)

Source	D.F.	Sum of Squares	Mean Square	F Value	Prob. > F	R-Squared	Equation
Model	1	302.65	100.88	47.73	<0.0001	0.37	$4.18-0.737*Sal+0.050*Sal^2-0.001* Sal^3$
Error	243	509.34	2.11				
Corrected	244	811.99					

ADDENDUM TO THE REPORT:

DEVELOPMENT OF DIAGNOSTIC APPROACHES TO DETERMINE SOURCES OF ANTHROPOGENIC STRESS AFFECTING BENTHIC COMMUNITY CONDITION IN THE CHESAPEAKE BAY

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1. Introduction

Dauer et al. (2002) submitted a report to the US EPA Chesapeake Bay Program Office on the development of diagnostic approaches to determine sources of anthropogenic stress affecting benthic community condition in the Chesapeake Bay. The objective of the study was to develop analytical tools capable of classifying regions in Chesapeake Bay identified as having degraded benthic communities into categories distinguished by the type of stress experienced by those communities. The tool was successful at identifying regions with high probabilities of sediment contamination. However, prior to implementation, it was recommended that the operational effectiveness of the diagnostic tool be further tested using additional validation data sets.

In this Addendum the results of two additional tasks are presented. First, the linear discriminant function was independently derived to verify the accuracy of the development of the function. Second, two additional putative validation data sets were used to assess the validity of the linear discriminant function.

2. Linear discriminant function

In this task it was discovered that four samples from the original calibration data set were not included in the derivation of the final linear discriminant function originally reported in Dauer et al. 2002. The final validation of the linear discriminant function with these additional four samples was identical to that reported in Table 21 for the Baywide scenario, i.e. using the All Province sediment contaminant classification, namely, with an overall percent correct classification of 75.14%. The new coefficients for this function are given in Table 1 of this Addendum (revised Table 24 of Dauer et al. 2002).

3. Additional validation data sets

Two putative data sets were used for further validation of the Contaminant Discriminant Tool (CDT) as presented in Dauer et al. 2002.

Elizabeth River Watershed

The first putative data set consisted of 125 random samples collected in 1999 from the Elizabeth River watershed (Dauer and Llansó 2003). An additional 100 random samples collected 25 per year from 2000-2003 were also used (Dauer 2001, 2002, 2003, 2004). All samples were analyzed using the CDT function and placed into categories based upon the posterior probability of inclusion into the Contaminant Group. Due to the high levels of contaminants recorded historically in the Elizabeth River watershed (Hall et al., 1992, 1997, 2002; Padma et al. 1998; Conrad et al. 2004), the *a priori* expectation was that a high percentage of samples declared degraded by the Benthic Index of Biotic Integrity would be placed into the Contaminant Group. The results from the Elizabeth River watershed are compared to results from the Virginia

Mainstem that is characterized as having low levels of contaminants and accordingly classified as of no environmental concern (USEPA 1999).

Our *a priori* expectation was that all branches of the Elizabeth River would show a higher percent area placed into the Contaminant Group compared to the Virginia Mainstem. For the Virginia Mainstem the number of sites placed into the Contaminant Group represented 11% of the entire stratum. Consistent with our *a priori* expectation, all strata in the Elizabeth River had higher proportions placed into the Contaminant Group, ranging from 40-92% (Table 2; Figure 1). These results indicate strong support for the CDT.

1996-2002 random data for Chesapeake Bay

The second putative data set consisted of random samples collected as part of the Maryland and Virginia Benthic Monitoring Program from 1996-2002. All samples were analyzed using the CDT function and placed into categories based upon the posterior probability of inclusion into the sediment Contaminant Group. The *a priori* expectation was that more samples collected near highly urbanized or industrialized watersheds would be placed into the Contaminant Group. Results are more difficult to interpret but the pattern of location of samples placed into the Contaminant Group is non-random (Table 3; Figure 2), and can be interpreted to be consistent with known patterns of sediment contaminant distributions for the entire Chesapeake Bay (e.g. see USEPA 1999). GIS maps show patterns of location that agree well with a priori expectations within highly contaminated regions of the Bay such as Baltimore Harbor (Figure 3) and the Elizabeth River (Figures 4 and 5). The maps were made with data placed on a 100 m grid and interpolated using a two-dimensional surface fitting algorithm.

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Table 1. Revised Table 24 of Dauer et al. (2002). Coefficients and cutoff values for the Baywide linear discriminant function for classifying severely degraded and degraded sites into the Contaminant and Other stress groups using "uncorrected" data.

Variable	Coefficient	Variable	Coefficient
Isopoda abundance	2.01518	Nereidae abundance	-0.28511
Isopoda diversity	-3.07226	Nereidae richness	-0.53535
Isopoda proportional abundance	9.45420	Nereidae proportional abundance	12.23099
Amphipoda abundance	0.38084	Oligochaeta abundance	0.43911
Amphipoda richness	-0.32010	Oligochaeta richness	1.37409
Amphipoda proportional abun.	-4.25029	Oligochaeta proportional abundance	-5.05367
Haustoriidae abundance	-3.85522	Tubificidae abundance	0.33669
Haustoriidae diversity	-1.39235	Tubificidae richness	0.96057
Haustoriidae proportional abun.	34.61687	Tubificidae proportional abundance	-2.27273
Ampeliscidae abundance	-1.57316	Deep deposit feeder abundance	-1.07320
Ampeliscidae richness	-1.79716	Deep deposit feeder richness	-2.43057
Ampeliscidae proportional abun.	25.88958	Deep deposit feeder proportional abun.	12.57963
Corophiidae abundance	37.26499	Suspension feeder abundance	1.05255
Corophiidae richness	-18.36548	Suspension feeder richness	-1.25065
Corophiidae proportional abun.	-2329.15377	Suspension feeder proportional abun.	2.17966
Mollusca abundance	2.52241	Interface feeder abundance	0.84134
Mollusca richness	0.74909	Interface feeder richness	-0.47052
Mollusca proportional abundance	-1.43165	Interface feeder proportional abundance	4.50630
Bivalvia abundance	-4.43466	Carnivore-Omnivore abundance	-0.05179
Bivalvia richness	1.28499	Carnivore-Omnivore richness	-0.00602
Bivalvia proportional abundance	-0.27727	Carnivore-Omnivore proportional abun.	3.13784
Gastropoda abundance	-1.23734	Total Abundance	0.18311
Gastropoda richness	-0.15477	Total biomass	4.75310
Gastropoda proportional abun.	-3.82240	Biomass to abundance ratio	-123.97124
Polychaeta abundance	0.05506	Infaunal species richness	-0.04107
Polychaeta richness	0.46294	Infaunal Shannon Wiener diversity	1.22042
Polychaeta proportional abun.	-5.08183	Infaunal species evenness	-2.50732
Spionidae abundance	-0.02286	Epifauna to Infaunal abundance ratio	4.41998
Spionidae richness	-1.89087	Epifauna species richness	-0.96505
Spionidae proportional abundance	4.02486	Epifaunal Shannon Wiener diversity	-1.11725
Capitellidae abundance	0.48588	Epifaunal species evenness	5.85736
Capitellidae richness	2.55550		
Capitellidae proportional abun.	-1.67289		

Cutoff Value = 2.56645

Table 2. Percent of the Elizabeth River 1999 strata placed into the sediment contaminant effect group using the contaminant discriminant function of Dauer et al. 2002 (posterior probability > 0.5). Scuffletown, Gilligan, Jones, and Paradise creeks are subsystems of the Southern Branch. Paradise Creek sampled in 2000. The Elizabeth River strata are compared to the Virginia Mainstem Stratum.

Stratum	Percentage of Stratum in Contaminant Group
Mainstem of the Elizabeth River	40
Lafayette River	60
Eastern Branch	64
Western Branch	72
Southern Branch	64
Scuffletown Creek	60
Gilligan/Jones Creek	68
Paradise Creek (2000)	92
Entire Elizabeth River watershed*	54
Virginia Mainstem	11

* Area weighted value

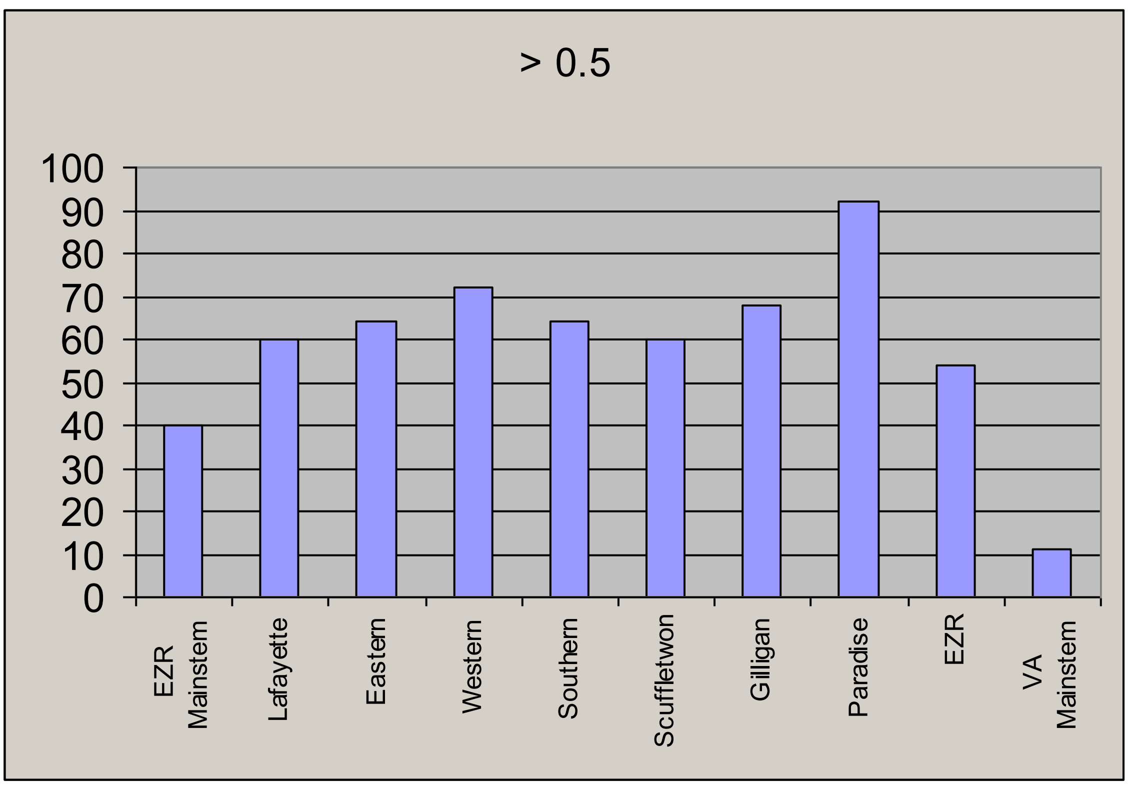

Figure 1. Percentage of stratum with a B-IBI value < 2.7 and placed into the Contaminant Group with a posterior probability > 0.5.

Table 3. Percent of the stratum placed into the sediment contaminant effect group using the contaminant discriminant function of Dauer et al. 2002 (posterior probability > 0.5). Data from 1996-2002. Elizabeth River data includes the intensive 1999 event and 25 random samples of the watershed from 2000-2002.

Stratum	N	Percentage of stratum in Contaminant Group
Lower (VA) Mainstem	175	10.9
Upper Bay Mainstem	175	17.7
MD Eastern Tributaries	175	16.6
Patuxent River	175	20.0
MD Middle Mainstem	175	17.1
MD Western Tributaries	175	24.6
Potomac River	175	31.4
James River	175	30.9
Rappahannock River	175	37.1
York River	175	38.3
Elizabeth River	275	52.4

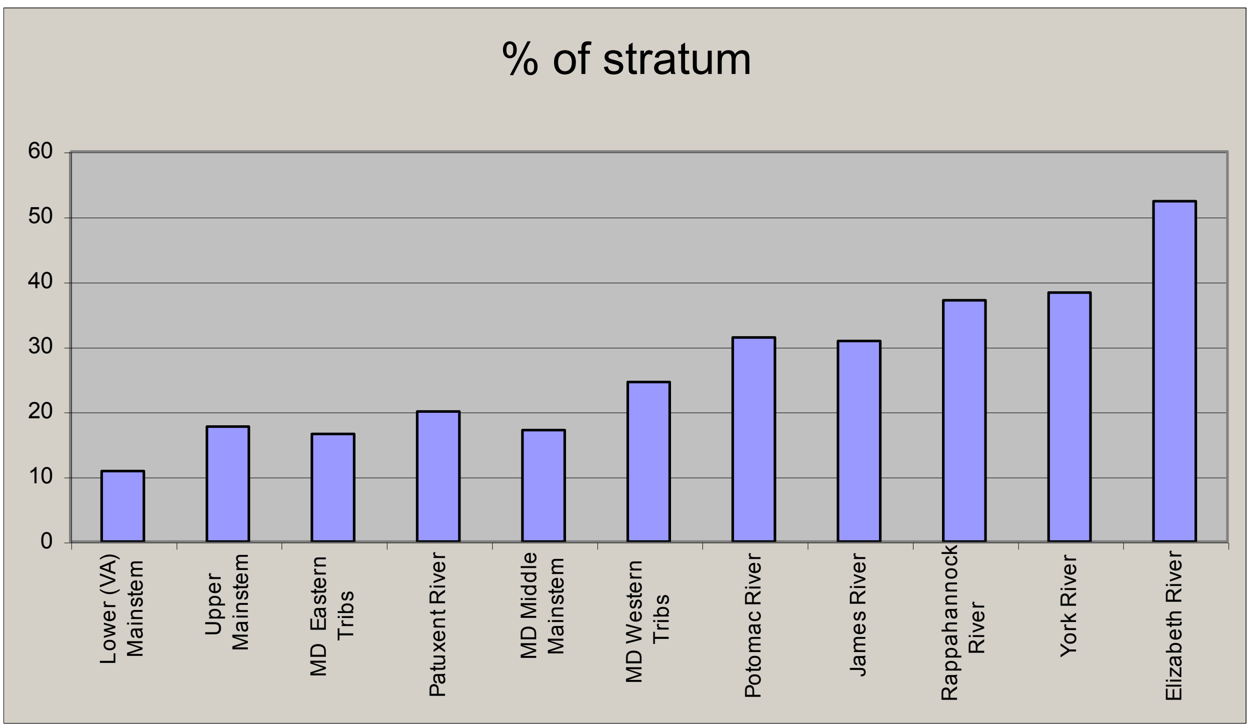

Figure 2. Percentage of stratum with a B-IBI value < 2.7 and placed into the Contaminant Group with a posterior probability > 0.5.

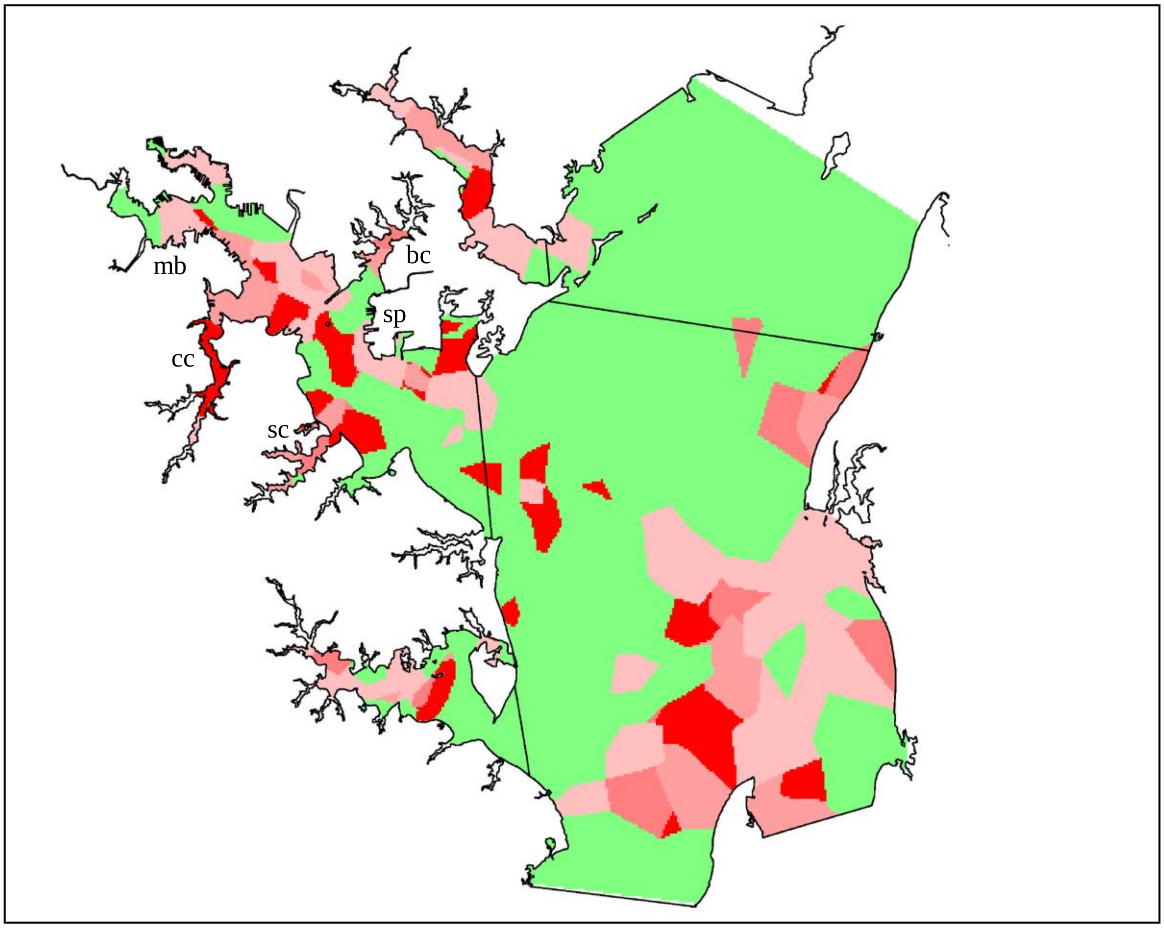

Figure 3. Diagnostic discriminant tool results and an interpolation fitting algorithm were used to classify Baltimore Harbor benthic communities into categories distinguished by the type of stress experienced by those communities. Red shading indicates degraded benthic communities stressed by toxic contamination (posterior probability in Contaminant Group > 0.5), with higher color intensity indicating higher probabilities of contaminant effects (>0.5 to <0.7; >=0.7 to <0.9; >=0.9). Salmon shading indicates degraded benthic communities stressed by other sources, most likely low dissolved oxygen (posterior probability in Contaminant Group <=0.5). Green indicates good benthic community condition. Middle Branch (mb), Curtis Creek (cc), Stony Creek (sc), and Bear Creek (bc) show contamination as likely source of stress. The deep basin north of Curtis Bay and the deep channel southwest of Sparrows Point (sp) shows other stress (low DO) as probable cause of degradation.

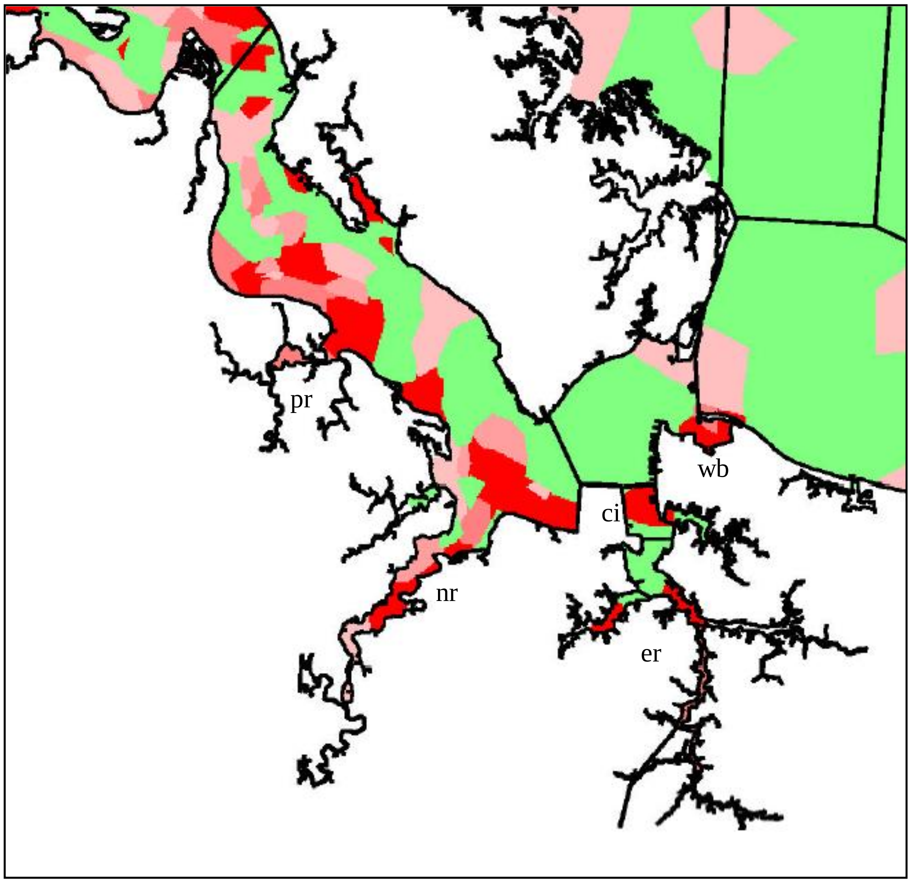

Figure 4. Diagnostic discriminant tool results and an interpolation fitting algorithm used here to classify lower James River benthic communities into categories distinguished by the type of stress experienced by those communities. Red shading indicates degraded benthic communities stressed by toxic contamination (posterior probability in Contaminant Group > 0.5), with higher color intensity indicating higher probabilities of contaminant effects (>0.5 to <0.7; >=0.7 to <0.9; >=0.9). Salmon shading indicates degraded benthic communities stressed by other sources (posterior probability in Contaminant Group <=0.5). Green indicates good benthic community condition. The Elizabeth River (er), Craney Island (ci), Willoughby Bay (wb), Nansemond River (nr), and Pagan River (pr) show contamination as likely source of stress.

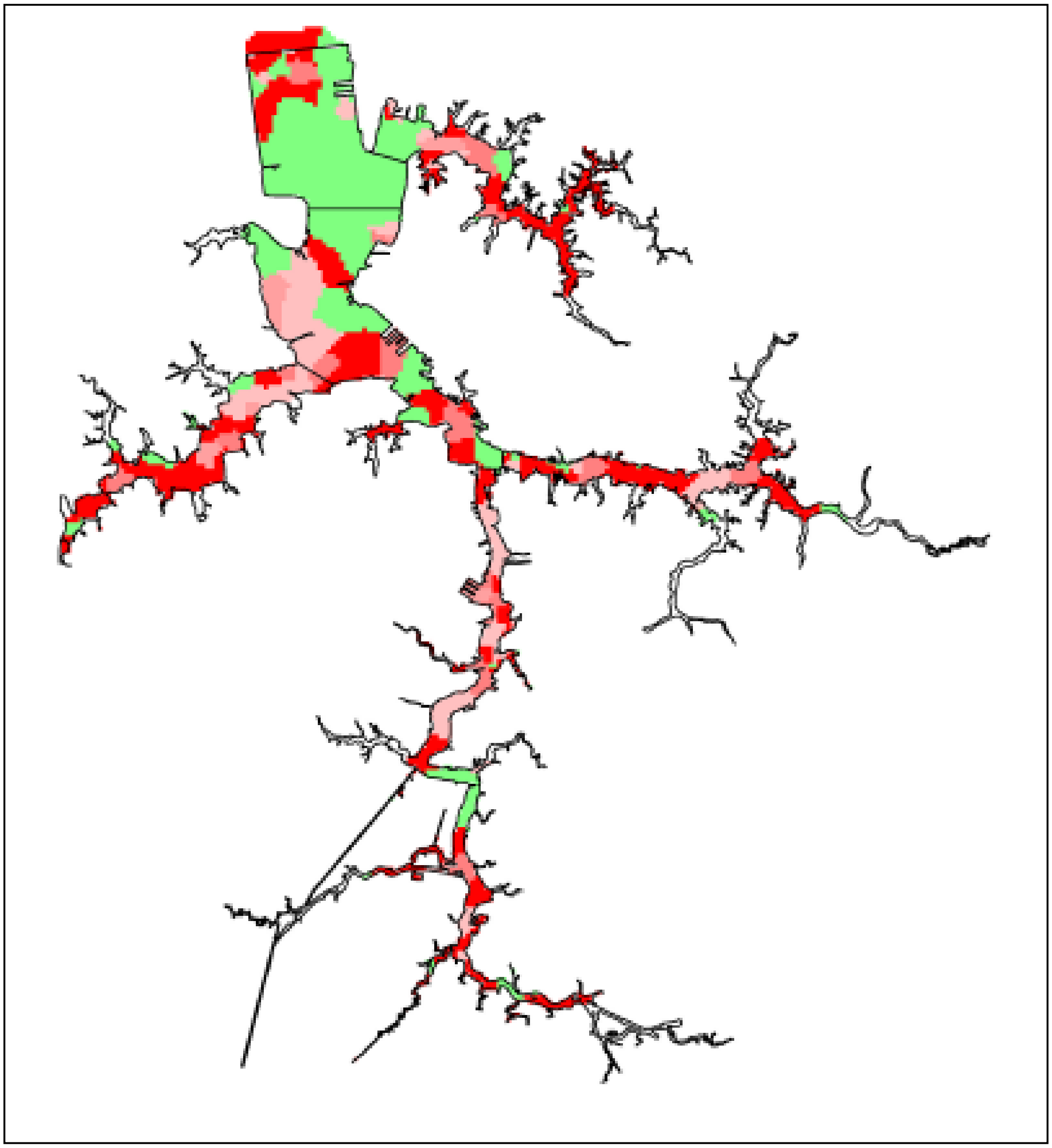

Figure 5. Diagnostic discriminant tool results and an interpolation fitting algorithm used here to classify the Elizabeth River watershed benthic communities into categories distinguished by the type of stress experienced by those communities. Red shading indicates degraded benthic communities stressed by toxic contamination (posterior probability in Contaminant Group > 0.5), with higher color intensity indicating higher probabilities of contaminant effects (>0.5 to <0.7; >=0.7 to <0.9; >=0.9). Salmon shading indicates degraded benthic communities stressed by other sources (posterior probability in Contaminant Group <=0.5). Green indicates good benthic community condition.